



The Chemical Fertilizer Industry in China

A Review and its Outlook

Edited by Fusuo Zhang, Weifeng Zhang, Wenqi Ma, *et al.*

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Preface

Series of Books on the Theories and Practices of Integrated Nutrient Management

The ancients said that knowledge resided in the tip of a writing brush. It is, therefore, the intention of this series of books to present a summary of the accumulated knowledge from our studies in nutrient management for more than 10 years. From the first project of internationally advanced agricultural science and technology introduced by the Ministry of Agriculture in 1996, on the application of rhizosphere theories and regulation technologies in the exploration of new fertilizer application techniques to optimize the growth of major crops in China, we have come to the totally new idea of integrated management of nutrient resources today. We would like to summarise our knowledge accumulated in this process. It is not merely a process of accumulated quantitative change in each and every project but more importantly, it represents a change in our mentality and a leap forward in our thinking.

There are at least four motivating factors that have brought this series of books into being that deserve special mention. They are as follows:

1. The very rapid socio-economic development in China improved the well being of the Chinese people. However, large quantities of plant nutrients applied to increase crop production have also resulted in negative effects on the environment and people's lives. Optimizing plant nutrient use, and increasing the efficiency of resources have become a matter of major concern with regard to agricultural and social development, particularly with respect to the environment and sustainable development. We are fortunate to be given the opportunity to shoulder the national mission of finding a solution to this important issue, something that is the envy of our foreign counterparts. Furthermore, the issue of plant nutrition has become a part of the main national economic arena. It is an opportunity to link plant nutrient sources with the destiny of our national socio-economic development. From this series of books, readers will realize the co-existence of this type of opportunity with challenges and responsibility with pressure.
2. With the enormous success and rapid growth of the Chinese economy, the Chinese government and the entire nation are longing for an even faster development and there is an urgent need for integrated technological innovations. With this, the technology of integrated nutrient management has emerged. Under the sponsorship of the Ministry of Agriculture, we organized a cooperative network from those in scientific research, teaching, extension of

technology, administration, industrial associations and large enterprises. A team of more than 300 experts from more than 80 organizations both inside and outside China was formed. In addition, we tried to combine the ideas and technologies of advanced countries like the United States, Great Britain and Germany and organizations such as the International Rice Research Institute (IRRI) and the International Fertilizer Industry Association (IFA). We carried out systematic and in-depth studies from different angles on the theories and technologies of regional integrated nutrient management based on the production systems of 12 crops that best represent the country. We also carried out a large amount of highly effective demonstration and extension work. The present series of books represent the synthesis and outputs of the cooperation.

3. Since the second nationwide general soil survey, there was a need for a key project to tackle soil and plant nutrition in the country. The important international co-operation Project, the introduction of integrated nutrient management and the establishment of its technical systems in China was launched because of the special trust and support received under favourable circumstances. Everyone cherished this hard-to-come-by opportunity and the entire group was immersed in an atmosphere of "we are in the right place at the right time and this is an opportunity not to be missed." All of us had a common wish; we should contribute to the rapid socio-economic development of China and the protection of its environment. We wanted to make a historical contribution by changing the backwardness of nutrient management in our country and greatly improve the efficiency of nutrient use, as an impetus to the sustainable development of China's agriculture. Our ideals and goals acted as an inspiration that encouraged us to work hard and to innovate. In the course of our research work, aside from paying great attention to the theoretical achievements, we placed special emphasis on the innovation, integration and condensation of the technical systems of nutrient management. We emphasize the exploration of an extension model for the technology and the effective application and its primary function in social development. It is also important that experiences and lessons learned from the establishment and effectiveness of demonstrations, training courses, academic activities, development of qualified personnel, social influence and project management be summed up. In the course of innovative achievements, precious experiences have been accumulated in scientific research, experiments, demonstrations and organizational management. Through this series of books, we hope to be

able to share these experiences and lessons learned with everyone.

4. With the rapid socio-economic development in China and the continuous improvement in the living standards of its people, integrated nutrient management will set the guidelines and technological measure for its adoption for increased crop production, increased efficiency in the utilization of resources and environmental protection. At the agricultural production levels, the core of nutrient management will be to achieve a quantitative balance between nutrient absorption during the entire growth period of a crop, that is, the effective supply of nutrients in the soil in synchrony or regulated and controlled in the root zone. At the regional and national levels, it is important to achieve a win-win situation for production and environment by quantifying, regulating and controlling the flow of nutrients in the food chain system: “resources – chemical fertilizer – farmland – animal husbandry – family – environment.” Through our work in these two aspects, with the efforts of our colleagues in plant nutrition and related disciplines, we hope to achieve great innovation in the technology of nutrient management while raising its level. We truly believe that the ideas expressed in this series of books will form an important guide in the sustainable development of Chinese agriculture and society in the future.

The following books will be included in our planned series:

- (1) “Integrated Nutrient Management” (2) “Outline of the

Techniques of Fertilizer Application by Formulation after Soil Tests” (3) “Crop Fertilization in Diagrams” (4) Introduction to the Theories and Technologies in Integrated Nutrient Management” (5) “Theories and Practices in Covered Dry Rice Cropping in China” (6) “Theories and Practices in the Integrated Nutrient Management for Cotton in Xinjiang” (7) “Theories and Practices in the Integrated Nutrient Management for Rice” (8) “Theories and Practices in the Integrated Nutrient Management for Flue-cured Tobacco” (9) “Theories and Practices in the Integrated Nutrient Management for Fruit Trees in Northern China” (10) “Theories and Practices in the Integrated Nutrient Management for Tropical and Sub-tropical Fruit Trees” (11) “Theories and Practices in the Integrated Nutrient Management for the Wheat-Maize Rotation System” (12) “Theories and Practices in the Integrated Nutrient Management for Vegetables” (13) “The Chemical Fertilizer Industry in China – A Review and Its Outlook” (14) Nutrient Flow and Strategies in the Integrated Management of Food Production and Consumption Systems of China” and (15) Nutrient Management and Quality of Agricultural Crops.” Of these, “Integrated Nutrient Management” was published in March 2003 and “Outline of the Technique of Fertilizer Application by Formulation after Soil Tests” in January 2006. The other drafts will be published in succession.

Zhang Fusuo
August 2006

From the Editor

With the rapid socio-economic development and continuous improvement of the people's living standards, chemical fertilizers have become indispensable for agricultural production. At the same time, people are ever more concerned about the adverse effects on the environment and the quality of agricultural produce as a result of excessive and improper fertilizer application. Good management and optimal application of chemical fertilizers as sources of plant nutrients has become one of the important measures in guaranteeing sustainable social development and in resolving the three socio-economic issues of agricultural villages (Nong Cun), farmers (Nong Min) and agriculture (Nong Ye), the so-called "San Nong" problems.

The development of the chemical fertilizer industry determines the quantity and quality of nutrient resources in the entire society. For more than half a century, the achievement of China's fertilizer industry has been brilliant. The industry has the world's largest fertilizer production and distribution systems. The volume of commodities accounts for 30-35% of the world's total volume. The total number of people involved in the industry makes up about 70% of the world total. The industry has contributed immensely to the overall development of the country. However, over a long period of time, the fertilizer industry in China has been so used to "satisfying domestic demand, adopting a policy of bigger sales at a small profit and receiving protection from the government" that it is becoming more and more incompatible with global economic integration and market-orientation after joining the WTO. Consequently, the sustainable growth of the fertilizer industry has become a hot spot that draws a great deal of attention.

Since the 1980s, the College of Resources and Environmental Science of China Agricultural University has been conducting wide-range and systematic research on the problems of chemical fertilizer application, and starting in the mid-1990s, attention was drawn to development of the fertilizer industry. In successive cooperation with Sinochem Corporation, China Phosphate Fertilizer Industry Association (CPFIA), China Nitrogen Fertilizer Industry Association (CNFIA), All China Federation of Supply and Marketing Cooperatives and China Phosphate and Compound Fertilizer Information Centre, the University, with the Ministry of Commerce and the Ministry of Communications of the People's Republic of China (PRoC) undertook and completed important research projects on production, marketing, transportation, storage and management of chemical fertilizers. Furthermore, systematic and in-depth studies were also carried out in

collaboration with international organizations and renowned chemical fertilizer research institutes such as FAO, UNESCO, IFA and IPI. Through these studies and research projects, a large volume of first-hand information was accumulated and a group of young, qualified personnel who are engaged in the management of chemical fertilizer were trained. Many academic papers with clear-cut views have been published. They filled the gap left by the transition from the old to the new system and these acted as an impetus to relevant domestic research.

Long-term research has given us the profound impression that the achievement of China's fertilizer industry that we see today has not come the easy way. Besides the painstaking effort by a few generations of "chemical fertilizer men," it also bears historical witness to China's perseverance in independent hard work to bring prosperity to the country. Moving on the present road towards sustainable development, the fertilizer industry in China is in dire need of review, for its future development, in order to systematically summarize the experiences and the lessons learned, trace the development paths of leading enterprises, carry out analysis of product innovation, the trend of market demands and analyse the trend of policy formulation. The objective is to provide references that will help the government enhance its macro-economic control, to help enterprises in putting their ideas into shape and to allow research workers identify their areas of study. In addition, the systematic, more comprehensive and easy-to-understand reference materials will benefit more than a million "chemical fertilizer men" throughout the country and hundreds of millions of agricultural producers. For these purposes, we have engaged the services of experts in certain key research institutes of chemical fertilizers all over the country in the production of this book.

This book is divided into 8 chapters. The first chapter gives a general account of the socio-economic importance of the fertilizer industry in China. The second chapter which is written by China National Chemical Information Centre, describes the development and the level of technology of the nitrogen (N) fertilizer industry in China, the present state of the industry, the market and policies. The third chapter which is a joint effort of the Information Centre of China Phosphate Fertilizer Industry Association (CPFIA) and the College of Engineering of Zhengzhou University, discusses the development and technological standard of phosphate (P) fertilizer industry, the present state of the industry, the market and policies. Chapter 4 discusses the course of development of the potash (K) fertilizer industry and its major activities

in China. This is the contribution from the Kali Salt Trade Branch of China Inorganic Salt Industry Association. Chapter 5, a contribution from Sino-Arab Chemical Fertilizers Co., Ltd. and the China Compound Fertilizer Network deals with the state of development of the compound fertilizer industry. In Chapter 6, the College of Resources and Environmental Science of China Agricultural University writes about the development of new types of fertilizers in China, in particular, slow/controlled-release fertilizers and foliar fertilizers. Chapter 7, written by Sinochem Corporation, gives a description of the system of fertilizer circulation and policy changes in China while in Chapter 8, the College of Resources and Environmental Science of China Agricultural University gives

an account of the outlook for chemical fertilizer resources and demand, the enterprises in the industry and policy trends.

The present book has been planned, organized and integrated by Zhang Fusuo, Zhang Weifeng and Ma Wenqi, written by more than 30 specialists and proofread by Zhang Sidai. Owing to our limited ability, there are bound to be careless omissions and we sincerely invite comments from our readers.

Editor
March 2007

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List of Acronyms, Symbols and Abbreviations

(as used in this book)

Acronyms

| | |
|--------|--|
| CIDA | Canadian International Development Agency |
| CIRAD | Centre de Cooperation Internationale en Recherche Agronomique pour le Developement (Agricultural Research Center for International Development) |
| CNFIA | China Nitrogen Fertilizer Industry Association |
| CPFIA | China Phosphate Fertilizer Industry Association |
| EEC | European Economic Council |
| EU | European Union |
| FAO | Food and Agriculture Organization of the United Nations |
| IFA | International Fertilizer Industry Association |
| IFDC | International Fertilizer Development Centre |
| IPI | International Potash Institute |
| ISO | International Organization for Standardization |
| NDRC | National Development and Reform Commission |
| PPI | Potash and Phosphate Institute of Canada (now International Plant Nutrition Institute (IPNI)) |
| PRoC | People's Republic of China |
| SACF | Sino-Arab Chemical Fertilizer Co., Ltd. |
| TVA | Tennessee Valley Authority |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| USA | United States of America |
| WTO | World Trade Organization |

Symbols

| | |
|---|--------------------------------------|
| Al_2O_3 | aluminium oxide |
| B | boron |
| $^{\circ}\text{C}$ | degree Celsius |
| Ca | calcium |
| CaCO_3 | calcium carbonate |
| $\text{Ca}_5\text{F}(\text{PO}_4)_3$ | fluorapatite |
| $\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$ | calcium dihydrogen phosphate |
| CaO | calcium oxide |
| $\text{Ca}-\text{PO}_4-\text{F}$ | calcium-phosphate-fluorine |
| CaSO_4 | calcium sulphate |
| C/H | carbon/hydrogen |
| Cl | chlorine |
| CO | carbon monoxide |
| CO_2 | carbon dioxide |
| Cu | copper |
| F | fluorine |
| FeO | iron oxide |
| Fe_2O_3 | ferric oxide |
| H_2 | hydrogen |
| HCl | hydrochloric acid |
| HCO_3 | bicarbonate ion (hydrogen carbonate) |
| Hg | mercury |
| H_2O_2 | hydrogen peroxide |

| | |
|---------------------------|--|
| H_2PO_4^- | dihydrogen phosphate |
| H_2SO_4 | sulphuric acid |
| K | potassium |
| K_2O | potassium oxide (potash) |
| KCO_3 | potassium carbonate |
| KCl | potassium chloride (or muriate of potash (MOP)) |
| KH_2NO_3 | potassium dihydrogen nitrate |
| KH_2PO_4 | potassium dihydrogen phosphate |
| KNO_3 | potassium nitrate |
| K_2SO_4 | potassium sulphate (or sulphate of potash (SOP)) |
| Mg | magnesium |
| MgO | magnesium oxide |
| MgSO_4 | magnesium sulphate |
| Mn | manganese |
| N | nitrogen |
| NaCl | sodium chloride |
| NH_3 | ammonia |
| NH_4^+ | ammonium |
| NO_2 | nitrogen dioxide |
| NO_3^- | nitrate |
| NO_x | nitrogen oxides |
| NPK | nitrogen-phosphorus-potassium |
| P | phosphorus |
| P_2O_5 | phosphorus pentoxide (phosphate) |
| S | sulphur |
| SiO_2^{2-} | silicon dioxide |
| SO_3 | sulphur trioxide |
| SO_4 | sulphate |
| Zn | zinc |

Abbreviations

| | |
|---------------|-----------------------------------|
| ABC | ammonium bi-carbonate |
| AC | ammonium chloride |
| aMDEA | activated methyl-diethanolamine |
| AN | ammonium nitrate |
| AP | ammonium phosphate |
| APP | ammonium polyphosphate |
| AS | ammonium sulphate |
| B | billion |
| BB | bulk blended |
| Bt | billion metric tonnes |
| Cal | calories |
| CAN | calcium ammonium nitrate |
| CCF | coated compound fertilizer |
| CIF | cost, insurance, and freight |
| cm^3 | cubic centimeter |
| CRF | controlled-release fertilizer |
| DAP | di-ammonium phosphate |
| DCD | dicyandiamide |
| DCS | distributed control system |
| FCMP | fused calcium magnesium phosphate |
| g | gram |
| GJ | gigajoule |
| ha | hectare |
| HQ | hydroquinone |
| jin | 1 jin = ½ kilogram |
| kg | kilogram |
| kJ | kilojoule |

| | |
|----------------|---|
| km | kilometer |
| kWh | kilo watt hour |
| L | litre |
| M | million |
| m ³ | cubic meter |
| MAP | mono-ammonium phosphate |
| mg/l | milligram per litre |
| mm | millimeter |
| MOP | muriate of potash (or potassium chloride (KCl)) |
| MPa | megapascal |
| Mt | million metric tonnes |
| mu | 15 mu = 1 hectare (1 mu=0.0667 ha) |
| MW | mega watt |
| NP | nitrophosphate |
| PAPR | partially acidulated phosphate rock |
| PR | phosphate rock |
| PRSF | pipe reaction spray fluidization |
| PVC | polyvinyl chloride |
| RMB | Renminbi (Yuan) |
| R & D | research and development |
| S/CR | slow/controlled-release |
| S/CRF | slow/controlled-release fertilizer |
| SCU | sulphur-coated urea |
| SOP | sulphate of potash or potassium sulphate |
| SRF | slow-release fertilizer |
| SSP | single superphosphate |
| STPP | sodium tripolyphosphate |
| Syngas | synthetic gases |
| t | metric tonne |
| T | trillion |
| UAN | urea ammonium nitrate |
| µm | micrometer |
| US\$ | US dollar |
| t/d | metric tonne per day |
| TSP | triple superphosphate |
| t/y | metric tonne per year |
| VAT | value added tax |
| y | year |

Chapter 1

Strategic Position of the Chemical Fertilizer Industry in China

The rapid socio-economic development in China is at an important stage of transition. The comprehensive establishment of a fairly well off society is facing a major challenge posed by energy, resources, environment and the three agricultural issues or problems, the agricultural villages (*Nong Cun*), farmers (*Nong Min*) and the agricultural industry (*Nong Ye*) referred to as the problem of “*San Nong*.” As a special industry involving resources and energy, affecting the “*San Nong*” problems and the quality of ecological environment, the chemical fertilizer industry is facing pressures and opportunities hitherto unknown to China.

How to realize the healthy development of the fertilizer industry, coordinate the supply and demand of chemical fertilizers and balance between increasing agricultural production on one hand and resources, energy and environmental safety on the other are matters of great importance to the achievement of sustainable development.

Since 2004, the Chinese government has been reviewing its policy for the fertilizer industry and a major reform of the industry is imminent. In order to cope with the present situation, one needs to have a well-founded knowledge of the important position of the fertilizer industry in China and its direction of development.

1.1 The fertilizer industry provides the fundamental assurance of food security

The Chinese say: “With food in hand, you have peace of mind.” China is the most populous country in the world; therefore, guaranteeing food supply is the most important challenge to agriculture in the national economy. China has managed to feed 21% of the world’s population with only 9% of the world’s arable land. Application of chemical fertilizer is one of the major contributing factors. Before the formation of new China, “traditional” agricultural production was practiced using crop straws, human and animal faeces, urine and green manure to maintain soil fertility. Grain production was at a relatively low level over a long period of time. After liberation, with the large volume of chemical fertilizer used, grain production increased rapidly as shown in Figure 1-1. Up to 1992, the contribution of chemical fertilizer to grain production reached 31-43% but then fell to about 10%. Chemical fertilizer is still the main pillar supporting grain production (Lin Bao and Li Jiakang, 1989; Ma Ji, 2006).

The application of chemical fertilizers plays a decisive role in increasing grain production. Information from FAO shows developing countries are able to increase the yield per unit area of grain crops by 55-57% through the use of chemical

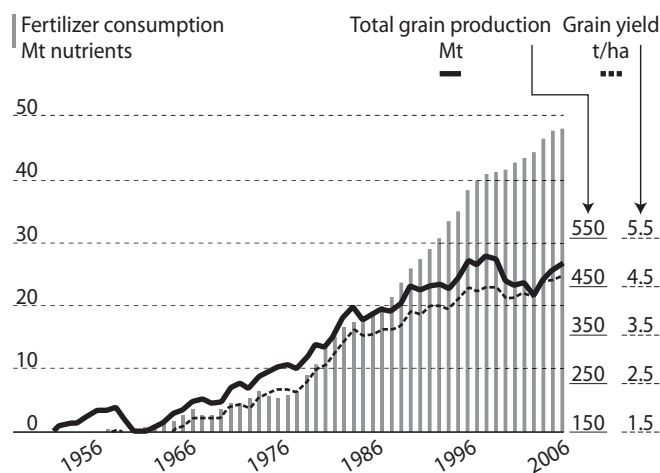


Figure 1-1 Trends in chemical fertilizer consumption, total grain production and production per unit area.

fertilizer, and their total production by 30-31%. Results of many experiments by the nationwide network of chemical fertilizer institutes indicate that chemical fertilizers can raise the yield per unit area of rice, maize and cotton by 40-50%, winter crops such as wheat and rape by 50-60% and soybean by almost 20%. Calculations of results from the nationwide network experiments indicate that out of the total grain production from 1986-1990, about 35% was due to chemical fertilizer application. Beyond all doubt, fertilizers represent the fundamental material that will guarantee increased grain production and food security in China. As pointed out by Nobel Prize winner and the father of the Green Revolution, Norman Borlaug (1998), for China to achieve its grain production target, proper application of fertilizer is the most important measure.

1.2 Chemical fertilizer is the base material for the improvement of nutritional standards

The application of chemical fertilizer not only guarantees the increase in grain yield, it also guarantees a big improvement in people’s nutritional level. In 2005, the per capita consumption of meat, eggs and milk in China reached 59.2 kg, 22.0 kg and 21.9 kg, respectively. Compared with 1980, there was an increase of 3.7, 6.5 and 14.1 times, respectively.

Production of large quantities of meat and dairy products, fruits and vegetables also depends on the scientific application of fertilizers. Results of research by Smil (2001) indicate that

the use of chemical fertilizer provides 40% of the nitrogen required by mankind, and in China, this proportion is as high as 54%.

In traditional agriculture, biological nitrogen fixation can only provide 120-150 kg N/ha. Each hectare of land can only provide 200 kg of protein which is sufficient to feed six or seven vegetarians. Whereas modern agriculture in developed countries that uses chemical fertilizer, fertilizer is able to produce 600-800 kg of protein per hectare of land and thus, can feed 20 to 30 people.

Although the per unit area crop yield in China is relatively low, after using chemical fertilizer, protein output for the three major grain crops (rice, wheat and maize) is 440-619 kg/ha. However, when the multiple crop index of 150% is taken into consideration, the annual protein output of China's cultivated land is even higher than in developed countries, and it may reach 660-929 kg/ha. This is why China can feed 21% of the world's population and improve the standard of living its population.

It is estimated that China's population will reach 1.4 billion by 2010 and 1.5 billion by 2020 (Decision of the State Council of the Central Committee of the Chinese Communist Party Concerning the Overall Enhancement of Population Planning and Birth Control in Resolving the Population Problem). According to basic needs (per capita grain ration of 400 kg) in the year 2007, grain requirement in 2010 and 2020 will be 500Mt and 580Mt respectively. However, when the requirement for improving people's nutrition is taken into consideration, grain demand will reach 640Mt in 2020. Where increasing the cultivated area is difficult, the only choice for addressing food security is to increase the yield per unit area of grain crops, and one of the most important measures to achieve this is through the use of fertilizers.

1.3 Chemical fertilizer is an important factor in increasing farmers' income

The "San Nong" problem of increasing farmer's income is a priority for the State and government. The development trend in the fertilizer industry has important effects on farmers' income which cannot be ignored. Statistics of "The 2006 Collection of Nationwide Costs and Benefits of Farm Produce" compiled by the Price Department of the National Development and Reform Commission indicate that the average production cost of "the three main grain crops" of China (rice, wheat and maize) is RMB363/mu (1 hectare = 15mu, the same below unless otherwise stated) with net profit of merely RMB15.08/mu. The amount of chemical fertilizer applied is 20.29 kg/mu with expenditure of RMB84.31/mu or 23% of the production cost, an input that is only smaller than manpower (Figure 1-2). Due to the price increase of chemical fertilizers, fertilizer input for the "three major grain crops" went up by RMB13.13/mu in 2005, resulting in a drop of 35.6% in the net profit of grain production. A small change in the price of chemical fertilizer will result in a swing of grain cultivation from profit to loss; therefore, chemical fertilizer has become the chief factor which affects farmer's production and income. According to the Ministry of Agriculture, among

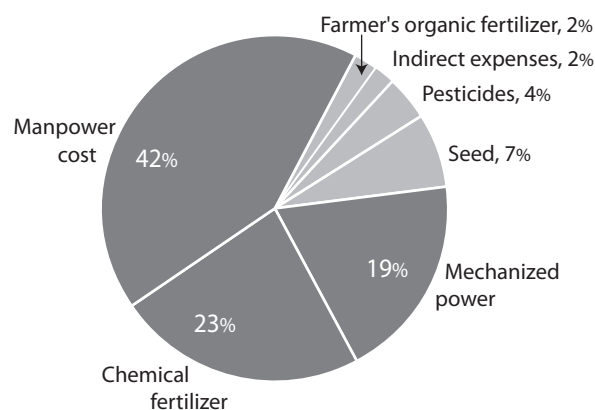


Figure 1-2 Components of production costs for the three major grain crops (rice, wheat and maize) in China, 2005.

the four problems that deserved special attention in the development of agriculture and the rural economy in 2004, the problem of price increase of agricultural resources ranked highest in the list. 34.8% of the increase in income brought about by grain price increases has been offset, thus greatly reducing the effect of the policy to increase the income of farmers. According to the Centre for Chinese Agricultural Policies of the Chinese Academy of Sciences, the high prices of agricultural resources topped the list of various problems affecting the farmers. It is for this reason that in 2004, the National Development and Reform Commission and the relevant departments formulated in 2004 a series of measures to promote circulation, guarantee supplies and promote price stability.

1.4 Chemical fertilizer production can aggravate the shortage of resources and cause tension in energy supply

Chemical fertilizer production relies on the relevant resources and it is a high-energy consumption industry. Table 1-1 shows that, in 2005, chemical fertilizer production in China consumed about 100 Mt of standard coal, which is about 5% of nationwide energy consumption. Consumption of anthracite and natural gas was 13% and 31%, respectively. Chemical fertilizer production uses 69% of China's sulphur resources, and presently, domestic sulphur resources are unable to satisfy the industry's needs. The volume of import accounts for one fifth of the world's sulphur trade. China imports nearly 7 Mt of muriate of potash (MOP) annually, making up one third of the volume of potassium salt traded in the world.

The development of chemical fertilizer production has also brought about the demand for growth in transport capacity. At present, the freight volume of goods and materials related to chemical fertilizer production is close to 170 Mt-kilometre per year, which is 11% of the volume of rail transport. With the rapid development of the fertilizer industry, shortage of resources and tension in energy supply will be further aggravated.

Table 1-1 Raw material consumption for fertilizer production in China: 2005

| Raw Material | Consumption for Fertilizer Production | Proportion of Fertilizer Production Consumption against Domestic Consumption (%) |
|--|---------------------------------------|--|
| Phosphate ore (standard ore) | 4.306×10 ⁷ t | 73 |
| Sulphur (elemental sulphur) | 1.143×10 ⁷ t | 69 |
| Potassium (K ₂ O) | 1.56×10 ⁶ t | 95 |
| Oil (crude oil) | 2.44×10 ⁶ t | 8 |
| Anthracite (standard coal) | 3.426×10 ⁷ t | 13 |
| Bituminous coal (standard coal) | 1.061×10 ⁷ t | |
| Natural gas | 1.01×10 ¹⁰ m ³ | 31 |
| Electricity | 5.89×10 ¹⁰ kW h | |
| Comprehensive energy consumption (standard coal) | 1.00×10 ⁸ t | 5 |

Note: The amounts of resources consumed in fertilizer production are calculated according to the actual volume of consumption per unit product of Chinese fertilizer enterprises and total fertilizer output.

1.5 The inappropriate application of chemical fertilizers can cause environmental pollution

Information and data from the National Bureau of Statistics of China indicate that the annual production and consumption of chemical fertilizers has reached 50 Mt, the highest level in the world. However, due to the low quality of fertilizer products and poor fertilizer application techniques, the use efficiency of nitrogenous fertilizers is less than 30%. Besides causing tremendous economic losses, this has also led to environmental pollution.

According to estimates, the value of nitrogenous fertilizers lost each year in China is above RMB40 billion (B). The loss goes mainly to water sources and to the atmosphere. It is reported that 30% of the existing drinking water in China

is polluted, and 64% of urban ground water suffers severe pollution which threatens the health of the inhabitants. 61% of inland lakes become nutritionally rich and “red tide” occurs frequently in the coastal waters, which threatens the national ecological security.

Economic losses caused by water pollution each year account for 1.46-2.84% of the Gross Domestic Product (GDP). Although such pollution is not only caused by chemical fertilizer, the large quantities of nitrogen and phosphorus nutrients used and their improper application have increased the possibility of environmental pollution.

Pollution by chemical fertilizer also adds to the emission of greenhouse gases. Currently, the level of carbon dioxide emissions in China is the second highest in the world. Chemical fertilizer production and related emissions of carbon dioxide, nitrogen and oxygen compounds manufacturing are major sources of greenhouse gases. This is going to be a thorny environmental and diplomatic issue in the future. Furthermore, gases and dusts emitted in the production of chemical fertilizer and in the course of its use severely affect air quality and human health. Besides causing the expansion of the hole in the ozone layer, nitrogen dioxide (NO₂) can also form particles which can lead to respiratory and eye diseases. They may also settle and fall with water as acid rain which has immeasurable effects on health and the environment.

At present, the fertilizer industry in China is an important industry possessing assets and with an output value of RMB280 billion (B). Its development supports farm production, animal husbandry, forestry and chemical industries and even the development of the bio-energy industry in the future. Increased food production through the use of chemical fertilizers has fed at least 520 million (M) nationwide. It is also related to farmers' increased income, environmental quality, utilization of resources and ecological safety. These have great significance in the establishment of a relatively affluent society in China. The healthy and sustainable development of the fertilizer industry requires the joint efforts of government, manufacturers and workers in the field of science and technology. There should be enhanced exchanges, more ideas, technical innovations, continuous provision of high quality products and services, as contributions to national development and the building of new agricultural villages.

Chapter 2

China's Nitrogen (N) Fertilizer Industry: Development and Outlook

2.1 Technological development of the nitrogenous (N) fertilizer industry

2.1.1 A technological review of China's N fertilizer industry

2.1.1.1 Technological breakthrough and important inventions in China's N fertilizer industry

The production of fertilizer N in China began in the 1930s and in 1949 the actual yearly production was 6,000 t of Ammonium Sulphate (AS). With the establishment of new China, great emphasis was placed on the development of N fertilizer and for over 50 years, investments in this sector was more than 80% of total investments in the chemical fertilizer industry. At present, the industry is a combination of small, medium and large N fertilizer plants spread throughout the country.

The N fertilizer industry is characterized by a high level of technical activity, high energy consumption, wide ranging impact on the environment and high investments. At the initial stage, before the formation of the People's Republic of China (PRoC), under conditions of economic difficulty and technological backwardness, China depended on imported technology. Whilst the Dalian Chemical Plant and the Yongli Ammonium Plant were going through continuous innovations, complete N fertilizer plants were brought in from the Soviet Union. These were set up by the Ji Hua Fertilizer Plant, the China National Petroleum Corporation Fertilizer Plant in Lanzhou and the three N fertilizer plants set up by the Taiyuan Chemical Industry Group.

In 1956, the Design Institute of the Ministry of Chemical Industry designed its own synthetic ammonia plants with an annual production capacity of 75,000 t. These were set up in the Sichuan Chemical Complex. The design took into consideration the situation in China and incorporated the advantages of established plants with improved techniques, shorten processes and increase efficiency and savings on investment. After several years, China had the ability to establish small and medium-sized ammonia fertilizer plants on its own.

In order to adapt to the needs of N fertilizer production, in 1958 the Design Institute of the Ministry of Chemical Industry drew up a final design based on the design and production experience of Sichuan Chemical Plant for synthetic ammonia with an annual production capacity of 50,000 t. The large Zhejiang Synthetic Ammonia Plant, the Shanghai Wujing Chemical Plant and the Guangzhou N Fertilizer Plant were built in succession. With the establishment of these three

plants, the N fertilizer industry of China entered a new stage where the Chinese designed, made the equipment and built the facilities themselves. Subsequently, they built and started production in the Kaifeng Fertilizer Plant in Henan Province, the Yunnan Liberation Army Fertilizer Plant, the Shijiazhuang Fertilizer Plant in Hebei Province, the Huainan Fertilizer Plant in Anhui Province and the Jianjiang Fertilizer Plant in Guizhou Province. All these are medium-sized N fertilizer plants.

Between 1964 and 1966, the Luzhou Natural Gas Chemical Plant in Sichuan Province was built with two sets of equipment brought in from overseas. One of these was a synthetic ammonia plant with an annual production capacity of 100,000 t brought in from Great Britain. This plant produced synthetic ammonia by the conversion of natural gas with pressurized steam. The other was a Dutch urea plant with an annual production capacity of 160,000 t that produces urea using the total recycle of aqueous solution method.

The construction of the Xingping Fertilizer Plant in Shaanxi Province began in 1965 by importing a synthetic ammonia plant with an annual production capacity of 50,000 t from Italy that produced synthetic gas by the process of partial oxidation of heavy oil. Complete plants for synthetic ammonia, nitric acid and ammonium nitrate were built and put into production by 1970. At the same time as the production of ammonium bi-carbonate (ABC) with the synthetic ammonia process of pressurized carbonation, eight medium-size N fertilizer plants were constructed, including the Baoji N Fertilizer Plant in Shaanxi Province.

During the 1960s, in order to adapt to the requirements of agricultural development and in combination with the state of affairs in China, the Ministry of Chemical Industry made a strategic plan for the development of small N fertilizer plants. The renowned chemist Hou Debang developed and perfected the production of synthetic ammonia and ammonium bi-carbonate by carbonation in small N fertilizer plants. The development of small N fertilizer plants occupies a unique and important position in the N fertilizer industry in China.

In 1973, due to the increasing demand for chemical fertilizers by the agricultural sector and the exploration for petroleum and natural gas, China imported from the United States, Holland, Japan and France, 13 large complete N fertilizer production plants with daily production capacities of 1,000 t of synthetic ammonia and 1,600-1,740 t of urea. Of these, ten used natural gas while the other three used light oil as raw material.

By 1979, all these imported plants were built and put into operation. This batch of large-scale N fertilizer plants were of internationally advanced standards at that time and

their introduction played a very important role in raising the standard of production techniques and management in the fertilizer industry in China, placing the country among the front runners in the world N fertilizer industry. These imported production plants can be classified in three types according to patents:

1. The Kellogg traditional process, the Kellogg TEC process, the Topsoe process, the AMV process, the Brown technique and the KBR technique that use natural gas and naphtha as raw materials;
2. The Texaco process and the Shell process that use residuum (see 2.3.3.1 (3)) as raw material;
3. The Lurgi gasification process and the Texaco coal water slurry gasification process that use coal as raw material.

These processes gather together the world's major technologies of synthetic ammonia processes. Urea technology includes the Stamicarbon CO₂ stripping process, the Mitsui Toatsu-Toyo process improved method C, the SNAM urea process and the ACES process.

Between 1980 and 1990, another 18 large N fertilizer plants were imported successively. They used residuum lump coal, coal water slurry and natural gas as raw materials. Advanced techniques of ammonia production by:

- German Uhde Company - ICI method of oil field gas conversion by steam
- German Lurgi - continuous vaporization of bitumite pure oxygen,
- Toyo process Shell method of Japan - from residuum
- Ube Texaco of Japan - from coal water slurry and
- German Linde Texaco - from Texaco residuum

were adopted for the establishment of large ammonia plants in Puyang of Henan Province, Lucheng of Shanxi province, Jinxi of Liaoning Province, Jianfeng in Chongqing, Hejiang of Sichuan Province, Jiujiang of Jiangxi Province, Hohhot of Inner Mongolia and Lanzhou of Gansu Province. The annual synthetic ammonia production capacity of all these plants reached 300,000 t.

After more than 20 years of importing technology and large-scale development, tens of billion US dollars have been spent. However, through these plants, several billion US dollars were also saved from the importation of chemical fertilizers along with the benefits of building N fertilizer production plants with international standards. In addition, they have given an impetus to greatly raise the domestic production technology of chemical fertilizers.

China's N fertilizer industry has gone through more than 50 years of development. Building medium-sized fertilizer plants, vigorously developing small-scale N fertilizer plants, importing large N fertilizer plants for the technological reform of old plants and structural improvements of products have enabled the present fertilizer industry of China to develop into one with more than 580 producing enterprises. China possesses the largest nitrogen-based production capacity in the world with a relatively advanced level of technology and equipment. From a single product manufactured in the past, there are now more than ten N fertilizer products that include urea, ammonium bicarbonate (ABC), ammonium nitrate (AN), ammonium sulphate (AS) and ammonium chloride (AC).

2.1.1.2 Experiences and lessons learned in the technical development of the N fertilizer industry

The main experiences and lessons learned in the technical development of the N fertilizer industry are related to raw materials. The development of China's N fertilizer industry evolved with coal as the raw material, giving it an edge to compete internationally. The main lesson learned was that with oil and gas as raw materials, the development of N fertilizer techniques did not meet the changes in resources available and market prospects, thus a portion of the enterprises had to carry out technological reforms.

The period from the initial stage of nation building to the 1960s saw the beginning of the N fertilizer industry in China. As the ability to manufacture synthetic gases (syngas) was limited, it was thought that using poor-quality brown coal as the raw material for manufacturing synthetic gas was the right move. These raw materials were mainly coke, coke furnace gas, anthracite and lignite.

Based on experience, it was found that gasification of lignite using boiling furnace caused serious pollution to the environment and to water systems. Subsequently efforts were concentrated on manufacturing syngas with coke. Since coke was a limited resource at that time, it was later substituted with anthracite as raw material. This was followed by the rapid development of medium and small-sized N fertilizer plants at the county, city and provincial level. This represented a new era for the synthetic ammonia industry.

In retrospect, using anthracite as the raw material with fixed-bed batch gasifiers for manufacturing syngas was reasonable as that resolved the major problem of the N fertilizer industry in China.

With the advancement of science and technology, three major problems appeared with regard to this technology:

Firstly, the singular supply of raw material. Up to the 1960s syngas was manufactured using local coke or anthracite. However, only the province of Shanxi had rich anthracite resources (it was only later that anthracite was found in the province of Guizhou and the autonomous region of Ningxia) and this resulted in a situation where small and medium-sized N fertilizer plants depended mainly on the anthracite from Jincheng in Shanxi Province. Long distances meant high transport costs, high levels of culms (broken coal) and high cost of raw materials. Many plants could not survive under these conditions.

Secondly, the high rate of culms led to a low utilization ratio of anthracite and the corresponding reduction in the production of lump coal as raw material for gasification. There were two reasons for the high rate of culms: 1) mechanized mining of coal and 2) the long distance of transport by rail or by road that breaks up the coal. At present, the utilization ratio of anthracite that arrives at the plant is only about 60%. Some N fertilizer plants use different binders to turn culms below 13mm into carbonised lime egg-shaped briquettes, paper pulp and clay egg-shaped briquettes and humic acid egg-shaped (or rod-shaped) briquettes to replace lump coal for gasification. Due to the low temperature of gasification, the technique had to be further improved.

Thirdly, a large volume of the gas was purged, thus wasting energy and causing severe pollution to the surrounding

environment. An atmospheric pressure and fixed-bed gasification oven enriched with oxygen and oxidation has been developed. This gives better results and improves the production environment.

Currently, coke and anthracite are the most common raw materials for synthetic ammonia production in China. There are limited sources of these and their technical and economic values are poor. In order to develop the chemical fertilizer industry on a large scale, China has begun looking for ways to increase production of cheap hydrogen and expand the sources of raw materials for synthetic ammonia. When much attention was being paid to testing the gasification of granular coal, it was found that manufacturing synthetic ammonia with heavy oil, crude oil and natural gas could simplify the process and equipment, reduce the amount of raw materials transported, facilitates increased automation, save infrastructure investment and lower production costs. This was one of the paths taken in the subsequent development of the N fertilizer industry. Around 1970, there were large finds of petroleum and natural gas resources in China and efforts were devoted to developing the N fertilizer industry with natural gas and petroleum products as raw materials. Due to an erroneous assessment of gas exploration in Sichuan Province, the very small gas production was insufficient for any to leave Sichuan. As a result, four N fertilizer plants for which natural gas was planned were forced to switch to naphtha as raw material. As naphtha was in short supply and its price was high, all four plants suffered severe losses. Currently, each plant is running at an annual loss of about RMB100 M and they have no choice but to switch to coal as the raw material which requires a huge investment. These are lessons that should be borne in mind when planning and building N fertilizer plants in future.

In summary, the major problems of the N fertilizer industry included the irrational structure of raw materials, high transport costs and the numerous small-scale N fertilizer plants. Owing to the continuously rising petroleum prices, small, medium and large scale N fertilizer plants that depend on high-priced oil as raw material have to carry out revamping by switching to natural gas and powdered coal as raw materials. For enterprises that use anthracite, they will have to use local cheap coal and advanced coal gasification technology. Large and medium-sized N fertilizer plants will mainly carry out revamping in energy-saving technology. Newly built N fertilizer plants should be concentrated in areas with rich natural gas and coal resources to realize the establishment of large bases for basic fertilizers. In addition, the N fertilizer industry in China has worked very hard in technical innovation, energy saving and increased production but these are mainly innovations in techniques and equipment. Innovation in fertilizer products has not even been scheduled. This is the key problem as to why a substantive leap of technology in the N fertilizer industry has yet to be achieved.

2.1.2 Technological breakthroughs and important inventions in the N fertilizer industry

2.1.2.1 Manufacturing ammonium bicarbonate (ABC) by the synthetic ammonia carbonisation process

The birth and development of small N fertilizer plants was decided by the economic conditions in China. In 1958, in order to cater for the urgent needs for agricultural development, according to instructions from the Party Central Committee, Peng Tao, the Minister for Chemical Industry at that time, pointed out that besides high investment and the long period of construction which were required for the production of AS and AN, lead and stainless steel were also needed. This did not comply with the situation in China. He then put forward the strategic concept of small N fertilizer plants. Results of experiments by agricultural research departments indicated that ABC had better fertilizing efficiency. In the experimental scheme of yearly production of 10,000 t of synthetic ammonia in combination with 40,000 t of ABC, the Design Institute of the Ministry of Chemical Industry found that they were able to directly carry out carbonisation to obtain ABC by making use of the reaction between the synthetic ammonia charge gas that contains more CO₂ and hydrogen. In this way, while purifying the synthetic ammonia charge gas, the CO₂ is fully used.

The renowned chemist Hou Debang led a research team to conduct experiments and research that achieved success in 1965. He introduced a new idea of combined base manufacture by merging the production of ABC with the production of synthetic ammonia, completing a new technology of manufacturing ABC with the technical process of synthetic ammonia by carbonisation. In the process of synthetic ammonia production, there is a process to absorb the CO₂ in syngas by water. Hou Debang envisaged washing with ammonia-water instead of water. He used the ammonia produced during synthetic ammonia production to generate ammonia-water that replaces water in CO₂ absorption. In this way, ABC is produced while purifying the syngas, enabling the combination of the process of de-carbonisation with the ammonia processing plant. With this method of establishing small N fertilizer plants, special materials such as stainless steel are not required and greatly reduce investment on energy consumption and production cost. It also reduces equipment manufacture, difficulty in installation and production operation and management. Furthermore, products could be used immediately, reducing losses due to nutrient decomposition and save on packaging costs. These advantages led to the chemical fertilizer development under the conditions in China at that time. Minister Peng Tao decided to make use of the existing synthetic ammonia plant at the Shanghai Research Institute of Chemical Industry and transform it into a small N fertilizer test plant with an annual production of 2,000 t of synthetic ammonia together with 8,000 t of ABC, for demonstration at the county level.

In the spring of 1958, Hou Debang cooperated with relevant organizations in Shanghai to carry out technical design, manufacture of equipment and installation tests. By the end of April 1958, the demonstration plant was built and was

operational on May Day. The process ran smoothly, producing the first batch of ABC fertilizer. Provincial cities adopted the complete set of equipment with fixed design and standardized manufacturing. 13 sets of N fertilizer experimental plants at the county level were built. From gasification with coal and coke to the production of ABC, the wide spread adaptability of this new technology was further tested in order to achieve commercialization and promotion to other areas. Experiences of these plants were noted. At the beginning of 1958, Shanghai Research Institute of Chemical Industry and Beijing Chemical Test Plant established experimental plants with annual capacities of 2,000 t and 10,000 t respectively. Subsequently, Dalian Chemical Industries Limited built a small experimental plant capable of an annual production of 800 t of synthetic ammonia and ammonia-water. From 1959 to 1960, a total of 200 domestic N fertilizer plants with small annual production were built one after another.

In the midst of carrying out their pilot tests, due to insufficient skill in the gasification operation, the composition of effective gas was slightly low while CO_2 was slightly high. In addition, there was a serious problem of ammonia leakage in the process such as absorption of ammonia by carbonisation and product separation, causing an imbalance of ammonia and CO_2 in the entire system. After carbonisation, the conversion gas still had a large volume of CO_2 being brought to the process of copper washing, causing overloading. After purification, the microelement index could not reach the technological requirements and the method of carbonisation was almost abandoned at its early stage. Through his experiments and research, Hou Debang put forward operational conditions and parameters to resolve ammonia absorption and the carbonisation process leading to stable and high production. He introduced the method of reducing the temperature of ABC and other measures that raised the stability of ABC. He gave guidance to various places in carrying out proper experiments and at the Danyang Chemical Fertilizer Plant in Jiangsu Province, he was the first to solve the balance between CO_2 and ammonia, achieving the objectives of stable and high production and low energy consumption. This marked the success of the new technology of manufacturing ABC by the technical process of synthetic ammonia through carbonisation. The technology was immediately promoted throughout the country and more than 1,000 plants were built in succession. Some plants went on to expand their capacity to increase production. From the middle of the 1970s, the production of small N fertilizer plants made up more than half of the country's N fertilizer output, contributing greatly to the agricultural development of China.

2.1.2.2 Manufacturing synthetic ammonia by the technical purification with three catalysts process

The development of N fertilizer industry in China started with the building of medium-sized N fertilizer plants. Besides providing large quantities of N fertilizer to agriculture, these medium-sized fertilizer plants also nurtured a large batch of talents for the chemical industry departments, provided many scientific achievements and accumulated relatively rich production experiences. Manufacturing of synthetic ammonia by the purification with three catalysts process is the most outstanding achievement in the scientific research.

At the end of 1964, Chief Engineer Chen Guanrong, Deputy Chief Engineer Huang Hongyu and others in the Number One Design Institute of the Ministry of Chemical Industry put forward the use of coal as raw material and the use of three catalysts (zinc oxide desulphurizing catalyst, low temperature conversion catalyst and methanation catalyst) for manufacturing synthetic ammonia by the process of purification. In the spring of 1965, the Ministry of Chemical Industry organized the relevant departments to launch a mass campaign and the Dalian Institute of Chemistry and Physics of China Academy of Sciences was put in charge of experiments in the formulation and method of preparation for two catalysts and one desulphurizer. The Shanghai Research Institute of Chemical Industry was put in charge of experiments on 1L primary particle catalyst and desulphurizer. Beijing Chemical Pilot Plant took charge of experiments on 200L catalyst and the catalyst plant of Nanjing Chemical Industry was in charge of trial production and actual production of catalysts. Upon examination and verification, the performance of the catalysts was good. In October 1966, the third stage of expansion of the Shijiazhuang Fertilizer Plant chose to manufacture synthetic ammonia by the purification with three catalysts process was completed and went into operation.

From 1964-1968, as one of the leaders of the group that developed the new technique of purification with three catalysts, Huang Hongyu led in the entire process, from research, pilot test to adoption of the technique by the production plants. He found that it was not easy to grasp the performance of methanation catalyst that used naturally-occurring diatomite as carrier and suggested replacing diatomite with alumina to facilitate standardisation of carriers and to facilitate the recovery of precious heavy metals from catalyst wastes. With regard to the production flow, Huang Hongyu advocated CO_2 removal before low temperature conversion. The plants that use coal or heavy oil, would save on steam and reduce consumption of hydrogen gas during methanation. With regard to equipment, he put forward many ideas for improvement, such as structural design of the desulphurization pump, changing mechanically sealed multi-spring structure to single spring, changing the sealed impeller to a half-open one and adding a filter to the front of the pump to solve the problem of blockage by suspension sulphur. During production, he solved key technical problems such as corrosion of equipment for desulphurization, material quality and structure of turbo recycle compressor and heat-exchanger pump. These improved greatly the three catalysts purification technique and achieved success in commercialization. This success in putting into production the three catalysts purification process through the Chinese' own efforts laid a sound foundation in the subsequent development of synthetic ammonia using natural gas and petroleum as raw materials.

2.1.2.3 Innovations in domestic production of large N fertilizer plants

At the beginning of the 1980s many people were worried about the risks of developing new technology. The design and construction organizations were rather keen on importing whole sets of installations. Chen Guanrong, Chief Engineer in the Ministry of Chemical Industry at that time stated that China should develop the industry based on the foundation of

imported technology and to raise the starting point in order to catch up with advanced standards in the world. He strongly advocated the adoption of introduced technology and innovation in order to achieve domestic production based on this foundation and reduce the long term dependence on foreign countries and lift China from the passive position of dependence. He put forward the concept of “the three steps to domestic production.” Step one, purchase the software package for advanced technology from foreign countries, design domestically and use equipment made in China. Step two, adopt the introduced technology to enable all equipment to be made domestically and partially improve the technology and process. Step three is innovation, that is, the integration of research, design and manufacturing to develop the application of China’s own new technology. The improvement and expansion of the Lunan Fertilizer Plant and the upgrading of the old system at the Sichuan Fertilizer Plant were accomplished through this idea of domestic production.

In the early 1960s, synthetic ammonia was obtained by using natural gas as raw material with a new technique that uses methanation to replace copper washing for the purification of syngas. When the first plant went into production, Chen Guanrong saw the significance of the technology to reduce cost and for the establishment of large-scale ammonia plants. He looked for a methanation process appropriate to Chinese resources and suitable for large N fertilizer plants with an annual production of 200,000 t.

In 1984, together with several experts, he produced the report “Concerning Domestic Foothold that Large Synthetic Ammonia Installations and Manufacture of Equipment Should Be Established” which won the support of the Ministry of Chemical Industry, the State Planning Commission and the Office of the Leading Group for Important Technical Equipment of the State Council. Arrangements were then made to upgrade the old system at the Sichuan Main Chemical Plant to one that used natural gas as raw material. The plant was made a model project in the made-in-China programme. In addition, a software package was introduced. The Number Eight Design Institute of the Ministry of Chemical Industry carried out engineering designs and domestic production of equipment. This project was built and went into production without a hitch.

In the mid-1970s the Texaco coal-water slurry gasification technique achieved success in foreign countries. In this technique, coal was ground into fine powder and mixed with water to form a suspension paste which was fed into the gasification furnace in the form of a fluid and converted into syngas under high temperature and pressure. Chen Guanrong put great emphasis on this and suggested that the software package for the technology be imported for the development of the entire set of water-coal slurry gasification technology. In 1978, he contacted the Science and Technology Bureau, the Chemical Fertilizer Department and the Planning and Design Institute of the Ministry of Chemical Industry and formed the water-coal slurry gasification promotion group. In 1984, they implemented the project of the transformation of the gas manufacturing system at Lunan Chemical Fertilizer Plant and officially started the project design.

In the process of developing the design programme, together with relevant experts, Chen Guanrong repeatedly

studied a set of totally new process: water-coal slurry pressurized gasification lower pressure with sulphur- NHD desulphurization decarbonisation - methanation, $\phi 1200$ axial diameter gas stream converter for manufacturing ammonia - urea production by full circulation of aqueous solution. The mission of designing and manufacturing the main equipment of coal grinder, gasification furnace and washing tower was accomplished. In June 1993, the modification and expansion of the Lunan Chemical Fertilizer Plant was completed, with its total investment far lower than importing the whole set of installations. In May and September of the same year, ammonia and urea of acceptable quality were successfully produced. In April 1994, the various parties carried out examination and assessment of the installations and the conclusion pointed out that: “Coal-water slurry pressurized gasification project design” is a success. Modifications were made on the basis of Texaco technology. The project operated with stability, indicating that this type of imported technology was worth promoting. The purification plant shortens the process flow, operation is stable and the technology achieves an advanced standard compared with the same type of technology elsewhere in the world. It is an extremely good method of purification that matches the coal-water slurry gasification technology and it can be made to suit local conditions for the promotion of its application. “

The synthetic ammonia and urea plants operate smoothly with flexibility and possess great production potential. In the “disposal of three waste” the emission standards have been adhered to, with very good economic benefits and the entire project has shown good economic results. The success of this set of new technology of coal-water slurry gasification and purification process carries great significance to the development of the N fertilizer industry in China under conditions of rich coal resources but relatively complex coal varieties.

2.1.3 Comparison of China’s level of technology for N fertilizer with that in advanced countries

At present, the overall strength and ability to produce N fertilizers and technical equipment possessed by China occupies a high position in the world. The production technology has reached an advanced level. However, compared with advanced countries, a gap still exists and this is reflected in the following aspects.

2.1.3.1 The scale of production is relatively small

Most domestic N fertilizer enterprises in China are decentralised management. The scale of production is from 10,000 – 100,000 t while in advanced countries scale is generally above 1 Mt. Besides, domestic N fertilizer enterprises are mostly of single-series. Currently, there are 29 plants with an annual production capacity for synthetic ammonia of 300,000 t/y, 52 medium N fertilizer enterprises with an annual production capacity of 60,000 to 180,000 t of synthetic ammonia and an annual production capacity of 120,000 to 300,000 t of urea. There are more than 500 small N fertilizers enterprises and most of them produce less than 60,000 t of synthetic ammonia annually. The majority of these

small-scale enterprises have little ability to protect themselves against risks.

On the other hand, other countries adopt single-series plants applying techniques that give maximum output. In the course of developing large-scale synthetic ammonia plants, emphasis is on key techniques and equipment, that is, preparation of syngas, ammonia synthesis and syngas compressor. This enables the annual production to range from 300,000 to 450,000 t in general. In recent years, synthetic ammonia plants built around the world are mostly super-large plants with an annual production of about 600,000 t and an annual production of urea of 1,050,000 t.

2.1.3.2 Constraints in raw material supply

The composition of raw materials used in production by domestic N fertilizer enterprises is varied with natural gas taking up 21%, coal coke 64% and the remaining 15% as residuum and naphtha. There are 15 large N fertilizer plants using natural gas as raw material with 52% capacity of the total production capacities of large plants. Seven plants use residuum and their production accounts for 24%; five plants use naphtha, producing 17%; while coal is used by two plants that produce 7 % of the total from large plants.

Among the medium-sized N fertilizer plants, those that use coal coke as raw material account for 62% of the total production capacity, 20% for those that uses residuum and 18% for natural gas as raw material. Coal coke is the main raw material used by small plants.

Plants that use natural gas account for less than 10% of all the plants. Therefore, the development of enterprises is restricted by the supply of raw materials and the lack of market competitiveness. The continuous rise of coal prices, natural gas, crude oil and power, the backwardness of production equipment and management skills, scarcity of energy-saving type equipment, low energy efficiency and severe environmental pollution resulted in some domestic N fertilizer plants working below capacity with poor economic returns.

Since the 1980s, medium-sized N fertilizer plants using residuum as their raw material experienced supply difficulties and high prices of raw materials, bringing great pressures on these plants. They proposed changing from oil to coal and adopting the technology of manufacturing syngas with coal-water pressurized gasification, a mature technology domestically. A few large synthetic ammonia installations using residuum as raw material were planned and set up but later suffered severe losses and were forced to stop production. These enterprises are faced with adjustment and reform in the composition of their raw materials.

About 87% of the small and medium-sized N fertilizer plants that use coal as raw material depend on anthracite from Jincheng region in Shanxi Province. As places of production of anthracite are concentrated in a few locations while the users are scattered, the supply of raw material cannot be guaranteed. Difficulty in transport and high prices make the continuation of production difficult. In addition, the inadequate supply of natural gas results in many of the enterprises unable to produce at full capacity.

2.1.3.3 There is room for technological development

Basically, large N fertilizer installations in China were built with imported technology and equipment from the 1970s and 80s. The level of technology at the time of introduction was advanced, but when compared with present foreign plants of the same type, the level of technology is much lower. This is mainly expressed in the weak transformation effort of the plants, relatively little adoption of new technology and the limited increase in production capacity. For example, the same types of plants in foreign countries are able to run at a capacity of 135-165% after they have been transformed, the domestic plants can only reach 120% of their capacity. The use of thin-wall tube in the one-stage converter, new conversion catalysts and advanced heat recovery technology adopted for revamping an installation have yet to be promoted and applied over a wide range of large plants.

For medium-size N fertilizer plants, problems such as the inadequate use of new technology, high-energy consumption for production, low load of plants and certain pollution caused by the production discharge exist. For the small N fertilizer plants, technology is relatively backward, equipment cannot be fully supported, and ammonia, energy and steam consumption are relatively high. Furthermore, the environmental pollution caused by the absence of a wastewater recovery system is relatively serious. Consequently, the application of new technology and enhancement of technological reform with regard to techniques and equipment should be strongly promoted among N fertilizer enterprises in order to survive, develop and grow in strength.

2.1.4 Technology and the outlook for development in the N fertilizer industry

Augmentation, integration, automation and combined production through the use of advanced technology and different techniques which are able to produce fertilizer on an economic scale, raising the utilization ratio of resources and energy, to reduce the emission of pollutants, to realize an effective extension of the industrial chain, to promote a comprehensive utilization and recycling economy, and to establish environmentally-friendly enterprises, make up the main stream for future technological development of the N fertilizer industry. It is specifically reflected in the following aspects;

2.1.4.1 Technology of manufacturing ammonia with low energy consumption

Synthetic ammonia is the basis of the N fertilizer industry. It occupies an important position in the national economy. In the course of producing synthetic ammonia a large quantity of energy is consumed. As a result, research for ammonia manufacturing technology with low energy consumption and the development of a new technology for synthetic ammonia is the focal point for the improvement of the N fertilizer industry. This technology has its foothold in the improvement and development of single technologies that include mainly mild transformation, gas turbine, decarbonisation and conversion with low heat consumption, low temperature purification, a more efficient synthetic ammonia loop and low-pressure synthesis. Through the application of these

technologies, the consumption of energy and materials in the complete production system is reduced. The best utilization of relevant resources in the system, implementation of graded utilization and circulatory utilization of energy according to the quality and amount of energy, implementation of matching process of energy utilization and energy demand to carry out development of synthetic ammonia system.

In the 1960s Kellogg (United States) took the lead in the development of natural gas as a raw material with large synthetic ammonia installations, using single-series and steam turbine as the driving force that lowered the energy consumption per tonne of ammonia to 41.9GJ, a great technological improvement.

In the 1980s, due to the effects of the worldwide energy crisis and the rise in the price of natural gas, some patent and engineering companies competed to develop new technologies that were able to lower the energy consumption per tonne of ammonia to 29.3GJ. Various low-energy consumption and large synthetic installations were set up and put into production. The actual energy consumption had achieved the anticipated target, thus enabling the synthetic ammonia industry to enter a new stage of its history. The following are the main innovations that increased production and saved energy and which can be used for commercial production.

1. The technology to obtain syngas

- a. addition of oxygen to the secondary reformer during the conversion of natural gas to enable the amount of reformed gas to be multiplied and lower the consumption of natural gas;
- b. carry out heat exchange conversion using the high-temperature reformed gas of the secondary reformer to increase production capacity of the reformed gas;
- c. addition of a pre-converter upstream of the steam converter in order to adapt to conditions of gas conversion with raw materials of high carbon and increase the production capacity of the converter;
- d. the technology of preheating burner air with flue gas in the convection section of the steam converter to save burner fuel and which is also capable of lowering the fume temperature of the converter
- e. preheat the boiler water supply using conversion waste heat or shifting reaction heat to save the consumption of natural gas used for conversion;
- f. use catalyst with low gas ratio to reduce consumption of steam used for conversion;
- g. use gasification with oxygen enriched air to replace intermittent gasification of fixed bed coal to enable the capacity of the coal gas furnace to be multiplied, raising the utilization ratio of coal and eliminating gas emission loss and pollution of the atmosphere.

2. The transformation and purification technique

- a. replacement of low and medium transformation with isothermal primary reforming of natural gas;
- b. the coal plant should use sulphur-resistant, low and medium temperature reforming catalyst for carrying out total low transformation technique and use methanation to replace the copper washing technique;

- c. develop and apply catalysts with low gas ratios to reduce consumption of steam;
- d. the technique of radial transformation furnace;
- e. add multi-stage flash evaporation to the Benfield Process for CO₂ removal to reduce energy consumption;
- f. activated methyldiethanolamine (aMDEA) carbon elimination low energy consumption technique.

3. Techniques of ammonia synthesis

- a. direct addition of molecular sieve dried fresh syngas to the synthesis converter to increase the net value of ammonia, to reduce circulatory gas volume and to save compression work;
- b. the ammonia synthesis converter uses radial internal parts and small catalyst granules to reduce resistance and raise the net value of ammonia;
- c. set up devices for slow blow-off to recover hydrogen and nitrogen.

4. Gas compressor

- a. use the three-dimensional flow compressor rotor;
- b. in normal pressure coal gasification gas synthesis, for the low pressure section, use the centrifugal compressor channelling into a reciprocating compressor at the high pressure section;
- c. in a medium plant, for medium pressure synthetic ammonia circulatory gas, use the cylinder type centrifugal compressor.

5. Technology of combined production

- a. the coal plant's medium pressure alcohol combination uses the methylation and methanation techniques to increase methanol products;
- b. gas transformation combined with urea for urea production, at the same time replacing the CO₂ elimination technique of synthetic ammonia;
- c. the technique of methanol production by oxygen addition and CO₂ addition to natural gas secondary reformer in the combined production of low pressure synthetic methanol;
- d. from the syngas for manufacturing synthetic ammonia, extract CO for the combined production of methanol raw material to carry out production of oxo methanol, formic acid and acetic oxide.

6. Urea technology

- a. use the UTI twin-converter-synthesis and partial medium pressure CO₂ stripping technique for urea conversion by total recycling of aqueous solution, by adding one synthesis converter, production capacity can be raised by about 60%. This greatly reduces the consumption of steam;
- b. urea condensate used as natural gas synthetic ammonia stripping saturation and natural gas treatment to save gas consumption of steam used in stripping;
- c. the technique of granulation for producing large urea granules.

2.1.4.2 Optimizing the choice of raw materials

At present, the N fertilizer industry is for the optimization and diversification of raw materials for manufacturing ammonia, adoption of advanced technology, reduction of production

costs and improvement of the environment. Adoption of a clean coal gasification technology to manufacture synthetic gas that is simple and feasible with raw materials available locally is an urgent issue for the small and medium-size plants that produce 60% of the total N fertilizer in China.

The coal gasification technology used in China is the water-gas converter process where the furnace is old and the technology backward. The utilization ratio is low and the price of raw material is high. Technological reform is badly needed.

For synthetic ammonia, the more commonly used technology in China is the Shell coal dust gasification. The main characteristics of this technology include the strong adaptability to the types of coal, high ratio of carbon conversion, low consumption of oxygen, high production capacity of a single converter, high heat efficiency, minimum maintenance, and safe and reliable. 15 sets of coal gasification installations using the Shell process were imported in succession. Of these, seven are used for the manufacture of synthetic ammonia. Shell Company provided the software package for basic design and the first Shell installation with the engineering and design details completed by the Wuhuan Chemical Engineering Company was started-up and fed with raw materials at 3:18pm on May 17, 2006. On that day, synthetic ammonia of acceptable quality was produced. It is reported that this installation is the first to go into production among the seven sets that adopt the Shell process to produce synthetic ammonia in China. It is also the first Shell coal gasification plant for the production of synthetic ammonia in the world. The establishment and operation of this installation is used, not only as a reference by the other similar installations, it is also hailed as an example of success in adopting foreign advanced technology to reform the domestic conventional industry.

The "oil change to coal" project implemented by the Hubei Shuanghuan Science and Technology Co., Ltd. accumulated a total investment of RMB719 M. Construction work began in June 2001. Originally, Shuanghuan produced 200,000 t/y of synthetic ammonia with high-priced heavy oil as raw material. The much cheaper coal dust from Henan Province replaced the heavy oil. In terms of raw material consumption, carbon conversion ratio and heat efficiency, the project showed distinct advantages over other similar techniques. According to estimates, the price difference between oil and coal under normal operation of the coal gasification installation, combustion of 1.7 t of coal is equivalent to 1 t of heavy oil. If 2 t of coal dust replaces 1 t of heavy oil, an annual production of 150,000 t of synthetic ammonia will reduce the production cost of the installation by about RMB200 M. Shuanghuan smoothly achieved the transformation from high-price oil to low-cost coal and it has fundamentally raised the core competitive power for its main product.

Presently, the domestic development of syngas technology by using coal dusts such as bituminous coal and brown coal, and coal-water slurry, apart from the advanced technologies of Shell coal dust gasification, the Texaco coal-water slurry gasification, Enders furnace coal gasification and GSP coal gasification from abroad, using the agglomerating ash process of coal gasification, is the dominant one. In particular, the new multi-nozzle (opposed type) coal dust pressurised gasification technology for which China owns autonomous

intellectual property rights where the energy consumption and investment are lower than technology imported from abroad has great promotional application values and good business prospects.

The N fertilizer using synthetic ammonia by gasification now occupies a main position in China and has enjoyed continuous and rapid development. In new and expanded plants, annual production capacity is mostly in the range of 150,000-300,000 t. Their raw materials of coal, petroleum and natural gas are restricted by domestic petroleum and natural gas resources. The production with coal as raw material is gradually showing its competitive advantage and it will be the trend in the future. At the same time, domestic gasification techniques have made relatively good progress. In the case of newly developed gasification techniques such as four-nozzle coal-water slurry pneumatic bed gasification, commercial demonstrations are being conducted while for dry coal dust pneumatic bed gasification, pilot plants are being operated. The pressurized fluidised technique has entered the stage of industrial development. The development of domestic gasification techniques will support the coal-based N fertilizer industry with technology of autonomous intellectual property rights to promote the comprehensive development of the synthetic ammonia industry.

2.1.4.3 Combined production and re-processing technologies

N fertilizer enterprises develop the combined production of hydrogen and carbon – multi-product techniques used in the chemical industry and integrated with synthetic ammonia installations to achieve the objective of maximum operations. At this juncture, N fertilizer enterprises can carry out the following:

1. Develop combined products according to technological conditions

When coal is the raw material for the production of synthetic ammonia, without shifting to CO, semi-water gas can jointly produce chemical products like methanol, formic acid, dimethylether and methylformate. The use of boiler steam was promoted to generate electricity by back pressure before applying the technique of combined heat and power production of steam from technical processes for the enterprises to fully make use of the advantages of resources and technology.

2. Development of new products according to comprehensive utilization

In the course of production, the enterprises emit large volumes of waste gases, wastewater and fag end. These wastes are also chemical raw materials that can be utilized. For example, furnace clinker from the gas manufacturing furnace and the boiler can be used to produce bricks for construction. If these wastes are recovered and utilized to develop new products, not only can the economic benefits of the enterprise be increased but environmental pollution can also be greatly reduced. These are good social as well as environmental benefits.

3. Development of new products based on integrated processing

Many products of N fertilizer enterprises are raw materials of other chemical productions. They are valuable for development and utilization. Integrated processing of these products can result in a series of chemical products with good economic benefits and good market potential such as hydrogen peroxide, dimethyl ether, tetrahydrofuran and methyl-carbonate.

2.2 Development of N fertilizer enterprises

2.2.1 Characteristics of the N fertilizer enterprises in China

N fertilizer enterprises in China are divided into three types according to their scale, that is, small, medium and large-sized facilities. The former National Economy Commission, the State Planning Commission, the State Statistical Bureau, the Ministry of Finance and the Ministry of Labour and Personnel jointly issued Document *Jing Qi* [1988] No. 240 which stipulated that: Enterprises of synthetic ammonia (with methanol) with an annual production capacity of above 300,000 t are termed as the Large I Type. Those with an annual capacity of 150,000-300,000 t are referred to as Large II Type. Enterprises whose annual production capacity is 60,000-150,000 t belong to the Medium I Type. Medium II Type refers to those with an annual capacity of 40,000-60,000 t. An enterprise with an annual capacity below 40,000 t is the Small Type.

Besides stipulating the types of synthetic ammonia enterprises, the Document also classified enterprises into Large, Medium and Small types based on annual production capacity. These enterprises include those of sulphuric acid, phosphate fertilizers (ordinary calcium, calcium-magnesium), phosphate ore and pyrite. The following is an account of the development of N fertilizer enterprises according to their type.

2.2.1.1 Establishment and development of large imported N fertilizer enterprises

In the 1970s China imported from Holland, Japan and France (Table 2-1), plants with a daily production capacity of 1,000 t of synthetic ammonia and 1,620-1,740 t of urea.

These imported plants were technically different because of the raw materials they used. Details of the relevant technologies are given in Section 2.1.

Owing to the increased price of energy, enterprises with fuel oil as raw material for the production of synthetic ammonia were forced to change their feedstock. The Guangzhou Petrochemical Plant that used light oil as raw material shut down their chemical fertilizer installation in 2002 and sent it to the Aksu Prefecture in Xinjiang Province at their own cost. The chemical fertilizer plant of Jinling Petrochemical industry used Texaco coal-water slurry gasification to produce synthetic ammonia. The N fertilizer plant of Anqing Petrochemical Industry, the Dongting N Fertilizer Plant of Baling Petrochemical and the Hubei Chemical Fertilizer Plant

used the Shell dried coal dust gasification for the production of synthetic ammonia. The plan to switch from light oil to coal by these three enterprises take effect in the later half of 2006 or in 2007. By adopting the Shell dried coal dust gasification process, the production cost will be reduced to a great extent. The Dalian Dahua Group adopted the Shell Process. Zhenhai Petrochemical Industry and the Jiujiang Branch of China National Petroleum Corporation switched from residuum to de-oiled asphalt. The fertilizer plant of Wu Petrochemical, Inner Mongolia Chemical Fertilizer Plant, Lanhua Company and Ningxia Chemical Plant have all switched to natural gas as raw material.

Driven by progress in technology and market competition, almost all the large N fertilizer enterprises are carrying out technical revamps or expansion with the objective of saving energy to increase competitiveness.

Yuntianhua Co. Ltd. carried out technological innovation that centred on increasing production by reducing energy consumption. Originally, the company had a synthetic ammonia plant with a daily production of 1,000 t built in the 1970s. Two relatively big revamps of energy saving to increase production were implemented in 1988 and 1995 and capacity reached 1,148 t of synthetic ammonia with actual total energy consumption per tonne of 34.1GJ. The third revamp took more than 3 years but the investment was less than RMB400 M. The revamp increased the capacity of synthetic ammonia production from 400,000 t/y to 500,000 t/y and the capacity of urea production from less than 600,000 to 750,000 t/y with total energy consumption per tonne of less than 33.9GJ. Whilst there was no increase in manpower, the scale of the enterprise expanded, energy consumption went down and the benefits were increased.

The chemical fertilizer plant of Cangzhou Dahua Co. Ltd. was also imported in the 1970s. In the 30 years of operation, two revamps have been carried out. The first was in July 1988 and involved six items, including the one-stage converter. On completion of the revamp, daily production of synthetic ammonia increased by 1.2% and energy consumption per tonne drop by 0.12GJ. From 1999 to 2001, taking the opportunity of a major repair, the second energy saving revamp was accomplished resulting in production increase and energy consumption reduction.

The chemical fertilizer plant of Daqing Petrochemical was set up in September 1976. The plant was originally designed to produce 300,000 t/y of synthetic ammonia and 480,000 t/y of urea. Since 1986, several hundreds of millions of Renminbi were invested for a large-scale technological revamp of the plant. In the 1990s production capacity of the synthetic ammonia and urea plants reached 360,000 t/y and 570,000 t/y respectively. 2004 saw another expansion and production of synthetic ammonia reached 1,500 t/d and the production capacity of urea was expanded to 2,300 t/d. This is an increase of 50% respectively when compared with the original design. Urea of excellent quality was produced at the beginning of November 2005. After the reform, not only did production increase, but energy consumption per tonne of ammonia was reduced. Consumption of ammonia per tonne of urea was also reduced.

The Chitianhua Group began planning to save energy and reduce consumption at the beginning of the 1990s. The

Table 2-1 List of Chinese enterprises that import large installations for N fertilizer production

| No. | Name of Enterprise | Raw Material for Synthetic Ammonia | Product |
|-----------------|--|------------------------------------|---|
| 1 | Sichuan Chemical Main Plant | Natural gas | Urea |
| 2 | Liaohe Chemical Fertilizer Plant | Oil field gas | Urea |
| 3 | Luzhou Natural Gas Chemical Industry | Natural gas | Urea |
| 4 | Cangzhou Chemical Fertilizer Plant | Oil field gas | Urea |
| 5 | Yunnan Natural Gas Gasification Plant | Natural gas | Urea |
| 6 | Chishui Natural Gas Gasification Plant | Natural gas | Urea |
| 7 | Chemical Fertilizer Plant No. 2 of Qilu Petrochemical (withdrew from chemical fertilizer production in 2002) | Oil field gas | Urea |
| 8 | Zhongyuan Chemical Fertilizer Plant | Oil field gas | Urea |
| 9 | Sichuan Tianhua Ltd. | Natural gas | Urea |
| 10 | Jianfeng Chemical fertilizer Plant | Natural gas | Urea |
| 11 | Jinxi Main Natural Gas Chemical Plant | Natural gas | Urea |
| 12 | China BlueChemical Ltd. (2 sets) | Natural gas | Urea |
| 13 | Chemical fertilizer plant of Daqing Main Petrochemical Plant | Oil field gas | Urea |
| 14 | Chemical fertilizer plant of Urumqi Main Petrochemical Plant (second set) | Natural gas | Urea |
| 15 | Ningxia Chemical Industry (second set) | Natural gas | Urea |
| 16 | Chemical fertilizer plant of Jinling Main Petrochemical Plant | Naphtha | Urea |
| 17 | Chemical fertilizer plant of Anqing Main Petrochemical Plant | Naphtha | Urea |
| 18 | Chemical fertilizer plant of Guangzhou Main Petrochemical Plant (withdrew from chemical fertilizer production in 2002) | Naphtha | Urea |
| 19 ¹ | Dongting Nitrogenous Fertilizer Plant of Baling Petrochemical Industry | Naphtha | Urea |
| 20 ¹ | Zhongshihua Hubei Chemical Fertilizer Plant | Naphtha | Urea |
| 21 | Chemical Fertilizer Plant of Zhenhai Main Petrochemical Plant | Residuum | Urea |
| 22 | Chemical Fertilizer Plant of Urumqi Main Petrochemical Plant | Residuum | Urea |
| 23 | Ningxia Chemical Plant | Residuum | Urea |
| 24 | Jiujing petrochemical Plant | Residuum | Urea |
| 25 | Chemical Fertilizer Plant of Lanhua Company | Residuum | Urea |
| 26 | Inner Mongolia Guhua Fertilizer Plant | Residuum | Urea |
| 27 | Synthetic Ammonia Plant of Dahua Group | Residuum | Ammonium nitrate, soda |
| 28 | Shanxi Chemical Fertilizer Plant | Coal | Nitric acid, nitric-phosphatic fertilizer |
| 29 | Weihe Chemical Fertilizer Plant | Coal | Urea |

¹ When the two enterprises of Dongting and Hubei imported their plants, they were set up using natural gas as raw material. Subsequently, as gas produced in Sichun was inadequate to supply other provinces, they switched to light oil. Production capacity dropped by 15%. After the revamp in 1988 and 1989 to increase production and save energy, production capacity was back to 100%.

technological revamp project, for the principal part of the installation for energy saving and increased production was completed in 1996. After 3 years of adjustment, improvement and optimization, the anticipated target was reached. An increase of 22% of synthetic ammonia compared with the original design was achieved and urea production increased by 30%. Overall energy consumption for synthetic ammonia production was decreased by 13.5%. At the same time, the process condensate was fully recovered and this eliminated pollution of water bodies. In November 2000, the project

went through the acceptance test by the Guizhou provincial government.

Many large chemical fertilizer plants such as the Lutianhua Group, the Huajin Group and Jianfeng Chemical Industry carried out revamps for energy saving, consumption reduction and production increase. It is the continuous revamps of the large fertilizer plants that spurs the ongoing progress made in the standard of synthetic ammonia production, thus reducing the gap with international advanced standards.

2.2.1.2 Medium enterprises – the cradle of development of China's N fertilizer industry

The development of China's N fertilizer industry began with the establishment of medium-sized plants. Beginning in the mid-1950s, with help from the former Soviet Union, chemical fertilizer plants of Jihua Company, Lanzhou Chemical Fertilizer Plant of PetroChina and the three chemical fertilizer plants of Taiyuan Chemical Industry Group Corporation with production capacity of 50,000 t of synthetic ammonia and 90,000 t of ammonium nitrate were set up. In addition, they designed their own installation with an annual production capacity of 75,000 t and set up the Sichuan Chemical Plant to produce ammonium nitrate. A fixed design for a yearly production of 50,000 t of synthetic ammonia was drawn up. During the 1960s, the synthetic ammonia branch of Quzhou Chemical Plant, Wujing Chemical Plant and Guangzhou N Fertilizer Plant were built. Later, the Kaifeng Chemical Fertilizer Plant in Henan Province, People's Liberation Army Chemical Fertilizer Plant in Yunnan Province, the Shijiazhuang Chemical Fertilizer Plant, Huainan Chemical Fertilizer Plant in Anhui Province and Jianjiang Chemical Fertilizer Plant in Guizhou Province were built.

During the mid-1960s, the Luzhou Natural Gas Chemical Plant and the Xingping Chemical Fertilizer Plant were set up with imported technology from Britain and Italy, the former using natural gas as raw material with urea as the processed product of ammonia while the latter's raw material was heavy oil with ammonium nitrate as the ammonia processed product. After more than 10 years of development, a total of 55 medium N fertilizer enterprises in the traditional sense were set up. Of these, 37 produced urea. The rest produced ammonium nitrate and ABC. Among these 55 medium N fertilizer enterprises, 33 used coal as raw material; nine used heavy oil and 13 used gas (including natural gas, oil field gas and coke-oven gas). These medium-sized N fertilizer enterprises are mainly divided into two types. One type was ABC plants with capacity of ammonia production equivalent to 45,000 t of NH_3 /year. Examples of this type include the Jiangxi Ammonia Plant, Baoji N Fertilizer Plant and Xuanhua Chemical Fertilizer Plant. The other type was urea production plants with capacity equivalent to 60,000 t of NH_3 /year. Shijiazhuang Chemical Fertilizer Plant, Yinchuan Chemical Fertilizer Plant and Lunan Chemical fertilizer Plant are examples.

At the end of the 1970s to early 1980s, a number of large synthetic ammonia plants and small N fertilizer plants that produced ABC, and medium N fertilizer enterprises entered the stage of adjustment of economic scale, with revamps of fertilizer types and energy saving. Eight medium N fertilizer enterprises that originally produced carbon ammonium switched to the production of urea.

At the start of the 21st century, 52 medium-sized N fertilizer enterprises still remain active, with an annual production capacity of 8.67 Mt, accounting for 21% of the total production of synthetic ammonia in China. 65.5% of the plants used coal coke as their raw material, 22.6% used natural gas (coke-oven gas) and 11.8% used heavy oil. By the middle of 2003, the number of medium N fertilizer plants was reduced to 49 with yearly production of synthetic ammonia reduced to

5.8 Mt, 15.3% of the total production of synthetic ammonia throughout the country.

With the reform policy and openness being implemented, injection of capital and participation of privately operated and powerful energy enterprises, changes in the composition of raw materials, expansion of plant capacities and progress in production technology, the Chinese N enterprises experienced great changes. The Xingping Chemical Fertilizer Plant (presently Xinghua Group Co., Ltd.) that used heavy oil as raw material was built in 1965. The production capacity then was 50,000 t of synthetic ammonia and 110,000 t of ammonium nitrate. After subsequent revamp, the annual production of synthetic ammonia reached 100,000 t. During the period 1991-1995, using its own capital, the annual production capacity for synthetic ammonia was raised from 100,000 t to 150,000 t. By the year 2000, the policy of "changing from oil to gas" was implemented. The revamp to expand the production of ammonium nitrate was carried out and the annual production capacity of synthetic ammonia reached 180,000 t and ammonium nitrate 330,000 t. The total industrial output value in 2004 was increased by 2.6 times compared with that in 2000. The Gaolianghe Branch of the Beidahuang Agriculture Co., Ltd. in the province of Heilongjiang will use heavy oil as raw material to produce 120,000 t of synthetic ammonia per annum and change the 200,000 t urea installation to one of Texaco coal-water slurry gasification using coal as raw material.

Supporting facilities also underwent corresponding revamps, enabling the production capacities for synthetic ammonia and urea to reach 180,000 t and 300,000 t respectively. Enterprises found it difficult to cope with the rising prices of heavy oil, and in 2001, the Changshan Chemical Fertilizer Group of Jilin Province adopted the technology of enriched continuous gasification to carry out a revamp. Due to a sharp increase in the price of anthracite, it was decided, in 2003, to adopt Enders technique. Construction was carried out and the effects were observed in the same year. Coal dust gasification and localization of materials were achieved, enabling the production capacity for synthetic ammonia to be raised from 120,000 to 180,000 t/y and the urea processing capacity from 200,000 t/y to 300,000 t/y. The cost of urea was correspondingly reduced by about RMB150/t. The success of this technical revamp enabled enterprises to free themselves from their predicament. Originally, the Tianjin Base Plant used heavy oil as the raw material in their production of synthetic ammonia. In 2003, the plant started the project of "switching from oil to coal" by adopting the technology of normal pressure agglomerating ash fluidised bed gasification from the Qinjin Gasification Equipment Co., Ltd. of Shaanxi Province. In the second half of 2005, test production proved to be successful and production costs were greatly reduced.

Participation by strong enterprises spurred the development of medium-sized N fertilizer enterprises. Jincheng Coal Industry Group started a joint venture with the government of Kaifeng City. In May 2004, the joint venture was listed as Kaifeng Jinkai Chemical Co., Ltd. There was effective reorganization of the assets of the synthetic ammonia system of the original Kaihua Group of Kaifeng City. Jincheng Coal Industry Group owned 51% of the shares. Based on 130,000 t/y of total ammonia, Jinkai managed to run the plant at full

capacity and expanded production to 160,000 t/y and carried out overall renewal of the existing production process. The company is getting ready to build another new production facility with a capacity of 180,000-300,000 t of total ammonia per year. Shijiazhuang Chemical Fertilizer Group Ltd. signed an agreement with Jincheng Coal Industry Group in August 2004 to establish Shijiazhuang Jinshi Chemical Fertilizer Ltd. with registered capital of RMB160 M. Jincheng Coal Industry Group held 56.3% of the shares. This provided strong support to the development of the Shijiazhuang Chemical Fertilizer Plant.

Participation by private enterprises also expedited the development of Chinese medium enterprises of N fertilizers. Ulashan Chemical Fertilizer Ltd. of Inner Mongolia was first built in 1970. In September 2001, the company turned from a state company to a privately operated joint stock company. Currently, the company has six subsidiaries. Synthetic ammonia capacities was raised from 80,000 t to the present 300,000 t, while urea capacities expanded from 60,000 t to 260,000 t. The ammonium nitrate capacities expanded from 110,000 to 280,000 t. Panjin Zhongrun Chemical Industry Ltd. is a big private enterprise formed after the acquisition of Panjin Chemical Industry Ltd. by Panjin Zhongrun Industries Group Ltd. of Liaoning Province. Since the existing supply of natural gas cannot be guaranteed, the enterprise is currently planning to reform its raw material for synthetic ammonia by replacing natural gas with local coal. Medium N fertilizer plants like Qian'an Chemical Fertilizer Plant and Hubei Jinyuan Chemical Industry Ltd. (former Exi Chemical Plant) were also converted to private operation.

According to the statistics of the Nitrogen Fertilizer Industry Association, in 2005, medium N fertilizer enterprises produced 7.3 Mt of synthetic ammonia, which contributed 15.8% of the total production and a year-on-year increase of 8.2%. Urea production was 7.4 Mt, which equated to 17.9% of the total production. Apart from urea, they also produce bases for ammonium nitrate, concentrated nitric acid, sodium nitrate, sodium nitrite and methanol.

2.2.1.3 Small N fertilizer plants – China's original creation

Small N fertilizer plants in China adopt carbonisation for ammonia synthesis in the production of ABC, a technology developed by the Chinese themselves. After decades of development, small N fertilizer plants are occupying an important position in the N fertilizer industry in China. According to the statistics of the Nitrogen Fertilizer Industry Association, in 2005, the accumulated production of synthetic ammonia throughout the country was 46.3 Mt. Of this, the quantities produced by large, medium and small N fertilizers enterprises were 8.4 Mt, 7.3 Mt and 30.6 Mt respectively. The Small N fertilizer enterprises here include those of ammonium phosphate. These quantities accounted for 18.2%, 15.8% and 66% of the total synthetic ammonia produced in the whole country respectively. The accumulated production of N fertilizers throughout the country was 32.0 Mt (conversion to 100% nitrogen content). Large, medium and small enterprises of N fertilizers produced 6.4 Mt, 4.3 Mt and 18.5 Mt respectively. These accounted for 19.9%, 13.5% and 57.7% of the total production of N fertilizers in the whole country

respectively. Total urea production throughout the country was 41.5 Mt (product quantity). Of this, large, medium and small enterprises of N fertilizers produced 13.1 Mt, 7.4 Mt and 20.9 Mt and their shares in the total production of urea in the whole country were 31.5%, 17.9% and 50.6% respectively.

During the 1960s, the renowned Chinese chemist Hou Debang took the lead in developing the process of combined production of synthetic ammonia and ABC. Danyang Chemical Fertilizer Plant was built and put into operation. It provided the experience for small N fertilizer plants in achieving industrial production. After several years of development, the technology began to mature. After 1966, the small N fertilizer industry developed rapidly. Counties began building their small fertilizer plants and by 1979, 1,533 small N fertilizers plants were built throughout the country. However, economic returns were poor in some enterprises which suffered severe losses. After continuous adjustment and redevelopment, some enterprises grew stronger while some closed down. Since the seventh five-year plan, small N fertilizer enterprises carried out extensive adjustments with regard to composition of products and technology. A total of 143 projects in 126 enterprises shifted from ABC to urea production and this changed the situation where small N fertilizer enterprises produced only low-analysis ABC. At present, among the small N fertilizer enterprises, about 120 are still producing urea.

The development of small N fertilizer enterprises shows the following features.

1. Capacity of installations is expanding continuously while the number of enterprises is decreasing.

Management of small N fertilizer enterprises are aware of drawbacks such as low-level technology, high cost of production and relatively outdated equipment. Once an opportunity arises, they seize it and expand their business. Changing from ABC to the production of urea provides an opportunity for the enterprises. In some, annual production of 30,000 t synthetic ammonia and 40,000 t of urea became 60,000 t of synthetic ammonia and 80,000 t of urea. Some originally small N fertilizer enterprises such as Luxi Chemical Industry in Shandong Province, Meifeng in Sichuan Province, Fengxi in Shanxi Province, Yihua in Hubei Province and Hualu and Hengsheng in Shandong Province have already developed into big enterprises with the capacity to produce more than 300,000 t of synthetic ammonia. In some enterprises, the production capacity for urea has exceeded 1Mt. Expansion of the scale of an enterprise enables the overall level of equipment, level of technology, level of management and competitiveness to be raised while greatly reducing production cost. Due to expansion and the gradual elimination of enterprises with poor management, the number of small enterprises was reduced from 1,533 in 1979 to 854 in 1996 and a further reduction to 497 in 2003. However, at about 50%, the share of small enterprises in the total production of N fertilizer in the whole country has not decreased.

2. The innovative system of organization has promoted the development of small N fertilizer enterprises

The depth of reform impelled the small enterprises to implement innovative system of organization. Great changes have taken place with respect to the system of management, form of organization, respect for property rights and mechanism of business operation. For example, the Linggu Chemical Industry Ltd. in Jiangsu Province carried out asset reorganization in the bankrupt Jiangyan Chemical Fertilizer Plant, acquired its asset control rights and enabled its annual production of urea to reach 130,000 t, with yearly profit and tax amounting to RMB10 M. With its successful expansion at low cost, Linggu Chemical Industry further implemented reform in the share system where staff and workers hold 55% of the total stock. Company property rights are transparent. This mobilized the zeal of the staff and workers. From March 2001 to April 2002 technological reform for the production of 120,000 t of synthetic ammonia and 200,000 t of urea was accomplished in merely 13 months. By 2002, production capacity of urea reached 450,000 t.

The Fengxi Fertilizer Industry Group set up in 1998 in the province of Shanxi joined hands with several small chemical fertilizer enterprises in Shanxi Province and, taking the Linqi Main Chemical Plant as its foundation, set up a "united fleet" of small fertilizer enterprises. This is yet another model of development among small N fertilizer enterprises. With the growth in strength of enterprises, they continued to open up new opportunities for development. In July 2003, the Fengxi Group and Jincheng Anthracite Mining Group Ltd. made joint investment to set up Shanxi Jinfeng Coal Chemistry and Technology Co., Ltd. Upon formation of the new company, plants were built at Gaoping and Wenxi in Shanxi Province for annual production of 300,000 t of synthetic ammonia, combined production of 520,000 t of urea and 60,000 t of methanol; 160,000 t of synthetic ammonia, combined production of 300,000 t of urea and 40,000 t of methanol respectively. The Wenxi project started production in 2005 and the Gaoping project started in the first half of 2006.

A large number of small N fertilizer enterprises, with the exception of big groups and joint-stock enterprises, adopted the stock co-operation system. With support from local government, state assets in some enterprises were withdrawn according to law to establish new private operations. The Alliance Group, Dongping Ruixing, Qilu Yihua and Yancheng Hengtong in Shandong Province all set up private operations that created very good conditions for the development of these enterprises. Similar events were taking place in other provinces.

3. Technological progress and the strong advocacy of technological reform have raised the standard of small N fertilizer enterprises

In past decades, small N fertilizer enterprises which were not satisfied with the status quo, continuously developed and updated their technology. They have a very strong self-motivation for improvement. In addition, most years the China Nitrogen Fertilizer Industry Association organized many technical exchange meetings where specific projects of technological reforms were drawn up. Finally, there is support from the State. Under the joint effort of the three parties,

technical progress made by the small enterprises is relatively fast. For example, the "energy saving technology for self-sufficiency in steam for the production of synthetic ammonia" is the method that uses systems engineering to gather all measures capable of reducing energy consumption from various sources and distribute them. This was the work of the Shouguang Chemical Fertilizer Plant in Shandong which considered the strength of each plant and became the first to achieve in getting rid of all fuel coal and the reduction of two types of coal into one. In addition, there is the technique of two streams of water in closed circuit circulation used in small fertilizer enterprises that saves water and reduces the expenses of waste disposal. These techniques are promoted throughout the country by the effort of the China Nitrogen Fertilizer Industry Association which gets partial financial support from the State. It is these large and small technical modifications which must be carried out every year that made possible the continuous drop in the various consumption values. At present, a handful of small N fertilizer enterprises have achieved the objective of coal consumption of less than 1,000 kg per tonne of ammonia production, power consumption lower than 1,000 kW h and process energy consumption lower than 10M Cal.

2.2.1.4 Experiences in the development of N fertilizer enterprises and lessons learned

After decades of hard work, the achievement of the N fertilizer industry in China has attracted worldwide attention. Production of N fertilizers is able to fully meet domestic needs with a small surplus for export. This is closely tied to the rapid development of China's N fertilizer enterprises. The development of large N fertilizer enterprises depended mainly on imported technologies. China has imported installations that use different raw materials. No doubt, this has expedited the technological advancement of the N fertilizer industry of China and minimized the gap with advanced standards in the world. With the limited state financing capability, the use of foreign funds contributed to the development. Besides, the importation of large fertilizer installations also promoted the domestic development of machinery. Drawing on the management expertise of foreign countries has expedited the improvement of domestic enterprises. In order to adapt to the requirements of imported installations, personnel qualifications had to be raised correspondingly.

To date, economic and technical indices of domestic small and medium-sized enterprises still have a long way to go, to be at par with big fertilizer enterprises. However, there are relatively more repetitions in importing large installations of N fertilizer. Many sets of installations using the same raw material and same technology are imported. There are restrictions on the use of foreign funds. There is insufficient adoption, self-initiated research and development or innovation. When an enterprise adopts a new installation technology, the risk is too high and the State does not have a corresponding mechanism for encouragement or avoidance of risks. Furthermore, a number of domestic enterprises use the same foreign technology without a standardized approach is another problem.

If production plants of large N fertilizer enterprises are "imported foreign commodities" then production plants

of small and medium enterprises are “locally born and bred.” Supported by the State’s policy of preference, small and medium enterprises of N fertilizer continue to grow in strength, making an important contribution to China’s agriculture. The term “*Xiao Dan Fei*” (“small N fertilizer”) is a legacy from the period of planned economy. In reality, many outstanding small N fertilizer enterprises have overtaken the medium enterprises or even the large enterprises. According to the statistics of the China Nitrogen Fertilizer Industry Association, among the 500 small of N fertilizer enterprises, there are seven whose annual urea production hits 500,000 t, 14 of them produce 300,000-500,000 t, and eight with 200,000-300,000 t. Small N fertilizer enterprises produce more than half of the urea output in the country.

The rapid growth of these small N fertilizer enterprises is due to their own continuous development, expansion of production, sustained technical updating, expansion of product types and creation of more and better ways of marketing, not to mention the support given by the association of the trade and State policies. There is yet another factor that drives the development of small N fertilizer enterprises – the importance the State attaches to agricultural development and the farmers’ demand for fertilizer. Even though the development of small N fertilizer enterprises has been very rapid, the overall level is still not high. Apart from advanced “star” enterprises, an appreciable number of them are in difficult positions due to various reasons. Today, when the market economy plays the main role, support and preferential policies of the State gradually weaken and the leading role played by the market will gain strength, the number of small enterprises will be reduced further. Those small N fertilizer enterprises that are performing well will be on equal footing with the large and medium-sized enterprises or may even overtake them. The remaining small enterprises will have to find a way out.

Changes in the raw materials policy is worth mentioning. The production of synthetic ammonia by N fertilizer enterprises in China started by using coke, coke-oven gas and lignite. As the use of boiling oven gasification of lignite severely pollutes the environment and water, every effort was put in to developing coke as raw material. Coke was a limited resource at that time and anthracite was used to replace it. This made possible the widespread development of small and medium enterprises throughout the country. Under the conditions at that time, it was rational to adopt fixed bed intermittent gas manufacturing. At present, there are more than 9,000 sets of fixed bed intermittent gas manufacturing furnaces in production. The progress in technology and increased requirements for environmental protection created difficulties for this type of gas manufacturing. Firstly, the small and medium-sized enterprises throughout the country depend mainly on anthracite from Jincheng in Shanxi Province. There are many enterprises that face the problem of “three highs” - high raw material price, high rates of broken coal and high transport costs. Secondly, following the level of mechanization in coal mining, the ratio of culms goes up and the production of lump coal goes down. Due to the long transport distance between the mine and plant, the utilization ratio of anthracite is only about 60%. The other 40% has to be processed (made into briquettes or bars) if it is to be used for manufacturing

gas. Finally, large volumes of exhaust gas are released, causing pollution to the surrounding environment (some enterprises have already taken measures of gas recovery). Solving the problems of long transport distances, the utilization of culms and coal dust, and the use of local raw materials for manufacturing clean coal gasification technology to obtain synthetic ammonia are the main considerations for small and medium-sized N fertilizer enterprises under revamp.

There are also lessons to be learned from N fertilizer enterprises that use natural gas and residuum as raw material. Zhijiang Plant of Hubei Province and Dongting Plant in Hunan along the Changjiang River originally planned to use natural gas from Sichuan (shortened to “Sichuan gas” below) as raw material. Due to the incorrect assessments of Sichuan gas reserves, gas could not be supplied outside Sichuan and the plants had no choice but to use naphtha. As a result of the present rapid rise in oil price, they are compelled to spend huge sums of money to switch from oil to coal. This should be a good lesson. In the latter part of the 20th century, medium N fertilizer enterprises that used residuum as raw material were under pressure because of the difficulty in purchasing residuum and its exorbitant price. Even with putting forward the idea of switching from oil to coal, China was still planning to build several large synthetic ammonia plants with residuum as raw material. When these plants were built, the difficulty in getting raw materials, and high prices caused severe losses and the plants’ had to shut down operations. Finally, they had to carry out reform in raw material. Some switched to natural gas and others, de-oiled asphalt. This lesson should be noted.

2.2.2 Examples of typical enterprises

After decades of development and many years of adjustment, annexation and stock ownerships, there are still more than 580 N fertilizer plants in China. There are many excellent examples and the following are a few of them:

2.2.2.1 Typical examples of large N fertilizer enterprises with trans-regional development

Chemical fertilizer and synthetic resin are the main products of the Liaoning Huajin Chemical Industry (Group) Ltd. It is a typical example of a large chemical industry enterprise with trans-regional operations. The company owns three production bases at Liaoning Panjin, Huludao and Xinjiang Kuche. The company has more than 10 branches, with total assets of close to RMB10 B. Annual production capacity of chemical fertilizers of this group of companies is: 900,000 t of synthetic ammonia, 1.6 Mt of urea and 200,000 t of compound fertilizer. The Liaoning Huajin Chemical Industry Group originated from Liaohu Chemical Fertilizer Plant. At the time of establishment, the plants produced 300,000 t of synthetic ammonia and 480,000 t of urea per annum. During the mid-1990s it acquired Jinxi Natural Gas Chemical Industry Co. Ltd., increasing its annual production capacity by 300,000 t of synthetic ammonia and 520,000 t of urea. In January 2006, Aksu Huajin Chemical Fertilizer Co., Ltd. in the Kuche Prefecture of Xinjiang Autonomous Region, an area of natural gas production, was set up. This increased further the company’s annual production capacity by 300,000 t of synthetic ammonia and 520,000 t of urea.

The path of development followed by Liaoning Huajin Chemical Industry Group was a new route opened up when N fertilizer enterprises using natural gas as raw material are faced with shortage of resources. It is a typical case of an N fertilizer enterprise integrating the advantages in resources, production, business operation, management and technology to become a strong group. This also complies with the present trend of chemical fertilizer production plants concentrating in areas of raw material production.

The Huajin Group Company's ability to achieve the integration of resources and technology and its strategic enterprise development has a lot to do with its own innovation. At present, Liaoning Huajin Chemical Industry Group has three state level research centres on chemical fertilizers, synthetic resin and precision chemical engineering. These form the coordination and organization of scientific research, production and market services and a closely coordinated operational mechanism. With natural gas production at the Liaohe Oil Field gradually decreasing and the Huajin Group lacking adequate gas supply, the company chose the American KBR heat exchange type conversion technology to revamp its synthetic ammonia installation. After the revamp, the full load synthetic ammonia comprehensive energy consumption was 37.9GJ/t and the single consumption of natural gas per tonne of ammonia was 765m³. After the revamp, the manufacturing cost of synthetic ammonia and urea was reduced by more than RMB200/t compared with the cost before the revamp, comparable with the advanced standard in the country. In recent years, the Huajin Group has carried out more than 50 items of technical reform on the imported plants, enabling them to increase their production capacity by 10%. While working on reform in the energy saving technology, the Huajin Group also put in effort to add value to its products and market competitiveness. By cooperating with domestic scientific research organizations, it has developed new products such as urea-based compound fertilizer, long-acting compound fertilizer, special compound fertilizer for rice plants and slow release urea and other new chemical products. The production and sale of its slow release urea has reached more than ten thousand tonnes, a leader among N fertilizer enterprises in China.

Faced with ever-increasing market competition, the Huajin Group will continue to innovate along the road of development. In the coming years, they will further expand their scale and increase their profits. On the basis of accomplishing a reform and expansion project for 460,000 t of ethylene and the revamp of 50,000 t ABC to 100,000 t the Panjin Base continues with the second phase revamp project at Liaohe Chemical Fertilizer. The second phase project will focus on reform of the plant to increase production by 50%, that is, 450,000 t/y synthetic ammonia and 720,000 t/y urea. In addition, the 200,000 t compound fertilizer installation will be expanded and revamped to produce 1 Mt/y. The company will invest RMB1.4 B in its Xinjiang base to set up the second chemical fertilizer plant that includes a 300,000 t plant of synthetic ammonia and 520,000 t of urea. Upon completion of the revamp and newly established projects, the Huajin Group will have a production scale of 1.4 Mt of synthetic ammonia and 2.3 Mt of urea to become one of the biggest N fertilizer producing groups in China.

2.2.2.2 Typical examples of large domestic chemical plants

The Hualu-Hengsheng Group of Shandong Province is a typical case of a small domestic chemical fertilizer plant that has successfully turned into a large chemical fertilizer enterprise. It was formerly known as the Dezhou Chemical Fertilizer Plant, built in April 1967 and designed to produce 5,000 t of synthetic ammonia per year. By 1979, it had accumulated losses of RMB3.8 M and the plant was on the verge of bankruptcy. Through the joint efforts of the local government and the enterprise, in 1990, production capacity for synthetic ammonia was raised from 10,000 to 60,000 t and the production capacity for ABC was raised from 40,000 to 240,00 t making it a medium-size enterprise. In July 1990, the enterprise invested more than RMB80 M to successfully switch to the production of 110,000 t of urea a year. It was the first small N fertilizer enterprise to do so. Production of urea brought a new opportunity for the development of the company. The group invested more than RMB200 M to expand the production of synthetic ammonia and to set up the second urea production line. In addition, the distributed control system (DCS) from Rosemount Company (USA) was introduced and with this, the company basically achieved automation in its operation. Profits increased considerably and annual profit and taxes amounted to more than RMB50 M. In February 1996, the company was renamed the Dezhou Hengsheng Chemical Industry (Group) Co., Ltd. In November 1998, the Shandong provincial government gave its approval to transfer the entire company to Shandong Hualu Group Co., Ltd. which was renamed the Shandong Hualu-Hengsheng Group Co., Ltd. Hualu-Hengsheng Group established its C₁ chemical product chain represented by methanol, formaldehyde, organic amine and dimethylformamide which enabled the company to widen its scope of development.

In the 21st century, the Hualu-Hengsheng Group has entered a new developmental stage of combat readiness and innovation. In September 2002, it invested a total of RMB1.4 B to adopt the opposed-type four-nozzle coal-water slurry gasification technology in China that enjoys intellectual property rights. The installation was established in 26 months. Single series and with coal as raw material, the large-scale plant could produce 300,000 t of synthetic ammonia per year. In December 2004, all processes of the entire system were started and it was a success at the first test operation. The plant scored a number of "firsts" in China, for the speed of its construction and financial savings for the same type of large plants of N fertilizer. It also achieved major breakthroughs in technology, processes and raw material plans. Commencement of production of this large domestic chemical fertilizer project with autonomous intellectual property rights symbolized the end of an era when China had to depend on imported large-scale plants of chemical fertilizer production and be controlled by others. As a result, Hualu-Hengsheng was able to leapfrog to become a large enterprise of N fertilizer and entered a new stage of development. Hualu-Hengsheng Group's urea plant with an annual production of 400,000 t began operation, enabling the Group's urea production capacity to rise to 1Mt/year. At present, the company has four subsidiaries and its total assets has reached RMB3.68 B. It has one listed company, that is, Shandong Hualu-Hengsheng Co., Ltd.

2.2.2.3 Typical example of a small N fertilizer enterprise that developed rapidly

The predecessor of the Hubei Yihua Group Co., Ltd. was "Yichang Regional Chemical Plant," a small N fertilizer enterprise established in 1977 at Huting Township, Zhijiang County in the province of Hubei. Its synthetic ammonia capacity was originally designed at 10,000 t/y. Its production grew to 35,000 t/y at the end of the 1980s. ABC was the only processed product of ammonia. Carbonisation briquette was the raw material used for the production of synthetic ammonia. Development of the company was not at all smooth. It was included in the list for shut down and transfer a number of times. In the 1990s, the company continued to carry out revamps and expansion. Production capacity of a single stream unit was 80,000 t of synthetic ammonia/year. Production capacity for a single-stream of urea installation was expanded from 40,000 to 110,000 t/y. In August 1996, Hubei Yihua "A" Share was successfully listed on the Shenzhen Stock Exchange. Through merger, trusteeship and Chinese-foreign cooperation, the group has become a large enterprise group with more than 10 subsidiaries, a listed company and three Chinese-foreign joint venture companies that cover three major business domains in chemical fertilizer, chemical engineering and thermal power. In 2003, the Yihua Group produced 680,000 t of synthetic ammonia, 840,000 t of urea, 28,000 t of pentaerythritol and 280,000 t of ammonium phosphate. Sales revenue for the whole year amounted to RMB2.05 B. Profit and taxes amounted to RMB 0.2 B, 2.5 times that of 2000. In 2003, another plant was built to produce 200,000 t of NPK compound fertilizer. At the end of 2004, through participation in the reform system of state enterprise of Xingyi Main Chemical Plant in Guizhou Province, Hubei Yihua acquired the plant and formed Guizhou Xinghua Co., Ltd. and Guizhou Yihua successively. With an investment of RMB500 M, work was started at Xingyi in February 2005 for Guizhou Yihua to produce 200,000 t of synthetic ammonia and 300,000 t of urea. After more than a year of construction, work was completed in June 2006 and the plant went into production. At present, Yihua has an annual production capacity of 1.2 Mt of synthetic ammonia and 1.8 Mt of urea. The "YIHUA" brand urea, the leading product in the fertilizer trade in Hubei province is exempted from inspection by the State. Yihua is also a large producer of MAP in China as it is capable of producing phosphate compound fertilizers of high analysis of 500,000 t MAP and 400,000 t of NPK. Of these, the "CHUXING" brand MAP is a product exempted from inspection by the State. Within the next 5 years the Yihua Group will further expand and enhance its coal, phosphorus and salt chemical capacity to achieve an annual production of 2 Mt urea, 400,000 t of methanol and 100,000 t of polyalcohol. The phosphorus chemical segment will establish a base that produces 3 Mt of phosphate compound fertilizer annually, including annual production of 1Mt of NPK, 1Mt of MAP and 1Mt of DAP. The sales revenue should amount to RMB10 B by the year 2008.

The following are some factors that have contributed to the rapid development of the Yihua Group:

1. The vitality of the mechanism of a private enterprise has accelerated the development of Yihua. The sales revenue of the Yihua Group was merely RMB500 to 600M a few years

ago. It reached RMB6.3 B in 2005. The private operation mechanism was one of the very important reasons. Apart from the Head Office and the mining company which are state-owned, all subsidiaries and new projects adopt the mechanism of private operation.

2. It makes full use of talents in the development of the enterprise. One of the basic reasons that contribute to the rapid development of the Yihua Group in recent years is the importance it has attached to human resource. The correct way of looking at talent is an important driving force for the development of Yihua. "Each according to his ability" is the principle adopted as a show of respect and engagement of talent. "Paper qualification is not a means to an end" is an important feature of Yihua's policy on its employees.
3. Innovate ways of management. The Yihua Group introduced many new ideas that resulted in unique management models. For example, the company adopted the principles of "five unifications" (in sales, project investment, finance, manpower and procurement) and the "four controls" (with regard to "security, tenders, non-production expenditures, and analyses and tests), the comparison method and internal competitive bidding. The model of "five unifications and four controls" effectively solved many difficulties encountered in management following the rapid development of the company. The method of comparison greatly reduced the unit cost of products and created the atmosphere of positive competition within the enterprise. More importantly, besides reducing the costs of procurement and operation, internal management of competitive bidding has eliminated "clandestine operation" in the operation of the enterprise. ④ Funds are guaranteed. As the performance of the Yihua Group continues to improve for three years in succession, the company was permitted to allocate shares by the China Securities Regulatory Commission and this has facilitated fund raising from the stock market. With good economic benefits of the enterprise, various banks are more than willing to provide funds and support to Yihua and the abundant sources of funds have created the necessary conditions for development beyond convention.

2.2.3 Comparison between China's N fertilizer enterprises with those in advanced countries

After decades of development, the N fertilizer industry in China has grown in size and strength. Be it from the number of products or varieties of products, N fertilizer enterprises are basically able to satisfy the needs of agriculture locally. During non-application periods, some of the products are exported in order to regulate the domestic fertilizer market. Compared with advanced countries, a rather large gap still exists in some respects. Examples include the scale of enterprises, degree of concentration of industry, levels of technology, energy consumption indices, research and development capacity and labour productivity.

2.2.3.1 China's N fertilizer enterprises are small and scattered

According to data issued by "Bulletin of Economic Data of Petroleum and Chemical Industry in China" (Volume 3, 2006)

up to December 2005, there were 571 N fertilizer enterprises throughout the country. In 2005, synthetic ammonia production in the whole country was almost 46 Mt, meaning that the average production of synthetic ammonia for each enterprise was only 80,000 t, which is about a quarter of an ordinary enterprise in advanced countries. In 2000, many enterprises went through mergers, association, adjustment, changes in the system of operation and expansion. The first single series plant with daily production of 600 t synthetic ammonia was set up by an American petroleum company in 1963. In the late 1960s, single series installations with daily production of 1,000-1,500 t of synthetic ammonia were brought on stream. By the end of the 1990s, the US had more than 50 N fertilizer plants with an average production capacity of 320,000 t/y. In 1998, the average production capacity of urea in the US was 8.5 Mt. Of these, the capacity of just 25 of them totalled 7.5 Mt/y, 85% of the total US capacity.

After decades of development, through acquisition, annexation and reorganization, big enterprises in the world stood out and their scale of production continued to go up. The biggest N fertilizer production company is Yara International (Norway) with an annual production capacity of 16 Mt of N fertilizers (including ammonia, urea, and ammonium nitrate). Yara International was formerly the Chemical Fertilizer Department of Norsk Hydro of Norway. Beginning in 1979, Norsk Hydro carried out a series of big acquisitions and annexations, and currently its presence is worldwide. In the 1980s, countries where acquisition or equity participation took place included the Netherlands, Sweden, Britain and France. Later in the 1990s, the company held shares, not just in Western Europe, but also in some chemical fertilizer production enterprises in Eastern European, Russia, the US, Thailand, Vietnam, Malaysia, Brazil, Morocco and Trinidad. Annual N fertilizer production of Yara International in 2005 was close to 13 Mt and production of synthetic ammonia was 5.3 Mt. To expand production capacity of N fertilizers, Yara International and Qatar Petroleum signed, in February 2005, an agreement to build a new plant in Qatar with annual production of 1Mt ammonia and 1.1 Mt urea. Apart from Yara International, Terra Industries Inc. of the US has N fertilizer production capacity of about 11 Mt. The N fertilizer production capacity of PSC and Agrium of Canada was 9.5 Mt/y and 7.2 Mt/y respectively. The N fertilizer production capacity of SABIC of Saudi Arabia was 5.6 Mt/y while Acron of Russia had a production capacity of 2.9 Mt/y. The advantages enjoyed by these super big N fertilizer-producing companies in the production and marketing of N fertilizers are becoming more obvious. Compared with these companies, there is a relatively large difference in the scale of production of N fertilizer enterprises in China. There is still a long way to go for China.

Currently, there are more than 30 big chemical fertilizer installations in China which are of economic scale (that is, reaching a scale by which production efficiency and energy utilization efficiency can be greatly raised.) However, nearly 50 medium-sized enterprises of N fertilizers with single sets have not reached even half of the economic scale and most of the 500 or so small enterprises of N fertilizers are of single set and their scale is only 10-20% of the economic scale. All

N fertilizer plants in advanced countries reach or even exceed the economic scale of large plants.

2.2.3.2 N fertilizer enterprises in China employ too many people and production efficiency is low

Under circumstances of similar scale, the number of workers employed by Chinese N fertilizers enterprises is several times more than that of enterprises in advanced countries. For example, for a plant of 300,000 t synthetic ammonia and 520,000 t urea, the number of employees in advanced countries averages 400. In China, a plant of the same category needs around 2,000 people. The problem of too many employees is more noticeable among the small and medium enterprises than in the big ones. After adjustment and change in the administrative system, the problem of having too many employees has improved slightly in some enterprises in recent years. More employees mean lower labour productivity and competitiveness is certain to decrease.

2.2.3.3 There is a gap in the level of technical equipment

Other than for the large, imported installations, particularly those that have undergone revamps and capacity expansions and have reached international standards, the small and medium-sized enterprises in China are relatively backward with respect to technical equipment.

About two-thirds of synthetic ammonia production in China uses coal coke as raw material. By far the majority of N fertilizer enterprises that use this type of raw material were built during the 1960s and 70s. Under the "8th and 9th Five-Year Plan" technological reforms in energy savings, productivity and product variations, were carried out in some of the small and medium-sized enterprises by switching from ABC to urea, with loans from the Asia Development Bank and the World Bank, allowing the technical level of these enterprises to be raised significantly. However, a large gap still exists when compared to the advanced international standards. For example, an important indication on whether or not the production technology for synthetic ammonia is advanced is the energy consumption per tonne of ammonia. Worldwide, synthetic ammonia plants that use natural gas as raw material make up more than 80% of the total. In advanced energy saving processes, the overall energy consumption of synthetic ammonia is 7M Cal/t (29.3GJ/t) and this can be lower in advanced enterprises.

In China, the overall energy consumption of large N fertilizer complexes is 31.1GJ/t for those with low energy consumption. In 2005, the average energy consumption per tonne of ammonia was 1.3 kg of standard coal/t (equating to 37.3GJ/t). The assessment index for energy consumption per tonne ammonia of Fudao Phase II of Zhonghai Petroleum using the most advanced imported technology was 27.4GJ. Large differences exist in the level of consumption among small and medium-sized N fertilizers enterprises that use coal coke as raw material. This high energy consumption of some enterprises is almost twice that of the most advanced countries. In 2005, the average energy consumption per tonne ammonia for small and medium enterprises that used coal as raw material was 2.1 kg standard coal (61.9GJ/t). The energy consumption per tonne ammonia in advanced

ammonia manufacturing process by coal gasification in foreign countries can be lowered to 41.0GJ/t. In China, the lowest energy consumption per tonne of ammonia among the medium-sized enterprises is 51GJ/t, quite a gap compared with foreign countries. The level of overall energy consumption of installations of synthetic ammonia of small and medium-sized enterprises that use coal as raw material is 54-62GJ/t. It can be seen from this that the overall technological standard of N fertilizer enterprises in China lags behind standards in advanced countries.

Relatively large differences exist in levels of energy consumption in the production of synthetic ammonia using different raw materials. The most ideal raw material for the production of synthetic ammonia is natural gas, whose advantages include low energy consumption, does not cause pollution to the environment, reduction of investments, shorter construction periods and requires smaller land areas. These are the reasons why natural gas as raw material for the production of synthetic ammonia enjoys absolute superiority in the world. With increases in the prices of petroleum, the concentration of construction of synthetic ammonia production plants in natural gas producing regions has become an obvious trend. China should encourage the production of synthetic ammonia by using natural gas as raw material in regions with rich deposits. China has limited resource of oil and natural gas but coal reserves are relatively high. Development of clean coal gasification technique to reduce the negative effects of synthetic ammonia production using coal as raw material is also another direction to take. Large chemical fertilizer plants such as the Jinlin Petrochemical and Chemical Fertilizer Plant, the Anqing Petrochemical and N Fertilizer Plant, the Baling Petrochemical and Dongting Chemical Fertilizer Plant and the Hubei Chemical Fertilizer Plant which originally used light oil as raw material are carrying out or have completed their "oil to coal" projects. In May 2006, Hubei Shuanghuan adopted the Shell dried coal dust gasification process for synthetic ammonia production. It was the world's first success and provided information to enterprises who adopt this technique for "switching from oil to coal."

2.2.3.4 Little input for research by N fertilizer enterprises in China

Technologies for N fertilizers that reach international standards in China are basically imported. Key technologies which arise from digestion, absorption and innovation are few in number. This situation is closely related to the low input in research and development made by fertilizer enterprises. Internationally, it is thought that enterprises which set aside more than 5% of their value of sales for research and development costs will have competitive power, 2% input will keep the enterprise going while less than 1% input means the enterprise will find it difficult to survive. In China, these enterprises spend only 0.5-1% of their sales revenue or even less for research and development. This has resulted in a very weak ability to carrying out research and development and the absence of its own core development organization and core technology. China is the largest country in the world which uses coal as raw material for the production of synthetic ammonia. Even though there is the coal dust gasification

technology with au tonne omous intellectual property rights, clean coal gasification technology is still mainly imported and it is difficult to build large installations.

2.2.3.5 Brands of N fertilizer enterprises have not really been established

China has a large number of N fertilizer enterprises with many brands. However, a brand name that is well known throughout the country has yet to appear. Taking urea, which makes up about 60% of the N fertilizers in the whole country as an example, many large urea enterprises have products of excellent quality but they enjoy the brand advantage only in the areas surrounding the enterprise that produces them. This is generally referred to as "branded product in the region." The "Daqing" brand of urea is popular in the province of Heilongjiang, that even brands of urea from other provinces which are RMB100-200 cheaper than "Daqing," local farmers still go after the "Daqing" brand. However, this brand of urea is not so popular in other places. The same thing happens to other brands. Even when the quality of domestically produced urea is exactly the same as urea from foreign countries and imported urea costs RMB100-200 more per tonne, farmers are still bent on buying the imported product (particularly when the volume of import was higher in recent years). This is because farmers still harbour the idea that imported products are better than domestic products, but in recent years, there has been some improvement. However, no urea producing enterprise has created a brand that enjoys popularity throughout the country. Enterprises have the heavy responsibility to establish a branded product of urea both inside and outside China.

ABC is an N fertilizer type unique to China. Even if it lacked good physical properties with low effective nutrient content in the past it played an important role in agricultural development and increase in food production. Production reached its peak of 10.1 Mt (equivalent to 59.6 Mt N) in 1996. With the rapid increase in the production of urea, the share of ABC in N fertilizers is gradually decreasing. However, ABC still has a market in China, particularly in economically less developed areas, where it is welcomed by farmers because of its lower price. In 2005, the production of ABC was 6.8 Mt (40.1 Mt N), which was 21.3% of the total production of N fertilizers throughout China in that year and 39% less than the 60.1% achieved in the peak year (1988). However, the absolute quantity of ABC merely went down by 1.4 Mt (actual product quantity of 8.1 Mt). This means that ABC as a product still has a place in China. The market will determine how long this type of product can survive and what its share of the total N fertilizer market.

2.2.4 Developmental prospects of fertilizer N enterprises

China is an agricultural country with a large population but a small area of arable land. With the needs of industrialization and urbanization, area of cultivated land is gradually decreasing. In order to satisfy the demand for food, rational increases in the application of fertilizer is one of the effective measures. In 2005, the production and demand for N fertilizers basically reached a balance, with a small quantity

for export. Enterprises producing N fertilizers will have to face brutal competition, not just domestically but competition from foreign enterprises as well. Consequently, N fertilizer enterprises must determine their directions of development, strengthen their weak links, carry out continuous technical reforms and greatly reduce the cost of production in order to stand firm in the fierce competition.

2.2.4.1 N fertilizer enterprises should increase in size and form groups

More than two-thirds of the N fertilizer production comes from the small and medium-sized enterprises. Large enterprises which comply with the economics of scale produce less than one-third of the total. Large N fertilizer enterprises enjoy an obvious advantage with regard to increased labour productivity, reduced cost of production, guaranteed product quality and optimization of business management. The ability for the small and medium-sized N fertilizers enterprises to survive is related to the conditions in China. With the development of a market economy and the expiry of the transitional period after joining the WTO, this situation will gradually change. With fair competition, the advantages of large enterprises will be more obvious, both internationally and domestically. Reorganization, annexation and acquisition by Yuntianhua has enabled the enterprise to grow much stronger. The acquisition of Jintianhua by the Huajin Group, the annexation of Tianhua by the Lutianhua Group and the controlling shares held in Tianye of Inner Mongolia by Zhonghaiyou Hainanfudao are all examples of enterprises getting larger and stronger. Having mining groups in the coal industry going into N fertilizer enterprises provides an injection of new vigour. In September 2004, the Shijiazhuang Chemical Fertilizer Group and the Shanxi Jincheng Coal Industry Group cooperated in a joint venture to set up the Shijiazhuang Jinshi Chemical Fertilizer Co. Ltd. The company came out of the red in that year.

From now on, N fertilizers enterprises should make rational adjustments to their scale and structure. They should build large-scale pillar businesses to achieve economies of scale to create the production capacity of large international N fertilizer businesses, with some weight in the domestic market. Through the mechanisms of joint ventures, asset reorganization and annexation, business groups with existing large-scale outstanding enterprises as the main body can be formed and where suitable, large-scale regional production and operation groups can be established. The final objective is to form 100-150 large N fertilizer enterprise groups with an average capacity of more than 400,000 t of synthetic ammonia per year per enterprise.

2.2.4.2 N fertilizer enterprises should go for comprehensive business development

At present, most of the N fertilizer enterprises in China are basically carrying out single production of N fertilizers. At the start of the 21st century, there was a slight improvement but more efforts are needed. The technology for the production of fertilizer N is more demanding (high temperature and high pressure) and the cost of production is relatively higher. The products are used in agriculture and are limited by the price of agricultural produce. Prices of N fertilizers cannot be set

too high. Therefore, N fertilizer enterprises can only survive on a marginal profit. For long-term development, they must rely on other products.

N fertilizer enterprises enjoy certain technological advantages in that the “head” and “tail” that result from the production of N fertilizers can be utilized for different purposes. The so-called “head” refers to the first process of “gas manufacturing” in the production of synthetic ammonia. After purification, the syngas produced by gas manufacturing is used as raw material for synthetic ammonia. By using similar or related techniques, C₁ chemical products with important market values such as methanol, dimethyl ether, methyl carbonate and acetic acid can be produced. There are N fertilizer enterprises which can also produce methanol. However, the scale is small and the benefits are not obvious. Notable benefits will only result from a certain scale. Enterprises with the expertise can produce hydrogen in combination to supply factories in the vicinity. Some domestic petrochemical enterprises use this method to produce hydrogen as raw material for oil refining. N fertilizer enterprises can also produce hydrogen peroxide in this way. For enterprises which use coal as their raw material, they can adopt the Shell technology of gasification of coal dust through high temperature and high pressure to manufacture gas that is used first for the production of chemical products with high added values such as synthetic ammonia, methanol, acetic acid and acetic oxide. Then it is used in combined cycle power generation and the production of town gas. The Yankuang Group in China is establishing a project which uses coal as its raw material, adopting the coal-water slurry gasification technology to produce 200,000 t of methanol per year, linked production of acetic acid and a 40MW gas power plant. In this way, more benefits are reaped and energy utilization becomes more rational.

The so-called “tail” refers to further processing of products produced by N fertilizer enterprises. Many enterprises have done this. For example, urea is used as raw material to produce urea-based compound fertilizers, slow-released fertilizers, melamine, cyanuric acid and urea-formaldehyde resin. In Europe, there is a type of aqueous solution of urea that contains 32.5% N called AdBlue. It is a chemical which treats vehicle fuel exhaust gas. It is stored in a 70-90 litres container on various types of vehicles which prevents it from mixing with the fuel such as diesel. When the engine is started, AdBlue is carefully injected into the exhaust pipe in the form of a mist. Under the action of a catalyst, the aqueous solution of urea is converted into ammonia and reacts with the exhaust gas causing the N_xO in the exhaust gas to be converted into harmless nitrogen and water, the so-called Selected Catalytic Reduction (SCR). After treating the tail gas, emission standards of Euro IV and Euro V can be achieved, with the consumption amount being 3-4 or 5-7% of the amount of diesel consumption (depending on driving, roads, quality of loading). Apart from lowering pollution, AdBlue can also save fuel by 5%. According to estimates by Yara International, the demand for AdBlue in Europe may reach 3.5 Mt/y by 2020. N fertilizer enterprises in China, particularly urea-producing enterprises should pay close attention to this technology in order to create the conditions for gaining market access.

2.2.4.3 Suitable raw material plants

N fertilizers are high-energy consumption products. The coal, oil (petroleum) and gas (natural gas) used as raw materials are in short supply in today's rapid economic development. China is relatively rich in coal but is poor in oil and gas. China has almost every type of synthetic ammonia plants that use different raw materials. N fertilizer-producing plants in China are closer to the areas of chemical fertilizer consumption. They are very scattered, leading to the high cost of raw materials, making it difficult for the enterprises to survive.

1. N fertilizer producing enterprises which use oil (naphtha, heavy oil, residuum) as raw material are currently carrying out changes in raw materials, otherwise they will not be able to survive. Looking at the present trend, China will not be building this type of plant in the future anymore.
2. In general, profits of N fertilizer enterprises which use gas (natural gas, oil field gas, coke-oven gas) as raw material are acceptable but there exist a number of problems which include inadequate sources of gas and the inability of enterprises to produce at full capacity. The most typical example is Cangzhou Dahua. In 2005, due to shortfall in gas supply, the plant was forced to shut down for nearly two years. Zhongyuan Dahua, the Liaohe Chemical Fertilizer Plant of Huajin Group and large chemical fertilizer enterprises of Sichuan were all facing the problem of inadequate supply of natural gas (associated from oil field gas). The large N fertilizer enterprises which use natural gas as raw material must be set up at places where the supply of natural gas can be guaranteed, otherwise it will not be possible to maximise profit. In Statistics of July 2004, about 70% of coke-oven gas was flared and discharged without being utilized. According to estimates, the amount of coke-oven gas that is supplied by independent coking plants each year is 24 B cubic metres but most of it is not effectively utilized. With the gradual development of coal layer gas, there are good quality raw materials which N fertilizer enterprises can use in the production of fertilizers. Capable enterprises should do something.
3. N fertilizer enterprises which use coal as raw material are the largest in number in China. They use mainly anthracite for which the areas of production are mainly concentrated in Jincheng, Shanxi Province. Enterprises which use anthracite but are far from Jincheng are at a disadvantage in market competition. In China, the use of coal (particularly coal dust or coal high in sulphur content) as raw material is more favourable for the development of enterprises of N fertilizers because China is rich in coal, if production conditions are right. Firstly, the method of gasification must be improved. Clean coal technology must be used. Production plants have to comply with environmental protection requirements. Secondly, the plants must be of economic scale. Next, plants must be set up in an area of coal production. Finally, there must be comprehensive utilization and development in the direction of multi-link production with clean coal gasification as the core technology.

2.2.4.4 N fertilizer enterprises have to develop new products and raise their standards of service

The nutrient efficiency ratio of N fertilizers in China is usually 30-35%, which is 10-15% lower than the world standard. The low efficiency rate of chemical fertilizers is manifested mainly in N fertilizers. Consequently, the development of new grades and raising the efficiency rate is the responsibility of N fertilizer enterprises. Some domestic enterprises have gone ahead but the work is rather limited. N fertilizer enterprises should set aside 3-5% of their sales revenue for research and development, cooperate with scientific research institutes and institutes of higher learning to develop low cost, slow (controlled) release fertilizer which is affordable to farmers. N fertilizer enterprises should also provide good agricultural services, take an active part in the application of the right fertilizer according to soil tests and produce fertilizers which are urgently needed by the farmers.

2.3 Market development for N fertilizers

2.3.1 Demand and the market

2.3.1.1 Demand

A large number of studies show that chemical fertilizers account for about 50% of the increase in grain production. Figure 2-1 that indicates from 1980 to 1998, owing to the continuous development of agriculture in China, the amount of chemical fertilizer applied was increasing yearly. Before 1993, the increase in the production of N fertilizers was relatively slow and could not meet domestic needs. Owing to the shortage of domestic N fertilizers, profits were higher for the enterprises. After 1993, a group of N fertilizers enterprises set up plants in different parts of the country and the production of N fertilizers increased rapidly. The supply in the market was greatly increased and, by 2000, production of N fertilizers became greater than demand. After 1998, as the cultivated area continued to decrease, the demand growth for N fertilizers also slowed down. The amount of N fertilizers applied basically remained stable. For the next few years, the actual amount of N fertilizers required will not increase rapidly.

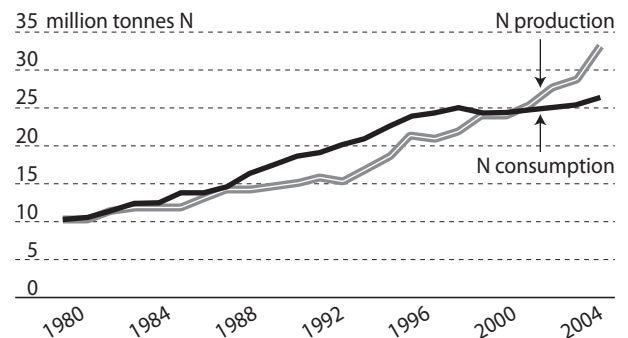


Figure 2-1 Production and agricultural consumption trend of nitrogenous fertilizers in China: 1980-2004.

According to the forecast by the Ministry of Agriculture and the Academy of Agricultural Sciences, the demand for N fertilizers in 2010 will be 31.3 Mt and, in 2030 it will reach almost 37 Mt. If calculations are made according to rational nutritional requirements of various crops in various regions and the actual amount used by the farmers, the amount of N fertilizers applied in China is already near to or has exceeded requirements. In 2000, the net amount of nitrogen in excess of demand throughout the country was 2.2 Mt .

A multitude of problems arising from irrational application of chemical fertilizers have caught the attention of many people. In 2005, the Ministry of Agriculture began launching formulated fertilizer application with soil tests. With the promotion of the technique of application of formulated fertilizers and the increase in fertilizer use efficiency, the increase in demand for N fertilizer will slow down. The scenario of excess supply exceeding demand in the N fertilizer market is beginning to emerge. Based on the production expansion plans in the existing N enterprises, the amount of fertilizer N produced may far exceed domestic demand.

The main types of nitrogenous fertilizers include urea, ABC, AC, AN and AS. Urea is the major N fertilizer type in China. In terms of production and consumption, it occupies the highest proportion among the many types of N fertilizers. As the nitrogen content of urea is as high as 46% and being a neutral fertilizer, its long-term application will not have any adverse effect on the soil. Therefore, a large amount of it is used in agriculture. 90% of urea produced in China is used for agricultural production with 10% used for industrial purposes. The speed of development in the production of urea in China is relatively fast. For three years, the proportion of urea in the production of N fertilizers throughout the country has been constant at more than 58%.

With continuous developments in agriculture, demand for urea also increases and this spurs a rapid increase in production. In the 1970s, the large chemical fertilizers plants imported by China went into successive production. The production of urea increased rapidly. After 1998, Chinese urea production was on the whole able to meet domestic

demand. In recent years, there has been a continuing increase in newly built and expanded urea plants and output has been increasing year on year. Total output of urea in China was 19.9 Mt in 2005, which was almost 10 times higher compared with the output of 10 Mt in 1977; on average, there was an increase of nearly 676,500 t each year (Table 2-2). The rapid increase in urea output contributed greatly to agricultural development in China, making it the largest producer and consumer of urea in the world. However, it should also be noted that owing to the increase in the yearly urea output, a surplus, in the N fertilizer market has emerged, impacting on the price of urea.

2.3.1.2 The market situation

Chemical fertilizer is a special commodity which always receives great attention from the Party and the Government. Policies depicted in "Monopoly of Agricultural Resources" Document *Guo Fa* No. 68 (1998), "One Major and Two Auxiliaries" of Document No. 45 (1994) to "Appropriate Competition" of Document No. 39 (1998) followed by "Scheme for the Reform and Improvement on the Regulatory and Control Mechanism for Chemical Fertilizer Prices" (draft seeking opinions) issued by the National Development and Reform Commission in July, 2005 in which "Two Cancellations, One Subsidy" was raised, fully explain the importance the State is attaching to chemical fertilizers. Whether or not the supply of chemical fertilizers can be guaranteed, or price levels are reasonable, will affect agricultural production, farmers' income and the economic development of agricultural villages which, in turn, will have important effects on resolving the "San Nong" (the three agricultural) problems.

During the period of planned economy, the State implemented unified purchases, sales and administration with regard to information on agricultural production such as chemical fertilizer. The State implemented the policy of "Low price and small profit", by which losses resulting in price reduction would be subsidized financially. At that time, regardless of whether it was imported or produced domestically, the price of urea was standardized at RMB428/t.

Table 2-2 Apparent consumption of urea in China: 1995-2005

| Year | Amount of Import (Product '000 t) | Amount of Export (Product '000 t) | Output ('000 t) | | Apparent Consumption ('000 t) | | % Change Consumption | Rate of Self-sufficiency /% |
|------|--------------------------------------|--------------------------------------|------------------|-------------------|-------------------------------|-------------------|----------------------|-----------------------------|
| | | | Product Quantity | Nutrient Quantity | Product Quantity | Nutrient Quantity | | |
| 1995 | 6962.5 | 46.6 | 17950 | 8257.0 | 24865.9 | 11459.0 | | 72.7 |
| 1996 | 5763.3 | 197.4 | 20600 | 9476.0 | 26165.9 | 12058.0 | 5.23 | 78.7 |
| 1997 | 3419.6 | 350.5 | 22900 | 10534.0 | 25969.1 | 11967.3 | -0.75 | 88.2 |
| 1998 | 119.1 | 125.1 | 26360 | 12126.0 | 26354.0 | 12144.7 | 1.48 | 100 |
| 1999 | 68.1 | 53.8 | 29730 | 13510.0 | 29384.3 | 13541.2 | 11.50 | 100 |
| 2000 | 0.025 | 961.4 | 30270 | 13924.0 | 29308.6 | 13506.3 | -0.26 | 103.3 |
| 2001 | 0.024 | 1270.7 | 31630 | 14550.0 | 30359.3 | 13990.5 | 3.58 | 104.2 |
| 2002 | 790.7 | 413.0 | 34820 | 16017.0 | 35197.7 | 16220.2 | 15.94 | 98.9 |
| 2003 | 139.2 | 2730.3 | 36350 | 16717.5 | 33758.9 | 15529.1 | -4.09 | 107.7 |
| 2004 | 38.0 | 3943.2 | 41820 | 19235.0 | 37914.8 | 17440.8 | 12.3 | 110.3 |
| 2005 | 71.0 | 1570.6 | 43370 | 19948.8 | 41867.0 | 19259.0 | 10.42 | 103.6 |

In 1985, the “Double-track pricing system” for energy and raw materials was implemented, that is, the internal pricing is uniformly formulated by the State while the external pricing is regulated by the market.

In the 1990s, China's chemical fertilizer market was mainly planned supply, assisted by market regulation. Prices of chemical fertilizer were partially market oriented. During the mid-1990s, chemical fertilizer prices went through the process of going from high to low and back to high again. When chemical fertilizers were at their peak in 1996, the retail price of urea reached RMB2,198/t. After 1997, owing to increased production and reduced purchase by farmers due to decrease in grain prices, the market trend of chemical fertilizers changed, with the price of urea remaining at RMB1,300-1,400/t over a relatively long period.

At the end of 1998, Document No. 39 of the State Council mentioned “Go further in the reform of the system of chemical fertilizer circulation and establish a system that suits the requirements of a socialist market economy, a system that allows market deployment of resources under the macro-regulation and control by the State.” The State's management of chemical fertilizer circulation was changed from direct and planned management to mainly indirect management. Planning by directives and unified distribution and acquisition were abolished and chemical fertilizer producers and operating business enterprises carried out purchase and sale activities on their own. Deployment of resources by the market was implemented.

With Document No. 39 of the State Council as the foundation, related Ministries and Commissions published the relevant supporting policies, gave guidance and promoted the move of chemical fertilizer circulation towards a market economy model. These further opened up the management of chemical fertilizer prices, exemption from value-added tax for some agricultural production materials and standardized the imposition of value-added tax (VAT) on urea which is produced and sold. In addition, the policy of collection followed by refund of VAT was implemented in 2001 and 2002. In 2001, the tax collected was refunded in full. In 2002, the refund was 50% and the policy of refund was stopped from 2003. All urea products were exempted from VAT in 2005. The policy of preferential treatment with regard to the cost of railway transport of chemical fertilizers continued to be implemented.

During the four years after 1998, chemical fertilizers entered the buyer's market and prices fell. At its lowest, the ex-factory price of urea was merely RMB850/t. Under the effects of market economy, the mechanism of “survival of the fittest” took shape. Many enterprises during the planned economy, in the three channels (the supply and marketing cooperative, the “three stations” of agriculture, production enterprises) were eliminated through competition because of high operational costs, thin profits and failure to make ends meet. By the end of 2003, there were less than 500 of the enterprises left. By the fourth quarter of 2003, large changes in the chemical market was in effect due to the increase in the cost of production, increases in domestic demand for fertilizer and the continuous rise of international fertilizer prices. The supply of urea became tight and prices rose sharply. In 2004, the price of urea continued to rise sharply and by the end of the year, the ex-factory price of urea was around RMB1,650-

1,800/t and the retail price was around RMB1,750-1,900/t. Compared with 2003, the level of increase was about 30%. In 2005, the overall price of urea was still high. In July, it reached its peak with the ex-factory price exceeding RMB1,800/t and the wholesale price generally exceeding RMB1,900/t. In many areas, the wholesale price broke the RMB2,000/t mark. Be it ex-factory, wholesale or retail price, since 1996 new records were set in many areas. In some areas, it was at a historical high.

In 2006, the State continued to implement government-guided prices on urea produced by large N fertilizers enterprises. Urea price was included in the list of prices set by the central government and the level of increase was raised from 10 to 15%. Although the price of urea was also relatively high in 2006, it dropped compared with the same period in 2005. As the price of urea has been high in the past few years (Figure 2-2), and the demand for chemical fertilizers by agriculture continued to increase, some enterprises built new urea plants or expanded their existing installations. Production capacities of urea gradually increased and output increased progressively year after year. A certain threat existed with respect to the price of urea which remained high.

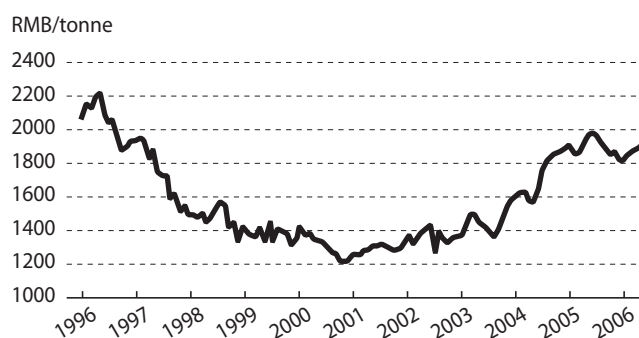


Figure 2-2 Urea retail price trend from 1996-2006.

2.3.1.3 Growth of the chemical fertilizer market

In July 2005, the National Development and Reform Commission promulgated the “Scheme for Reform and Improvement on the Regulatory and Control Mechanism for Chemical Fertilizer Prices” (Draft seeking opinions) in which market reform of the mechanism of chemical fertilizer regulation and control was raised. The core content “Two cancellations, one subsidy” was the abolition of price restrictions on chemical fertilizers and the abolition of preferential treatment policy on production and circulation of chemical fertilizers, and granting of subsidy for grain growers.

As this reform has important effects on the chemical fertilizer industry, it caused uproar among fertilizer enterprises. It also allowed the chemical fertilizer industry to see the first emergence of the impending market economy and the violent market shake up and reshuffling which will confront all chemical fertilizer enterprises. Even though there was much dispute with regard to the reforms, change in the industry was something that was accorded with the will of the people and the general trend of events. The complete market-orientation of chemical fertilizer prices is the final objective of reform.

1. Existing problems of reform

The “two cancellations” would lead to increases in the production cost and price increases of chemical fertilizers would be unavoidable. Subsequently, due to the original pattern of supply and demand being broken, there would be a period of fluctuation in the chemical fertilizer market, a process of digestion, adaptation, adjustment and reorganization.

2. Progress of reform

Under the abolition of the policy of preferential treatment in July 2005, draft reform by the National Development and Reform Commission, means that three steps will be carried out. Firstly, cancellation of preferential treatment in the price of heavy oil used for chemical fertilizer production, in accordance with the policy on the price of natural gas, price adjustment for railway transport costs, small increases in the price of natural gas used for fertilizer production, final achievement of having the planned internal and external prices of natural gas on the same track, and abolition of the subsidy for DAP. Secondly, the abolition of preferential price for power, for coal and for the cost of railway transport, encourages energy production enterprises and railway transport to sign long term contracts with large chemical fertilizer production enterprises and large distribution enterprises in order to guarantee production and transport of chemical fertilizer. Thirdly, abolition of the preferential treatment for refunding VAT.

The market orientation of the system of chemical fertilizer circulation is progressing steadily. At the end of 2005, the National Development and Reform Commission stipulated that beginning 26 December 2005, the ex-factory price of natural gas supplied to industry and urban areas by the various oil and gas fields will be raised by RMB50-150 per thousand m³ and natural gas used for the production of chemical fertilizers be correspondingly raised by RMB50-100. At the beginning of 2006, based on the average approved price, the extent of increases to the ex-factory price was from 10 to 15%, with the maximum ex-factory price reaching RMB1,725/t. This enabled the price of urea to be closer to the market price. In June 2006, the National Development and Reform Commission issued a notice with the decision to raise the selling price of electrical power throughout the country by 2.5 fen (RMB0.025) per kilowatt beginning 30 June 2006.

Subsequently, the various provinces successively published a scheme of adjustments to the price of electrical power. In these adjustments neither the State nor the local authorities mentioned the policy of preferential treatment to chemical fertilizer enterprises and the price of electrical power was adjusted upwards. It can be seen that the preferential treatments being given to chemical fertilizer enterprises by the State gradually decreased. Prices of chemical fertilizers got closer to the market prices and gradually turned to the market-oriented direction.

2.3.2 Import and export

2.3.2.1 Import

In recent years, as the main type of N fertilizers, the production of urea is increasing rapidly. Before 1997, the output of urea in China was unable to satisfy the demand of domestic agricultural production. There was a sizable quantity of import each year. In some years, an excess of urea imports caused an impact on the domestic market, resulting in low urea market price. For example, in 1996 and 1997, there was a great drop in the price of urea produced domestically. One important reason was the excessive import of urea, causing a great impact on domestically produced urea. Finally, the State had to make the decision to temporarily halt the import of urea.

From the changes in the data given in Table 2-3, it can be seen that before 1988, China was unable to satisfy the demand for agricultural production, and the amount of urea imported continued to increase, with the peak of 8.5 Mt in 1988. Subsequently, with the increase in urea production in China, the amount of imports declined. After 1997, with the clear-cut national policy not to import urea, the import in the period 1998-2001 was very small and imported urea posed no threat to market price of the domestic product.

In December 2001, China joined the World Trade Organization (WTO). According to relevant undertakings, and the “Interim Measures for the Management of Tariff Quota on the Import of Chemical Fertilizers,” the National Economic and Trade Committee specified that the import quota of urea for the year 2002 was 1.3 Mt with a subsequent annual increase of 500,000 t, finally reaching 3.3 Mt five years later. Within the quota, there was a levy of a 4% tariff while

Table 2-3 Import and export of urea in China (Computed as product quantity, '000 tonne): 1981-2005

| Year | Volume of Import | Volume of Export | Year | Volume of Import | Volume of Export | Year | Volume of Import | Volume of Export |
|------|------------------|------------------|------|------------------|------------------|------|------------------|------------------|
| 1981 | 2598.9 | – | 1990 | 8135.0 | – | 1999 | 68.0 | 54.0 |
| 1982 | 3261.6 | – | 1991 | 7005.1 | – | 2000 | 0.025 | 961.0 |
| 1983 | 4252.4 | – | 1992 | 7483.5 | 0.7 | 2001 | 0.025 | 1271.0 |
| 1984 | 4398.6 | – | 1993 | 3607.0 | 2.4 | 2002 | 790.0 | 413.0 |
| 1985 | 3822.1 | – | 1994 | 3133.3 | 56.1 | 2003 | 135.0 | 2730.0 |
| 1986 | 3014.3 | – | 1995 | 6962.5 | 46.6 | 2004 | 38.0 | 3943.0 |
| 1987 | 5564.8 | – | 1996 | 5763.3 | 198.0 | 2005 | 71.0 | 1571.0 |
| 1988 | 8492.2 | – | 1997 | 3419.6 | 351.0 | | | |
| 1989 | 7940.7 | – | 1998 | 119.1 | 125.0 | | | |

a high tariff of 50% was levied outside the quota. During the first year of resumed urea imports by China, that is, in 2002, many were concerned that the import of urea would once more have an impact on the domestic urea market. In reality, apart from the relatively large import of 790,000 t in that year, annual imports in subsequent years were small and did not constitute a threat to the Chinese urea market.

The above is the result of the very rapid growth of the urea industry in China in recent years. In 1996, the annual production capacity of urea in China was 20Mt. However, the urea industry in China has been growing very rapidly in recent years. Several large urea installations were built. Medium N fertilizer enterprises expanded their production while small enterprises switched from ABC to urea. This enabled the production capacity of urea to be greatly increased and China became the largest urea producing country in the world. By 2005, urea output in China exceeded 43 Mt. In 2006, China augmented its urea production capacity by 4 Mt. The total production of urea in the whole country will exceed 45 Mt. However, demand for urea in China in the year 2006 is about 43 Mt. Domestic urea production can fully satisfy the demand. Therefore, it is reasonable that urea import volume will be decreasing year after year.

It can be seen that increases in the quota does not mean that the actual volume of import will increase with it. In addition, quota is no longer the key factor influencing the import of chemical fertilizers. Instead, the market balance is becoming the major factor influencing imports. This indicates that the market mechanism of China's chemical fertilizer is gradually maturing after joining WTO.

2.3.2.2 Export

Due to the inability of urea production in China to satisfy domestic needs, urea was not, as a rule, exported. In some years, only a small quantity was exported (see Table 2-3) and export figure reached 10,000 t level in 1994. Since importation of urea ceased in 1997, domestic production increased continuously. Besides fully satisfying domestic needs, export of large quantities of urea began in the second half of 2000.

In contrast with the gradual reduction of imports during the period 2001-2004, Chinese exports of urea maintained a strong growth momentum. Even though the State adopted a policy of restrictions on the export of urea and abolished tax reimbursement in 2004, in order to guarantee supply to the domestic market and price stability, the policy did not have any substantive effect on the export of urea in 2004. Owing to the high price of urea internationally and domestic price restrictions China's export of urea was greatly increased. In the whole year, 3.9 Mt of urea was exported, the highest level in the history of urea exports. This represented a year-on-year increase of 44.4%. In that year, China exported 747,000 t of urea in the month of November alone, the highest monthly record.

In 2005, the State exerted greater regulatory control over the export of chemical fertilizers by announcing the policy of imposing a provisional tariff on urea. From 1 January 2005, an additional provisional tariff of RMB260 per tonne was imposed on all urea exported from China. As from 1 June 2005, the imposition of a provisional export tariff of RMB260 per tonne of urea was halted. From 1 June to 31 October 2005, a seasonal

provisional tariff of 30% was imposed. From 1 November to 31 December 2005, this was reduced to 15%. The objective of the increase in the provisional tariff was to control any rise in the price of domestic urea as a result of increased export and to guarantee the availability of fertilizers domestically. Owing to the additional provisional tariff imposed, China's urea became less competitive in the international market and the export of urea was effectively controlled. In 2005, the volume of exports of urea from China fell to 1.6 Mt. From January to September 2006, the seasonal provisional tariff of 30% continued to be imposed on the export of urea and only 571,000 t of urea was exported from January to June.

Urea is a high energy consuming industry. The export of urea is equivalent to the export of energy resources. Presently, domestic energy resources are in short supply. Prices go up continuously. From now on, the State will certainly continue to restrict the export of urea. Furthermore, looking at the trend of domestic urea prices, restriction on the export of urea has basically guaranteed domestic supply. This helped to lower the domestic price of urea, thus protecting the interests of the farmers.

2.3.3 Raw materials and transport

2.3.3.1 Raw materials for the production of N fertilizers

Raw materials used for the production of synthetic ammonia in China include coal (65%), natural gas (28%) and heavy oil (7%). Coal used in the production of synthetic ammonia is anthracite. There is only a small number of enterprises which adopt the Texaco, Lurgi, or Enders furnace methods or the agglomerating ash process to produce synthetic ammonia without using anthracite. Descriptions of the main raw materials used in the production of synthetic ammonia are as follows.

1. Coal and coke

Up to the end of 2005, proven reserves of anthracite in China was 113 Bt or 11% of proven coal reserves. In the same year, the output of anthracite in China was 304 Mt or 18% of coal production in the country. The amount of anthracite used in gas manufacturing in chemical fertilizers is about 40 Mt. Production sites are concentrated mainly in Jincheng of Shanxi Province, Shitanjing of Ningxia Au tonne omous Region, Jiaozou and Yongcheng of Henan Province. Of these, anthracite from Jincheng is of the best quality.

Requirements of anthracite for fixed bed normal pressure gasification used for the production of synthetic ammonia are:

- Fixed carbon (dry basis) $\geq 70\%$;
- ash (dry basis) $< 20\%$;
- volatile matter (dry basis) $< 8\%$;
- sulphur content (dry basis) $< 1\%$;
- moisture (wet basis) $< 7\%$;
- thermal stability $\geq 60\%$;
- ash fusion temperature (T_2) $> 1,250^\circ\text{C}$;
- mechanical strength $> 70\%$;
- granulometry 25~75mm

In order to resolve the problem of inadequate source of anthracite or to save cost, some enterprises also utilize anthracite powder to make lumps (coal cake, coal bar) to

take the place of lump anthracite. When the Lurgi method is used for gasification, coal of smaller granule size (2-4mm) with poorer mechanical strength and thermal stability can be used. A wider variety of coal can be used for Texaco coal-water slurry gasification and Shell dried coal dust gasification.

2. Natural gas

At present, proven natural gas reserves as recoverable resources in China amounts to about 14 trillion m³. Up to the end of 2003, proven natural gas as geological reserves amounted to 3.9 trillion m³. The proven natural gas recoverable reserves reach 2.5 trillion m³ (not including the oil-field d gas associated recoverable reserves of 0.4 trillion m³). At present, the level of proven natural gas in China is 17.6%. There are five concentrated regions in the country, mainly found on the Bohai Bay and Songliao Plain in the east, the central and central eastern parts of the provinces of Shaanxi, Gansu and Ningxia, the eastern, central and north eastern parts of Sichuan and Chongqing, Lenghu, Nanbaxian and Sebei of Qinghai Province, Tarim and Tuha in the Xinjiang Autonomous Region. Natural gas can be divided into "dry gas" and "wet gas." The composition of the "dry gas" is almost completely methane with a high degree of purity and less paraffin gases above ethane. On the other hand, "wet" gas contains about 10% mixed gases of paraffin above ethane. The "wet" gas in China is mostly oil field associated gases. According to statistics, throughout the world natural gas is used mainly as domestic fuel and for power generation, the proportion utilized by the chemical industry is relatively low, about 10-20% of the total consumption and mainly used in the production of synthetic ammonia and methanol. Natural gas is a clean source of energy with high heating value, easy combustion and low pollution. It is a domestic and industrial fuel of excellent quality and an ideal raw material for the production of synthetic ammonia.

3. Heavy oil

The fuel oil used as a raw material for the production of synthetic ammonia is usually heavy oil and refining residuum. In an oil refinery, the product at the bottom of the tower when the point of distilling off under normal pressure distillation is above 350°C, is referred to as heavy oil. The distillate at above 520°C obtained by distillation of heavy oil under reduced pressure distillation is called residuum. It is a common practice to call the heavy oils obtained by various methods of advanced processing as heavy oil. Heavy oil is composed of carbon, hydrogen, oxygen, nitrogen, sulphur and ash. In general, the hydrogen content is 10-13%, carbon at 85-88%, oxygen and nitrogen not exceeding 1% and sulphur at 0.1-1.5%. The ash contains elements including sodium, magnesium, vanadium, nickel, iron and silicon whose total amount does not exceed 0.3%. Carbon and hydrogen are the main components in manufacturing the raw material gas of synthetic ammonia. Their ratio is indicated by C/H. Oil density is lower with low C/H and higher thermal value. Oil with higher thermal value consumes less oxygen and the effective gas (CO + H₂) obtained is greater. Most of the oxygen and nitrogen in heavy oil exist as chemical compounds in the form of neutral colloid or asphaltine. It is easy to separate out carbon from these substances during pre-heating of heavy oil

causing sedimentation and blocking of filtration net and finer tubes. Chemical compounds such as sulphur, sulphides, thioether and thiophene in the heavy oil are harmful substances in the production of synthetic ammonia which must be eliminated.

2.3.3.2 Change of raw materials and development trends in the production of N fertilizers

Since Haber successfully developed the method of industrial synthesis of ammonia in 1909, the synthetic ammonia industry has been around for nearly a hundred years. In the early days, coke-oven gas, hydrolytic and electrolytic hydrogen making and water gas generated by gasification of coking coal were used as raw materials for synthetic ammonia. The industry began turning to natural gas, naphtha oil and heavy oil as raw materials in the 1970s.

After 50 years of development, the synthetic ammonia industry in China has grasped the techniques of producing synthetic ammonia using many types of raw materials in solid and liquid forms such as coke, anthracite, lignite, coke-oven gas, natural gas, oil field associated gas and liquid hydrocarbon. The co-existence of coal, petroleum and natural gas as raw materials and of small, medium-size and large plants in the production of synthetic ammonia is something unique to China.

In recent years, the synthetic ammonia industry has developed very rapidly. Large scale, low energy consumption and clean production are becoming the main streams in the development of synthetic ammonia plants. The main direction taken in technological improvement is research and development for catalysts with better performance, for lowering the pressure in ammonia synthesis, developing new methods of purifying raw material gas, reducing fuel consumption, recovering and using rationally low heat energy. At present, China is the world's largest producer of synthetic ammonia, followed by Russia, the US and India. The total production from these countries is more than half of the world's production. The majority of the synthetic ammonia plants which use natural gas as raw material enjoy the advantages of low investment, low energy consumption and low cost of production. When the price of natural gas is reasonable, producing chemical products with natural gas as raw material enjoys the benefits of low investment and very strong competitive power. The production of ammonia using natural gas as the raw material accounts for 80% of total world production. In the two major natural gas producing countries, the US and the former Soviet Union, the synthetic ammonia and methanol produced with natural gas as raw material accounts for more than 90% of their total domestic production.

With the rise in crude oil price, methods of making ammonia with coal are once again receiving much attention. Looking at the present fuel reserves in the world, coal deposits are 10 times the sum of petroleum and natural gas reserves. Compared with heavy oil, the cost of manufacturing gas with coal is lower. 2.3 t of coal can replace 1 t of fuel oil and the overall cost is merely 40% of the cost of fuel oil. In China's China's 11th Five-year Plan," research and development of advanced coal gasification technology is enhanced, with active promotion of advanced coal gasification technology,

and expansion of the sources of raw materials for chemical fertilizer and to implement localization of raw materials. In the future, coal as raw material for producing synthetic ammonia, will be the direction of development taken by China.

2.3.3.3 Transport of raw materials to N fertilizer industries

The major raw materials for the production of N fertilizers are lump coal, natural gas and heavy oil. As China has inadequate natural gas supply and the cost of heavy oil is high, the ratios of these two as raw material in N production are gradually decreasing. Below is a detailed account of the transport of lump coal and its effects on the future development of the industry.

1. The overall situation of coal transport

Following the rapid development of the market economy in China, the total length of railways in China is 73,000 km. These railroads account for 23% of the world's transport volume or 6% of the world's mileage. Even with this efficiency, transport of goods by railway can only satisfy 47% of the total demand of domestic transport. The quality of transport has not adapted to national economic and social developments. When railway transport is tight, it can only satisfy 30% of the needs of coal transport. Bottlenecks in transport led to only 10% annual growth in the effective supply of coal in China which is very difficult to meet, with the annual growth in the requirement for coal being over 14.8%. It is a difficult task to alleviate the tight situation in the transport of coal.

2. Contradictions between the distribution of raw material and the location of enterprises

In China, there is an extreme imbalance in the distribution of anthracite deposits. The reserves are mainly concentrated in the central and western regions. However, enterprises that produce urea, the main N fertilizer that uses coal as raw material, are scattered throughout the country. With the exception of Beijing, Shanghai, Guangdong Province, Qinghai Province and the Xicang Autonomous Region, urea is produced in all provinces, autonomous regions and municipalities directly under the central government. The industry is mainly concentrated in the various provinces, cities and autonomous regions in Eastern China, south central China and the southwest of China. The total output of urea in these regions accounts for 65% of the national production.

Most of the urea enterprises are far from the areas of raw materials sources. This is a serious structural imbalance in geographical distribution. As a result, transport has become the most important issue in guaranteeing the normal operation of the plants that uses coal for manufacturing syngas. This structural imbalance, where sources of raw materials are concentrated and production plants are scattered, not only increases the volume of raw materials transported, thus aggravating the distance travelled, it also increases the delivered price of coal and the production cost of urea. Regional imbalance in the amount of resources for N fertilizers arises easily, causing sharp changes in the selling price of N fertilizers. Increases in the cost of production of N fertilizers directly weakens the competitive power of the enterprises. It also indirectly affects investment in agriculture and farmers'

keenness on cultivating their lands. Consequently, in the "11th Five-year Plan", the government vigorously promoted the structural adjustment of raw materials to motivate the N fertilizer industry and to optimize the distribution of the industry to satisfy the agricultural development of China.

2.3.4 Policies, laws and regulations

As chemical fertilizer supports agriculture, its production has always been given much attention by the government. Small enterprises of N fertilizers have been enjoying policies of preferential treatment with regard to raw materials, transport, taxation, electrical power and gas. These have spurred the rapid development of the N fertilizer industry. Besides helping to solve the problem of food and clothing, the development of the N fertilizer industry has also ensured bumper harvests for China's agriculture. Historically, these achievements have always been a result of the guarantees and support given by the government. A brief account of the policies, laws and regulations related to N fertilizers is given below.

2.3.4.1 Important policies, laws and regulations related to N fertilizers in 2005 to 2006

1. Tax policy

The tax policy on urea deals mainly with the regulation of the balance between the export and domestic demand. In order to reduce the price of chemical fertilizers and guarantee domestic demand, on 13 May 2005, Customs Tariff Commission of the State Council issued a notice concerning provisional customs tariff on the export of urea with the decision to impose tariff of 30% between 1 June to 31 October 2005 and 15% during the period 1 November to 31 December. On 29 December 2005, a notice to continue the temporary halt to tax reimbursement for the export of urea, DAP and MAP was jointly issued by the Ministry of Finance, State Administration of Taxation and the National Development and Reform Commission. In 2006, in order to augment the total amount of domestic resources and ensure the supply of chemical fertilizers during the peak season, the relevant authorities made the decision to continue imposing provisional tariff on urea export at 30% for the period of January to September. During off-season between October and December, the tariff rate was adjusted downward to 15%.

2. Price policy

Since the reform and the opening of the system of chemical fertilizer circulation, the State stipulated the 7% comprehensive rate of difference in the prices of chemical fertilizer, that is, from delivery to retailing, the comprehensive rate of operational difference cannot exceed 7% (including indirect expenses incurred in distribution that include interest for bank loans, management fees and warehousing charges but not inclusive of direct miscellaneous charges for transport). At the beginning of 2005, a price restriction measure was announced. According to stipulations of the measure, the delivery price of large urea enterprises with an annual production above 300,000 t was limited to RMB1,500/t. On this basis, fluctuation of 10% in both directions was allowed. On 1 July 2005, the scope of limiting the ex-factory price of urea

was extended from the annual production capacity of 300,000 t of synthetic ammonia to enterprises of urea production with production capacity of equal to or above 150,000 t/y. In 2006, the State continued to implement a government-guided price on urea produced by large enterprises by the central authority (annual production capacity above 300,000 t of synthetic ammonia per year). Upward fluctuation was raised from 10 to 15% whilst there was no limit for downward fluctuation.

3. *Off-season reserves*

At the end of 2004, in order to guarantee the production of chemical fertilizers throughout the year, the government started implementing off-season reserves of chemical fertilizers at the central authority and the local authority levels. In January 2005, the National Development and Reform Commission and the Ministry of Finance jointly announced the "Provisions Governing the Commercial Reserves of Chemical Fertilizers During Off-season" and on 1 November 2005, the Development and Reform Commission and the Ministry of Finance formulated the "Supplementary Provisions Governing the Commercial Reserves of Chemical Fertilizers During Off-season."

4. *Laws and regulations concerning transport*

For a long period of time, goods and materials which supported agriculture, and chemical fertilizers were transported by rail with freight rate No. 2 basis. In April 2006, in order to relieve the contradiction caused by the low cost of railway transport of goods, a notice was issued by the National Development and Reform Commission which stated that from 10 April, the consolidated freight for railway transport of goods would be raised from the present 8.6 fen (RMB 0.0861) per t-km on average to 9.1 fen (RMB 0.091). On average, the freight per t-km was raised by 0.4 fen (RMB 0.004). The cost of goods operation was raised from an average of 5.3 fen (RMB 0.053) per t-km to 5.8 fen (RMB 0.058). Railway construction fund that charges 3.3 fen (RMB 0.033) per t-km remained unchanged. Under the price adjustment, the present freight will remain unchanged along the four railway routes of Dalian-Qinhuangdao, Feng-Sha-Da, Beijing-Taiyuan and Beijing-Qinhuangdao.

5. *Regulation of the price of electrical power*

The chemical fertilizer industry has been enjoying the policy of preferential treatment given by the State for its power consumption. The price of electricity has been lower than for other industries. To regulate the price of electrical power and solve the problem of rising coal price, development of regenerative energy, desulphurization reform of power plants and insufficient funds for the establishment of a electrical network, the scheme of regulation of the price of electrical power was announced on 28 June 2006 by the National Development and Reform Commission, with the decision to increase the price of electrical power by 2.5 fen (RMB 0.025) per Watt on the average throughout the country, starting 30 June 2006.

2.3.4.2 *Macroscopic trends of policies, laws and regulations*

2006 was the first year of the "11th Five-year Plan," a crucial period in the rapid development of the national economy and structural regulation for China. The country continued to enhance the overall production capacity of agriculture, prioritize the support for grain production and maintain stable food prices. More emphasis was placed on the ability for self-innovation and encouraged N fertilizer enterprises to actively apply advanced techniques to reform a traditional industry and vigorously develop a recycling economy. With regard to the regulation of industrial structure, the State has given in the "11th Five-year Plan" special mentions of the expedition of the market orientation of the N fertilizer industry. There are two reasons: first is the requirement brought by complete entry into WTO and integration into global trading; and secondly, is the inevitable result of macroscopic regulation and control by the State. Consequently, during the period of "11th Five-year Plan," the State gradually abolished the various preferential treatments given to raw materials, electrical power, transport and taxation enjoyed by the chemical fertilizer industry. Of these, an increase in the price of natural gas and the abolition of preferential prices for electrical power are all indications of an expedited process of market orientation of the chemical fertilizer industry. After 2006, there is a good possibility that the tariff quota of chemical fertilizers will be abolished and the sale (wholesale, retail) of chemical fertilizers will be further opened. The chemical fertilizer industry will be faced with no preferential treatment domestically and stiff competition from trans-national companies externally.

Chapter 3

China's Phosphorus (P) Fertilizer Industry: Development and Outlook

The phosphate fertilizer industry of China started in 1942. In that year, the Yudian Phosphate Fertilizer Plant was built in Kunming City of Yunnan Province to produce single superphosphate (SSP) at 1 t/d. As sales were limited, the plant was shut down after a half year of operation. When the new China was established in 1949, the country was without a phosphate fertilizer enterprise. There were only two enterprises in Keelung and Kaohsiung of Taiwan Province that were producing 30,000 t/y of SSP.

After 1952, the Bureau of Chemical Industry, Ministry of Heavy Industry began research on phosphate fertilizer technology, development and construction of industrial plants. In 1958, utilizing results of research and experiments and with help from the Soviet Union, industrial plants with annual outputs of 400,000 t and 200,000 t of granular SSP were built in Nanjing of Jiangsu Province and Taiyuan of Shanxi Province. These laid the foundation for the earliest phosphate fertilizer industry in China.

For over 50 years, development of China's phosphate fertilizer industry has basically been the same as developments of phosphate compound fertilizer industries around the world, that is, from low-analysis products to high-analysis ones and from single nutrient type to compound types. Enterprises grew from small to larger sizes and their locations switched from the vicinity of the market to the vicinity of raw material-producing areas or to a port. Processing of products changed from an acid or thermal process to a mainly acid one. As for technological development, self-research and development became a combination of self-development and imported technology followed by innovation and breakthrough as the main line of thought. In the past 10 years, on the basis of self-innovation, digestion and absorption of imported technology, the phosphate fertilizer industry has had many great achievements in terms of technological progress and innovation and these spurred the industry's rapid development.

In 2005, phosphate fertilizer production throughout the country reached 11.3 Mt P_2O_5 , overtaking the US for the first time to take the top producer position in the world. The apparent consumption of 11.7 Mt P_2O_5 has ranked first successively for the past three years. The spectacular achievements in the development of phosphate compound fertilizers are mainly reflected in the following four aspects:

1. There has been a big increase in the output of products. From a single grade with low-analysis, the industry developed to include high-analysis products, compound fertilizers and multi-grades. SSP and fused calcium magnesium phosphate (FCMP) grew from less than 1,000 t P_2O_5 in 1955 to 4.5 Mt P_2O_5 in 2005. Output of high-analysis

phosphate compound fertilizer (NPK, monoammonium phosphate (MAP), diammonium phosphate (DAP), triple superphosphate (TSP) and Nitrophosphate (NP)) increased from 146,000 t P_2O_5 in 1980 to 6.8 Mt P_2O_5 in 2005 and their proportion of the total phosphate fertilizer output rose from 3.5% to more than 60%. The proportion of phosphate group compound fertilizers (NPK) increased from 2% (100,000 t P_2O_5) in 1994 to 12% (1.4 Mt P_2O_5) in 2005. The self-sufficiency rate and domestic market share of local phosphate fertilizer continued to grow while dependence on imported phosphate fertilizers went down. In 2006, the production of phosphate and high-analysis compound fertilizers continued to maintain a high growth rate. Phosphate fertilizer output throughout the country was 12.1 Mt P_2O_5 , of this, high-analysis phosphate fertilizer output was 8.2 Mt or 67.8% of the total production of phosphate fertilizer. Output of all low-analysis phosphate fertilizers, such as SSP and FCMP, was 3.9 Mt or 32.2% of the total production of phosphate fertilizers. Product composition was further improved.

2. With a higher level of technology and better equipment, the industry is able to achieve augmentation of scale and domestic production. At present, the average capacity of a new phosphate fertilizer unit in China has reached 300,000 t/y P_2O_5 , 300,000 t/y MAP, 600,000 t/y DAP and 800,000 t/y of sulphuric acid. The rate of domestic production by using domestically designed key equipment, spare parts and fittings of medium and large installations of phosphate was above 90%. Technological level was comparable with advanced level in the world while the investment was equivalent to 1/3 in the past.
3. Achievement of optimal resource deployment and increases in the extent of centralization of the industry has resulted in the establishment of a number of phosphate compound fertilizer group of companies with million-tonne capacity that combines mining and fertilizer. These include the Yuntianhua Group Co. Ltd. (Yunnan Sanhuan Chemical Industry, Yunnan Furui Chemical Industry, Yunnan Honglin Chemical Industry, Yunnan Yunfeng Chemical Industry), The Guizhou Hongfu Industry and Development Co. Ltd. and the Guizhou Kailin Chemical Fertilizer Co. Ltd. They have enhanced their competitiveness in the international market.
4. Economic benefits in the trade have improved. In 2000, there were 1,020 phosphate fertilizer enterprises and 1,118 in 2005. In 2000, the debt ratio for the whole industry was 67.4%. In 2005, it dropped to 60.8%. Sales income increased from RMB29 B to almost RMB97 B. Total amount of profit in the industry increased from RMB470 M to RMB5.6 B.

3.1 Development of phosphate fertilizer products

3.1.1 Major types of phosphate fertilizer products in China

Phosphate fertilizer products are classified according to nutrient content and production technology. Based on nutrient content, the products can be divided into low-analysis and high-analysis phosphate fertilizers. Low-analysis phosphate fertilizers are products with a P_2O_5 content of less than 20%. These mainly include SSP and FCMP. High-analysis phosphate fertilizers are products with P_2O_5 content greater than 40%. These mainly include ammonium phosphates; monoammonium (MAP) and diammonium (DAP), NPK, Nitrophosphate (NP) and triple super phosphate (TSP). This type of classification has not been seen in other countries. The so-called "low" analysis phosphate fertilizer merely refers to the low content of P_2O_5 . If secondary and micro-nutrients are included in the fertilizer product, then the effective nutrient of SSP and FCMP would reach 40-60%.

3.1.1.1 Single superphosphate (SSP)

Single superphosphate (SSP) is the earliest type of chemical fertilizer and the earliest produced by chemical processing in the world. The Englishman John Lawes obtained the British patent to produce SSP by using sulphuric acid and guano. He set up his plant and became the first to produce SSP as a commercial fertilizer. In 1942, China began using the *Kunyang* phosphate rock (PR) (P_2O_5 content of 37.9%) to produce SSP containing 17% P_2O_5 at Kunming, Yunnan Province. It was the first phosphate fertilizer grade in China. SSP is made by the reaction of PR and sulphuric acid. It is a readily available water-soluble phosphate fertilizer. Its main components are $Ca(H_2PO_4)_2 \cdot H_2O$ and anhydrous calcium sulphate. It contains 12-20% of P_2O_5 , 5% of free acid and a pH value of about 3. It also contains 10-16% S, 17-28% CaO or some MgO. SSP appears greyish white, light grey, dark grey or brown. It is a loose and porous powder, granular or in lumps. SSP can be used directly as a single phosphate fertilizer or as raw material for compound fertilizer.

At present, SSP is the second biggest phosphate product produced in the world, after ammonium phosphate (AP). Annual world output of SSP has been estimated at around 7-9 Mt P_2O_5 or 20% of total world output of phosphate fertilizer since 1980. In 2005, output of SSP in China was about 4.2 Mt P_2O_5 or product quantity of 32 Mt.

3.1.1.2 Fused calcium magnesium phosphate (FCMP)

Fused calcium magnesium phosphate (FCMP) was developed and applied later on. In 1939 the German S. Arthur and other researchers were the first to obtain the patent for FMP fertilizer in the laboratory. In 1943, J.H. Walthall and others at the Tennessee Valley Authority (TVA) in the USA completed their pilot studies on FCMP. In 1946, the Permanent Metallurgical Company of California, USA, began using an electric furnace to produce FCMP. In China, the Taiwan Fertilizer Company tried manufacturing FCMP containing 18-20% P_2O_5 in 1951. During the period 1958-1959, the Beijing Chemical Industry

Experimental Plant and the Zhejiang Lanxi Chemical Fertilizer Plant adopted the blast furnace with cold air cycling to produce FCMP.

FCMP is a type of vitreous phosphate fertilizer formed by melting PR and a fusing agent (containing magnesium and silicon minerals) at temperatures above 1,400°C, followed by rapid hardening with water. Effective components of FCMP are α - $Ca_3(PO_4)_2$ crystallite, a vitreous compound mainly of phosphorus (P), silicon (Si), calcium (Ca) and magnesium (Mg) and without a definite molecular formula and molecular weight. The P_2O_5 content of the product is 12-20%. FCMP has very low solubility in water but 90% or more can dissolve in a 2% aqueous solution of citric acid. It is a slow-release, citric acid-soluble phosphate fertilizer that is alkaline (pH 8.0-8.5). It also contains secondary and micronutrients such as citric-soluble MgO 8-20%, CaO 25-32%, SiO_2 20-30%, FeO 1-2% and Mn 300-800 mg/kg, Zn 50-210 mg/kg and Cu 10-66 mg/kg. Products of FCMP are usually in powder form suitable for use as a base fertilizer. They are more suitable for acidic soil and crops that are sensitive to phosphorous. Unlike ordinary calcium-silicon fertilizers, almost all the silicon and calcium in FCMP are absorbed by the plant's root system.

At present, both the Chinese production and export of FCMP (not including production in the Taiwan region) occupies the top position in the world. In 2005, China's output of FCMP was about 300,000 t P_2O_5 , or more than 2 Mt of product.

3.1.1.3 Triple superphosphate (TSP)

In 1872, Germany was the first to use phosphoric acid by wet process to produce TSP with P_2O_5 at 43-45%. In 1890, the US began production of TSP in Baltimore. In 1907, the USA built a 5,000 t/y plant in Charleston, in the state of Carolina, and achieved commercial production for the first time. In China, a 50,000 t/y plant of TSP by thermal-process phosphoric acid was set up at Liucheng, in the province of Guangxi in 1976. This was the beginning of the China's TSP history.

TSP is a phosphate fertilizer containing 40-50% of P_2O_5 made by the decomposition of PR using phosphoric acid. Its P_2O_5 content is equivalent to three times the effective P_2O_5 content of single super phosphate (SSP); thus, it is referred to as "triple" or "double" or simply "TSP." TSP is a readily available and water soluble fertilizer. Its major component is $Ca(H_2PO_4)_2 \cdot H_2O$. Granular TSP can be directly applied as base fertilizer, topdressing, seed fertilizer or as mixed fertilizer and raw material for the production of compound fertilizer. It is widely suitable for various grain crops and economic crops and various types of soil, particularly in Northern, Northeast and Northwest China where there are P deficiencies. In 2005, China's production of TSP was about 480,000 t P_2O_5 , which equate to 4.3% of the total output of phosphate fertilizers in China. The product quantity produced was about 1.1 Mt.

3.1.1.4 Nitrophosphate (NP)

The commercial production of nitrophosphate or nitric phosphate (NP) was based on the invention of Erling B. Johnson of the Odda Smelt Company of Norway in 1928. During the mid-1950s, the Shanghai Research Institute of Chemical Industry carried out research on many methods of producing NP. In 1964, it cooperated with the Phosphate

Fertilizer Plant of Nanjing Chemical Industry C. Ltd., and the Design Institute of Nanjing Chemical Industry and completed a pilot project of 3,000 t/y of NP by carbonisation. In 1984, a plant of NP fertilizer with a capacity of 165,000 t/y, which decomposed PR by mixing nitric and sulphuric acid, was set up at Kaifeng Fertilizer. In 1987, the indirect refrigeration technology was imported from Yara (formerly Norsk-Hydro) of Norway using coal as raw material. A complex with a capacity of 300,000 t/y of ammonia, 540,000 t/y of nitric acid and 900,000 t/y of NP fertilizer was built at the Shanxi Chemical Fertilizer Plant (now the Tianji Group). It is the biggest NP plant in the world.

NP is a nitrogen-phosphorus compound fertilizer made from the decomposition of PR with nitric acid. The composition of the product includes water and citric soluble phosphates, ammonium nitrogen (NH_4^+) with long-lasting fertilizer effect and readily available nitrate nitrogen (NO_3^-). The NP process can produce two-nutrient or three-nutrient compound fertilizers. It can regulate the water solubility of P_2O_5 in the product and this makes it a good fertilizer. It is more suitable for crops growing on dry land, particularly tobacco and oranges. NP fertilizer is particularly effective when applied on grain crops like wheat, maize, rice and economic crops such as rapeseed, tea and cotton. It is very suitable for soils of low and medium fertility. Besides increasing yield, NP is also able to raise the quality of cash crops. As a base fertilizer, NP gives better effects. The nitrogen forms of NP (half of it in NH_4^+ and the other half as NO_3^-) and nutrient proportions are better than other compound fertilizers. Therefore, its yield-increasing ability is slightly higher than ammonium based fertilizers with equivalent nutrient levels. Besides it has stable fertilization effects. It is popular among farmers because it has good physical properties, is easy to store, transport and apply.

In 1989, China produced 21,000 t NP fertilizers, which occupy 0.56% of the total phosphate fertilizer output in that year. At 130,000 t P_2O_5 , output was the highest in 1999, accounting for 2% of the total production of phosphate fertilizers in that year. In 2005, China produced 71,000 t P_2O_5 of NP representing 0.6% of the total production of phosphate fertilizer or 620,000 product tonnes.

3.1.1.5 Ammonium phosphate (AP)

Ammonium phosphate (AP) fertilizers consists mainly of monoammonium phosphate (MAP) and diammonium phosphate (DAP). The others are ammonium polyphosphate (APP), a dehydration product of ammonium phosphate. These are followed by urea-phosphate, ammonium sulphate phosphate and ammonium nitrate phosphate which are compound fertilizers composed of ammonium phosphate and urea, ammonium sulphate or ammonium nitrate.

In 1920, the American Cyanamid Company began producing MAP and in the 1930s, the company Dorr turned it into industrial production. In 1954, the USA produced DAP on an industrial scale for the first time. In 1966 the Phosphate Fertilizer Plant of Nanjing Chemical Industry Co Ltd established the first industrial installation with a capacity of 30,000 t/y of DAP in China. In 1983, the former Chengdu University of Science and Technology (which is now annexed by Sichuan University) and the former Sichuan Yinshan Phosphate Fertilizer Plant successfully developed

the technique of manufacturing MAP by the neutral slurry concentration process and in 1988, the industrial experiment in producing 30,000 t/y of MAP by slurry concentration and spray-drying granulation was accomplished.

MAP is a water-soluble and quick-acting compound fertilizer and one of the major grades of high-analysis phosphate compound fertilizers.

MAP is a white powder or white granules with characteristics as follows:

| Characteristics/Specifications | Granular MAP Powder MAP |
|--|------------------------------|
| Density | 1.80g/cm ³ |
| Tap density | 0.96 – 1.04g/cm ³ |
| Total nutrient content (TN + A P_2O_5) | |
| Phosphoric acid concentration process | ≥ 56% ≥ 55% |
| Slurry concentration process | ≥ 50% ≥ 46% |
| Total Nitrogen (TN) | ≥ 10% ≥ 8% |
| Available Phosphorus (A P_2O_5) | |
| Phosphoric acid concentration process | ≥ 46% ≥ 47% |
| Slurry concentration process | ≥ 40% v 38% |
| Percentage of water-soluble phosphorus (W P_2O_5 /A P_2O_5) | |
| Phosphoric acid concentration process | ≥ 87% ≥ 83% |
| Slurry concentration process | ≥ 65% ≥ 65% |
| Free Moisture | ≤ 2% ≤ 9%/v 6% |
| Granule size | (1-4mm) ≥ 80% |
| Average compressive strength of granules | ≥ 20 N/granule |

DAP is in the form of fine brown granules with a high granular compressive strength. It is neutral, with density of about 1.62 g/cm³ and tap density of 0.96-1.04g/cm³. It has good solubility in water and acid. The specification of DAP is as follows: total nutrient content (TN + A P_2O_5) ≥ 51%. Total nitrogen (TN) ≥ 13%, in which effective phosphorus is (C- P_2O_5) ≥ 38%. The percentage water-soluble phosphorus (W P_2O_5 /C- P_2O_5) is ≥ 84%; free moisture ≤ 2.5%, granule size (1-4mm) ≥ 80% and the average compressive strength of granules ≥ 20 N/granule. DAP is a water-soluble quick-acting compound fertilizer. It is also one of the major grades of high-analysis phosphate compound fertilizer.

MAP and DAP are generally used for topdressing. They are also used for the production of NPK compound fertilizers, and as raw material for bulk blending (BB) fertilizers. It is widely suitable for application on grain and cash crops and various types of soil. It is particularly suitable for application in the dry northwest, and north and northeast China where the rainfall is low.

The nutrient content of ammonium polyphosphate (APP) is even higher. As it forms chelates with metal ions, it is not easy for the degradation of effective phosphorus to occur in the soil. Therefore, it can be used as a carrier for micronutrient fertilizer and is a good raw material for the production of liquid fertilizer. Urea-phosphate is a high-analysis NP compound fertilizer. Its urea-N and nitrate-N each has its unique agrochemical characteristics. Ammonium thiosulphate has good physical properties. It does not absorb

technical reform and scientific research, imported more than ten sets of medium and large size phosphate plants besides setting up more than 80 small size AP plants by relying on China's own technology. When these projects went into production, the scale and composition of the phosphate fertilizer industry was greatly improved, enabling output of phosphate fertilizers to increase rapidly from 1.8 Mt of P_2O_5 in 1985 to 6.2 Mt P_2O_5 in 1995. The increase was 4.4 Mt P_2O_5 over a period of 10 years. The products covered all grades of phosphate fertilizers – DAP, MAP, TSP, NP, NPK, SSP and FCMP. At this stage, SSP and FCMP were still the dominant products that accounted for 85% of the total phosphate fertilizer production in 1995.

In the “9th Five-Year Plan” (1996-2000), due to inadaptability of imported plants to Chinese PR as raw material, these plants failed to effectively meet their production capacities and the increase in the output of phosphate fertilizers was limited, from 5.8 Mt P_2O_5 in 1996 to 6.6 Mt P_2O_5 in 2000, a net increase of 880,000 t P_2O_5 over a period of 4 years. High-analysis phosphate fertilizers increased by 1.3 Mt P_2O_5 while low-analysis phosphate fertilizers decreased by 370,000 t P_2O_5 . The share of compound fertilizer production increased from 15 to 35%. During this period, some small AP enterprises switched to the production of compound fertilizers. A majority of the medium and large scale phosphate fertilizers enterprises worked hard to reduce assets and debts, reorganize the enterprise, and optimize resources and asset allocation and to extricate themselves from the difficult position in order to adapt to the transition from a planned to a market economy and build a modern enterprise system.

During the “10th Five-Year Plan” (2001-2005), the production technology of the phosphate fertilizer industry in China gradually matured. On top of that, in 2000, the policy of “reducing the import by 2 Mt of fertilizer with domestic production” was formulated. With the encouragement under the relevant policy of preferential treatment, production of phosphate fertilizer grew with unprecedented speed and total output jumped from 6.6 Mt of P_2O_5 in 2000 to 11.3 Mt of P_2O_5 in 2005, a net increase of 4.6 Mt of P_2O_5 in 5 years. This increase in output came mainly from high-analysis phosphate fertilizers (high-analysis phosphate fertilizers increased by 4.4 Mt of P_2O_5). Of this, the net increase in ammonium phosphate was 3.4 Mt of P_2O_5 and the net increase in NPK was 760,000 t of P_2O_5 . Low analysis phosphate fertilizer production increased by 190,000 t of P_2O_5 . The proportion of high-analysis phosphate fertilizer increased from 35 to 60%.

The rapid development of the phosphate fertilizer industry also brought about a series of problems:

1. The rapid development in the production of AP during the 8th, 9th and 10th Five-Year Plans resulted in the capacity of DAP and MAP plants exceeding the actual volume of consumption by the end of the 10th Five-Year Plan (end of 2005). During the “11th Five-Year Plan,” there are still eight enterprises building or planning to build AP installations. The annual capacity will reach 5.8-6.2 Mt of product. The AP industry faces tough challenge in market development.
2. The excessive development of high-analysis phosphate fertilizers will certainly lead to a reduction in the output of SSP and FCMP (the trend is the same in China, Japan

and South Korea). High-analysis phosphate fertilizer production wastes resources and has negative effects on the environment. If FCMP is produced, low-grade PR can be directly utilized without beneficiation or discharge of tailings. If SSP is produced, it is not necessary to discharge phosphogypsum; the gypsum will be applied to the soil together with phosphate fertilizer. It is, thus, a phosphate fertilizer that improves the soil. The phosphoric acid by wet process that produces 1 t of P_2O_5 will subsequently generate about 4.8 t of phosphogypsum. Therefore, the rapid development of AP in recent years has caused enormous harm to the environment. In the production of AP, there is urgent need for further enhancement in the control of “the three wastes” headed by phosphogypsum; research and development in the comprehensive utilization of new techniques, protection of resources and the environment to realize zero emission by clean technology for AP.

Resources exert enormous influence on the development of phosphate fertilizer products. At present, phosphate fertilizer products are showing diversification in the composition of types/grades and excellent price ratio. Compared with other phosphate fertilizer producing countries such as the USA, Morocco and Russia, the biggest difference is that China's low-analysis phosphate fertilizers (SSP and FCMP) have higher output, basically maintained between 3-4 Mt of P_2O_5 . Since more than 85% of phosphate fertilizer product is raw material cost, the price advantage and geographical advantage enjoyed by low-analysis phosphate fertilizers to a certain extent relieves the market pressure resulting from competition between domestic high-analysis phosphate fertilizers and imported products that provide the very important time and space competition for the development of high-analysis phosphate fertilizer in China.

3.1.3 Types of phosphate fertilizer that should be developed in the future

3.1.3.1 Single superphosphate (SSP)

Enhancement of direct and rational utilization of low and medium grades PR, reduction of discharge of solid wastes, appropriate replenishment of plant nutrients, are realistic and objective requirements of a resource saving and recycling economy. As SSP contains micro and secondary elements such as sulphur and calcium in comparison with high-analysis phosphate fertilizers (TSP, based on equal amounts of nutrients), its price is lower and more adaptable to the overall economic level of the many agricultural villages. SSP occupies a considerable proportion in the production of phosphate fertilizers. The output and amount of application should not be shrinking; instead, there should be expansion. Compared with high-analysis phosphate fertilizers, apart from its weaknesses in transport, storage and management, obvious problems with regard to the physical and chemical properties of SSP still exist. For example, SSP has a definite period of curing and, contains free acids that are corrosive to the packaging and containers for storage and transport. In addition, lump formation is common creating application difficulties. These problems should be solved.

3.1.3.2 Fused calcium magnesium phosphate (FCMP)

The production of high-analysis phosphate fertilizer entirely through beneficiation and using the acid method is very difficult. Besides, there is a large waste of phosphate in the beneficiation. To use PR for the production of FCMP is relatively simple and economical. Through the proper selection of rock and the appropriate fusing agent or partial mixing and burning of medium and high-grade rocks, it is possible for the phosphate content of FCMP fertilizer to reach 16-18% which is a moderate figure. Owing to a lack of resources of potassium minerals in China, in the course of producing FCMP, by mixing and burning potash feldspar partially, potassium resources can be utilized fully. In the course of manufacturing FCMP by burning, it is possible to remove the heavy metals partially that makes fertilizer application safer to the environment.

China has been the country with the largest production and sale of FCMP. Due to the impact of high-analysis phosphate fertilizers, some people are of the opinion that, with its low phosphate content, FCMP is backward and a product that should be eliminated. In recent years, the production and sale of FCMP has been fluctuating at a low level. In view of the conditions in China, the FCMP industry should be reactivated as soon as possible. It is suggested that with effective P at 12-14% P_2O_5 , it should still be called FCMP fertilizer. With the effective P $\geq 15\%$ P_2O_5 , it should be referred to as fused phosphate fertilizer. For fused phosphate fertilizer, its specification can be made reference to the Japanese standards. Apart from the specified percentage content of P_2O_5 , it is required that the percentage content of effective MgO and percentage of effective SiO_2 and alkalinity are also indicated. FCMP does not absorb moisture, forms no lumps and does not corrode the packaging or container. Research and development in the production of granular FCMP should be advocated. However, there are shortcomings in its production and application. For example, in the course of production with particle diameter exceeding $175\mu m$ it consumes much electrical power and heavy dust is emitted. The product is in powder form and this causes many inconveniences to transport, application and management. Improvement is required.

3.1.3.3 Triple superphosphate (TSP)

TSP is an important grade in the export of phosphate fertilizers. As high technology is required in the production process of TSP with regard to reactivity of secondary PR and for economic reasons, it is only appropriate to maintain a certain output in the provinces of Yunnan and Guizhou which are near the Southeast Asian market and where the grade of PR and reactivity are suitable for producing TSP. In 2005, the eight phosphate fertilizer enterprises in Yunnan Province produced 1.1 Mt of TSP of which 840,000 t (including SSP) of the products are exported, bringing in revenue of US\$13,891 M.

3.1.3.4 Nitrophosphate (NP)

Production of nitrophosphate (NP) requires high-grade PR with good reactivity but the Tianji Group in Shanxi Province is far from the provinces of Yunnan and Guizhou regions with good quality PR. With the continuous expansion of phosphate fertilizer plants at locations of PRs, the source of

the PR as raw material will become the decisive factor which determines the survival of the grade in question. In 2005, the Shanxi Tianji Group was the only enterprise producing NP in China. In 2006, the Henan Jinkai Company (formerly the NP Branch of Kaifeng Chemical Fertilizer Plant in the province of Henan) resumed its production of NP. This product is marketed mainly in the major food grain producing regions in the provinces of Henan and Shandong.

3.1.3.5 Monoammonium phosphate (MAP) and diammonium phosphate (DAP)

Ammonium phosphate (AP) fertilizers will still be the main type of phosphate fertilizer in the future. However, the problem of environmental pollution caused by its by-product, phosphogypsum, needs an urgent solution. In 2005, 33Mt of fluorine-containing phosphogypsum was generated in China as a result of the production of AP. At present, domestic phosphogypsum is growing at the rate of 15% each year and the accumulated amount is nearly 100 Mt. Owing to technical and other reasons, disposal is difficult and the utilization ratio is less than 10%. Chemical gypsum, piled up mountain-high, is occupying large areas of land and, after soaking in rainwater over a period of time, harmful substances such as soluble P_2O_5 and fluoride find their way into the environment, causing serious soil and water pollution. In April 2004, in its circular concerning investigation of environmental risks, the State Environmental Protection Administration included the Phase II project of the Yunnan Sanhuan Co. Ltd. with a capacity of 1.2 Mt of AP and the Phase II project of the Yunnan Furui Chemical Co. Ltd. with a capacity of 600,000 t in the list of 20 enterprises with great environmental risks. In the report on the results of investigations of environmental risks, phosphogypsum residue was classified as hazardous waste for the first time. Data exceeding the standards were the indices of pH value and concentration of inorganic fluorides leached out (not including calcium fluoride) under the control of the National Catalogue of Hazardous Wastes, that is, pH value ≤ 2.0 and the concentration of inorganic fluorides leached (not including calcium fluoride) ≤ 50 mg/l. The two enterprises were required to submit a special supplementary report on the assessment of environmental risks and carry out rectification. The two enterprises faced the risk of shutdown or reorganization. This means that whether or not the entire phosphate fertilizer industry is able to achieve comprehensive utilization of phosphogypsum concerns not just ecological improvement but it has become the bottleneck that limits the development of the entire industry.

3.1.3.6 Special purpose NPK fertilizer

As there are large changes in soil conditions in recent years, compound fertilizers that are commonly used have become less effective. Compound fertilizers used by farmers have been strengthened from 45% (15-15-15) to 54% (18-18-18). Fertilizer application per unit area has not changed but the total nutrient input has increased. However, instead of yield increases, crop production is showing a decreasing trend. Under the present campaign of prescribing fertilizer according to the results of soil tests, it is required that special-purpose fertilizers for the corresponding crops be linked with this technique. In addition, when considered from a level

presently acceptable to agricultural producers, the “fool” or “easy-to-use” (a type of fertilizers that is very popular) and special-purpose fertilizers should also comply with this requirement. Consequently, top dressing with special-purpose fertilizer partially combined with nitrogenous fertilizer will be the major way for fertilizer application.

PRs in China are mainly low and medium grades and beneficiation is difficult. Phosphorus resources which cannot be regenerated will be diminishing. We should actively promote and implement development strategies of ecological technology for phosphorus resources, develop new types of phosphate fertilizer or methods of processing that are economical, effective and energy-saving. For example, powdered PR which can be directly applied as fertilizer for acidic soils, partially acidulated phosphate rock (PAPR), biological phosphate fertilizer or the development of various new types of energy-saving techniques. All these are technologies of fertilizer ecology. In this regard, the International Fertilizer Development Centre of the US (IFDC), le Centre de Cooperation Internationale en Recherche Agronomique pour le Developement (CIRAD) of France and scientific research departments of many countries and the Institute of Soil Science, Chinese Academy of Sciences have all used low quality PR and carried out studies on the method of production and fertilization efficiency of “partially acidulated phosphate rock (PAPR).” The volume of sulphuric acid used is only 30-60% of the theoretical volume. Even though the fertilization efficiency is slightly lower than totally water soluble fertilizers, it saves resources and reduces costs.

In order to raise the efficiency ratio of phosphate fertilizer, efforts should be made with regard to processes and products, models of fertilizer application, soil improvement and crop cultivation. These include the development of water soluble phosphate fertilizers, provision of accurate applications of fertilizer according to the crop requirements, development of new types of fertilizer by taking into consideration soil characteristics, in order to overcome fixation of phosphorus by iron and aluminium ions, and the enhancement of conversion and absorption abilities with regard to highly insoluble P.

3.2 Technological development in the phosphate fertilizer industry

The phosphate fertilizer industry is a resource dependent industry. P, S and synthetic ammonia are the three major raw materials for the phosphate fertilizer industry in China. China has sizable reserves of phosphorus resources. However, many are of low and medium grade rocks (P_2O_5 content of 14-24% means low grade; P_2O_5 content greater than 24% means medium grade; and P_2O_5 content greater than 30% means high grade), high in impurity and beneficiation is very difficult. There is a severe shortage of sulphur resources. China's own resources depend mainly on sulphuric acid as pyrite and a by-product of smelting fumes. For more than 50 years, China has gone through different stages of research and development of phosphate fertilizer technology, importation of large installations/technologies, digestion and innovation. These were mainly centred on the characteristics of P and S resources, which led to the development of the “technique of

concentrated sulphuric acid reacting with ground PR slurry for the production of SSP. A burden calculation method by the glass structure factor for the production of FCMP, the slurry concentration process for AP, the technique of potassium chloride (KCl) conversion for manufacturing S-NPK, the technique of combined production of sulphuric acid and cement with phosphogypsum, the technique of rapid extraction of phosphoric acid and the conventional method of combined production of DAP and MAP by the slurry concentration process, are all production techniques for phosphate fertilizer at advanced levels throughout the world and they enjoy autonomous intellectual property rights in China. China has found a developmental path of techniques that suit conditions in China and which have Chinese characteristics. This has catapulted China from zero production at the initial stage of nation building to the position of top producer in the world with a full range of grades/types and a complete industrial system with designing, scientific research, equipment manufacture, construction and installation, production, sale and agrochemical services.

3.2.1 Technological development of China's phosphate fertilizer industry in comparison with advanced technologies in the world

3.2.1.1 Development of single superphosphate (SSP) technology

After 1953, the Chemical Engineering Bureau of the former Ministry of National Heavy Industry made arrangements for the Hangzhou Branch of the Chemical Engineering Laboratory (subsequently annexed by Shanghai Chemical Engineering Research Institute) to begin technological research to test the manufacturing of SSP at the Lianyungang Jinping Phosphorus Mine in the province of Jiangsu. During the period of 1952-1957, 4 small size SSP plants of 20,000-60,000 t/y capacity were built in Harbin of Heilongjiang Province, Liaoyang in Liaoning Province, Jinan in Shandong Province and Hengyang in Hunan Province. In 1955, using choice ground PR from the Lianyungang Jinping Phosphorus Mine in Jiangsu Province, as raw material, a pilot plant of 10,000 t/y SSP was set up at the Shanghai Acid Manufacturing Plant (now the Number One Experimental Plant of Shanghai Chemical Engineering research Institute). In 1958, by utilizing the results of research and adopting vertical paddling and rotating formation technique, industrial installations of granular SSP with capacities of 400,000 t/y and 200,000 t/y were established respectively in Nanjing of Jiangsu Province (formerly Huadong Phosphate Fertilizer Plant, later renamed the Phosphate Fertilizer Plant of Nanjing Chemical Industry Co Ltd) and in Taiyuan of Shanxi Province (Shanxi Phosphate Fertilizer Plant, later renamed as Phosphate Fertilizer Plant of Taiyuan Nanjing Chemical Industry Co Ltd). It was then that China's earliest foundation for a phosphate fertilizer industry was laid. At present, the capacity of the largest single series installation in China is 400,000 t/y SSP.

1. Brief description of technology

Production of single superphosphate (SSP) is divided into the two processes of vertical paddling-rotating formation and belt formation. In both, SSP is made by the decomposition of

PR with sulphuric acid. The outstanding advantage is its low requirement for PR allowing ore with above 24% P_2O_5 to be used. Secondly, the production technology is relatively simple, investment in plant construction is low and the economy of scale to obtain the best benefit is small. In the early and middle stages of development of phosphate fertilizer, SSP was always the main product.

The process flow for SSP is divided into the work processes of ore milling, adding acid, mixing, reaction, crushing, curing, granulation and fluorine recovery. Based on the difference in rock grinding and acid addition, the process flow can be divided into "dilute acid ground rock method" (dry method) and the "concentrated acid rock paste method" (wet method). The former uses 60-78% sulphuric acid and dry ground rock with 90% passing through a 147 μ m sieve. The latter uses 93-98% sulphuric acid and PR paste with more than 90% passing a 147 μ m sieve, with water content of 26-28% (fluidity of the rock paste differs according to the concentration of the sulphuric acid and the hydrophilic property of the PR). The "concentrated acid rock paste method" is a technology developed by China itself during the 1960s. Its special feature is adding water to the PR, milling it into a paste and allowing it to react with sulphuric acid. This eliminates the dust pollution caused by dry milling in the "dilute acid ground rock method" and improves the production environment.

2. Domestic development

SSP production and sale in China occupies the top position in the world. The largest scale producer for a single series has reach 400,000 t/y (product quantity). The major enterprises include the Phosphate Plant of Jiangsu Nanjing Chemical Industry Co Ltd, Guangdong Zhanhua Co. Ltd., the Sichuan Longman Group, the Yunnan Honglin Chemical Co. Ltd., the Anhui Tongling Chemical Industry Group, the Yunnan Hunyang Phosphate Fertilizer Plant, the Shanxi Taiyuan Phosphate Fertilizer Plant, the Hunan Zhuzhou Chemical Co. Ltd. and the Gansu Jinchang Chemical Industry (Group) Co. Ltd. Domestically, the "concentrated acid rock pulp method" technique was developed, Zhengzhou University launched the "Research on improving physical and chemical properties," shortening maturing time during the stacking and curing of SSP and the improvement of product quality. Yang Kedun and others of the former Ningxia Phosphate Fertilizer Plant invented the new type of SSP jet mixer and Sichuan University developed SSP containing organic matters.

The technical development of SSP in China concentrates on equal rock allocation, concentrated acid rock paste, reduction of water content of PR paste and increase in flowability, using low and medium grade PR or high magnesium rock ($MgO/P_2O_5 \leq 9\%$), new type of mixing reaction installation, adding activator and anti-caking agents to prevent lump formation, shortening the period of stacking and curing, granulation and disintegration, energy saving, waste water treatment, unorganised emission treatment of gas containing fluorine, production of SSP containing organic matter or microelements, and packaging of products. All of these have shown good results.

In September 1997, Zhang Baolin, Tang Jianwei and others in the former Zhengzhou University of Technology

(presently Zhengzhou University) launched the "Research on improving physical and chemical properties, shortening the maturing time of the period of stacking and curing, and the improvement of the materiality of the product SSP." Based on the characteristics of the different PRs in China, after continuous selection, testing, repeated matching, and carrying out experiments with compressed sacks and stacking in bulk, they developed an additive (activating foaming agent) for the process of reaction of serial acid hydrolysis. After adding the activating foaming agent to the former mixing installation of single super phosphate, fluidity of the ore pulp was improved. The rate of conversion to fresh fertilizer was raised by 3-15% with the product not forming lumps. The chemical properties were stable, without degeneration, and fluorine loss was reduced (can be partially reduced to below 5%). The production environment was obviously improved. In 2000, the project was awarded the Class II Award for Progress in Science and Technology by the province of Henan. In 2001, the SSP production process without stacking and curing was included in "A Guide to Areas of Priority in High Technology Industry for Current Development with Preference" promulgated by the National Development and Reform Commission and the Ministry of Science and Technology and was included as a national demonstration engineering project. This technology has since been applied in more than 50 plants with good results.

The mixer used in the production of SSP is a mechanical agitating mixer that comes in the vertical, horizontal, single-paddle and multi-paddle forms, all of which require a driving force. The volume is big and consumes many materials with high cost. Due to corrosiveness of sulphuric acid and wear and tear of materials, the paddle blades are easily damaged and production has to be stopped for carrying out replacement or repair. At the former Ningxia Phosphate Plant, Yang Kedun designed a type of "new mixing installation for SSP that does not consume energy." Inside this installation, there is a special structure in the form of a short tube which is divided into 3 parts: charge-in part, mixing part and discharging part. At tens of kilograms, its volume is very small. The materials are resistant to corrosion, wear and tear and high temperature. There is no need for repairs and maintenance. It can be used continuously over a long period and is easy to manufacture. It eliminated some of the drawbacks of the mechanical agitating mixer and partially replaced various types of such mixers. Up to 2001, production plants in more than ten provinces were using the new type of mixing installation and obtained appreciable economic benefits.

3. Developments abroad

In other countries, the technique of "dilute acid ground rock method" is mainly used. This is basically similar to enterprises in the same category in China. Since 1980, world annual output has been fluctuating around 7-9 Mt of P_2O_5 or 20% of total world output of phosphate fertilizers. Major producing countries include Australia, New Zealand, Egypt, Brazil, Vietnam, Bangladesh, Kazakhstan and Zimbabwe. At present, SSP is second only to AP as the largest fertilizer grade in the worldwide production of phosphate fertilizers.

4. Outlook for domestic and foreign technological and economic development

Domestically, both the “concentrated acid rock paste method” and the “dilute acid ground rock method” are unique in some way and have definite competitive advantages. In terms of technical innovation and the technique of producing conventional products, they are able to reach or surpass advanced international levels. In other countries, they have accumulated experiences with regard to shortening and ending stacking and curing periods, improvements in the quality or granulometry of the product, the utilization of mixed sulphuric and phosphoric acid for the production of double superphosphate, recovery and utilization of fluorine and environmental protection.

3.2.1.2 Technological development of fused calcium magnesium phosphate (FCMP)

1. Brief description of technology

FCMP fertilizer is a type of vitreous phosphate fertilizer formed by melting PR and a fusing agent (containing magnesium and silicon minerals) at a high temperature of above 1,400°C, followed by rapid hardening with water. PR containing more than 16% of P_2O_5 can be used as raw material. The fuel is mainly coke or anthracite. A blast furnace is the main fusion furnace used. Cyclone, open-hearth or electric furnaces can also be used. The production process is classified as a blast furnace, cyclone furnace, open-hearth or electric furnace process. Their differences lie in the source of energy consumed for production. The fuel for blast, cyclone and open-hearth furnaces is mainly coke, anthracite or heavy oil whilst the electric furnace uses electrical energy. The production of FCMP does not have stringent requirements with regard to PR quality. Even low and medium grade PR containing iron, aluminium and magnesium, which is not suitable for the production of SSP, can be used for producing FCMP. Besides, their prices are lower.

The process flow of FCMP is divided into the following work process: PR is broken into lumps or in agglomeration of powdered rock. The PR and fusing agent are melted at high temperature and the molten mass is rapidly hardened with water. The water is removed, followed by drying and milling. The technical difficulties are the very high melting point of PR ($Ca_5F(PO_4)_3$, about 1,650°C, and high energy consumption. This poses many difficulties in industrial implementation. The addition of a fusion agent during the production of FCMP such as serpentine, dolomite or quartzite, enables the melting point of the material to be reduced, allowing industrial production under conditions of 1,400-1,450°C.

2. Domestic development

In view of the fact that the impurity content of China's PR is high and there is inadequate sulphur-containing resources, in 1953, the route taken by processing of phosphate fertilizer in China was using both acid and thermal process. From 1953, plants, research and design units in Sichuan, Yunnan, Zhejiang and Beijing launched the R&D and manufacture of FCMP. The first industrial installation using the open-hearth furnace method was built at the Leshan Phosphate Fertilizer Plant in Sichuan Province. At this juncture, the first FCMP

plant that used an electric furnace to produce FCMP in the USA was about 10 years away. In 1958, a ϕ 1.2m and 2.8m high water-cooling jacketed type blast furnace was built at the Beijing Chemical Industry Experimental Plant. With an output of 30-40t per day, it marked the official appearance of the blast furnace technique in China. In 1959, the former Ministry of Chemical Industry convened the 1st national meeting at Lanxi, Zhejiang Province to exchange experiences in the improvement of the production of FCMP. In addition, the production technique of using a blast furnace was recommended. During the period of 1963-64, the Dongxiang Phosphate Fertilizer Plant in Jiangxi Province (now the Jiangxi Phosphate Fertilizer Plant) successfully transformed two idle iron-smelting blast furnaces, one of ϕ 1.3m with a volume of 13m³ and the other of ϕ 2m with a volume of 40m³ to blast furnaces for FCMP with a capacity of 30,000 t/y and 40,000 t/y respectively. With reduced energy consumption and stable operation, they were perfect for producing FCMP by the blast furnace process. From then on, the blast furnace process spread rapidly throughout the country. In 1966, FCMP produced in China reached 389,000 t. The product quantity already exceeded Japan and took the top place in the world.

The invention of the “blast furnace technique” was the main contribution to the production technology of FCMP in China. Xu Xiuchang of the former Zhengzhou Institute University of Technology (now called Zhengzhou University) invented “A burden calculation method by the glass structure factor” (PR for producing FCMP, with more than 16% P_2O_5 can be used as raw material). Tang Jianwei of the former Zhengzhou Institute University of Technology wrote the software for the burden technique for FCMP (which obtained the first batch of software copyrights in China). Then there is the use of the technique of “beneficiated burden material, strong wind, high temperature and high pressure” (output is doubled and consumption of coke reduced by 40%). The Luzhai Chemical Fertilizer Co., Ltd. in Guangxi Province, the Dongxiang Phosphate Fertilizer Plant in Jiangxi Province and the Zhanyi Phosphate Fertilizer Plant in Yunnan Province achieved good results in energy saving, reduction of consumption and waste treatment. The industrial production of FCMP as a by-product at Wuchang Power Plant in Hubei Province using the cyclone furnace was realized. There are also the techniques that use an agglomeration of powdered rock, white coal ore and anthracite instead of coke, for the manufacture of granular fertilizer and the production of high-grade FCMP (more than 20% P_2O_5) using PR containing 28-30% P_2O_5 .

3. Development in foreign countries

Japan carried out research during the period 1947-1966 and developed the electric furnace and open-hearth furnace techniques for FCMP production. In mid-1960, they exported this techniques and products to South Africa, Brazil and South Korea. In 1986, Japanese production of FCMP was 350,000 t, 10% of their total phosphate fertilizer output. Japan, Brazil and South Africa mainly adopted the electric furnace process for production. Electricity consumption was 700-2,100 kW·h/t. The larger the volume of the electric furnace, the lower will be the electricity consumption. There is no fuel ash in the molten material in the electric furnace process so the product quality is high. The environment of operation is

clean and the process is easy to operate and control. Japan and South Korea adopted the open-hearth furnace for production with energy consumption of 180 litres of heavy oil per tonne of finished product.

The technique of producing FCMP by the blast furnace process developed by China has been exported to Vandian-Hanoi, Vietnam.

4. Outlook for domestic and foreign technological and economic development

China has a great deal of mature experience with regard to the R&D and production of FCMP by blast furnace. In general, energy consumption by the blast furnace process is lower than the electric and the open-hearth furnaces and has, therefore, a relative competitive advantage. The electric furnace is suitable for production in areas where there is plentiful cheap electrical energy or where there is seasonal low demand for electricity. The cyclone furnace developed in China that produces FCMP as a by-product is superior to the blast furnace process, the open-hearth furnace process and the electric furnace with respect to energy consumption, which makes it the most advantageous process. However, some technical and management problems still remain.

3.2.1.3 Technological development of NP based NPK

Taking into consideration the inadequate sulphur resources in China, low phosphogypsum output in the production of NP based NPK is advantageous as no S based raw materials are required, thus limiting the emission of F compounds and the environmental impact. At the beginning of the 1950s, China began conducting research and pilot tests in the manufacture of NP. During the 1960s, many processes for the production of NP based NPK were studied but many difficulties appeared in the course of implementing their industrial production. Even though some installations were built by adopting the results of the studies, the scale was small and there was no technology breakthrough.

1. Brief description of technology

The reaction in the decomposition of PR by nitric acid is easy to carry out. The temperature of decomposition is usually between 50 and 55°C. The phosphate yield by reacting PR with nitric acid is high. The resultant slurry after the reaction is soluble, thus the ground PR as raw material can be slightly larger in particle size. Apart from acid-insoluble substances, almost all the major components and secondary components are soluble; the yield (or efficiency) of reacting PR with nitric acid can reach about 99%. Technically, the NP process requires PR of higher quality and, there are many process steps (unit operations) in the technology and the process flow is rather complex. Stainless steel is required in order to prevent corrosion. This, coupled with high investment in infrastructure, has greatly hampered development of this technology. Based on the different methods of precipitating and separating the calcium from the PR there are five types of production processes:

1. The refrigeration process (Odda method): as typified by the Yara (Norway) technology the Hoechst-Uhde technology from Germany, the Kamka-Nitro technology and the BASF technology. Total nitrogen (TN) content of the products is

greater than 25% and the P_2O_5 content is greater than 11%. The major components are (NH_4NO_3) , MAP and calcium hydrogen phosphate $(CaHPO_4)$.

2. The nitric-sulphuric acid (salt) process where a nitric and sulphuric acid mix is used to dissolve PR followed by the addition of a sulphate compound to the acidic slurry. A typical technique is the thiamine circulation process of DSM, Holland.
3. The nitric-phosphoric acid method uses the mixed acids of nitric and phosphoric acids to react the PR. A typical installation is that of P.E.C. in France.
4. The nitric acid-carbonation process which uses nitric acid to react PR. The ammoniated slurry is treated by using ammonia and carbon dioxide gases. This process is the creation of P.E.C. of France.
5. The nitro-SSP process (the Lonza process) has a plant established in Lausanne, Switzerland. Products grades include 6-10-12 and 14-12-16.

2. Domestic developments

Currently, China has two types of NP based plants. One is in the Kaifeng Chemical Fertilizer Plant (Kaifeng Group) in Henan province which was designed by China in 1984. This plant adopted the process of mixed acid of nitric and sulphuric acid to react PR to produce 130,000 t of NP based NP (24-14.5-0) and 35,000 t of NPK compound fertilizer (17-13.5-19). However, due to technical problems, production in 1998 could only achieve about 50% of its capacity. Another is in Lucheng, Shanxi Province, Chemical Fertilizer Plant (now the Tianji Group) which imported from Yara the technique of indirect refrigeration using coal as the raw material to produce 300,000 t/y of ammonia, 540,000 t/y of phosphoric acid and 900,000 t/y of NP based NPK. In 1987, there was an investment of RMB1.6 B for a new NP unit. Its daily capacity was 2,973 t of NP (26.7% N, 12.9% P_2O_5) and it was the largest installation for the production of NP based NPK. However, as some equipment was not of the right design, the separation of acid-insoluble substances was poor. The PR quality did not comply with the technical requirement of ($P_2O_5 > 31.5\%$, $MgO \leq 1\%$). In 1997, after 10 years of constant reform and improvement, the annual production was only 645,500 t. In 2005, the total product production was 620,000 t. Since the NP installation of the Shanxi Chemical Fertilizer Plant went into production China has not built other NP based NPK plants.

3. Developments abroad

After 1970, in sulphur resource-deficient Central Europe, the development of NP technology was rapid. A large number of installations went into production in Romania, Hungary, Bulgaria and the former Soviet Union. The refrigeration process is the technology most widely used globally. It offers the largest capacity and is a process with a developmental future. Germany, Holland and France developed some other production methods and even built experimental plants. However, the scale of its installations has never overtaken the scale of the refrigeration process. The Yara (Norway) refrigeration process has 15 sets of installations in East Europe and China.

4. The outlook for domestic and foreign technological and economic development

The development of NP based NPK fertilizer industry requires the supporting ammonia and nitric acid production units. However, the flow process of newly built ammonia and nitric acid installations is rather long. There are more equipment parts. A large amount of stainless steel is consumed. As a result, investment costs for infrastructure is too high. Furthermore, it demands higher quality PR with ($P_2O_5 \geq 31.5\%$, $MgO \leq 1\%$). There is also a higher quality requirement for the equipment used. In addition, as a compound fertilizer, the adjustable range of the N/ P_2O_5 ratio of NP based fertilizer is smaller. Consequently, during the 1980s, although China spent a huge sum of money building three sets of large NP installations [Jinan Chemical Fertilizer Plant, Kaifeng Chemical Fertilizer Plant and Shanxi Lucheng (Tianji) Chemical Fertilizer Plant, and Tianji is the world's largest NP production installation], due to the investment structure and for technical and economic reasons, production in the three enterprises has never been able to achieve their designed capacity. The Jinan Chemical Fertilizer Plant is in a state of shutdown with huge losses.

The difference with foreign countries with regard to technological equipment is not obvious. Domestic enterprises should solve problems concerning the source of PR, the technology for using domestic PR, marketing and agrochemical services.

3.2.1.4 Technological development of triple superphosphate (TSP)

During the 1960s, China began developing production technology for TSP. At the same time, phosphoric acid by the wet process and by the thermal process was being developed. The TSP thermal process installations (using phosphoric acid by thermal process) built in 1976 had high production costs. In 1982, relying on domestically developed technology and equipment, the first set of wet process TSP installation (daily production of 110 t P_2O_5 and annual production of 100,000 t of TSP) was built in Yunnan. The annual production capacity has now reached 200,000 t.

Compared with AP, the production of TSP is able to save 25-30% sulphuric acid. However, because the phosphoric acid used to produce TSP is of medium strength, its ability to react with PR is weaker than strong sulphuric acid. Thus, the PR to be used as raw material (commonly known as secondary PR) should be of high quality, with good reactivity and fine particle size. Besides, there must be a system set up for milling the dry rock into powder. Under the circumstances of the phosphorus resources in China, it is difficult for phosphate producers in most regions to meet the requirements of their production technology. Furthermore, TSP contains only nutrients of P. When used in the production of NP compound fertilizers, it is mixed with urea giving rise to an additional reaction, enabling the water of crystallization to turn into free water causing the fertilizer quality to deteriorate. At present, TSP is only produced in the provinces of Yunnan and Guizhou where PR is of high grade with good reactivity. Products are mostly exported to Southeast Asia.

1. Brief description of technology

The process for producing TSP can be divided mainly into four types:

1. The Den process (curing with concentrated acid);
2. The slurry process (granulation by dilute acid re-feeding);
3. Direct granulation with fresh fertilizer; and
4. Curing with dilute acid re-feeding.

2. Domestic development

The TSP industry in China was developed on the foundation of the SSP industry, using mainly the Den process. The conventional technique of the Den process is the reaction between ground PR and sulphuric acid followed by the separation of liquid from solid to obtain dilute phosphoric acid by the wet process. Concentrated phosphoric acid is obtained after concentration. Presently, most of the granular triple super phosphate (GTSP) in China is produced using dilute phosphoric acid (38-40% P_2O_5). The installation can also produce MAP/DAP/NPK. Concentrated phosphoric acid and PR carry out a mix reaction. The resultant substances of reaction are stacked for curing, granulation, drying, sieving and, if necessary, coating to prevent lump formation. The product is obtained after cooling.

Owing to the reasons above, TSP techniques have not gone far in China. Of the three sets of large installations imported during the "8th Five-Year Plan," with the exception of the Yunnan Phosphate Fertilizer Industry Co. Ltd. the others switched to the production of DAP or NPK. Jingxiang Dagukou in Hubei Province which produced 560,000 t of TSP annually has switched to the production of 500,000 t of NPK and 150,000 t of MAP each year. The two sets of plants of Hongfu in Guizhou Province that produced 800,000 t of TSP/y were revamped to produce 1.2Mt of DAP/y. Also, two sets of local equipment plants with joint annual production of 480,000 t of MAP were built.

3. Development abroad

In the 1940s, there was great development in the production of TSP. Besides drawing from the experience of intermittent mixer and chamber type formation technology of SSP, various new techniques were gradually developed based on the characteristics of raw material reaction. These include the Kuhlman process in France, the TVA process in the US, the AZF process in France, the Jacobs-Dorrco process, the jet-spray granulation process and the fresh fertilizer direct granulation by the former Soviet Union.

During the period of 1960-1970, TSP accounted for 20% of phosphate fertilizer in the world. In the period of 1966-67, it accounted for 30% of the total production of phosphate fertilizer. Subsequently, its pace of development gradually slowed down. After 1992, only one or two enterprises in the USA continued their production, with an annual output of 1.3 Mt of P_2O_5 . In recent years, major TSP producing countries include Russia, France, Brazil, Morocco, Indonesia, Algeria, Pakistan and Mexico.

4. Outlook for domestic and foreign technological and economic development

In China, the basic guiding principle for the TSP industry is to import technology followed by gradual domestic

development. Little difference exists between foreign and domestic enterprises in terms of production technology. After years of investigation, China has accumulated definite experience in the utilization of domestic PR. With regard to the distribution of TSP, the emphasis is to establish enterprises in the vicinity of mines where there is shortage of synthetic ammonia resources. This is to pair up the mine and fertilizer production so that fertilizer will be transported, not the raw material. In China, PR producing areas are located in the southwest. There is a strong advantage with regard to export to Southeast Asian countries.

TSP is a single P element fertilizer. Domestic sales are not brisk. High loan interests, and the high reactivity requirements of secondary PR caused two of the three large TSP projects established in the 1990s, with enormous investments by the State, to switch to the production of DAP and NPK. The third enterprise, the Yunnan Phosphate Fertilizer Industry Co. Ltd. (Dahuanglin) took the measure of “converting debts into shares” and set up the Yunnan Furui Chemical Industry.

From the development of TSP both domestically and in foreign countries, it can be seen that the path of compound fertilizer is the route to be taken. Therefore, for TSP product enterprises, apart from switching to the production of AP and NPK, they can try linking with urea enterprises to produce bulk blend fertilizer products. This is to make up for the unfavourable effects of single nutrient fertilizers.

3.2.1.5 Technological development of ammonium phosphate (AP)

1. Brief description of technology

MAP and DAP are together referred to as ammonium phosphate (AP). Its production involves neutralization of phosphoric acid by ammonia to obtain slurry, followed by granulation and drying. It has good physical and agrochemical properties with relatively high nutrient content. MAP has good heat stability and will only decompose at about 200°C. It does not absorb moisture readily and has high solubility in water. Its theoretical N content is 12.2%, P_2O_5 61.8% and $N:P_2O_5 = 1:5.1$. Heat stability of DAP is not high with large volume of ammonia escaping at about 80°C. Its theoretical N content is 21.2%, P_2O_5 53.8% and $N:P_2O_5 = 1:2.5$.

Overall, production technology of AP is classified into two categories: phosphoric acid concentration and slurry concentration processes. In the former, the phosphoric acid is generally concentrated to 50-54% P_2O_5 using the dihydrate process, followed by ammonia neutralization. In the latter, 20-25% dilute phosphoric acid (filter acid) is neutralized by ammonia before concentrating the neutralized slurry.

2. Domestic development

Development of AP products and pilot experiments began in China during the 1950s. In 1966, the Nanjing Chemical Industry Co. built the first set of plants by adopting technology and equipment developed domestically with 50 t/d P_2O_5 capacity of phosphoric acid and 30,000 t/y capacity of DAP. With this, the history of AP began in China. Production technology of AP is classified into “phosphoric acid concentration process” and “slurry concentration process.” The phosphoric acid used in the former is concentrated to 50-54% P_2O_5 by the dihydrate

process followed by ammonia neutralization. In the latter, 20-25% dilute phosphoric acid is neutralized with ammonia before concentrating the neutralized slurry. Of these, AP by the “slurry concentration process” was in accordance with the new technique developed based on the characteristics of PR in China. This technique is able to utilize medium grade PR that contains more impurities (the technical requirement of the slurry concentration process is, $P_2O_5 \geq 28\%$, $MgO \leq 2\%$); but for the production of high-analysis phosphate fertilizer, the technical requirement of the conventional process is $P_2O_5 \geq 30\%$, $MgO \leq 1.2\%$).

Technical characteristics and technological progress of AP by the “slurry concentration process”

Starting in the 1980s, China conducted research on the technique of AP by the “slurry concentration process.” In 1988, the former Chengdu Science and Technology University (presently annexed by Sichuan University) and the former Sichuan Yinshan Phosphate Fertilizer Plant worked together in response to the characteristic of high impurities content in the PR from the Sichuan Jinhe Mine [27% P_2O_5 , 3% MgO , 5.8% R_2O_3 (R_2O_3 refers to the combined content of Fe_2O_3 and Al_2O_3)] by adopting the technique of neutralization of dilute phosphoric acid with ammonia, dual effect concentrated slurry. They successfully developed the technique of the “slurry concentration process” that is entitled to autonomous intellectual property rights. The product specification is 11-42-0 with P_2O_5 water solubility at 70%.

The concentration of neutralized slurry is a key innovative technology of AP by the “slurry concentration process.” It also distinguishes itself from the conventional process of manufacturing AP by re-neutralization of phosphoric acid concentrate. This allows the rational utilization of the heat of ammoniation reaction, simplification of flow process, increase in the life-time of production equipment, achievement of energy saving by reduction of consumption and an increase in the level of production technology. The technique of manufacturing AP by the “slurry concentration process” is able to make use of the low and medium grade PR with high content of impurities from China’s rich deposits to produce MAP and guarantees a place for PR resources domestically.

For more than 20 years, through research and development of key techniques, laboratory studies, pilot experiments, industrial demonstration and large plants, production capacity of single series AP by the “slurry concentration process” has expanded from 30,000 to 200,000 t/y. Throughout China, complexes with production capacity of nearly 3 Mt/y have been built. It is one of the major technical routes taken for the production of AP in China. With regard to the major developments in the various links of this technology, the following techniques have been accomplished: “technique of comprehensive enhancement of thermal equilibrium,” “external circulating rapid ammoniation reactor,” “integral process of phosphoric acid ammoniation and slurry concentration,” and “dilute acid tubular ammoniation reactor.” In addition, the flow process of “forced closed-cycle evaporation” that saves energy efficiently and its relevant equipment were successfully developed to replace the “open-cycle.” Techniques of “pumpless material feeding” and “pumpless gunting” simplified the flow process,

raised the rate of operation and improved the operational environment. The successful development of good quality, low consumption technology of "slurry concentration process for DAP" enabled the production of different grades to cover all AP products. On improvement, the flow of "AP production by the neutralized slurry concentration process" is simple, stable, mildly corrosive, low in energy consumption, causes little pollution, requires low investment, has low production costs and high productivity; advantages that are becoming more obvious.

In 2001, by carrying out analysis and assessment of more than 10 large imported plants that were producing DAP by the conventional process, Sichuan University found that, to different extents, these plants carried the problems of big investment, poor benefits and high-energy consumption. Finally, by combining the characteristics and technical reliability of "AP production by the neutralized slurry concentration process," the innovative production of DAP and MAP by combining the neutralized slurry concentration process and the conventional process was put forward. In July 2002, at the Guizhou Hongfu Industrial Development Co. Ltd., the first set of combined production installations with an annual production of 200,000 t of MAP was built. This was a breakthrough achieved with regard to technological optimisation and enlargement of the production installation. On 22 December 2003, with respect to the national technological innovative project of "Packaged technology and equipment for the combined production of DAP and MAP" jointly undertaken by the Sichuan University and the Guizhou Hongfu Industrial Development Co. Ltd. passed the appraisal by the Ministry of Education. The project integrated the achievements of a number of technological innovations in AP production by the slurry concentration process and in equipment. It adopted the techniques of "forced circulation ammoniation evaporation reactor," "energy saving by second utilization of vapour from the neutralization reaction," "high-efficiency hot-blast furnace for heating air," "control of online measurement of the extent of neutralization and the distributed control system (DCS)." Actual practice has indicated that the slurry concentration process is not just suitable for the medium grade crude rock found in China; it is equally suitable for domestic PR of the best quality. The process can produce MAP (12-52-0) of excellent quality that complies with international quality standards. In addition, the operation of the plant is more stable and reliable.

Importation of medium and large scale AP plants and digestion and absorption of the technology

During the period of the 8th Five-Year Plan and the 9th Five-Year Plan, many medium and large scale plants of high-analysis phosphate compound fertilizer were imported. In December 1987, a 120,000 t/y DAP plant (Iprochim technology) was imported and set up at Tongling in Anhui Province. In 1989, the Nanjing Chemical and Phosphate Fertilizer Plant and in 1990, the Dalian Chemical and Ammonium Phosphate Plant each imported a 240,000 t/y DAP – 216,000 t/y NPK installation (Davy-TVA technology). In December 1990, the Qinhuangdao Sino-Arab Chemical Fertilizer Company in Hebei Province established a 480,000 t/y DAP – 600,000 t/y NPK plant (AZF technology). In 1992,

Yunnan Yunfeng built a 240,000 t/y DAP – 200,000 t/y NPK plant (Davy-TVA technology). In 1996, the Huangmailing Phosphate and Chemical Industry Group in Hubei Province set up an 180,000 t/y MAP installation (Jacobs's technology). In 1997, Gansu Jinchang set up a 120,000 t/y DAP installation (AZF technology). The Luzhai Chemical Fertilizer Co. Ltd. in Guangxi Province imported a 240,000 t/y DAP installation in 1999 (Espindesa technology). With the importation of plants of high-analysis phosphate compound fertilizer and a number of MAP, DAP and NPK technologies such as the American Davy-McKee pipe reactor – rotary drum granulator, the French AZF technique of manufacturing DAP by the twin-pipe reactor and the Spanish Ert-Espind single-pipe reaction primary ammoniation, the establishment and application of these projects and techniques have enabled the production of phosphate compound fertilizer and the technological level in China to be basically on a par with other countries.

When the large imported plants are operating, the processes are being improved all the time. For example, the new process flow of the single-pipe reactor of the Sino-Arab Chemical Fertilizer Company (that is, the process flow of single-pipe reactor – rotating drum granulation) is an improvement based on the conventional pre-neutralization trough – rotating drum granulator flow and AZF twin-pipe reactor process flow which has great advantages such as stable and reliable production, high rate of P₂O₅ water solubility, good appearance, easy quality control, in particular its adaptability to raw materials, flexibility in product transformation and simple operation. It could well be the first choice for process in the days to come.

On the basis of imported technology, in October 1991, the first large Chinese-made plant of 240,000 t/y DAP was built in the Guixi Chemical Fertilizer Plant in Jiangxi Province. This installation used the pre-neutralization and slurry granulation process. In 1993, a Chinese-made installation of 120,000 t/y DAP was set up in Honglin (formerly the Honghezhou Phosphate Fertilizer Plant) in Yunnan Province.

During the period of the 10th Five-Year Plan, China built another four large AP plants of Sanhuanjiaji Chemical Fertilizer Co. Ltd. (600,000 t/y of DAP) in Yunnan, Kailin Group in Guizhou Province (formerly Kaiyang Phosphate Mine) (240,000 t/y DAP), Fuling Chemical Industry in Chongqing (240,000 t/y DAP) and Furui Company in Yunnan (600,000 t/y of DAP). At the same time, many enterprises explored the potential and revamped their plants and expanded. At the end of the 10th Five-Year Plan (the end of 2005), production capacity of DAP installations in China reached 6.6 Mt and production capacity of MAP was about 7.2 Mt. At present, through digestion and absorption of imported technology and the adoption of locally developed technology, some phosphate fertilizer enterprises with sound operation and good resources are establishing several medium and large scale ammonium phosphate plants. The usage rate of Chinese-made equipment, spare parts and component parts has reached 90%.

Development of the technology of wet-process phosphoric acid
Phosphoric acid is the important raw material for the production of phosphates. It is also a primary product in the production of AP. Its sources include the thermal-

process (electric furnace) phosphoric acid and wet-process (decomposition of PR by acid). Basically, AP plants build supporting and corresponding wet-process phosphoric acid plants. Following the import of high-analysis phosphate compound fertilizer, a number of phosphoric acid production techniques were introduced. Examples are techniques of extraction of phosphoric acid such as Iprochim, Rhone Poulenc, Prayon, Yara (hemihydrate-dihydrate process), OXY (hemihydrate process), Dorr and Badger.

In the early 1990s, quite a number of enterprises looked at the quality of PR, thinking that PR grading (P_2O_5 content) was the only index for the assessment of phosphorus quality. Pricing of PR was also based on this. By the 1990s, some enterprises gradually came to realize that harmful impurities of Fe_2O_3 , Al_2O_3 and MgO had greater effects on the production of phosphoric acid than the grade of PR. They adopted strict control on the quality of PR that entered the plant as raw material and scientific ways of rock allocation so that the quality of rock pulp remained stable and the required standards were fully achieved. They also controlled the water content and fineness of the rock slurry to facilitate crystallization and growth of calcium sulphate and to ensure the rate of extraction efficiency of the reaction of the PR.

At the initial stage of building medium and large-sized phosphoric acid plants in China, designs were according to the property and composition of good quality PR. After the plants had gone into production, some enterprises faced difficulties in production because they had no access to good quality PR and technical and economic indices failed to achieve design requirements over a long period of time. The supply of PR was even worse for the small phosphoric plants. The grade of PR was low. The content of impurities was high and with many rock suppliers and mixed phosphates used in the production made the conditions even more difficult.

Comparison between the thermal process and the wet process for the production of phosphoric acid:

Heat energy consumed by the thermal process is 3.4 times that of the wet process with electrical energy consumption 13.4 times higher. Through purification, the wet-process phosphoric acid replaces thermal-process. In terms of quality, the wet-process can adapt to different requirements at a lower cost. After purification, the cost of production of phosphate by the wet process is reduced. Fluoride is one of the major impurities in the wet-process. As fluoride has a wide range of uses industrially, it can be recovered in the course of the purification of wet-process phosphoric acid, for making by-products. This increases benefits in the process and the utilization ratio of resources.

Successful establishment of large Chinese-built AP plants

Under the leadership of the former Ministry of Chemical Industry, manufacturing plants and design departments carried out systematic development and manufacture of equipment and instruments. To achieve domestic production, large plants helped lay the solid foundation with the development of equipment and instruments such as the series of acid resistant pumps, large slurry circulation pumps, large air coolers, hot air blowers, large decelerators, stirrers, large revolving-leaf type filters, large rotation desk filters, low vacuum cooling devices, air spraying coolers, large internal

re-feed guniting kilns, vibrating screens, fluidizing drying columns (manufacturing powder AP), automatic online analysers of SO_3 of wet-process phosphoric acid and the pH of neutralized slurry.

The slurry concentration process of AP production fully explores the potential of an installation to double, treble or even more, the installation's capacity, greatly reducing energy consumption and cost. For a production installation originally designed for an annual capacity of 30,000 t, a further investment equivalent to two sets of installations (that is, investment to expand capacity is equivalent to investment in the original installation), capacity of the installation has reached 240,000 t/y with investment of less than RMB300 per tonne. The size of an installation for the production of AP by the slurry concentration process is comparable to an imported large-scale installation by the "conventional process."

Under the prerequisite of achieving domestic production by project design and ensuring that large installations are advanced and reliable, there was breakthrough in the promotion of domestic production of equipment. China built, on its own, three plants at Yunnan Sanhuan that produced 300,000 t/y of wet-process phosphoric acid, 600,000 t/y of DAP and 600,000 t/y of sulphuric acid respectively. At Yunnan Furui, the three plants built produce 300,000 t/y of wet-process phosphoric acid, 600,000 t/y of DAP and 800,000 t/y of sulphuric acid. Among the six large plants, the installations that manufacture sulphuric acid, only vanadium catalysts of the best quality and "key parts" of the mist eliminator were imported. For the installations of wet-process phosphoric acid, apart from low flash slurry pumps and part of the extracting agitator blades, domestic production was basically achieved. For the equipment required for the large DAP installations, the amount that had to be imported was somewhat more, the major items being re-feeding and the drying bucket elevators (the chassis is made by processing domestically), crushing machines, screening units and granulator and draught fans for drying the tail gas. From the condition of operation of these six large installations, with the exception of low temperature heat energy of sulphuric acid that could be recovered, the overall technology of the plants and management levels attained international standards and are very close to the advanced levels elsewhere in the world.

3. Developments abroad

In 1920, the American Ammonium Cyanide Co. used thermal process phosphoric acid as raw materials to build a 25,000 t/y MAP (11-48-0) plant. In 1954, it built a DAP plant in the US with wet-process phosphoric acid as the raw material. In 1961, TVA developed an installation that used pre-neutralization – rotating drum ammoniation granulation to produce DAP (18-46-0) products. In the mid-1970s, the US, France and Spain developed the pipe reactor to replace the trough type neutralizer, thus simplifying the equipment and reducing energy consumption.

In 1969, in response to the poor quality of Kara-Tay PR, the former Soviet Union developed the slurry concentration process and built an installation of 150,000 t/y of granular MAP (10-40-0) in the present-day Uzbekistan. Later, another five sets of single series installations of slurry concentration process with a scale of 130,000 t were set up. Their production

capacity was about one third of the total AP capacity of the former Soviet Union.

The main objectives of reforming the production technology of AP are the reductions in energy consumption, increases in the production capacity of equipment, reduction of the consumption index of raw materials and reductions in environmental pollution. Major foreign technologies and equipment include the following: the rapid ammoniation reactor developed in the former Soviet Union; the pressure ammoniation reactor by Fisons Co. of Britain; the deflector type pressure reactor and the pipe reactor.

4. Outlook for domestic and foreign technological and economic development

Drawing on the experience of foreign countries, China has developed the "slurry concentration process" that can utilize the rich deposits of PR, with relatively high content of impurities. This technology has assured a foothold for the PR resources in China. It has also laid the foundation for the replacement of imports. As the production of DAP requires phosphoric acid of higher quality as raw material and, under circumstances where good quality domestic PR is not in abundant supply, the use of low and medium grade PR for the production of MAP is suiting, to some degree, the local conditions. Analysed on production characteristics and from the perspective of composition, the merits of MAP are greater than those of DAP, therefore, there is no need for China to seek the development of a DAP industry.

During the 1980-90s China imported a number of advanced MAP, DAP and NPK technologies. Examples are the American Davy-McKee pipe reactor – rotary drum granulator, the French AZF technique of manufacturing DAP by the twin-pipe reactor and the Spanish Ert-Espind single-pipe reaction primary ammoniation. The establishment and application of these projects and techniques have enabled the production of phosphate compound fertilizer and technological level in China to be at par with other countries.

3.2.2 Technological breakthroughs and important inventions in the phosphate fertilizer industry

3.2.2.1 Production technologies of fused calcium magnesium fertilizer (FCMP)

1. The blast furnace technology for the production of FCMP

As described in the earlier part of this chapter, in June 1963 and February 1964, the Jiangxi (Dongxiang) Phosphate Fertilizer Plant revamped two idle iron-smelting blast furnaces of FCMP with a capacity of 30,000 t/y and 40,000 t/y respectively. The blast furnaces took the shape of a waist drum, water leg cooling bosh, charging-up by double-charging bell and high stock column operation. Hot air at about 300°C was used to reduce the fuel consumption of the blast furnace. The production capacity was raised from 1.5 t/(m³·h) to 2.8-3.1 t/(m³·h). The furnace charge went smoothly and operation was normal. When serpentine containing 0.2-0.3% nickel was used as the charge mixture, each tonne of calcium magnesium phosphate fertilizer could yield 15 kg of ferrophosphorus containing nickel (4-6% nickel, 8-15%

P, S ≤ 0.5%). The production of FCMP by blast furnace ingeniously utilizes the water-cooling body furnace to bring about condensation of fused charge inside the blast furnace and the sediment of condensation gives protection to the furnace body, thus, solving the problem of corrosion of the furnace body under high temperature, a problem experienced throughout the world. The Class II Invention Award by the National Science and Technology Commission was conferred on this achievement.

2. Burden calculation by glass structure factor

In 1958, the iron smelting blast furnace was revamped and was used for the production of FCMP. In the Henan Chemical Engineering College (formerly Department of Chemical Engineering, Zhengzhou Institute University of Technology presently School of Chemical Engineering, Zhengzhou University), a young teacher by the name of Xu Xiucheng found in his research work that Japanese scholars had carried out a large amount of laboratory studies with regard to the vitreous materiality of FCMP and the conditions of the production technology, but they did not manage to establish a theoretical mathematical model that provided guidance to production. Through the results of laboratory studies by these Japanese scholars and following the vitreous structure "network – matted crystal theory," he put forward the idea of the formation of the vitreous body of FCMP by the short-range order crystallite of Ca-PO₄-F and the long-range disorder network of [SiO₄]_n. In addition, he put forward the assumption that the process of producing FCMP is the formation of networks of suitable sizes that prevent the matted crystal growing and at the same time the matted crystal must be easily absorbed and utilized by the roots of crop plants. He established a mathematical model and mathematical expression that characterized network sizes. By using the manual calculator driven by gears available at that time, he worked on the Japanese laboratory data and established the "Burden calculation by glass structure factor for producing FCMP" that is based on theoretical analysis. In 1963, the young teacher went a step ahead of the Japanese scholars by lifting batching in the production of FCMP from an "experience module" to mathematical analysis guided by theory. In May 1979, after the presentation of this achievement at the Symposium on the Conference of Technological Development for Chemical Fertilizer held in conjunction with the inauguration of the National Chemical Fertilizer Association in Shanghai, it immediately caught the attention of Feng Yuanqi, deputy chief engineer of the Department of Chemical Fertilizer, Ministry of Chemical Industry. He organized nationwide tests and promoted the achievement. During the 1980s the "Burden calculation by glass structure factor for producing FCMP" was tested and verified for industrial application by the Yunnan Guangming Phosphorus Plant, the Jiangxi (Dongxiang) Phosphate Fertilizer Plant, the Hubei Liujiachang Phosphate Fertilizer Plant and the Henan Xinyang Phosphate Fertilizer Plant. Under the leadership of the Phosphate Fertilizer Office, Chemical Fertilizer Department of the former Ministry of Chemical Industry, a number of national training classes were held to promote the method to the entire industry. This resulted in plants of FCMP that largely used low-grade PR

containing 16-24% P_2O_5 to produce FCMP that contains 12-18% effective P_2O_5 . During the 10 years from 1993 to 2002, China produced a total of 55 Mt FCMP in product quantity with an average nutrient content of about 15% P_2O_5 by direct use of about 60 Mt of low-grade PR. Enormous economic and social benefits were generated and these raised the sustainable utilization of resources tremendously. The Class IV National Invention Award was conferred on this achievement.

3. Technological route of “fine materials, strong wind, high temperature and high pressure”

The Shaoxing Steelworks in Zhejiang Province has the largest blast furnace for FCMP in China, with a volume of 82 m³. Over the years, the plant has been depending on fine raw materials, strong air blast and high air temperature to enhance production of the blast furnace. It is a progressive domestic enterprise with the lowest coke consumption. Since 1980, Luzhai Chemical Fertilizer Plant carried out technical revamp on its 45 m³ blast furnaces, continued to improve its equipment composition, enhance purification of coal gas, raise the temperature of hot air and use only fine materials for the furnace. These measures doubled the plant's output. The plant's coke consumption was reduced by 30% and energy consumption was the lowest in the country.

4. Development of product technology of FCMP

In the course of production of FCMP, other nutrient components can be added for producing compound fertilizers containing a number of nutrient components. For example, by adding potash feldspar to replace quartz stone in production, some FCMP plants in the provinces of Jiangsu, Hunan and Jiangxi were able to manufacture FCMP containing 2-3% of citric acid soluble K_2O . Using PR containing 3-6% K_2O as raw material, the Ermei Gaoqiao Phosphate Fertilizer Plant in Sichuan Province produced FCMP directly. Phosphate fertilizer plants of Sichuan Chengdu and Jiangxi (Dongxiang) added N, K, and B as raw materials in their production process to produce NPK compound fertilizer and Ca-Mg-B-phosphate.

3.2.2.2 The technique of “concentrated acid rock pulp process” for single superphosphate (SSP)

The “concentrated acid rock pulp process” is a new technology for the production of SSP developed during the 1960s. After a long period of exploration by technicians of phosphate fertilizer enterprises in the provinces of Sichuan, Fujian and Jiangsu, in response to the local problem of high rainfall with a long rainy season, large investments were injected in building warehouses for PR. The new technology ingeniously diverts the water that was used to dilute the concentrated sulphuric acid to the wet grinder of the PR; carried out direct mixing of the 92.5-98% concentrated sulphuric acid with the wet ground PR, after reaction and curing, powdered SSP is produced. The measured concentrated sulphuric acid is added to the mixer to react with the wet ground phosphorus pulp. This is advantageous because unlike in the “dilute acid powdered rock process,” the processes of adding water to dilute the concentrated sulphuric acid and then proceeding with the cooling and temperature adjustment are both omitted. Since water is added to the PR for wet grinding, drying of the rock

is not necessary so there is no need to be concerned with rain and snow and it can be stacked in the open. This raises productivity and reduces the amount of equipment required. Wet grinding of PR generates less powder and dust than dry grinding. This improves the operational environment and working conditions. However, compared with dry grinding, the wear and tear of the steel ball in the grinder is 4-6 times higher. To increase the fluidity of the rock pulp to facilitate transport, the minimum water content varies according to the type of rock. Hydrophilic PR pulp has a high water content causing the water content of SSP to exceed quality standard requirements. As a result, the product is sticky and wet and there is caking that affects product quality.

3.2.2.3 Ammonium phosphate (AP) production by the “slurry concentration process”

Since more than 90% of China's PR resources are of a low or medium grade which are difficult to select, there is serious scale formation in the heater for phosphoric acid concentration when a “conventional process” is used to produce AP. The deposit layer is hard, compact and cannot be cleaned. Industrial production cannot be achieved over a long period of time and this has seriously limited the development of high-analysis phosphoric compound fertilizer.

Starting in the 1970s, at the former Chengdu Institute of Technology (later becoming the Chengdu University of Science and Technology and presently annexed to the Sichuan University), Zhong Benhe, Zhang Yunxiang and others carried out systemic studies on the formation of the two types of deposits of concentrated phosphoric acid and AP slurry, the mechanism of scale formation, studies on the properties of AP slurry and studies on the correlation coefficient of the rheological properties of concentrated slurry. From the results of these studies, it was found that impurities during the neutralization of wet-process AP of low and medium grade rock produced domestically were the first to separate out. The deposit layer that became concentrated under conditions of weak acidity was mainly of loose porous and easy to clean T and U compounds and AP. This was completely different from the compact and hard deposit that cannot be cleaned, generated by concentrated phosphoric acid. Compared with phosphate solutions, the boiling point of salt solution neutralized by ammonia was obviously lower. This provided a reliable basis for the achievement of an effective concentration that reduced steam consumption for industrial production. Based on these studies, the “new technology of AP production by the slurry concentration process” which proposed the use of medium grade PR as raw material and concentrated AP slurry to replace concentrated phosphoric acid was put forward. In 1984, with the strong support from people like Lin Le, Assistant Section Chief of the Phosphate Fertilizer Section of the Department of Chemical Fertilizer of the Ministry of Chemical Industry, Zhong Benhe, Zhang Yunxiang and the Sichuan Yinshan Phosphate Fertilizer Plant's Wei Wenyan achieved long-term stability in the operation of the technology of “double effects of slurry concentration” after going through modular tests, the “6th Five-Year Plan” pilot test and the 30,000 t/y industrial test during the “7th Five-Year Plan.” This ended the history of the inability to produce AP with domestic medium grade

rock and changed the undesirable situation of long-term dependence on imported high-analysis phosphate compound fertilizer in the entire country. Subsequently, more than 80 sets of 30,000 t/y plants were built in 21 provinces throughout the country. Expansions followed and currently the output of AP by the slurry concentration process has reached 6 Mt/y, accounting for more than 60% of the total AP output and more than 25% of total phosphate fertilizer. This has achieved the target of increasing the scale and the manufacture of domestic installations. If calculated from an annual production of 6 Mt, the annual value can reach RMB12 B with profit and tax of nearly RMB2 B. Based on the calculation that each kilogram of fertilizer increases grain yield by three kilograms, the yield increases can be 18B kg. After the deduction of fertilizer costs, the benefit from the increase in agricultural output each year is close to RMB20 B. This substitution for imports saves the country more than US\$1.3 B in foreign exchange. The economic and social benefits are obvious.

Industrial production indicates that compared with conventional processes, the slurry concentration process shows greater adaptability to PR and it can utilize directly the large quantity of medium grade PR that the conventional process cannot use, to produce AP. This leads to most of the phosphate fertilizer plants throughout the country using medium grade PR of 26-28% P_2O_5 for the production of high-analysis AP containing 44-48% effective P_2O_5 . The corrosiveness of concentrated slurry is mild and it is easy to solve the problem of equipment materials. The operational life is long. The heater for slurry concentration does not easily form scale and the deposits are easy to clean. These benefits opened a new route for the rapid development of AP in China. This achievement was listed by the National Development and Reform Commission as one of the eight achievements in science and technology in China since the 6th Five-Year Plan. It has become the major technological route for the production of high-analysis compound fertilizer in China, for building a modern AP industry with autonomous intellectual property rights, and a leading international technology with outstanding socio-economic benefits. In 2001, Zhong Benhe, Zhang Yunxiang and Ying Jiankang put forward the new idea of "combining the installation producing DAP by the conventional process and the installation producing MAP by the slurry concentration process, using the latter to encourage and improve the production and operation of the former." Later, this idea and its excellence and feasibility were expounded and proven in detail and recommended to the Guizhou Hongfu Industrial and Commercial Development Co. Ltd., which has the largest PR and fertilizer base in China. This technological innovation became a reality in ten months with a set of large Chinese-made installations with capacities to produce 200,000 t of powdered MAP/y. It has strongly encouraged the expansion of capacity and the reduction of energy consumption in these phosphoric acid and DAP plants. The installations also achieved their targets and stable production. It set a new record in China with regard to construction progress and the speed of achieving production targets.

The Guizhou Hongfu Industrial and Commercial Development Co. Ltd. installed a new plant and the powder MAP produced by the installation is currently the best

powdered product in terms of physical characteristics and quality and it has two ready markets, inside and outside China. The final investment in the newly built plant of 200,000 t/y of powdered MAP is RMB 19.6 M, less than RMB100 per tonne of output capacity. However, its annual increase in sales is 27% giving an output-input ratio as high as 14.5.

The Class I Scientific and Technological Progress Award were conferred by the Ministry of Chemical Industry on the series of technologies for the production of AP by the "slurry concentration process" in 1986. In 1988 it was conferred the Class I National Science and Technology Progress Award. As the technology of producing AP by the "slurry concentration process" continued to score enormous results in the promotion of projects, industrial production and augmentation of scale, it was further conferred, in 1995, the Class I Scientific and Technological Progress Award by the Ministry of Chemical Industry and the national patent for invention. In 1996, it won the first "YILIDA" Science and Technology Award and in 1999 the Special Class Science and Technology Progress Award by the Ministry of Education. In 2004, the "Large-scale Chinese-made plant for the production of AP by the slurry concentration process project" won the Class II National Scientific and Technological Award.

3.2.2.4 Systematic study on the national development of phosphorus resources

A priority scientific and technological State project under the 7th Five-Year Plan - "Systematic study on the national development of phosphorus resources" was accomplished. For the application of systems engineering in the project, values used in geology, mining, beneficiation, chemical processing, environmental protection, transport, raw materials and energy supply are all in accordance with the consolidated system of values. An in-depth appraisal was carried out in eight major regions of phosphate mines throughout the country. In addition, there was a system of support for the policy decision to develop phosphate resources throughout the country which put forward a detailed proposal on the objectives and planning in the development of phosphate resources in China. The project was conferred the National Class II Scientific and Technological Progress Award and the Class I Scientific and Technological Progress Award by the Ministry of Chemical Industry. Professor Cheng Siwei who was the Director of the Science and Technology Institute of the Ministry of Chemical Industry, Deputy Minister of the Ministry of Chemical Industry and presently the Deputy Chairman of the National People's Congress Standing Committee was the overall person in charge of the project. He is responsible for formulating the overall scheme of the project, organizing a research team, proposing a system of appraisal values for the regions of PR, establishing a model of strategic plan for phosphorus and the overall design of a support system for policy decisions in the development of phosphorus resources. He plays the key role in the project. Tang Jianwei, Hua Yixiang, Xu Xiucheng and others from the former Zhengzhou Institute of Technology (presently, Zhengzhou University) participated in the study on "Support system for the micro policy decisions on phosphate fertilizer subsidiary systems of FCMP fertilizer."

3.2.2.5 Combined production of cement and sulphuric acid by phosphogypsum

At the end of 1990, with the rapid development of high-analysis phosphate compound fertilizers, output from the supporting wet-process phosphoric acid grew rapidly. Output of phosphogypsum as a by-product was more than 3 Mt each year. Finding a solution to the problem of phosphogypsum discharge and its re-utilization was increasing in urgency. From 1983, the former Shandong Wudi Sulphuric Acid Plant (now the Main Plant of Lubei Chemical Industry), the Jinan Yuxing Chemical Plant and the Chemical Research Institute of Shandong Province jointly completed an industrial experiment of combined production of sulphuric acid and cement with 7,000 t/y of gypsum salt. Based on the previous industrial experiment with gypsum salt in 1990, the former Ministry of Chemical Industry invested in the main plant of Lubei Chemical Industry in Shandong and linked up with a 30,000 t/y ammonium phosphate plant to establish an installation that utilized phosphogypsum to produce 40,000 t/y of sulphuric acid and 60,000 t/y of cement (called the 3-4-6 project in short). This built up the experience of using phosphogypsum as a raw material in the combined production of sulphuric acid and cement. This was the first set of ammonium phosphate - sulphuric acid - cement combined production plants. Verification of the results indicated that the production capacity of the plant exceeded the designed capacity by 15%. In 1999, the Main Plant of Lubei Chemical Industry's 15-20-30 project, that is, the 150,000 t/y of AP, 200,000 t/y of sulphuric acid and 300,000 t/y of cement project went into operation. The establishment of such installations achieved economic, social and environmental benefits. They complied with the principles of a recycling economy, an ecological technique that makes full use of resources.

The technology of combined production of cement and sulphuric acid by phosphogypsum developed and designed in China has the following characteristics: The dihydrate phosphogypsum should meet the following requirements of $\text{SO}_3 \geq 40\%$, $\text{SiO}_2 \leq 8\%$, $\text{P}_2\text{O}_5 \leq 1\%$, $\text{F} \leq 0.35\%$ and the phosphogypsum does not require purification. It is not necessary to use the foreign technique of calcination at high temperature for the dehydration and drying of dihydrate phosphogypsum or dehydration of phosphogypsum to hemihydrate phosphogypsum to reduce energy consumption. The heat consumption in making the cement clinker by a rotating kiln is lower than the 7,500 kJ/kg in other countries.

3.2.2.6 The new production technology for powdered MAP by the Process of Pipe Reaction Spray Fluidization (PRSF)

Zhang Yunxiang and others in Sichuan University developed the new production process of "Pipe Reaction Spray Fluidization" (PRSF) under low pressure for powdered MAP. In this technology, phosphoric acid and ammonia are neutralized in a pipe reactor. For AP slurry counter-flow spray fluidization drying, the usual low-pressure centrifugal pump is used to replace the high-pressure, difficult-to-maintain triplex pump and the heat of neutralization and flash vaporization technique are fully made use of to save energy in a significant way. The available P content is as high as 20%, in the form of phosphoric acid sludge. The acid sludge does not

return to the phosphoric acid system, this greatly improves the production environment of phosphoric acid and increases the production capacity. Poor quality powdered coal is used for the indirect heat exchange of the hot-blast furnace. The technique of highly efficient automatic dust removal by the end gas from powdered MAP notably reduces manual cleaning, improves the environment, extends the production cycle and greatly raises the production capacity. The project of 200,000 t/y of powdered MAP built with this technology passed the appraisal at the Yunfeng Co. in Yunnan Province on 13 July 2006.

3.2.2.7 Technology for the selection and use of phosphate rock (PR)

Phosphate resources in China commonly contain relatively high level of MgO , Al_2O_3 and Fe_2O_3 , and the P and gangue minerals are finely embedded and distributed. Selection by flotation will be more effective. Flotation is the method most commonly used for beneficiation in China. The progress in the technique of flotation has enabled the policy of raw material in the phosphate fertilizer enterprises to turn gradually from "anything will do" to one of "choice materials." After the establishment of the first 1.2M t/y large-scale meta-sediment PR flotation plant in 1958 – the Jinping Phosphorus Beneficiation Plant in Jiangsu Province, in 1976, a 300,000 t/y medium-size magmatic PR flotation plant was built at Maying Phosphorus Mine in the province of Hebei. The establishment of these two flotation plants signified that China had adapted the enrichment technique of apatite that is easy to beneficiate. In 1986, the first 1.5 Mt/y large-scale beneficiation plant for the direct flotation of sedimentary phosphorite was built and put into production at the Jingxiang Wangji Phosphorus Plant in Hubei Province, thus enabling China to achieve breakthrough in the beneficiation of sedimentary phosphorite. Following the direct flotation technology, enrichment techniques such as baking and digestion of sedimentary phosphorite, scrubbing and de-sliming, counter-direct (or direct-counter) flotation and heavy-media separation were developed. Among these techniques, direct flotation, counter flotation, scrubbing and de-sliming and heavy-media separation have successfully solved the problem that sedimentary phosphorite could not be used to produce DAP which, at that time, was a worldwide difficulty.

3.2.3 Important events in the technological development of phosphate fertilizer and an introduction to some technical experts

3.2.3.1 Important events in the technological development of phosphate fertilizer

1. An important symposium on phosphate fertilizer was convened soon after the establishment of the People's Republic of China (PRoC)

In September 1953, the Chemical Industry Bureau of the former Ministry of Heavy Industry convened a symposium in Beijing which bore great significance to the establishment and development of the phosphate fertilizer industry. At the symposium, the objectives of development of phosphate fertilizer production and the problems in the development

of P resources were discussed. It was suggested that China should begin by carrying out scientific studies on the production of SSP with PR from the Jiangsu Jinping Mine and the preparation for the construction of a plant. In addition, the Department of Geology was asked to increase the exploration for P mines in order to clarify resources of phosphate fertilizer.

2. The first national meeting to exchange experience on FCMP

In November 1959, the former Ministry of Chemical Industry convened the first national meeting to exchange experience on FCMP at Lanxi in Zhejiang Province, which confirmed FCMP as a grade of phosphate fertilizer. Conditions of the production technology of the "blast furnace method" were recommended and problems of short life span of furnace, high energy consumption and unrefined product were pointed out. After the meeting, a number of FCMP plants were established throughout the country.

3. Design and establishment of the first production workshop for precipitated calcium phosphate

In 1964, the former Zhejiang Chemical Research Institute and the Guangxi Chemical Research Institute carried out treatment of PR by hydrochloric acid and pilot tests on the production of precipitated calcium phosphate separately and obtained the data required for building a plant. Subsequently, based on the data from the pilot tests, the Zigong Honghezhen Chemical Plant in Sichuan Province and the Nanning Chemical Plant in Guangxi Province built, separately, production workshops for precipitated calcium phosphate with an annual production of 3,500 t of fertilizer and 1,500 t of animal feed additives. 14 production plants with annual production of 1,000-5,000 t and a total output of more than 20,000 t were constructed in the provinces of Shandong, Jiangsu, Hubei and Jiangxi.

4. Design and establishment of the first pilot test workshop for nitrophosphate based NPK

In 1964, the Phosphate Fertilizer Plant of Nanjing Chemical Industry Co. built a pilot test workshop that could produce 3,000 t of NP based NP(K) annually. By using the carbonation process, product containing 18% N and 12% P_2O_5 were produced. In 1968, the Phosphate Fertilizer Plant of Nanjing Chemical Industry Co. applied the mixed acids method (nitric acid and sulphuric acid) at the pilot test plant to carry out tests and production of compound fertilizer with N, P, and K. In 1978, the plant applied the method of indirect cooling to carry out a pilot test of NP based NP (K), with the product containing 27% N and 13.5% P_2O_5 and water solubility of phosphate greater than 65%.

5. Design and establishment of the first DAP plant

In 1966, the Phosphate Fertilizer Plant of Nanjing Chemical Industry Co. built a single tank phosphate plant with multiple paddles and air-cooling, with an output of 50 t/d of P_2O_5 and another plant of multiple-trough neutralization and granulation by gunite that could produce 30,000 t/y of DAP.

6. Design and establishment of the first installation for the production of TSP and sodium tripolyphosphate (STPP) by thermal-process phosphoric acid

In 1976, the Guangxi Liucheng Phosphate Fertilizer Plant (later the name was changed to the Guangxi Phosphate Chemical Plant) built 2 sets of thermal-process phosphoric acid production plants based on the design of Jiang Shanxiang and other engineers from the Design Institute of Nanjing Chemical Industry Co. One set produced 18,000 t annually, using yellow phosphorus as raw material. The other had an annual production capacity of 7,000 t, using P mud as raw material. Phosphoric acid concentration was 60%, to be used for TSP (annual production of 50,000 t) and STPP. Due to the high cost of TSP production by the thermal process, production was discontinued.

7. Design and establishment of the first plant for the production of TSP by the wet-process phosphoric acid

In 1982, installations with daily production of phosphoric acid with 110 t of P_2O_5 and an annual production of 100,000 t of TSP were built at the Yunnan Phosphate Fertilizer Plant.

8. Successful development of a new technology that produces solid MAP by the "slurry concentration process"

In 1984, the Sichuan Yinshan Phosphate Fertilizer Plant and the former Chengdu University of Science and Technology (now Sichuan University) collaborated in the development of a new technique for the production of solid MAP by the "slurry concentration process," using the Jinhe PR that contains relatively more Fe, Mg and Al impurities and which is difficult to enrich.

9. Publication of the first issue of the magazine "Phosphate and Compound Fertilizer" at the former Zhengzhou Institute of Technology

In July 1985, under the direct leadership of Yu Min, Head of the Phosphate Fertilizer Section of the Department of Chemical Fertilizer of the former Ministry of Chemical Industry, the first issue of the magazine "Phosphate and Compound Fertilizer" was published at the former Zhengzhou Institute of Technology (now Zhengzhou University). The Chief Editor was Professor Xu Xiucheng. In that year, a trial issue was published in which the following message was conveyed: "This magazine aims to act as a window for looking into the phosphate fertilizer industry, as a bridge for exchanging information about the various types of fertilizer and as a bond linking the agricultural, industrial and commercial sectors." It won the support of the fertilizer trade, agricultural departments and agricultural resource departments and became an influential magazine in the realm of China's phosphate compound fertilizers.

10. Formation of the China Phosphate Fertilizer Industry Association (CPFIA)

In April 1990, the CPFIA was formed in the city of Kunming in Yunnan Province, with Fu Mengjia as the President and Wu Xiyan as Secretary General. In October 1993, The Association convened the 4th meeting of the first Standing Committee during which Lin Le was elected to be the President. In June 2004, the 14th phosphate fertilizer annual meeting and the

meeting to elect the new officers were held in Nanjing in Jiangsu Province. Wu Xiyan was the new President and Xiu Xuefeng was elected Secretary General. Since its formation, the Association has been playing an important role with regard to planning, technological development and policy reform. It has become a capable assistant to the government department in charge and an organization giving helpful guidance to enterprises concerning developments in the industry. For example, the series of books on the production technologies of small AP plants published in 1991 gave clear indications as to the course to be taken by the 100 or so small phosphate fertilizer enterprises throughout the country. Through the promotion of project establishment by the State, the Association laid the foundation for the development of the slurry concentration process for the production of AP. It also pushed for the promotion of "Red Sun" type NPK production technology.

The CPFIA also encouraged policy development, providing the fundamental conditions for the good development of the market for phosphoric compound fertilizer. In June 1992, the Association helped to bring about the same taxation policy for domestically produced and imported DAP. In April 1997, with the effort of the various parties, tax exemption for phosphoric compound fertilizer was extended from the end of 1997 to 2000. With much effort, freight charges for PR were changed from freight Charge No. 4 to Freight Charge No. 2. The rail transport base price per tonne was reduced from RMB5.2 to RMB4.2. In 1999, the Association facilitated the implementation of the policy of "Substitution of the manufactured products for similar imported products" which was a great contribution to the rapid development of the phosphate fertilizer industry of China in the 21st century. In addition, the Association follows international and domestic trends very closely, working very much for the interests of the State and the farmers and actively tries to establish brand names with national advantages. The Association gives assistance to the former National Economic and Trade Commission in establishing a warning mechanism for the phosphate fertilizer industry. It distributes materials on popularisation of science and propaganda materials to the farmers free of charge. At present, member organizations of the Association number more than 400. Each year, a meeting is held to exchange experiences with products and technologies for phosphate compound fertilizer and attracts around ten thousand participants.

3.2.3.2 Some technical experts in the phosphate fertilizer industry

1. *Jiang Shanxiang*, male, of Han nationality was from the Wu County, Jiangsu Province. He was a senior engineer and professor in the Design Institute of Nanjing Chemical Industries Co. Born on 11 November 1910 he died on 8 November 1994. He laid the foundation for the yellow phosphorus industry in China. He was also one of the pioneers of the FCMP industry. In 1928, he joined the Yongli Alkali Plant (now the Tianjin Alkali Plant). In 1940, he was responsible for building the first 100 kV·A yellow phosphorus electric furnace in Changshou County, Sichuan Province (now Changshou County in Chongqing City). In 1950 he

was responsible for building the first FCMP electric furnace. During the 1960s he was in charge of the self-baking electrode yellow phosphorus electric furnace at the Guangxi Liucheng Phosphate Plant, the largest in China. During the 1970s he put forward the idea of building yellow phosphorus bases in the regions of Yunnan and Guizhou. During the period 1980-90, he was engaged in the developmental work of defluorination of phosphoric acid and the production of phosphoric acid by the kiln process. He had devoted his entire life to the phosphate fertilizer industry of China.

2. *Wu Peizhi*, male, of Han nationality was from Chengzhou, Zhejiang Province, a senior engineer and professor, and he enjoyed special subsidies from the government. Born on 13 July 1921 he died on 10 January 2001. Wu Peizhi was engaged in the research and development of phosphoric acid and phosphate fertilizer over a long period of time. He was one of the pioneers and had contributed enormously in the phosphate fertilizer industry of China. In 1953, he completed the "Study on the Methods of Analysis of PR" which laid the foundation for PR analysis in China. In 1956, he completed the "Study on the Manufacture of Wet-process Phosphoric Acid by using Jinping PR, Kunyang PR and Jinping Selected PR" which laid the foundation of research work in wet-process phosphoric acid. In 1958, he completed his study on "Hemihydrate Process and Anhydrous Process of Kaiyang PR and Jinping Selected PR" and this was the start of research work on the direct manufacture of high-analysis phosphoric acid. In 1959, a 1.5 m² disk filter was successfully made and this laid a sound foundation for the development of this type of filter in China. In 1963, he completed the "Pilot Test on the Study of Technology of Manufacturing Wet-process Phosphoric Acid by the Dihydrate Process." In 1975 he completed the "Study on the Technology of Manufacturing Phosphoric Acid by the Hemihydrate-dihydrate Process." In 1977 he carried out the "Study on the Manufacture of Chloro-ammonium by the decomposition of PR with Hydrochloric Acid." Wu Peizhi was devoted to the phosphoric industry of China. In 1957 he founded the "Carry Out the Hemihydrate-dihydrate Process under Conditions of Inadequate Sulphuric Acid." It was the first attempt internationally. In his later years, he was devoted to research on "Manufacture of Concentrated Phosphoric Acid by the Hemihydrate-dihydrate Process." Wu Peizhi was a teacher for the first batch of postgraduate students after the reform of the system for postgraduate student intake and he guided 13 students. He compiled, translated and published the book "Study on the Important Phase Diagrams in the Phosphate Fertilizer Industry." He wrote and published "Methods of Analysis of PR and Phosphate Fertilizer" and "Wet-process Phosphoric Acid." He also published more than 10 papers in magazines such as "Phosphate and Compound Fertilizer." These works and papers have become guidebooks in the phosphate fertilizer industry of China.

3. *Xu Xiucheng*, male, of Han nationality hails from the She County in Anhui Province. He was born in September 1936. He is a professor of Zhengzhou University and Chief Editor of the magazine "Phosphate and Compound Fertilizer." In 1957 he graduated from the Department of Chemical Engineering of Tianjin University, majoring in inorganic

substance engineering. For 50 years, he has been teaching, R&D, industrialization, commercialization, information, international trade and international academic exchanges in the field of chemical fertilizer. He took the course of "Development of Technologies and Equipment for Chemical Fertilizers" as his discipline of study. He has published more than 100 academic papers. "A burden calculation method by the glass structure factor" for the production of FCMP was his invention by which the lowest grade of PR that could be utilized directly was reduced to 13.5% P_2O_5 , allowing the PR for FCMP production to be generally reduced to 16-22% P_2O_5 . This is a special contribution to the direct utilization of low-grade PR. Later, he headed the Research Institute of Phosphate and Compound Fertilizer at the former Zhengzhou Institute of Technology (presently Zhengzhou University). He developed many types of coated slow-release and controlled-release fertilizers using FCMP, partially acidulated phosphate rock (PAPR) and bivalent metallic ammonium-potassium phosphate as coating material, thus, initiating the new technology of coated compound fertilizer. In 1997, he was conferred the Class II Technological Invention Award by the Ministry of Chemical Industry for his work on "Coating of slow-release and controlled release fertilizer with another fertilizer and its manufacturing process." In 1998 he received a Class III National Invention Award. In recent years, he began doing research on a new process of fertigation that has a higher efficiency rate and rhizospheric fertilizer application, and proper utilization of low-grade P and K rocks of China.

4. Zhong Benhe, female, of Han nationality was born on 17 November 1937. She is a professor of Sichuan University guiding PhD students in chemical technology. She is a leading scholar of academy and technology in the subject of chemical technology in Sichuan Province. Her major subjects of research include phosphoric acid, phosphate compound fertilizer, P chemical industry and environmental engineering. She has spent a long period of time in the areas of phosphate fertilizer and the P chemical industry. Her research bore fruit and she contributed greatly to the utilization of medium grade P resources in China. She was the leading personality in the research for the new technology of "Production of AP by the slurry concentration process" and carried the responsibilities for the country's important projects in the four (the 6th to the 9th) Five-Year Plans. She was the person in charge of all the projects during this period. Besides accomplishing the missions in scientific research, she was also responsible for design plans and issues that should be taken into consideration in the projects. Recently, she accomplished a large-scale installation of 200,000-300,000 t/y for AP production by the neutralized slurry concentration process and the technique of combined production. She was involved in the design, placing of the order, construction, completion, the 72-hour examination and verification and the entire technological transfer. She was in overall charge of the Yunnan Furui and Zhonghua Kailin projects. She presented important subjects of scientific research that attracted the attention of the State and put the results of research into engineering projects. All these were important contributions to China's chemical fertilizer industry in the establishment of own intellectual property rights and outstanding socio-economic

benefits. Presently, she is an executive director of the CPFIA, director of the China Sulphuric Acid Industry Association, member of the Chemical Fertilizer Committee of Chemical Industry and Engineering Society of China, director of China Chemical Industry Design Centre for Sulphuric Acid and Phosphate Fertilizer, member of Environmental Science of Sichuan Province and deputy director of the Environmental Engineering Professional Committee.

5. Zhang Yunxiang, male, of Han nationality hails from Yibin, Sichuan Province. He was born in November 1939. He is a professor of Sichuan University, guiding PhD students in chemical technology. He is a leading scholar of academy and technology in Sichuan Province. He graduated from the Department of Chemical Engineering, the former Chengdu Institute of Technology (former Chengdu University of Science and Technology, now Sichuan University) in 1964. Beginning in 1993, he enjoyed special subsidies from the government. In 1996, he was approved as a guiding professor for PhD students of Chemical Technology. He is a technical committee member of the National Fertilizer Standardization Committee, technical member of the China Chemical Industry Design Centre for Sulphuric Acid and Phosphate Fertilizer, assistant group leader of the Science & Technology Consultant Group of the National Phosphate Industry, Appraisal Expert of the China Postdoctoral Fund and director of Sichuan University-Wengfu Phosphorus Chemical Industry Technical Centre. His major areas of research are the phosphate chemical industry and phosphate compound fertilizer, chemical industry and environmental protection, green chemistry and recycling economy (solid waste treatment and comprehensive utilization, smoke desulphurization), new techniques in chemical industry, new technologies, manufacture and development of new equipment and new products.

Over a long period he has been engaged in the research of defluorinated phosphate fertilizer, SSP, precipitated phosphate and wet-process phosphoric acid and ammonium phosphate production by the slurry concentration process. Important achievements such as the new technology of AP production by the neutralized slurry concentration process that he accomplished working with Professor Zhong Benhe was conferred the Class II Important Science and Technology Achievement Award of Sichuan Province (1985), Class I Science and Technology Progress Award by the Ministry of Chemical Industry (1986), Class I National Science and Technology Progress Award (1988), the first national YILIDA Science and Technology Award (1996), Special Class Science and Technology Progress Award by the Ministry of Education (2000). The "Domestic production of AP by the slurry concentration process" with a production capacity of 60,000 t/y was conferred the Class I Science and Technology Progress Award by the Ministry of Chemical Industry (1995). The "Integral process of AP ammonisation and slurry concentration technology" was conferred the Class III Science and Technology Progress Award by the Ministry of Education (1988). The "Outer loop oxidation reactor" was conferred the Class III Science and Technology Progress Award by the province of Anhui (2000). "Manufacture of organic phosphate fertilizer from urban garbage" was conferred

the Class II Science and Technology Progress Award by the Ministry of Education (2000). "Large-scale AP installation by the slurry concentration process" was conferred the Class II National Science and Technology Progress Award (2004). In 1991 he received the Sichuan Province Class I Outstanding Science and Technology Worker Award between 1986 and 1990 conferred by the Sichuan Provincial Government. In 1998 he received the Chinese Outstanding Individual in Academic Research Award jointly conferred by the Chinese Academy of Sciences and the former National Education Commission (presently National Education Ministry). He was responsible for the demonstration project of State high technology industries "Manufacture of high-analysis three-nutrient compound fertilizer by the comprehensive use of phosphogypsum residue" which has achieved significant progress. He has been awarded three patents of invention and four State patents for practical and new products. He has published a large number of scientific papers and a number of books. He has made tremendous contributions to the technical development of phosphoric compound fertilizer, teaching and scientific research in China.

3.2.3.3 Planning, design organizations and some experts of the phosphate fertilizer industry

The Nanjing Design Institute of China Petroleum and Chemical Corporation is the most important design unit in the phosphate fertilizer industry of China. It was called the No. Seven Design Institute of the Ministry of Chemical Industry and the Design Institute of Nanjing Chemical Industry. The Nanjing Design Institute of China Petroleum and Chemical Corporation were formed in 1958. For the past 50 years, the directors, in succession, include Hou Yuting, Jiang Shengjie, Zhao Leiran, Xie Meng, Fu Wenlong, Xu Jingming, Ying Xietang and Liu Peilin. The post of Chief Engineer was held by Jiang Shengjie, Miao Tianchang, Jin Wenbin, Xu Jingming, Han Qingchun, Chen Yuru, Wang Mingyuan and Zhuo Suduan over the years. On 23 May 2005, the China Petroleum and Chemical Corporation carried out reform and reorganization in the Nanjing Chemical Industry Co. and the Nanjing Chemical Plant to establish the present Nanjing Chemical Co. Ltd. (abbreviated as "Nanhua Co."). The predecessor of Nanhua Co. was the Ammonium Plant of Yongli Chemical Industry Co. which was set up in 1934 by the well-known patriotic industrialist of modern China, Mr. Fan Xudong. It was one of the earliest chemical industry bases in China. Nanjing Design Institute belongs to Nanhua Co. and it is a large-scale comprehensive Class A chemical industry design institute. It is a design and technical centre for projects on sulphuric acid and phosphate fertilizer design and powder technology throughout the country. The level of technology is in a leading position domestically.

3.2.4 Outlook for the development of technology and processes of phosphate fertilizer

During the 11th Five-year Plan, a scientific review will be implemented in the technological development of phosphate fertilizer in China to build a resource-saving and environment-friendly type of society and to uphold the spirit

of a recycling economy. To develop a recycling economy in the production of phosphate fertilizer in China, an ecological process must be guaranteed. That is, the production system of phosphate fertilizer has to be organized to become a reaction type flow of "resources – products - renewable resources." As far as possible, use resources and energy sources that enter the system to achieve the situation of "low exploitation – high utilization – low emission" (one high with two low). The sharp contradiction between the environment and development has to be fundamentally eradicated to realize sustainable development. For this reason, development of the following ecological processes should be advocated.

1. Development of energy-saving ecological industries

An energy-saving ecological industry requires that in the course of mining for the PR, the exploitation should be as rational as possible. Abandoning a low grade rock for a high grade one should not be allowed. In the course of processing, phosphorus loss should be reduced to the minimum to raise the rate of P recovery.

Henceforth, there should be a preferential policy for the establishment of different phosphate fertilizer types by adopting PR of different grades. For example, encourage the use of low-grade PR ($P_2O_5 < 20\%$) or stripped PR waste in the production of FCMP, develop a technology to utilize PR of a lower grade with a higher content of impurities for the production of phosphate compound fertilizers and develop a technology that produces phosphoric acid by the kiln method that utilizes PR of low and medium grades.

2. Development of ecological industries that exploit resources

PR in China is mainly of low and medium grades with difficulty in beneficiation. Direct application of ground PR, PAPR, biological phosphate fertilizer and the development of various types of energy-saving processes are ecological processes. In producing phosphate fertilizer, based on the conditions in China, SSP and FCMP development should be enhanced. The International Fertilizer Development Centre (IFDC) in the USA, le Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement (CIRAD) in France and scientific research departments of many countries and the Institute of Soil Science, Chinese Academy of Sciences have all used low quality PR and carried out studies on the method of production and fertilizer efficiency of PAPR. The volume of sulphuric used is only 30-60% of the theoretical volume. Even though the fertilizer efficiency is slightly lower than totally water soluble fertilizers, it saves resources and reduces cost.

3. Development of ecological industries with comprehensive utilization of resources

PR contains beneficial elements and minerals such as fluorine, iodine, trace elements, radioactive elements and manganese, magnetite containing vanadium and titanium, ilmenite, graphite and vermiculite. Through the study of their deposits, patterns of distribution, content and conditions for overall utilization, the comprehensive use of these resources can be achieved.

4. Development of ecological industries that utilize substitution of resources

To raise the utilization ratio of phosphate fertilizer, efforts should be made with regard to fertilizer processes and products, fertilizer application models, soil improvement and crop cultivation. For example, in the development of water-soluble phosphate fertilizer, provide accurate fertilizer applications based on the P requirement of the crop. New types of fertilizer should be developed in combination with soil characteristics in order to overcome the fixation of P by Fe and Al ions in the soil. Starting with the improvement of plant genotypes, enhance the plants ability to convert and absorb insoluble P.

Furthermore, there should be perseverance in technological innovations of product and benefits. There should be promotion in the upgrading and renewal of phosphate fertilizer products, active development of new products and increases in the utilization ratio of phosphate fertilizer by way of autonomous intellectual property rights and autonomous core technology. Continuation of the appropriate import of new technologies, digestion, absorption, innovation and domestic manufacture of equipment and making full use of the production capacities of plants already established. There should be more input in the beneficiation technology with regard to low and medium grades PR and efforts to achieve a relatively large breakthrough and progress in the enrichment beneficiation technology of PR during the term of the 11th Five-Year Plan. The comprehensive utilization of phosphogypsum should be enhanced and the substitution of natural gypsum with phosphogypsum as cement set retardant and for the production of building materials encouraged. All these are for the achievement of coordination of economic, social, environmental and resources for sustainable development.

The key technologies for the protection of the environment; special compound types of slow-release, controlled-release fertilizer, fertilizer application techniques and relevant equipment are subjects of priority in the science and technology development of the State. More effort should be put in the development of a technique to accelerate the release of P in order to increase the efficiency rate of phosphate fertilizer. There should be an active promotion of slow/controlled-release fertilizer in the form of coated compound fertilizer in which urea or ammonium is coated using FCMP, partially oxidised ground PR and Mg-AP. The history of development of the phosphate fertilizer industry indicates that it is only through the close attention to finding of solutions for the proper use of PR that the sustained development of the industry can be assured.

3.3 Development of phosphate fertilizer enterprises

For 50 years, from without any enterprise of phosphate fertilizer at all to having small enterprises, followed by large ones, from weak enterprises to strong ones, the industry has gone through a difficult path of development. From the initial stage of establishment of the PRC to the end of the 1990s, phosphate fertilizer enterprises were investments by the government and other business enterprises. During the

period of the 7th and 8th Five-Year Plans, the State invested close to RMB30 B to set up nearly 100 high-analysis phosphate fertilizer plants of all sizes. In addition, supporting P and S mines were opened. In the process of changing to a market economy, these enterprises went through competition and elimination and only those with a guaranteed supply of resources or those in regions with better transport conditions survived.

After the period of development during the 9th and 10th Five-Year Plans and the structural reforms, these enterprises turned from a single state-owned investment body and collective economy to diversified groups with a stock ownership system. The enterprises depended on technological innovation, relatively small investments and a huge amount of assets in stocks to enable their production capacity to expand rapidly and multiply. Through joint operation, stock participation, cooperation, annexation and lease, some financially capable and far-sighted enterprises implemented the combination of industrial links of raw materials, products, sales and usage that gave rise to large groups such as the Yuntianhua Group, thus forming phosphate fertilizer bases with million-tonne productions in the provinces of Yunnan and Guizhou and Yichang of Hubei Province. Economic benefits of phosphate fertilizer enterprises in China were greatly improved. Data in the past 10 years are shown in Table 3-2

Up to 2005 there were a total of 395 phosphate fertilizers enterprises and 723 compound fertilizers enterprises distributed in 28 provinces, cities and autonomous regions throughout the country. The numbers of employees was 103,000 and 133,000 respectively. Total assets were RMB31.9 B and RMB61.3 B. In general, the total output value of a phosphate fertilizer enterprise at current price was RMB30.5 B. The total amount of profit and tax was RMB2.4 B and RMB4.7 B, the total net profit was RMB1.7 B and RMB3.9 B. There were 97 enterprises in deficit, with total losses amounting to RMB110 M. In 2005, there were 104 enterprises that produced high-analysis compound fertilizer. Of these, 21 produced DAP (output of 5.0 Mt or 2.3 Mt of P_2O_5); 55 were MAP producers (output of 5.5 Mt or 2.6 Mt of P_2O_5); 54 produced NPK three-nutrient compound fertilizers (output of 17.1 Mt of NPK in product quantity or 1.3 Mt of P_2O_5); seven produced SSP (output of 1.1 Mt or 482,000 t of P_2O_5) and one produced NP (output of 621,000 t or 71,000 t of P_2O_5). The production of SSP and calcium magnesium phosphate was 4.5 Mt of P_2O_5 , or 39.7% of the total phosphate output in the whole country.

3.3.1 Characteristics of phosphate fertilizer enterprises development in China

3.3.1.1 Development of the phosphate fertilizer enterprises in China from the establishment of PRC to the 7th Five-Year Plan

The phosphate fertilizer industry of China started at the early stage of the establishment of the PRC. By the end of the 7th Five-Year Plan (1990), under the guidance of a planned economy, the phosphate fertilizer industry of China set up many phosphate fertilizer plants that produced mainly low-analysis products according to the principle of "emphasizing the market while giving consideration to natural resources."

Table 3-2 Statistics on phosphate compound fertilizer enterprises in China:1987-2005

| Year | No. of Enterprises | No. of Enterprises Incurring Losses | No. of Employees ('000) | Total Assets RMB100 million | Assets & Liabilities % | Sales Revenue RMB100 million | Amount of Profit & Tax RMB100 million | Net Profit RMB100 million |
|----------------------------------|--------------------|-------------------------------------|-------------------------|-----------------------------|------------------------|------------------------------|---------------------------------------|---------------------------|
| Phosphate fertilizer enterprises | | | | | | | | |
| 1987 | 595 | 38 | | | | | | 4.0 |
| 1988 | 580 | 26 | | | | | | 6.2 |
| 1990 | 637 | 119 | | | | | | 3.5 |
| 1993 | | | | | | | | -1.1 |
| 1994 | 510 | 129 | 299 | 87.7 | | - | - | 0.6 |
| 1995 | 464 | 79 | - | 199.7 | 71.3 | - | - | 3.1 |
| 1996 | 465 | 131 | - | 227.8 | 71.9 | - | - | 0.98 |
| 1997 | 453 | 180 | - | 303.8 | 77.1 | - | - | -3.2 |
| 1998 | 438 | 160 | 225 | 238.1 | 74.5 | 128.9 | -0.4 | -0.8 |
| 1999 | 549 | 190 | 251 | 314.7 | 71.6 | 143.6 | -1.5 | -2.1 |
| 2000 | 552 | 205 | 214 | 308.0 | 74.2 | 131.7 | 1.0 | -2.2 |
| 2001 | 524 | 161 | 189 | 306.7 | 70.1 | 148.8 | 2.9 | -0.7 |
| 2002 | 484 | 152 | 160 | 290.1 | 70.6 | 148.3 | 2.7 | -0.2 |
| 2003 | 461 | 132 | 136 | 309.9 | 75.4 | 173.8 | 3.2 | -0.7 |
| 2004 | 431 | 92 | 102 | 267.9 | 60.3 | 220.0 | 15.5 | 9.0 |
| 2005 | 395 | 97 | 103 | 319.3 | 62.2 | 289.3 | 23.7 | 16.8 |
| Compound fertilizer enterprises | | | | | | | | |
| 1996 | 67 | 24 | - | 50.8 | 74.6 | - | - | 1.4 |
| 1997 | 42 | 15 | - | 61.8 | 72.8 | - | - | 2.7 |
| 1998 | 46 | 12 | 24 | 79.3 | 68.5 | 47.2 | 3.4 | 3.3 |
| 1999 | 456 | 111 | 77 | 168.8 | 66.7 | 126.9 | 7.5 | 7.0 |
| 2000 | 455 | 112 | 83 | 239.0 | 57.1 | 151.6 | 10.1 | 7.6 |
| 2001 | 464 | 94 | 83 | 258.0 | 57.2 | 174.1 | 11.8 | 8.8 |
| 2002 | 464 | 85 | 82 | 291.9 | 58.2 | 197.0 | 11.1 | 8.0 |
| 2003 | 553 | 109 | 95 | 347.5 | 58.7 | 286.2 | 16.6 | 12.9 |
| 2004 | 612 | 101 | 124 | 517.4 | 58.4 | 471.7 | 30.8 | 24.3 |
| 2005 | 723 | 120 | 133 | 613.0 | 60.0 | 579.8 | 47.2 | 39.9 |

Note: Data before 1995 include enterprises of compound fertilizer

During the 10 years 1960-70, the production of phosphate fertilizers used mainly PR from Kaiyang and Kunyang and imported from Morocco as raw material to produce SSP of better quality. Phosphate fertilizer output increased from 193,000 t to 907,000 t of P_2O_5 .

From 1970 to 1980, output of phosphate fertilizer increased tremendously to 2.3 Mt of P_2O_5 . Due to a failure of supply from the phosphate mines and sulphuric acid production to meet the demand, PR grades and quality dropped abruptly (impurity contents, particularly content of carbonate went up, causing consumption of acid to increase), seriously affecting the production of SSP. The P_2O_5 content of product dropped from 18 to 12% and there was an all-round rise in the consumption of raw material. For calcium magnesium phosphate, because the scope of burden was wider and the main impurity content of PR in China is dolomite, the effects on the production and quality of calcium magnesium phosphate are relatively less.

From 1970 to 1975, rock consumption and acid consumption by SSP production increased by 35% and 15% respectively. The consumption of coke for calcium magnesium phosphate went up by 18%. At the same time, effective P_2O_5 in the two products dropped from 16 to 12% while costs went up by 21%. Subsequent to 1980, after a shake-up of the enterprises, there was an improvement in the quality of the products but acid consumption still remained high. The average grade still dropped by one. The cost of SSP and calcium magnesium phosphate increased again.

During the period of the 6th and 7th Five-Year Plans (1981~1990), in accordance with major projects of construction under the 7th Five-Year Plan of the State, "phosphate fertilizer bases" were set up in Tongling of Anhui Province, the Guixi Chemical Fertilizer Co. Ltd. in Jiangxi Province, Nanhua in Jiangsu Province and Dahua in Liaoning Province. These enterprises were mostly located in areas with S

resources and were close to large-scale metallurgy companies in order to utilize S resources or digest the sulphuric acid, a by-product from the smelting gas.

In September 1987, during the period of the 7th Five-Year Plan, the State Council of China convened a routine meeting to specially study the strategic course in the development of the chemical fertilizer industry. In order to guarantee demand for grains, China's fertilizer production needed to increase appreciably both in quantity and quality. A solution had to be found for the inadequate output of phosphate fertilizer that had existed over a long period and the serious imbalance in the ratio of nitrogen and phosphorus. Major problems that existed in the production of phosphate fertilizer were the low quality and low grade of PR, rises in the indices of consumption and increases in production cost.

At the end of the 7th Five-Year Plan, in 1990, there were 637 phosphate fertilizer enterprises in China. Of these, more than 80% were small enterprises with an annual capacity of below 30,000 t of P₂O₅. Most of the medium and large scale enterprises had capacities only of 30,000-50,000 t of P₂O₅. The major medium and large scale phosphate fertilizer enterprises were distributed mainly in the regions in the eastern part of the country where there was a shortage of resources close to the market of agricultural demand and where the economy was relatively well developed. In 1990, China produced a total of 4.1 Mt phosphate fertilizer, 94% being SSP and calcium magnesium phosphate.

At the end of the 7th Five-Year Plan, major enterprises producing SSP with a production scale of more than 150,000 t/y product quantity included the following:

| Name | Province (or City) | Year Production Started |
|--|--------------------|-------------------------|
| Harbin Main Chemical Plant | Heilongjiang | 1953 |
| Liaoyang Chemical Plant | Liaoning | 1954 |
| Taiyuan Phosphate Fertilizer Plant | Shanxi | 1958 |
| Phosphate Fertilizer Plant of Nanhua Co. | Jiangsu | 1958 |
| Jinchang Chemical Plant | Gansu | 1988 |
| Qingpu Chemical Fertilizer Plant | Shanghai | |
| Suzhou Sulphuric Acid Plant | Jiangsu | |
| Nantong Phosphate Fertilizer Plant | Jiangsu | |
| Xuzhou Phosphate Fertilizer Plant | Jiangsu | |
| Longhai Phosphate Fertilizer Plant | Fujian | |
| Xijiang Main Chemical Plant | Guangxi | |
| Beihai Chemical Fertilizer Plant | Guangxi | |
| Jingmenshi Phosphate Fertilizer Plant | Guangxi | |
| Shimen Phosphate Fertilizer Plant | Hunan | |
| Songbai Chemical Fertilizer Plant | Hunan | |

These were major large-scale SSP enterprises at that time. Most of them were located close to markets of agricultural demand. Some enterprises possessed a definite quantity of S or P resources.

At the end of the 7th Five-Year Plan, major FCMP producing enterprises with a production capacity (product quantity) of more than 100,000 t/y included the following:

| Name | Province | Year Production Started |
|--|----------|-------------------------|
| Dongxiang Phosphate Fertilizer Plant | Jiangxi | 1963 |
| Luzhai Main Chemical Plant | Guangxi | 1964 |
| Ermei Gaoqiao Phosphate Fertilizer Plant | Sichuan | 1964 |
| Xinyang Phosphate Fertilizer Plant | Henan | 1965 |
| Changde No. 1 Chemical Plant | Hunan | 1966 |
| Fuquan Phosphate Fertilizer Plant | Guizhou | 1966 |
| Donghai Phosphate Fertilizer Plant | Jiangsu | |
| Jinhua Phosphate Fertilizer Plant (Jinhua Dazheng Industries Co., Ltd.) | Zhejiang | |
| Pingdu Phosphate Fertilizer Plant | Shandong | |
| Fuzhou FCMP Plant | Fujian | |
| Fuzhou Phosphate Fertilizer Plant | Jiangxi | |
| Qinyang Phosphate Fertilizer Plant | Henan | |
| Zhongxiang Phosphate Fertilizer Plant | Hubei | |
| Xixi Phosphorus Mine | Hunan | |
| Yuxi FCMP Plant | Yunnan | |

Among these major large-scale FCMP plants, quite a number were located in regions of Zhejiang Province where phosphate resources were either non-existent or not in abundance, and in the main agricultural provinces such as Fujian and Hunan that are close to the market. Besides, there were some FCMP plants in the provinces of Yunnan and Guizhou but here, the initial capacity was mostly below 100,000 t/y.

Before the 8th Five-Year Plan (1991), even though the distribution of phosphate fertilizer from medium and large scale SSP and FCMP enterprises had taken into consideration resource conditions, the main factor was still the proximity of the agricultural market (product sales). This was related to the economic conditions at the place of building the plants. Yunnan and Guizhou are important producing regions for phosphorus resources. However, as they are considered remote provinces, their economy was not well developed. Fundamental transport conditions were poor and the level of fertilizer utilization was not high. They were treated mainly as major provinces of natural resources that supply PR to the major phosphate fertilizer enterprises located in the interior regions. During the early 1960s, when the construction of blast furnaces was being promoted to save investment, many of them used small blast furnaces, left behind from the great steel smelting operations of 1958, in order to begin their businesses. Consequently, the distribution of FCMP showed, in varying degrees, evidence of that period.

3.3.1.2 Characteristics of the development of phosphate fertilizer during the period of the 8th Five-Year Plan (1991-1995)

With the economic reform and more thorough implementation of the open policy, the planned economy switched to a market economy. In 1987, after it was raised at the 151st meeting of the State Council to vigorously develop high-analysis phosphate compound fertilizers, the phosphate fertilizer industry, particularly the medium and large scale enterprises of high-analysis phosphate compound fertilizer, developed in leaps and bounds.

In the 8th Five-Year Plan, the guiding thoughts concerning the distribution of phosphate fertilizer took into consideration conditions of natural resources, public utilities and the place of chemical fertilizer application in order to optimize resources. Specific arrangements were the setting up of chemical fertilizer plants at P and S mines for the production of high-analysis fertilizer to supply local areas and satisfy the needs of the entire country and to consider the construction of high-analysis fertilizer plants in major grain-producing areas where there were problems with the supply of chemical fertilizer and where there were definitely natural resources which relieved the problem of supply and demand. Based on this guiding thought, for large-scale phosphate compound fertilizer projects listed in the 8th Five-Year Plan, apart from projects already implemented in the resource-rich provinces of Yunnan, Guizhou and Hubei which include plants at Yunfeng (the Yunnan Yunfeng Chemical Co. Ltd.), Honghe (the Yunnan Honghe Phosphate Fertilizer Plant), Dahuanglin (the Yunnan Phosphate Fertilizer Industry Co. Ltd.), Wengfu (Guizhou Hongfu), Dagukou (Hubei Jingxiang Dagukou), Huangmailing (the Hubei Huangmailing Linhua Industry Group) and Jinchang (the Gansu Jinchang Chemical Industry Group Co. Ltd.), there were other projects that were mostly without or poor in P resources, including Guangxi Luzhai, Shandong Jinini, Sichuan Yibin Chuannan and the Hebei Xuanhua Chemical Fertilizer Group Co. Ltd., each producing 240,000 t/y of ammonium phosphate, the Jilin Chemical Industry Co. produced 300,000 t/y of NP and Guangdong Yunfu (the Yunfu City Phosphate Fertilizer Plant) that produced 400,000 t/y of TSP. However, in the course of specific practical operations among these projects, with the exception of Guangxi Luzhai which was implemented because of political factors, others located at the major agricultural markets in North China, Northeast China, Sichuan and Shandong and projects in the economically advanced Guangdong Province failed to be implemented as a result of the switch to market economy, creating problems of funds, resources and economic benefits. Those projects which failed to be implemented were supposed to have had a total capacity of 1.1 Mt (converted to 500,000 t of product).

During the 8th Five-Year Plan, some established large-scale enterprises located in the provinces of Yunnan, Guizhou and Hubei with phosphorus resources failed to reach the designed capacity due to a number of reasons.

With regard to major projects in the 7th and 8th Five-Year Plans under the model of a planned economy, most of them used foreign capital for construction. The large and comprehensive model of construction was a considerable burden. Also, increases in loan interest, exchange rates and

inflation caused the project investment to balloon. Most of the projects lacked the basic funds for project construction and the enterprises were forced to carry the heavy debt load. Furthermore, the chemical fertilizer market was at its low point, causing losses from the day the project went into production. In order to relieve the market situation, the State implemented a policy of preference towards enterprises of phosphate compound fertilizer. In the Document "Circular Concerning Raising the Price of Electric Power"> [Planned Price (1994) No. 87] issued by the former National Development and Reform Commission, the Ministry of Electric Power stipulated that there would be preferential treatment with regard to electric power consumption for the production of chemical fertilizer by small and medium scale enterprises. After the promulgation of the Document, there were, to a certain extent, positive effects.

3.3.1.3 Characteristics of the development of phosphate fertilizer during the period of the 9th Five-Year Plan (1996-2000)

In the 9th Five-Year Plan, the State gradually made it clear that the construction of phosphate fertilizer projects had to be implemented in accordance with the policy of "combining the mine and fertilizer production." There should be a continuous optimization of resource allocation, to raise the overall economic benefits of the enterprises, implement "replace rock transport with fertilizer transport," reduce pressure from rail transport and meet the requirements of agriculture. However, due to the fact that some of these projects were planned and started during the period of the 8th Five-Year Plan and were completed in the 9th Five-Year Plan, they went through a number of adjustments of foreign exchange rates and the RMB interest rates, resulting in a large increase in the total investment of the project. Utilizing foreign investment to import technology and equipment enabled the production capacity and level of technological installations to be raised appreciably, but the economic price paid was also very heavy. The enterprises bore heavy internal and external debts and incurred losses over a long period of time.

During this period, the State extended great support to phosphate compound fertilizer enterprises by way of its policies. Besides continuing with the execution of the policy of preferential treatment with regard to electric power consumption for the chemical fertilizer production by small and medium scale enterprises formulated in 1994, the following policies of preferential treatment were successively introduced.

Beginning in 1996, enterprises producing phosphate fertilizer and compound fertilizer (Production Licence issued by the former Ministry of Chemical Industry) were exempted from the electric power construction fund. Beginning in 1997, there was a preferential transport price (Price No. 2) for the transport of phosphate fertilizer, PR and pyrite and there was exemptions from import VAT for the import of DAP and compound fertilizer within the plan of the State. The import by the Sino-Arab Chemical Fertilizers Co. Ltd. of phosphoric acid, MOP, SOP and AN, as raw materials, enjoyed an exemption from customs duties and a refund of VAT. Nanhua Co. and Dahua Co. also enjoyed the above-mentioned policies for their imported phosphoric acid.

At the beginning of 2000, the CPFIA called for preferential treatment for the transport of phosphate fertilizer products and raw materials and other favourable policies on the price of electric power and tax exemptions. This has provided a good policy environment for the development of phosphate fertilizer enterprises. In collaboration with the National Petrochemical Bureau, the Association managed to convert debts into shares, discounts for technical revamps, utilization of assets, substitution of manufactured products for similar imported products and the assigned allocation of MOP. These were effective measures taken to get enterprises out of their plight. In that year, nine phosphate fertilizer enterprises were short-listed for recommendation; seven enterprises of high-analysis phosphate compound fertilizer that had achieved their targets were included for subsidized technical reform and they managed to achieve a certain quota of MOP. With regard to the 34 NPK enterprises whose scale was above 100,000 t/y and their mission of substituting manufactured products for similar imported products, they would be selling their products at their own prices. In 2000, the volume of DAP import was reduced by 1 Mt and there was basically no import for NPK.

At the end of the 9th Five-year Plan in 2000, phosphate compound fertilizer enterprises numbered 1,007, of which 552 were phosphate fertilizer and 455 compound fertilizer enterprises. The extent of the loss incurred by phosphate fertilizer enterprises (that is, the ratio of enterprises incurring losses) was 37.1%, with profits at RMB220 M. The extent of loss incurred for compound fertilizer enterprises was 24.6%, with profits at RMB760 M. Overall, there were many plants producing phosphate compound fertilizers. Their production capacity was small and the industry had a low level of centralization without a clear, professional division of labour. The degree of centralization of low-analysis compound phosphate fertilizer was low whilst that of high-analysis compound phosphate fertilizers such as DAP and NPK compound fertilizer was relatively high. Compound phosphate fertilizer enterprises were finding it very difficult to turn around.

3.3.1.4 Characteristics of the development of phosphate fertilizer during the period of the 10th Five-Year Plan (2001-2005)

In the first year of the 10th Five-Year Plan, there were 524 phosphate fertilizer enterprises. 16 of them were medium and large scale high-analysis phosphate fertilizer enterprises. The rest were SSP, FCMP or AP enterprises using the "slurry concentration process." It was in the last 10 years that MAP, DAP and NPK came into the picture in China. Some of the large plants had just been set up. Due to restrictions of external conditions (funds and market), only a handful of plants achieved their production targets. However, the cost of production was going down year-on-year. For example, the full cost of products from the Yunnan Honghe Phosphate Fertilizer Plant, Guixi (Jiangxi Guixi Chemical Fertilizer Co. Ltd.) and Yunlin (the Yunnan Phosphate Fertilizer Industry Co. Ltd.) was actually lower than the CIF cost of imported chemical fertilizers.

During the 10th Five-Year Plan, the rationale of "the combination of mine and fertilizer and the integration of

acid with fertilizer" was further confirmed. It was proposed to fully rely on the basic set-up of existing medium and large scale phosphate compound fertilizer enterprises in the provinces of Yunnan, Guizhou, Hubei and Anhui in order to further optimize the conditions of supporting resources, starting the construction of phosphate compound fertilizer bases at the appropriate time and expediting the development of high-analysis phosphate compound fertilizer. The degree of centralization of the industry was increased to enable the phosphate compound fertilizer industry to be more reasonable in terms of regional structure. Besides, from the batch of "combination of mine and fertilizer" projects established since the 8th Five-Year Plan, resolution of the problems of those with poor economic returns and those unable to adapt to the development of the market economy are a key issue for the further development of China's phosphate fertilizer industry during the 10th Five-Year Plan and up to 2015.

During the 10th Five-Year Plan, the State requires state-owned medium and large enterprises to basically complete the tasks of sorting out property rights, responsibility and authority, separation of politics and business and the establishment of a modern business system run by the science of management. There should be the consolidation of sound responsibilities and authorities, co-ordinated operations, and an effective and standardized corporate management structure. With regard to state-owned medium and large scale enterprises, standardized reform in the company system was carried out. Through standardized listing of Chinese-foreign joint venture and mutual equity participation, the enterprises were gradually reformed to become multiple stock holding companies with limited liability that gets financing from society and the capital market. This put the companies under strong pressure to raise the rate of returns in response to the demands of the investors, thus forcing enterprises to continue carrying out innovations in mechanism, products, technology, services and capital so as to operate, in all respects, according to market rules. A more thorough internal reform of an enterprise was carried out to establish a sound and effective mechanism of encouragement and restriction. The objective was to achieve a management system where there was mobility of personnel, hiring and firing and flexibility in income, thus encouraging and mobilizing the initiative and creativity of the employees. Up to May 2004, five phosphate compound fertilizer enterprises were listed; one of them withdrew later on. The number listed was still small and financing capability and channels needed enhancement. The Xiyang Group of Liaoning Province, the Tongling Chemical Industry Group of Anhui Province, the Honghe Phosphate Fertilizer Plant in Yunnan, the Anqiu Aobao Chemical Co., Ltd. and the Zibo Bofeng Compound Fertilizer Co. Ltd. of Shandong Province, the Hongda Co. Ltd. and the Shifang Yingfeng Industries Co. of Sichuan Province achieved good results with regard to transformation of operational mechanism. After this, enterprises were brought back to life, turned from deficits to profits and were glowing with newfound vitality.

In order to resolve the problem of a group of medium and large scale phosphate compound fertilizer enterprises weighed down by debts incurred by the import of installations, for both subjective and objective reasons, the State implemented the policy measure of "debts transformed to shares" thus, helping

them to overcome their difficulty in three years. From 1999, beginning with the Guixi Chemical Fertilizer Plant of Jiangxi Province as the first “debts transformed to shares” enterprise, the majority of state-owned medium and large enterprises implemented this measure to different extents. For example, the Jingxiang Chemical Plant in Hubei Province managed to change RMB3.6 B of debts to shares. The Hongfu Industries Development Co., Ltd. of Guizhou Province transferred RMB3.0 B of debts to shares. In the Huangmailing Linhua Industry Group Co. the amount transferred was RMB1.7 B. It was RMB170 M in the Yunnan Phosphate Fertilizer Co. Ltd., RMB300 M in the Tongling Chemical Industry Group in Anhui Province, and RMB325 M in the Yunnan Linhua Industry Group. In addition, the Jinchang Chemical Industry (Group) Co. Ltd. of Gansu Province, the Tianji Coal Chemical Co. Ltd. of Shanxi Province, the Kailin Group of Guizhou Province, the Huashan Chemical Industry Group of Shaanxi Province, the Honghe Phosphate Fertilizer Plant of Yunnan Province, the Luzhai Chemical Fertilizer Co. Ltd. of Guangxi Province and the Yunnan Petrochemical Group also carried out “debts to shares” in different degrees. Finance and asset management companies became shareholders of these enterprises. The China Xinda Co. even became the shareholder with controlling interests in the Guixi Chemical Fertilizer Plant in Jiangxi Province, the Hongfu Industrial and Commercial Development Co. Ltd. of Guizhou Province, the Huangmailing Linhua Industry Group Co. in Hubei Province, the Dahuanglin (Yunnan Phosphate Fertilizer Industry Co. Ltd. and the Tianji Coal Chemical Co. Ltd. of Shanxi Province). The above enterprises of “debts transformed to shares” achieved some success in their subsequent operations by greatly reducing their financial burdens. According to estimates of the Guixi Chemical Fertilizer Plant, after converting their debts to shares, financial expenses for each tonne of DAP could be reduced by more than RMB100. However, after converting debts to shares, due to inadequate capital for volume increase, production capacity (capital for storage volume) was still not put to full use in a number of medium and large scale enterprises of phosphate compound fertilizers which were still in a dire state. They did not realize their wish of turning “bad loans” into “good assets” and the “debts to share assets” still restricted their development and even their survival.

In order to solve the problems that existed in the production and construction of medium and large scale enterprises of P and compound fertilizers and to adjust the composition of phosphate fertilizer products, the State Council gave approval for some of these enterprises to carry out “technological reform with discountable interest.” Projects that adjusted their product composition by technological reform with discountable interest and put up by the National Economic and Trade Commission, examined and assessed by the former National Petroleum and Chemical Industry Bureau include the Yunnan Phosphate Fertilizer Plant, the Honghe Phosphate Fertilizer Plant in Yunnan Province, the Yunfeng Co. in Yunnan Province, the Tongling Copper Chemical Group in Anhui Province, the Guixi Chemical Fertilizer Plant in Jiangxi Province, the Hongfu Industrial and Commercial Development Co. Ltd. in Guizhou Province, the Luyuan Chemical Industry Group in Shandong Province, the Kaifeng

Kaihua Group in Henan Province, the Peiling Chemical Co. Ltd. in Chongqing City, the Jinchang Chemical Industry (Group) Co. Ltd. in Gansu Province and the Luzhai Chemical Fertilizer Co. Ltd. in Guangxi Province.

In August 2003, a symposium in Beijing, on the policies of development of phosphate fertilizer, was attended by leaders from the 26 major high-analysis phosphate compound fertilizer enterprises. During the symposium, proposals dealing with policies were raised with regard to the five big phosphate fertilizer enterprises and the development of the phosphate fertilizer industry in China. The five big enterprises were Luzhai in Guangxi Province, Dahuanglin (the Yunnan Phosphate Fertilizer Industry Co., Ltd.), Wengfu in Guizhou Province, Dagulou (Jingxiang in Hubei Province) and Huamailing (the Huamailing Linhua Industry Group Co. in Hubei Province). Leaders of the State Council presented an important report.

Since 2003, the phosphate industry actively promoted the strategy of brand names. A report was presented to the China Brand Names Promotion Committee to list high-analysis phosphate compound fertilizer products in the catalogue of branded products of China. In that year, the Guizhou Hongfu Brand of DAP and the Shanxi Tianji Brand of nitrophosphate were assessed as “branded products of China” (Table 3-3).

Table 3-3 List of newly branded phosphate compound fertilizer products in China in 2005

| Name of Product | Registered Commodity Name | Manufacturer |
|------------------------------------|---------------------------|---|
| Three-nutrient compound fertilizer | Xi Yang | Xiyang Group |
| | Yan Yang Tian | Hongri Akang Chemical Co., Ltd., Shandong Province |
| | Lu Bei | Lubei Enterprise Group Head Office, Shandong Province |
| | Lu Xi | Luxi Chemical Co., Ltd., Shandong Province |
| | Sa Ke Fu | Sino-Arab Chemical fertilizers Co., Ltd. |
| MAP | Feng Tian | Fengtian Fertilizer Industry Co., Ltd., Jiyuan City |
| | Yun Ding | Hongda Co., Ltd., Sichuan Province |
| | Hong Fu | Hongfu Industries & Development Co., Ltd., Guizhou |
| | Chu Xing | Yihua Group Co., Ltd., Hubei Province |
| | Rui He | Ruihe Chemical Fertilizer Co., Ltd., Jiangsu Province |
| | Teng Sheng | Sinochem Chongqing Peiling Chemical Co., Ltd. |

In December 2004, the subject of “Study on the Assessment of International Competitiveness of the Chinese Phosphate Fertilizer Industry” passed the experts’ examination and appraisal organized by the Ministry of Commerce and the appraisal by the China Petroleum and Chemical Industry Association. This was the second subject of research of this nature dealt with domestically following that for the automobile industry. Through this systematic research,

Table 3-4 The top four phosphate fertilizer (P₂O₅) producing provinces in China in 2005 ('000 tonnes)

| Province | Phosphate Fertilizer Output in 2005 | Production Capacity in 2005 | Province | High-analysis Phosphate Fertilizer Output in 2005 | Production Capacity in 2010 ^f | Province | Low-analysis Phosphate Fertilizer Output in 2005 | Production Capacity in 2010 ^f |
|----------|-------------------------------------|-----------------------------|----------|---|--|----------|--|--|
| Yunnan | 2154 | | Yunnan | 1595 | | Hubei | 678 | |
| Hubei | 1605 | | Guizhou | 1063 | 2483 | Sichuan | 661 | |
| Guizhou | 1367 | 2843 | Hubei | 926 | | Yunnan | 559 | |
| Sichuan | 1138 | | Shandong | 845 | | Guizhou | 327 | 36 |

f = forecast

the basic situation of the phosphate fertilizer industry was brought to light.

During the period of the 10th Five-Year Plan, with the condition of P resources in China, enterprises increased their input in the development of technology to attract and nurture scientific and technological talents with innovative ability and, in response to actual production, continue to develop and simplify practical technology such as equipment enhancement, energy-savings to reduce consumption and reduced cost of production. Up to 2005, enterprises achieved great progress in terms of production scale, technical installations, business administration and marketing service. During the 10th Five-Year Plan, the main characteristics of the development of the phosphate compound fertilizer industry are as follows:

1. The phosphate fertilizer industry moved towards locations of P resources. The degree of centralization of the industry increased and the scale of enterprises grew. During the period of the 10th Five-Year Plan, phosphate fertilizer in China was moving closer to locations of phosphorus resources. Phosphate fertilizer output in Yunnan, Guizhou, Sichuan and Hubei increased from 44.4% at the end of the 9th Five-year Plan (2000) to 55.7% in 2005 (Table 3-4). High-analysis phosphate fertilizer increased from 42.5 to 59.9%.

AP enterprises in China are mainly concentrated in PR producing regions and the province of Anhui. In 2005, the top five DAP producing provinces were Yunnan, Guizhou, Anhui, Shandong and Hubei. These five provinces accounted for 77.7% of the total DAP output of the entire country. The top five producers of MAP were Hubei, Sichuan, Guizhou, Yunnan and Chongqing City. Their output accounted for 82.6% of the total production in the country (Table 3-5).

Table 3-5 Order of DAP, MAP & NPK output by province in 2005 ('000 tonnes P₂O₅)

| Location/Province | DAP Output | Location/Province | MAP Output | Location/Province | NPK Output |
|-------------------|------------|-------------------|------------|-------------------|------------|
| The whole country | 2330 | The whole country | 255 | The whole country | 1350 |
| Yunnan | 750 | Hubei | 580 | Shandong | 660 |
| Guizhou | 470 | Sichuan | 460 | Hubei | 200 |
| Anhui | 280 | Guizhou | 450 | Guizhou | 93 |
| Shandong | 160 | Yunnan | 360 | Jiangsu | 92 |
| Hubei | 140 | Chongqing | 260 | Hebei | 81 |

Development of NPK three-nutrient fertilizer was mainly located near areas of the chemical fertilizer market. In 2005, the top five phosphate NPK producing provinces were Shandong, Hubei, Guizhou, Jiangsu and Hebei. Their output was 83.8% of the total production in the country.

The top 10 producers of phosphate fertilizer (converted to pure P₂O₅) in 2005 were Yuntianhua, Guizhou Hongfu, Anhui Tonghua, Shandong Lubei, Hubei Chuxing, Sinochem Peiling, Xiyang Group, Guizhou Kailin, Sichuan Hongda and Hubei Yangfeng. Their total output was almost 4 Mt of P₂O₅ or 35.1% of the total production of phosphate fertilizer, an increase of 76.3% over the same period in 2004 (Table 3-6).

Table 3-6 Phosphate fertilizer output of the top 10 enterprises of China in 2005 ('000 tonnes P₂O₅)

| Order | 2005 | | 2004 | |
|-------|--------------------|--------|--------------------|--------|
| | Name of Enterprise | Output | Name of Enterprise | Output |
| 1 | Yuntianhua | 1362 | Guizhou Hongfu | 587 |
| 2 | Guizhou Hongfu | 637 | Yunnan Sanhuan | 446 |
| 3 | Anhui Tonghua | 321 | Shandong Lubei | 285 |
| 4 | Shandong Lubei | 291 | Anhui Tonghua | 273 |
| 5 | Hubei Chuxing, | 239 | Hubei Yangfeng | 243 |
| 6 | Zhonghua Peiling | 238 | Yunnan Honglin | 223 |
| 7 | Xiyang Group | 234 | Hubei Chuxing, | 201 |
| 8 | Guizhou Kailin | 218 | Zhonghua Peiling | 197 |
| 9 | Sichuan Hongda | 210 | Sichuan Hongda | 183 |
| 10 | Hubei Yangfeng | 205 | Yunnan Yunfeng | 178 |
| | Sub-total | 3955 | Sub-total | 2244 |

Note: The Yuntianhua Group consists of Yunnan Sanhuan with 472,000 t P₂O₅, Yunnan Furui with 316,000 t P₂O₅, Yunnan Honglin with 220,000 t P₂O₅, Yunnan Yunfeng with 177,000 t P₂O₅, Jiangchuan Tianhu with 175,000 t P₂O₅.

In 2006, the actual physical quantity of DAP output of 25 enterprises was about 6 Mt. The three large-scale plants of Hubei Yihua, Guangdong Zhanhua and Hubei Dagukou went into production and large-scale plants of Yunnan Furui, Guizhou Kailin and Yunnan Jiangchuan were producing at full capacity, thus the increase in output was relatively large. The volume of sales was 5.7 Mt and the production and sales ratio was 94.9%. The apparent consumption of DAP was 6.6

Table 3-7 Top 10 producers of DAP, MAP and NPK compound (mixed) fertilizers in 2005 ('000 tonnes)

| Diammonium Phosphate | | Monoammonium Phosphate | | NPK Compound (mixed) Fertilizer | |
|----------------------|--------|------------------------|--------|---------------------------------|--------|
| Name of Enterprise | Output | Name of Enterprise | Output | Name of Enterprise | Output |
| Yuntianhua | 1599 | Yuntianhua | 500 | Hubei Yangfeng | 1297 |
| Guizhou Hongfu | 886 | Sichuan Hongda | 457 | Linyi Shidanli | 1202 |
| Anhui Liuguo | 606 | Guizhou Hongfu | 430 | Liaocheng Luxi | 1162 |
| Shandong Lubei | 353 | Hubei Chuxing | 406 | Zhong-A Chemical Fertilizer | 983 |
| Guangxi Luzhai | 256 | Zhonghua Peiling | 286 | Xiyang Group | 975 |
| Huangmailing | 253 | Hubei Yangfeng | 244 | Changzhou Zhongdong | 931 |
| Zhonghua Peiling | 211 | Hubei Xinagyun | 242 | Shandong Shikefeng | 824 |
| Jiangxi Guixi | 175 | Guizhou Kailin | 242 | Shandong Jinzhengda | 805 |
| Shaanxi Huashan | 125 | Jiangsu Ruihe | 202 | Shandong Lubei | 792 |
| Guizhou Kailin | 111 | Gongxian Zhongzheng | 182 | Yisadefu | 645 |
| Sub-total | 4575 | Sub-total | 3191 | Sub-total | 9617 |

Mt, with a self-sufficiency rate of 90.2%. The stock balance increased and the balance was 580,000 t at the end of the year. Basically, there was self-sufficiency in DAP. There were 59 NPK compound fertilizer enterprises that produced 22.4 Mt. Of this, output of phosphoric compound fertilizer was 9.7 Mt. Output from the eight enterprises of Hubei Yangfeng, Sino-Arab, Liaoning Xiyang, Shandong Luxi, Shandong Shidanli, Shandong Jinzhengda, Zhongdong and Shikefeng exceeded 1 Mt (Table 3-7) or 40% of the total sales volume.

2. The level of technology and equipment in the industry had obviously gone up during the 10th Five-year Plan. There was tremendous progress made in promoting larger Chinese-made plants. Installations (with a production capacity of 300,000 t/y phosphoric acid; 600,000 t/y DAP; 200,000-300,000 t/y MAP; 600,000 t/y NPK compound fertilizer; 400,000 t/y sulphuric acid produced from pyrite; and 800,000 t/y sulphuric acid production from S) were Chinese-made plants. Investment in installations was greatly reduced and market competitiveness greatly enhanced. [Note: "large-scale high-analysis phosphate compound fertilizer plants" refer to the single series installation of acid production with S and output of 600,000 t/y (converted to the pure form) and the single series installations for the production of wet-process phosphoric acid with output of 300,000 t/y (converted to the pure form) and the single series installations of DAP with output of 600,000 t/y (actual product quantity), with all three plants set up in the same production area as centralized supporting installations for the realization of optimization of resources].

3. There was improvement in economic performance. In 2000, there were 1,007 phosphate fertilizer enterprises. The figure was 1,118 in 2005. In 2000, the asset liability ratio was 67.4% for the entire industry; in 2005, it dropped to 60.8%. Sales income increased from RMB29.0 B to RMB96.9 B. The total amount of profit for the entire industry grew rapidly from RMB470 M to RMB5.6 B.

During the period of the 10th Five-Year Plan, there were problems in the development of the phosphate compound fertilizer industry in China:

1. Centralization of the industry was still low. The number of small and medium enterprises accounted for about 70% of the total number of phosphate compound fertilizer enterprises in the industry and their output was about 50% of the total. There were few large-scale backbone group enterprises with international competitiveness.
2. Supply of raw materials was tight and prices increased sharply. Supply of the main raw materials for phosphate fertilizer, PR, pyrite (or S), synthetic ammonia and MOP was tight. China is not rich in PR. In recent years, phosphate fertilizer enterprises in provinces that lack PR often have to reduce or stop production due to the problem of supply. For some enterprises that are far from P sources and are short of N, their survival will be difficult.
3. There was high demand for investment resulting in supply being greater than demand. In some regions, there was blind investment in phosphate fertilizer and repeated low-level constructions. Production capacity for phosphate fertilizer increased too rapidly and there was excess of supply over demand.

In 2006, there were 1,243 enterprises of phosphate compound fertilizer throughout the country. There were 260,000 people working in the industry, an increase of 2.8% over 2005. The increase in industrial added value was RMB28.2 B, an increase of 6.37% over 2005 and accounted for 38.6% of the fertilizer manufacturing industry. Sales were RMB124.2 B, an increase of 19.9% over 2005. Due to a rise in the price of PR and increases in transport costs, the selling price of DAP fluctuated while the selling price of MAP and NPK compound fertilizer was lower than the 2005 level. At RMB5.7 B, an increase of only 1% over 2005, the total profit for the industry remained at the 2005 level, accounting for 31.1% of the fertilizer manufacturing industry. The total amount of profit and tax was RMB7.9 B, an increase of 6.6% over 2005. In 2006, 238 phosphate compound fertilizer enterprises incurred losses. This represented 19% of the total number of enterprises. The loss incurred was RMB400 M, an increase of 83.3% over 2005.

3.3.2 Important events in the technological development of phosphate fertilizers and the introduction to some well-known entrepreneurs

3.3.2.1 Some important events in the development of phosphate fertilizer enterprises

1. The first Chinese-foreign joint venture of phosphate compound fertilizer

In 1985, the Sino-Arab Chemical Fertilizers Co. Ltd. (abbreviated as SACF in English, with "Sa Ke Fu" as its trademark) was set up in the city of Qinhuangdao in the province of Hebei. It was a joint investment of China, Tunisia and Kuwait, a large NPK compound fertilizer producing enterprise. The total investment was US\$58 M and it was the biggest economic cooperation project that China had with third-world developing countries at that time. It was upheld as "a model of South-South cooperation" by Deng Xiaoping.

SACF adopted the "pipe reactor-ammoniation rotating drum granulation process," using liquid ammonia, AN, urea, phosphoric acid, MAP and K salt as raw materials to produce AP and various types of NPK compound fertilizers. At the same time, SACF created the "new technology of producing SACF granular compound fertilizer" enabling the production capacity of the installation to increase from 480,000 t/y to 720,000 t/y. The total production capacity reached 1.4M t/y in 2004. By exceeding its designed capacity by 50%, the plant achieved an advanced level in the world for the same type of installations. SACF also collaborates with more than 50 scientific and research organizations, including the Chinese Academy of Agricultural Sciences and has developed the "Sa Ke Fu" series of compound fertilizers for special purposes that numbers more than 60 types. These types of fertilizer are developed to suit the different regions and different crops. Besides, there are more than 10 fertilizer grades that have opened the eyes of Chinese farmers to the idea of scientific fertilizer application. These include the high-nitrogen topdressing fertilizer 20-10-10 and the once-only fertilizer 26-10-12. Such fertilizer grades have driven the development of the technique of balanced fertilizer application by the domestic compound fertilizer industry. The products contain granules of even sizes with flexible nutrient ratios. The company is able to produce different types of NPK compound fertilizers of low, medium and high grades, with many forms of nutrients, for example, nitrogen is included in the form of ammonium, nitrate and urea.

2. The first to create a Chinese branded product of DAP and presently the biggest single phosphate compound fertilizer enterprise in China

The Guizhou Hongfu Industrial and Commercial Development Co. Ltd. formed in Guiyang on 29 June 1994, was the biggest base for phosphate compound fertilizers that was set up with investments by the State during the period of the 8th and 9th Five-Year Plans. It included the Wengfu Phosphorus Mine and the Wengfu Phosphate Fertilizer Plant. It has built a production capacity of 3.50 Mt/y of PR, 2.4 Mt/y of fine PR, 2 Mt/y of sulphuric acid, 800,000 t/y of phosphoric acid and 1.7 Mt/y of AP. It was also equipped with its own special railway track capable of handling 3.45 Mt of freight.

The technology at the Wengfu rock and fertilizer base is mainly imported from abroad. American and German technology of beneficiation was imported. It was the counter flotation magnesium reduction process. German Lurgi technology is used for the sulphuric acid installation. For the phosphoric acid installation, the 4th generation dihydrate process from Belgium was used. Norway's Norsk Hydro slurry concentration process was adopted by the TSP plant while the aluminium fluoride plant used the ARCO process from the US. In Wengfu, stripping operations were done with a 10m³ excavator and a 77-t wagon. The home base possessed a 46km pipeline for transporting the rock-pulp. The four major plants at the Wengfu Phosphorus Mine were built with a basic design provided by Mitsubishi and Mitsui of Japan and Rayson of the US. Key equipment was imported. Advanced DCS or PLC control systems were used on imported and revamped technology input to the production installations. Hongfu will strive to build a group enterprise with sales revenue of RMB10 B by 2015.

3. The first to produce TSP by the production of wet-process phosphoric acid and a phosphate fertilizer enterprise entitled to import-export operations

The Yunnan Sanhuan Chemical Co. Ltd. was a state owned large enterprise set up as a result of the change in the administrative system of the former Yunnan Phosphate Fertilizer Plant in December 2001. The former Yunnan Phosphate Fertilizer Plant was the first in China to produce TSP by applying the technology of wet-process phosphoric acid. Besides, it was entitled to import-export operations. During the eight years from 1996 to 2003, it successively established plants producing acid from S with capacities of 80,000 t/y (120,000 t/y after technological revamp), 200,000 t/y, 330,000 t/y and 600,000 t/y. It also set up an installation of 180,000 t/y of MAP, a 600,000 t/y DAP installation (a joint venture with the American Jiaji Co., Zhong Hua Co. and Yantai Nongzi Co. and went into production in July 2002). Together with the existing production capacity of high-analysis phosphate compound fertilizer, the Yunnan Sanhuan Chemical Industry established a production capacity of 1.4 Mt/y of sulphuric acid, 500,000 t/y of wet-process phosphoric acid, (including 150,000 t/y of refined phosphoric acid), 340,000 t/y of TSP, 180,000 t/y of MAP, 600,000 t/y of DAP, 100,000 t/y of compound fertilizer, 18,000 t/y of SOP, 10,000 t/y of potassium phosphate and 100,000 t/y of SSP. Production technology for the wet-process phosphoric acid, TSP and sulphuric acid used in the Yunnan Phosphate fertilizer Plant led the industry throughout the country. From 2005 to 2006 a new plant for the production of 1.2 Mt of AP would be erected which would enable the production and sale of phosphate compound fertilizers of the company and the joint venture to exceed 2 Mt.

4. The largest nitrophosphate (NP) production base in China

The largest NP production base in China is the Shanxi Chemical Fertilizer Plant located in the city of Lucheng in the province of Shanxi. In 1997, the whole plant changed its system of administration to become the Tianji Coal Chemical Industry Group Co., Ltd. The enterprise started off in the early 1980s and was designated by the State as a

major construction of the 6th Five-year Plan. It was the first and largest modernized enterprise in China that produced high-analysis compound fertilizer using coal as the raw material. It was set up by importing 11 patented technologies and equipment from eight countries, including Germany, Japan, France and Norway. It is presently also an efficient compound fertilizer production base with the longest process flow. In September 2001, the Tianji Group invested RMB300 M in setting up a project that could produce 270,000 t of phosphoric acid annually. This foundation-laying project marked the third effort by the Tianji Group in their business growth. The project was completed and put into production at the end of that year. Construction work for a plant with an annual capacity of 400,000 t of synthetic ammonia and a plant with an annual capacity of 600,000 t of urea with an investment of RMB1.5 B-RMB1.6 B, in Gaoping County, was started on 29 July 2004. On 18 June 2006, the entire process flow in the production system was ready to enter the stage of testing and test production. After more than 20 years, the total assets of the Tianji Group are worth RMB3.5 B, with the annual sales income approaching RMB1.5 B. Annually, the company is capable of producing 600,000 t of synthetic ammonia, 810,000 t of phosphoric acid, 900,000 t of NP (or 1Mt of nitrophoska), 200,000 t of porous AP for industrial use, 450,000 t of urea and 200,000 t of calcium ammonium phosphate. The company applies the strategy of a big group and currently, it is a modern enterprise group of "one parent company with ten subsidiaries." There are ten production plants, one marketing company directly under the parent company, one research and development centre, an information management centre, an investment holding company and ten subsidiary companies with independent corporate status.

5. The first phosphate compound fertilizer enterprise applying the idea of a recycling economy and the biggest base for the production of sulphuric acid with gypsum

The predecessor of the Shandong Lubei Enterprise Group Head Office was the Shandong Wudi Sulphuric Acid Plant. Currently, it has an annual production capacity of 1 Mt of SOP-compound fertilizer, 600,000 t DAP, 1 Mt sulphuric acid and 900,000 t cement. It is the largest base for the manufacture of sulphuric acid with gypsum. It has developed the key technology of binding through technological integration and innovation to establish the green industrial and ecological chains of ammonium phosphate – sulphuric acid – cement combined production, multiple use of seawater, clean power generation and combined production of saline and alkali, thus establishing a system of ecological industries that resolves the conflict between industrial development and environmental protection and achieved the transformation of a conventional chemical industry from a "sunset industry" to a "green industry." It has established an ecological business operation model that allows sustainable growth in the 21st century and becomes a model in the use of ecological and scientific technology in the development of a recycling economy in China. The enterprise was listed as a national selected test project with annual production of 150,000 t AP, 200,000 t of combined production of sulphuric acid and cement from gypsum, in the 9th Five-Year Plan for National Economic and

Social Development and the Programme for Development for Long-Range Objectives in 2010. When finished, the project would adopt achievements in innovative technologies to enable the production capacity of the installation to double and reach the scale of "30-40-60" to lay the foundation for a leading position in the trade of phosphate compound fertilizer and acid production with gypsum.

6. The first high-efficiency nitrogen-phosphorus compound fertilizer production plant imported from abroad

The establishment of the Liuguo (literally *six-nation*) Chemical Co. Ltd., (formerly the Ammonium Phosphate Plant of Tongling Chemical Industry Group Co., Ltd.) (Shortened to "Liuguo Co."), started in 1986 as a major project during the 7th Five-Year Plan. It was the first set of high-efficiency N-P compound fertilizer production plant introduced from a foreign country by China. The project occupied 132 hectares of land. Investment in Phase I of the project was RMB440 M with the technology and equipment coming from France, Italy, Austria, the former German Federal Republic, Romania and China. The project was completed and went into production at the end of 1987 and was designated as a major established base of S and P. After reforming its system in 1996, the Liuguo Co. changed its name to "The Tongling Chemical Industry Group Co. Ltd." with 12 subsidiary companies, six holding subsidiaries and two equity participation subsidiaries. In 1999 RMB420 M was injected into the phase I installation to carry out a technological revamp that would increase the production capacity of DAP of excellent quality by 240,000 t. After more than 10 years of development, the company now has the capacity to produce 200,000 t of phosphoric acid, 400,000 t of DAP, 200,000 t of sulphuric acid and 30,000 t of high-analysis compound fertilizers. At present, the company has 650 employees, with fixed assets at a net value of RMB698 M. It is a large state-owned enterprise.

7. The largest enterprise group of high-analysis phosphate compound fertilizer

In 1974, the State imported 13 sets of large fertilizer plants and ethylene installations for US\$4.3 B. One of the installations is the Yunnan Natural Gas Chemical Plant (abbreviated to "Yuntianhua") located at the border between the provinces of Yunnan and Sichuan mainly for the production of synthetic ammonia and urea. In 1997, Yuntianhua changed its system of administration entirely to become an authorized state-owned sole investment company with limited liability and it initiated the formation of Yunnan Yuntianhua Ltd. which became listed. In April 2000, through the transfer of ownership, the entire Honghe Phosphate Fertilizer Plant, one of the domestic enterprises of high-analysis phosphate compound fertilizer, was brought into the Yuntianhua Group and the name was changed to the Yunnan Honglin Chemical Co. Ltd. With this, Yuntianhua went into the phosphate compound fertilizer industry. In 2001, the entire Yunnan Provincial Chemical Research Institute was brought into the Yuntianhua Group, becoming a core business organization of the Yuntianhua Technological Centre. In January 2002, in the reorganization of the Jianglin Group Chemical Plant, the Yuntianhua Group withdrew RMB19.3 M in cash and became the controlling shareholder of the new company – the Yunnan Jiangchuan

Tianhu Chemical Co. Ltd. with 55% stock ownership, with the intention to augment the production of phosphate compound fertilizers. In November 2002, Yuntianhua made an initial investment in the Yunnan Phosphate Fertilizer Industry Co. Ltd., one of the five big phosphate fertilizer projects (commonly referred to as "Dahuanglin") to set up a synthetic ammonia project capable of producing 500,000 t/y. At the same time, through the transfer of stock ownership, the phosphate compound fertilizer industry platform of the Yunnan Furui Chemical Co. Ltd was established. This was followed by the leasing of the wet-process phosphoric acid and TSP assets of Dahuanglin by Furui. In addition, the thermal process phosphoric acid and the yellow phosphorus plants were transferred to Yunnan Malong Industries before the essential inputs of Yuntianhua and secondary reorganization. Finally, problems of asset structure and debts were settled to enable the development of Dahuanglin to enter a sound cycle of economic activities. At present, the Yunnan Furui Chemical Co. Ltd. has a total capacity of acid production from sulphur of 1.1 Mt/y; wet-process phosphoric acid of 400,000 t/y and 1.2 Mt of high-analysis phosphate compound fertilizers (DAP, MAP, TSP), thus making the Yuntianhua Group the main entity of phosphate compound fertilizer at the national level. In the same year, Yuntianhua invested in the setting up of the Yunnan Tianchuang Science and Technology Co. Ltd. for the development of a refined phosphate industry. In 2005, by the acquisition of stock ownership, the Group controlled the stocks of Yunnan Malong Industries Group Co. Ltd. taking another step in the establishment of a business platform for the phosphate industry. In 2005, all assets of the Yunnan Yunfeng Chemical Industry Co. Ltd. originally controlled by the Yunnan Petrochemical Industry Group Co. Ltd. were transferred to the Yuntianhua Group. In March 2005, through capital increase and stock expansion, Yunnan Sanhuan Chemical Ltd. was officially formed after the total change in the system of administration and reorganization of the operational assets of the original Yunnan Phosphate Fertilizer Plant. Yunnan Petrochemical Industry Group Co. Ltd. held 77.69% of the stocks. In June 2006, this stock ownership was transferred to the Yuntianhua Group. In the same year, the Yunnan Provincial Chemical Construction Co. and the Yunnan Linhua Group also joined the Yuntianhua Group. On 26 July 2006, the Group started grouping all the five companies under its banner with AP as its main business and worked on its listing in Hong Kong. These five companies were Jiangchuan Tianhu, Honglin Chemical Industry, Furui Chemical Industry, Sanhuan Chemical Industry and Yunfeng Chemical Industry.

Through the integration of the various PR enterprises and other P type resources, Yuntianhua has become the largest P industry company in China. After integration, the Yuntianhua Group is a company that deals mainly with chemical fertilizer, the organic chemical industry, new materials of glass fibre, the salt chemical industry, PR beneficiation and the P chemical industry

8. Development based on the integration of low-analysis phosphate fertilizer producing enterprises

The predecessor of the Yunnan Honglin Chemical Co. Ltd. was the Yunnan Provincial Honghe Phosphate Fertilizer Plant.

It was a large, state-owned, top-quality chemical production enterprise and one of the 13 large high-analysis phosphate compound fertilizer producers in China. The company was located in the city of Kaiyuan in the southern part of Yunnan Province. Its construction began in 1966. After more than 30 years of construction and development, it became a major large-scale phosphate compound fertilizer producing enterprise designated by the State. It has advanced technology and equipment with a complete range of intermediate products. It is capable of producing series of products of S, P, F salts and synthetic ammonia. Its total assets are worth close to RMB1.4 B. The yearly sales revenue is close to RMB600 M and its export earnings are more than US\$25 M.

In order to fully make use of the advantages of the production technology of its low-analysis phosphate fertilizer and effectively lower the operational cost of such fertilizer, the Hong Lin Chemical Co. Ltd. depends on its production and management experience accumulated over the years. The company utilizes the advantages of its brand name, management, technology and resource according to conditions in different enterprises. It adopts stock control, lease of assets, and authorized and contractual operations to carry out integration of four phosphate fertilizer plants in Yunnan after which total production capacity reached 640,000 t. The business operation of the enterprise was good with its production capacity and profit margin greatly increased. The Honglin Co. is striving to control the production capacity for SSP at 2 Mt within 3 years.

9. The first attempt at the integration of enterprises producing FCMP

The Fuquan Phosphate Fertilizer Plant in the province of Guizhou is a medium-size Type II state enterprise. It is the largest FCMP producing enterprise in the province of Guizhou, with 40 years of experience in the production of FCMP. The annual production of FCMP (powder form, sand grain form, granules) is 250,000 t. The production of SSP (powder form, granules) is 80,000 t and that of compound fertilizer is 50,000 t. In 2004, the total value of industrial output broke the RMB100 M mark to reach RMB120 M. Currently, it is Guizhou's backbone enterprise in chemical fertilizer production. In terms of output and quality, it tops the list in Guizhou. The company has 867 employees, 200 of them professional and technical personnel.

In the past 10 years, due to the impact of high-analysis phosphate compound fertilizer and inadequate publicity, users are not well informed about FCMP and both output and sales were declining. In order to consolidate the strength of the industry and raise people's awareness on FCMP as a quality and cheap product that contains P, Mg, Si and Ca and as a form of good utilization of natural resources, in 2002, led by the Fuquan Phosphate Fertilizer Plant in Guizhou Province, the Head Office of a "joint operation" was set up by 14 enterprises of FCMP in the province of Guizhou. The director of the Fuquan Phosphate Fertilizer Plant, Huang Xingzhong assumed the posts of Chairman and General Manager. However, due to a lack of clear-cut cooperation, the Head Office was closed after operating for only several months. This led to a great reduction in the production of FCMP in Guizhou Province. Many enterprises even shut

down their operation. At present, due to pressure from market competition in phosphate fertilizers, the desire to have a joint effort to build up a brand name for FCMP, to enhance the ability to resist risks and to explore and open more marketing opportunities has provided a new driving force to integrate the trade. By using the experience of failures in the past, the Fuquan Phosphate Fertilizer Plant is working hard on a new integration plan with the objective of contributing to the development and growth of the industry of FCMP in China.

10. Examples of success of enterprises that have grown from the mining industry to a combined mining and fertilizer operation

On 18 January 1996, the PR Mineral Bureau of Kaiyang was changed to the Guizhou Kailin Group Co. Ltd. which is now mainly in the business of mining and phosphate chemical industry besides engaging in real estate, trading logistics, precise chemical engineering and social services. The company has an annual production capacity capable of producing 2.5 Mt of PR (including phosphate pebbles and ground PR), 160,000 t MAP, 240,000 t DAP, 100,000 t TSP, 100,000 t SSP, 75,000 t ammonia, 130,000 t AP, 200,000 t NPK compound fertilizer, 15,000 t calcium hydrogen phosphate to be used as animal feed, 15,000 t yellow phosphorus and 18 M plastic bags. The company is capable of developing 30,000 m² of real estate in a year. The annual export earnings amount to US\$25 M.

Mining is the fundamental business of the Kailin Group, which enjoys exceptional advantages in terms of natural resources. Proven deposits of PR amount to 413 Mt which represent 78% of the PR of excellent quality in the regions under the state programme. The average grade of P₂O₅ is as high as 33.73%. It is the only important base of raw materials that can be used directly for the production of high-analysis phosphate fertilizer and compound fertilizer without beneficiation. It holds the balance in the development of phosphate compound fertilizer industry in China.

Since obtaining the entitlement to self import-export operations, the various products of the Kailin Group have established a good reputation in the international and domestic markets. Annual export earnings total US\$25 M. The Kailin Group has worked out the development strategy of achieving the targets of sales income of RMB2 B, RMB5 B and RMB10 B in three successive five-year periods and builds the Kailin Group into a large, modern enterprise group. On 18 June 2003, the three parties of Sinochem, Guizhou Kailin Group Co. Ltd. and the Guiyang Industry Investment Holding Company formed a joint venture with excellent prospects – the Guiyang Zhonghua Kailin Chemical Fertilizer Co. Ltd. which signalled the beginning of reorganization and integration in the phosphate compound fertilizer industry.

11. The first AP plant designed and manufactured in China

The predecessor of the Jiangxi Guixi Chemical Fertilizer Co. Ltd. was the Jiangxi Guixi Chemical Fertilizer Plant, a large-scale enterprise built with imported advanced technology and key equipment from the State for the improvement of chemical fertilizer composition and expediting the development of high-efficiency phosphate compound fertilizer. It was a major project in the 7th Five-Year Plan and was meant for

the digestion of sulphuric acid as a by-product in the Guixi Smelting Plant of Jiangxi Copper Co. for achieving the objective of “combination of acid and fertilizer.” Construction of the project was started in 1988 and in 1999 it was completed and went into production. It produced 120,000 t of phosphoric acid and 550,000 t AP and NPK fertilizer per year. The Jiangxi Guixi Chemical Fertilizer Co. Ltd. is a modern phosphate compound fertilizer enterprise jointly initiated by the China Xinda Asset Management Corporation, the Jiangxi Provincial Investment Corporation, the China Haohua Chemical Industry (Group) Head Office and the Jiangxi Provincial Petrochemical Group Corporation in August 2000 and approved by the State on the basis of “conversion of debts to shares” by the former Jiangxi Guixi Chemical Fertilizer Plant. Total assets of the company amounted to RMB1.4 B, and it occupied an area of 246.3 hectares. At present, there are 2300 employees and the various categories of technical personnel number more than 600.

The Jiangxi Guixi Chemical Fertilizer Co. Ltd. has advanced technology, a mature process and excellent equipment. The main equipment reached internationally advanced standards. The 120,000 t phosphoric acid plant was the first “R-P dihydrate process” of phosphoric acid production, a patented technology with key equipment imported from the French company of Speichim. The AP plant was the first set of plants designed and manufactured in China after digesting and assimilating the advanced technology from abroad. In 1997 the company imported the internationally most advanced pipe reactor technology and equipment and carried out a technological revamp and the expansion of production capacity, thus enabling the plant to increase its output from 240,000 t to 300,000 t. Also, the direct control system (DCS) was implemented. After the technological revamp, the various economic and technical indices of the installation achieved the best international level.

In 2002, a plant with production capacity of 100,000 t of S based compound fertilizer, an installation producing 150,000 t of phosphoric acid and an installation producing 300,000 t of NPK/DAP were built. An installation capable of producing 300,000 t of phosphoric acid and one producing 600,000 t of NPK/DAP have been planned before 2010. When the time comes, the annual production capacity will be 1.5 Mt of chemical fertilizer and 570,000 t of phosphoric acid.

12. The S-based NPK process developed by China and the largest S-based NPK compound fertilizer plant

The predecessor of the Shandong Hongri Group was the Head Office of the Linyi Chemical Plant. It was built in 1965. In 1993, it changed its system of administration to a share-issuing enterprise. In June 1997 it was established as a large-scale chemical enterprise group and the biggest domestic sulphur based NPK compound fertilizer producer. It became one of the 520 major enterprises in the country and one of the 136 major enterprises in Shandong Province. Hongri S-based compound fertilizer is manufactured with a production technology with autonomous intellectual property rights. Equipment for low-temperature conversion of KCl, direct use of dilute phosphoric acid, pipe reactor ammonia neutralization, gunite granulation and drying and cooling by fluidized bed or revolving drum were all made

domestically. The Hongri Group leads the whole country in compound fertilizer and relevant technologies. It established the first S-based sulphuric acid production plant with an annual capacity of 400,000 t and a synthetic ammonia plant of 100,000 t/y, relying on its own technology and capability. In doing so, it created the record as having the shortest construction period for similar installations in the chemical fertilizer trade.

3.3.2.2 Some renown entrepreneurs who have emerged in the phosphate fertilizer industry

On 1 May 2005, the State Council announced its commendation of 2,969 model and meritorious workers. Among these, four people in charge in a phosphate fertilizer enterprise were chosen to be model workers at the national level. They were: He Haoming, Chairman of the Head Office of Guizhou Hongfu Industrial and Commercial Development and Secretary of the Party Committee; Hu Huaweng, Chairman and General Manager of the Hubei Xiangyun (Group) Chemical Industry Co. Ltd.; Wang Xiyi, Deputy General Manager of the Anhui Liuguo Chemical industry Co. Ltd. and Wang Chuan, the Zhonghua Chongqing Peiling Chemical Industry Co. Ltd.

3.3.3 The current situation of phosphate fertilizer enterprises in China compared with those in advanced countries

3.3.3.1 Low-analysis phosphate fertilizer enterprises

In China, the types of phosphate fertilizers are gradually changing from single-nutrient to multiple nutrient high-analysis phosphate fertilizers. From 2000 to 2003, the ratio of single-nutrient type phosphate fertilizers (i.e., FCMP and TSP) in the country's phosphate fertilizer output dropped from 67.5% to 53.9%. The absolute volume of conventional low-analysis phosphate fertilizers (SSP, FCMP) increased from 4.3 Mt to 4.6 Mt of P_2O_5 . Its ratio in phosphate fertilizer output dropped from 64.6 to 50.7%.

During the period of the 10th Five-year Plan, in conjunction with the rapid development of the phosphate fertilizer industry, enterprises of low-analysis phosphate fertilizers adopted the strategy of taking the market as a guide and produced according to sale. These enterprises placed great emphasis on quality and actively launching agrochemical services. Great efforts were made to create product brand names to establish enterprise image. There was close co-operation with agricultural capital in circulation and agricultural research departments for mutual benefits. This formed a preliminary agrochemical service system of production, circulation and application as a co-ordinated process. SSP produced by the Guangdong Zhanhua, SINOPEC (Zhongshihua) Nanhua Corporation, Anhui Tongguan and Yunnan has been very popular among farmers. FCMP produced by Guangxi Luzhai, Guizhou Fuquan and Yunnan Guangming sells very well.

3.3.3.2 High-analysis phosphate fertilizer enterprises

Since the first half of 2006, high-analysis phosphate compound fertilizer has maintained its rapid growth while the production of low-analysis phosphate fertilizer dropped. From January to April, output of phosphate fertilizer was 3.9

Mt, a year-on-year increase of 8.0%. Of this, the output of high-analysis phosphate compound fertilizer was 2.4 Mt, a year-on-year increase of 20.0%, accounting for 61.9% of the total output of phosphate fertilizer. Output of low-analysis phosphate fertilizer was 1.5 Mt, a year-on-year decrease of 7.1%, accounting for 38.1% of the total output of phosphate fertilizer.

Among the major exporting countries of high-analysis phosphate compound fertilizers, in terms of relationship between the upper and lower stream of the industrial chain, scale of enterprise (10,000 t of P_2O_5), quality of raw materials, labour productivity (sales income in millions of RMB)/total number of people), cost of production (production cost per unit phosphate fertilizer with pure nutrient content, RMB/t of P_2O_5), profit margin [(profit before tax/net assets)×100%], research and development input by enterprise (research and development input as a ratio of sales income in percentage) and transport capability are the differences between major international enterprises of phosphate compound fertilizers. Production was manifested in the following aspects:

1. Separation of upstream resources and downstream markets in the production of phosphate fertilizer

In most of the enterprises, the mine and the fertilizer units are separated. The production and business operations of enterprises are seriously restricted by the supply of PR and synthetic ammonia. According to analysis, in the past two years, as a result of an inadequate supply of PR and synthetic ammonia, at least 15% of the production capacity of phosphate fertilizer enterprises was lying idle. Due to the low level of centralization of the industry and distribution of PR, and synthetic ammonia the phosphate fertilizer enterprises are scattered. Production capacities do not support each other. Phosphate fertilizer enterprises compete for PR and synthetic ammonia, resulting in negative competition and affecting the healthy development of the phosphate fertilizer industry. The majority of phosphate fertilizer enterprises are small and scattered, without the economic advantages of scale. Some small and medium scale enterprises are backward in their technology, material and energy consumption is high with serious wastage of resources and energy.

2. The scale of enterprises is generally small with a low degree of centralization of the industry

After the American chemical fertilizer companies of Cargill and IMC merged to form the company Mosaic, its scope of business covered N, P and K fertilizers. In 2004, its phosphate fertilizer production of 12.6 Mt was the world's largest. Its potash fertilizer production of 10.2 Mt put it in the second position. 22.4 Mt of PR was used. This was the second largest production in the world. Output of synthetic ammonia was 1.2 Mt which placed them in the sixth position in North America. Sales income reached US\$4.5 B which ranked them among the top 500 by Fortune.

Compared with an international enterprise such as Mosaic, the scale of production of the top ten enterprises of high-analysis phosphate compound fertilizers in China is relatively small. There is still a long way to go in terms of production capacity, fertilizer types and sales income. For instance, the scope of business of Sinochem Fertilizer, the largest

domestic chemical fertilizer enterprise in China, includes N, P and K fertilizers. Its import of chemical fertilizer exceeds 7 Mt. Domestically, it controls about 1.4 Mt of high-analysis phosphate compound fertilizers. It participates in the development of potash fertilizer in Qinghai Province. Domestically, in the major chemical fertilizer markets, Sinochem Fertilizer owns chain stores that spread far and wide. It is becoming a large, comprehensive chemical fertilizer enterprise covering the various sectors in the business of chemical fertilizer and owns upstream and downstream resources in the industrial chain. Currently, the production capacity of high-analysis phosphate compound fertilizer of the Yuntianhua Group takes the top spot in Asia. In 2005, the total output of DAP and MAP was 2.1 Mt.

3. P and S resources severely limit the competitiveness of China's phosphate fertilizer enterprises

The technology and equipment of large DAP and MAP plants have attained or are approaching internationally advanced levels. However, due to the poor quality of PR, its unit consumption of sulphuric acid is high but there is little difference in the unit consumption of synthetic ammonia. The cost of production of PR, sulphuric acid and synthetic ammonia accounts for more than 85%. Owing to the high unit consumption, the average cost of raw material of enterprises in China goes up. According to the analysis of survey data from 2000 to 2003, there are large differences in the cost of production for the various high-analysis phosphate fertilizers produced locally in China, with cost of production of DAP at about RMB1,300 per t on average; MAP at about RMB1,100 per t; NPK at about RMB800-1,200 per t and TSP at less than RMB1,000. P and S resources are becoming a limiting factor in the continuous large-scale development of the phosphate fertilizer enterprises. Based on the scale of exploitation of more than 10 Mt each year, the high-grade rock in the P mines may not last for 10 years. High-grade rock is becoming a limiting factor to the phosphate industry in China, particularly in the development of a high-analysis phosphate fertilizer industry. At the same time, CIF price for imported S as raw material in 2003 was US\$40-50 per t. It went up to US\$90-93 per t in 2004, causing a big increase in the costs of sulphuric acid and phosphoric acid and the ability of the enterprise to make profit is reduced. Compared with imported phosphate fertilizer, competitiveness is obviously reduced.

4. Economic performance of high-analysis phosphate fertilizer enterprises has been generally raised

From 2003 the development of high-analysis phosphate fertilizer enterprises in China appeared to be accelerating. Economic benefits were generally raised. Comparison between China and foreign countries shows the rate of return on total assets of the top ten enterprises of phosphate fertilizer is generally higher than international enterprises. Only the condition of assets of the Jordanian company of IOPH was better than Chinese enterprises. In recent years, the rapid increase in production and sale of high-analysis phosphate fertilizer in China restrained American and European exports to China, resulting in the reduction of profits in some of the enterprises in these countries.

5. Inadequate rail transport capability has further restricted the development of the phosphate fertilizer industry

Production of high-analysis phosphate compound fertilizer is mainly in the provinces of Yunnan, Guizhou, Hubei and Sichuan while markets for the products are mainly located in regions of north, northeast and east China. Sale of products depends solely on rail transport. In recent years, the rate of meeting the requirements of transport demands by many phosphate fertilizer enterprises was only 50%-60%. Taking Yunnan as an example, when Yunnan Furui and Sanhuan Zhonghua went into production after the completion of the 1.2 Mt DAP plant, the limitation that rail transport exerts on the marketing of phosphate fertilizer products will be even more pronounced.

Through wide-ranging comparisons of scale (output), benefits (returns on assets), product costs, market share and technological standards (unit product consumption), it is clear that high-analysis phosphate fertilizer enterprises in China are numerous, with small scale, low economic benefits, poor brand image and weak competitiveness. Compared with China, advantages in Morocco, Tunisia, Russia and the US come mainly from the scale of enterprises and production costs. Even though the US is the world's largest phosphate fertilizer producing and exporting country, its advantages at present come from the larger scale and higher labour efficiency in production. But low profits and higher production costs place the USA behind Morocco, Tunisia and Russia. For Chinese enterprises, they lag behind, in terms of scale and production efficiency, and the only profit is at the middle level. The industry in China is encountering a domestic market with a huge demand. The pull of this vigorous demand is in some way an assurance of profit.

3.3.4 Outlook for the development of phosphate fertilizer enterprises

With China's accession to WTO and linking up with the world market, competition intensifies. In the 11th Five-Year Plan, the State has proposed building phosphate compound fertilizer plants in the provinces of Yunnan, Guizhou and Hubei and enhancing the management of mineral resources.

1. There should be rational exploitation of PR which is plentiful but not rich in content. Grade and utilize the rock to ensure sustainable growth. A province endowed with P should take into consideration the conditions of transport, the ability to provide resources, market demand and the need to guarantee a definite volume of PR to be transported out as a commodity. Subsequent reforms with regard to the production and expansion of PR and phosphate fertilizer capacity should be guided by the outlook of scientific development by proving that there is a market, good economic benefits and plentiful resources in order to optimize the economic scale and product varieties.

2. Treat economic benefits as the centre, resources and assets as the bonds, integrate the factors of production according to the industrial chain for achieving the state of being complementary to each other and for sharing the resources. Through the regulation of assets, industrial enterprise, raw

material and product structure and by way of expansion at low cost, bring about large scale and group formation. Set up five to ten large backbone groups with the competitiveness to deal with raw materials, production, transport, marketing and agrochemical services. For example, In Yunnan, phosphorus chemical enterprises throughout the province were reorganized into three large enterprise groups through adjustment and integration to comprehensively increase their competitive advantage and industrial standards. Guizhou Province has started building the "Guizhou Provincial Phosphorus Chemical Enterprise Group" to emphasize the development of high-analysis phosphate fertilizer with the plan of achieving its business income of RMB6 B by 2010 with phosphate compound fertilizers as the main products. With regard to the fine chemical industry, it is planned to have 50 phosphate products by 2010 and main business income of RMB4 B. Total income of RMB10 B from phosphates, RMB2 B for profit and tax and export earnings of US\$1 B have also been planned. With government adjustment, control and support, superior phosphate chemical enterprises such as the Xingfa Group, the Yangfeng Group and Huangmailing of Hubei Province are keen on integration by uniting and organizing small and medium scale enterprises and setting up a large enterprise group. Phosphate mines and enterprises should link up to extend the industrial chain to increase added values. Phosphate mines and phosphate fertilizer enterprises, exploitation and beneficiation should link up to raise the efficiency ratio of low-grade rock to reduce wastage of natural resources.

3. Change the economic model of the unilateral pursuit of phosphate fertilizer production to raise competitiveness of the enterprise. Looking at the phosphate fertilizer projects being built, whether it is the total capacity or the capacity for DAP and MAP, they have exceeded the requirements of agriculture. The external extension growth model of pursuing phosphate fertilizer production and the rapid growth of the capacity of high-analysis fertilizer installations should be changed. China should depend on the advantage of having 25% of the market share in the world and emphasize increasing its enterprise competitiveness. In development with adjustment, it is hoped to nurture 20 "Chinese branded products," with a guarantee of physical distribution and increases in the economic benefits of enterprises to enable them to have stronger international competitiveness and higher market shares.

4. Small and medium-sized, conventional low-analysis phosphate, and compound fertilizer enterprises still have definite room for development. Small and medium-sized enterprises should head in the direction of "special purpose, fine, unique and new" products, switching from the production of basic fertilizers to the production of fertilizers for special purposes. They can convert themselves into diversified enterprises with functions of agrochemical services, producing and operating compound fertilizers for special purposes. This will give them their own competitive advantage and win them the space for survival. The production process of SSP is relatively simple. There is no solid discharge and there is good fertilizer efficiency. There is no competition with high-analysis phosphate compound fertilizer and there

is still plenty of room for development. In recent years, due to the rapid increase in the price of energy source such as coke, economic benefits of FCMP enterprises have been very poor. Production continues to drop and enterprises continue to disappear from the scene. Viewed from the condition of phosphorus resources in China, there is still important potential for the hot process route. There is a need to adopt some special measures and policies to preserve FCMP and some backbone enterprises to enable them to continue to exist and develop and to accumulate experience for the future development of the phosphate fertilizer industry.

The distribution of compound fertilizer enterprises is not even. Large enterprises that are exempted from quality inspection by the State are concentrated in the provinces of Jiangsu, Shandong, Henan, Anhui and the southwest regions. There are fewer large enterprises in the west, northeast, northern China and coastal regions of the southeast, in particular, in areas where a number of provinces meet. Even in Jiangsu, Shandong, Henan and the southwest regions, distribution is not balanced. For example, in the case of Jiangsu, Shandong, Henan and Anhui, there is a high concentration of large enterprises in southern Shandong, southern Jiangsu, central and southern Anhui and central Henan while there are relatively few enterprises in other parts of the provinces. This type of unbalanced distribution is very unfavourable for the purchase of raw materials and marketing of the enterprises which should set up branches in suitable areas in the long term. This is beneficial for the development of multiple brands.

3.4 The external environment in the development of the phosphate fertilizer industry

3.4.1 Demand and the market

3.4.1.1 The phosphate fertilizer market during the period of planned economy

At the initial stages of establishment of the PRC, due to constraints of natural resources, technology and funds, the time was not right for building up the phosphate fertilizer industry on a large scale. The State decided to develop ground PR as the main activity during the period of the 1st Five-Year Plan (1953-1957) in order to make up for the shortage in bone meal at that time. On the other hand, increases in the import of SSP continued. In 1953, the amount of imports once reached 55,000 t. Before 1960, organic manure was the main fertilizer used in agriculture. By the end of 1970, the use of chemical fertilizer was actively promoted. Before the economic reforms in the 1980s, planned economy was practised in China. There was a state monopoly for the purchase and marketing of chemical fertilizer. The marketing cooperatives (or agricultural material production companies) carried out the purchase and sale. There was planned allocation. The ex-factory price and selling price were determined uniformly by the State Administration of Commodity Prices. The fertilizer commodity market did not exist. Farmers applied whatever they were allocated.

In the 1980s China carried out a reform of its economic system. Agricultural villages implemented family combined production contract systems. From 1982 to 1986, the central government promulgated five No. 1 documents in an attempt to fully mobilize the vigour of the farmers. The demand for chemical fertilizer went up. Market demand far exceeded supply. However, during the 6th Five-Year Plan (1980-1985), the development of the phosphate fertilizer industry was still slow, with output fluctuating around 2.3 to 2.6 Mt of P_2O_5 . As the amount of phosphate fertilizer application increased year after year, the import of phosphate fertilizer in 1984 was already 57% of the phosphate fertilizer produced in China. During this period, the State was carrying out planned purchase and marketing for products inside the plans of medium and large enterprises. For production that exceeded the planned output, independent selling was allowed. For products of small enterprises, the former Ministry of Commerce made selected purchases and marketing. For those not selected for purchase, the enterprises could produce and sell on their own. The price of chemical fertilizer, sold through one's own channels, was in principle, determined by the local Administration of Commodity Prices. During this period, even though market demand was far greater than supply, the retail price of chemical fertilizer was still gradually decreasing (prices went down by 10-20%).

From 1984 to 1985, large volumes of high-analysis chemical fertilizers, such as urea and DAP, were imported. The volume of imported phosphate fertilizers was 1.0 to 1.3 Mt of P_2O_5 respectively, close to 40% and 57% of the output in that year. At the same time, prices for the acquisition of grain crops was rather low and relative benefits of agriculture dropped. Farmers were cold towards inputs to the land and were not willing to apply more fertilizer. All these reasons resulted in the severe shrinkage of the domestic phosphate fertilizer industry (at that time major fertilizers were low-analysis SSP and FCMP). In 1985, phosphate fertilizer output was reduced sharply to 1.8 Mt of P_2O_5 . For the first time after the establishment of the PRC, domestic phosphate fertilizer became a slow-selling commodity.

3.4.1.2 The stage of transforming a system of planned economy to one of market economy

During the period of the 7th Five-Year Plan (1986-1990), following the transformation of China's economic system to a market economy and the State emphasis on agriculture, there was brisk sale of chemical fertilizers that fell short of demand. The "two-tiered system" was implemented for pricing chemical fertilizers. The State executed fixed prices for planned products under the state instructions and under the state guidance. Market regulation was carried out according to the price of fixed retention by the enterprise or the price of excess production sold through the enterprise's own channels. The "two-tiered system" of fertilizer pricing was an important turning point when the chemical fertilizer market changed from a planned economy to a market economy. In 1986, retail prices of chemical fertilizer began to rise sharply. In 1987, prices rose further. The share of fertilizers fixed at a low price by the State that could be purchased by farmers was not even 30%. The rest was purchased at market price. In order to resolve the low supply problem of phosphate fertilizers

in the 7th and 8th Five-Year Plans, the State confirmed the construction projects of "acid fertilizer" and "rock fertilizer" bases to accelerate the development of the phosphate industry. During the period of the 7th and 8th Five-Year Plans, phosphate output increased at a faster rate, of about 2 Mt of P_2O_5 every 5 years (increase from 2.3 Mt of P_2O_5 to 4.1 Mt of P_2O_5 to 6.2 Mt P_2O_5). The increase was 77 and 51% respectively.

In April 1994, the State Council approved the "Request for Instructions Concerning the Method of Administration of the Price Reform of Chemical Fertilizer" by the former State Planning Commission in which it proposed the method of administration of price reform of chemical fertilizer. The enterprise would determine its own ex-factory price within the range permitted by the State. The rate of difference in operation (that is, transport and warehousing expenses incurred in the course of the circulation of chemical fertilizer) or rate of profit (that is, the government's specification on the rate of profit) was implemented for controlling the price of regulated releases and retail prices, thus ending the strict control on the price of chemical fertilizer by the planned economy system. The "two-tiered system" of fertilizer pricing was abolished and the initial stage of a market mechanism for the pricing of chemical fertilizer was established.

3.4.1.3 The opening of chemical fertilizer market to foreign countries after joining the WTO

In November 1998, to expedite the progress of the chemical fertilizer market, the "Circular of the State Council Concerning Deepening the Reform of the System of Chemical Fertilizer Circulation" (Document No. 39, 1998, the State Council) made new provisions on the chemical fertilizer business, price and channels of import of chemical fertilizers. The administration of the circulation of chemical fertilizers by the State would be changed from direct, planned administration to indirect administration to give full play to the fundamental functions of market distribution. Production plans for domestic chemical fertilizer under instructions and the centralized distribution and purchase plans were abolished and enterprises' business operation would carry out purchase and sale activities on their own. Chemical fertilizer producing enterprises could sell their products to the "Three Stations" in agriculture and enterprises that use chemical fertilizer as raw material. They could also sell directly to the farmers at fixed points.

On 11 December 2001, China became an official member of the World Trade Organization (WTO). Based on the agreements reached with relevant countries, China undertook the following 5 articles:

1. On joining WTO, the administration of the import of chemical fertilizer will be changed from an absolute quota to a tariff quota. Tariff quotas refer to the implementation of a low tariff (5%) within the quota, while high tariffs (50%) will be implemented on imports outside the quota. The tariff quota administrative system is constituted by factors that include the amount allowed during the base period of the quota, the annual growth rate of the quota, the tax rate inside and outside the quota, and the proportion of non-state-operated trading.
2. The amount allowed during the base period of quotas for phosphate fertilizers was 5.4 Mt with an annual rate of

increase of 5%. Annual imports would reach 6.9 Mt 6 years later. The amount allowed during the base period of quota for NPK compound fertilizer was 2.7 Mt with an annual rate of increase of 5%.

3. The tariff for chemical fertilizers dropped from an earlier 5% to 4%.
4. A partial monopoly was implemented for imported chemical fertilizer but the proportion of non-monopoly channels (non-state-operated trading) was increasing year-on-year at the rate of 5%. At the initial stage, the proportion of non-monopoly channels for DAP was 15% and for NPK, 10%. By 2009, the maximum proportion would not exceed 49%.
5. On expiry of the 5-year transitional period after China's accession to WTO, foreign business would be allowed to engage in the retail and wholesale of chemical fertilizers in China.

At the end of 2006, after joining WTO and at the expiry of the transitional period, tariffs were adjusted downward and the import of grains and agricultural produce increased. This will enhance the structural adjustment in agriculture. The overall trend for the structural adjustment in agriculture is a relatively stable area of grain cultivation, with active adjustment in the areas of cultivation of different varieties and the steady increase in the area of cash crops. There is not much effect on the total demand for chemical fertilizer. Instead, the demand for adjustment in the types of chemical fertilizer will be more strongly felt.

Owing to foreign capital entering the domain of fertilizer circulation in China, there will be direct competition from large, international companies with regard to sales and services. This will have a big impact and effect on sales, services, and production and business operations of the domestic fertilizer industry. Besides, there will be increased risks and difficulties in business operation. The State is gradually abolishing the protective and preferential policies that support the domestic chemical fertilizer production, such as reduction or exemption of value-added tax (VAT), favourable price for electric power and transport charges. Based on estimates, there will be a reduction in economic benefits of about RMB9 B for the entire trade and this is going to have a big impact on fertilizer enterprises. If the international competitiveness of domestic phosphate compound fertilizer enterprises is not enhanced immediately, imported chemical fertilizers, in particular imported phosphate fertilizers, will have severe effects on chemical fertilizers produced in China. Among the phosphate fertilizer producing enterprises, the impact on high-analysis phosphate compound fertilizers will be larger. Due to restrictions caused by the supply of P and S resources and higher investment in construction, the tax inclusive full cost of the majority of domestic high-analysis phosphate fertilizers is higher than the tax inclusive CIF cost of imported products. Similarly, the tax inclusive full cost of most N, P and K compound fertilizers is higher than the tax inclusive CIF cost of imported products.

3.4.1.4 Effects of foreign agricultural policies on the fertilizer industry

In June 1992, the EEC / EU adopted a new joint agricultural policy that gave consideration to both agriculture and

the environment. The policy objective was to cut down environmental pollution by the agriculture sector. It adopted measures such as the reduction of prices of agricultural produce in the region, the reduction of agricultural expenditures and the emphasis and encouragement of the adoption of production methods that are favourable for reducing environmental pollution. The Common Agricultural Policy (CAP) of the EU had tremendous effects on the chemical fertilizer industry in its member countries. The rules of competition required the member countries to abolish direct subsidies for chemical fertilizer, abolish mutual import duty imposed on raw materials of chemical fertilizer and finished products among member countries and reduce tariffs on product entering the EU. At the same time, the policy of having prices of agricultural produce higher than international prices protects the farmers from being harmed by international competition. The implementation of this policy resulted in intensified international competition. In addition to this, changes in the international market led to the merger and reorganization of the chemical fertilizer industry, in particular the phosphate fertilizer industry inside the EEC/EU. At the same time, it enhanced the position of countries with an advantage in raw PR resources (such as Morocco, the USA and the Gulf countries).

Starting the early 1990s, the EU invested 1.5 to 2 B Euros to carry out structural reforms and adjustments in the chemical fertilizer enterprises. Some chemical fertilizer plants that polluted heavily or lacked development potential were closed. Reforms with modern facilities and adjustments were carried out in the remaining plants to enable them to have better competitiveness and to produce products that better meet environmental requirements in the EU and to raise product quality. In the adjustments to the industrial structure, chemical fertilizer enterprises in the various countries generally suffered losses between 1992 and 1993. They began to balance their profit and loss in 1994 and in 1995 they began to show a profit. After these structural reforms, the EU closed a total of 66 large plants and reduced half of the employees. Even though they optimized the industrial structure, production capacity was greatly reduced. The production capacity of nitrogenous fertilizer and phosphate fertilizer was reduced by 25% and 33% respectively. In terms of its status in the import and export of chemical fertilizer, the EU has changed from being a very important region of imports and exports in the 1960s-90s to currently being one of the chief import regions.

3.4.1.5 Consumption of phosphate fertilizer products

China is the world's largest phosphate fertilizer market. Its consumption accounts for 30% of the global tonnage. In recent years, changes in the composition of cultivation of agricultural crops and the continued decrease in the area for cultivation (from 130 M hectares in 1996 to 123.3 M hectares in 2005) have aggravated the pressure on unit area production. Demand for phosphate fertilizers increased rapidly as a result of continuing increases in the amount of phosphate fertilizer applied (Table 3-8).

Table 3-8 Apparent consumption of phosphate fertilizer (P₂O₅) in China: 1980 to 2005

| Year | Amount of Application of Phosphate Fertilizer in '000 t | Apparent Consumption of Phosphate Fertilizer in '000 t ¹ | Output of Chinese Phosphate Fertilizer in '000 t | Volume of Import '000 t | Volume of Export '000 t | Phosphate Fertilizer Self-sufficiency Rate ² /% | Market Share of Chinese Phosphate Fertilizer in the Domestic Market ³ /% |
|------|---|---|--|-------------------------|-------------------------|--|---|
| 2005 | | 11674.1 | 11249.3 | 1203.6 | 778.8 | 96.4 | 89.7 |
| 2004 | | 10791.2 | 10174.5 | 1405.2 | 788.5 | 94.3 | 87 |
| 2003 | | 9975.1 | 9084.8 | 1564.3 | 674 | 91.1 | 84.3 |
| 2002 | | 10257 | 8053.8 | 2714.6 | 514.4 | 78.5 | 73.5 |
| 2001 | | 8886.7 | 7394.4 | 1860.2 | 367.9 | 83.2 | 79.1 |
| 2000 | | 8312.3 | 6634.4 | 1956.9 | 279 | 79.8 | 76.5 |
| 1999 | | 8860 | 6550 | 2460 | 146 | | |
| 1998 | | 9160 | 6630 | 2530 | | | |
| 1997 | 6894 | 0 | 6410 | 2593 | | | |
| 1996 | 6585 | 0 | 5750 | 2565 | | | |
| 1995 | 6324 | 0 | 6190 | 2840 | | | |
| 1994 | 6007 | 0 | 4970 | 2229 | | | |
| 1993 | 5751 | 0 | 4168 | 1279 | | | |
| 1992 | 5157 | 0 | 4553 | 2230 | | | |
| 1991 | 4996 | 0 | 4555 | 2838 | | | |
| 1990 | 4624 | 4996 | 4116 | 1551 | | | 94% was |
| 1989 | 4189 | 0 | 3663 | 1554 | | | low-analysis |
| 1988 | 3821 | 0 | 3607 | 1394 | | | phosphate |
| 1987 | 3719 | 0 | 3239 | 1166 | | | fertilizer |
| 1986 | 3598 | 0 | 2325 | 479 | | | |
| 1985 | 3109 | 0 | 1758 | 900 | | | |
| 1984 | 3286 | 0 | 2360 | 1342 | | | |
| 1983 | 3514 | 0 | 2666 | 1029 | | | |
| 1982 | 3448 | 0 | 2537 | 632 | | | |
| 1981 | 2956 | 0 | 2508 | 499 | | | |
| 1980 | 2733 | 0 | 2308 | 395 | | | |

¹ Apparent consumption of phosphate fertilizer = Amount of phosphate fertilizer resources (domestic output + volume of import)

² Phosphate fertilizer self-sufficiency rate = Domestic output of phosphate fertilizer / Apparent consumption

³ Market share of Chinese phosphate fertilizer in the domestic market = (Domestic output of phosphate fertilizer - Volume of export) / Apparent consumption

Note: China's net import of phosphate compound fertilizer in product tonnes: 1.0 Mt of DAP, 2.2 Mt of three-nutrient compound fertilizer. Exports in product tonnes: 840,000 t SSP and about 200,000 t FCMP.

3.4.2 Trading and prices

3.4.2.1 The effect of trade and prices on the development of the phosphate fertilizer industry

1. Trading and price of phosphate fertilizer before 2000

China began importing phosphate fertilizer in the 1960s. From the time of establishment of the PRC to the 1980s, the policy of planned purchases and marketing by the State was the norm with regard to imported chemical fertilizers.

The phosphate fertilizer types imported by China were mainly potash fertilizers, DAP and compound fertilizers. In 1983, the amount of phosphate fertilizers imported reached 1 Mt of P₂O₅. Before 1985, the price of imported fertilizers was fixed according to the domestic ex-factory price. If there was no domestic ex-factory price, after negotiations with the foreign trade company and based on the supply price determined for the provinces, autonomous regions and municipalities directly under the central government and by the Head Office of the supply and marketing cooperatives, a

price would be fixed after deducting certain expenses from the price of regulated supply. During that period, China was practising planned economy and over a long period of time, the government implemented the policy of low prices and meagre profits in fixing the prices of chemical fertilizers. Most of the profits derived from technological reform and expansion of scale of the enterprise went to the circulation of products. In formulating product prices, a planned economy does not consider the fact that funds required for development such as technological progress and equipment renewal have to come from the profits generated by the marketing of products, neither does it involve itself in the problem of loans required for operating the enterprise. These became hidden problems in the subsequent transformation of the enterprises to operation under the market economy.

In 1991 the import of phosphate fertilizers rose to 2.8 Mt of P_2O_5 . During the period 1991-1999, the imports of phosphate fertilizers was fluctuating around the volume of 2-2.8 Mt of P_2O_5 . (4-5 Mt DAP in product quantity, 2-2.6 Mt of NPK in product quantity). At the time of maximum fertilizer imports, the volume was about 30% of the total international traded volume of chemical fertilizers. The consistently high volume of import of phosphate fertilizers hastened the introduction of the policy of "substitution by manufactured products for similar imported products." At that time the nominal tariff for the import of chemical fertilizers was 5%. The provisional tax rate was 3%, which was lower than the tax rate in developing countries (for example, 7% in India and Brazil).

In November 1998, the "Circular of the State Council Concerning Deepening the Reform of the System of Chemical Fertilizer Circulation" (Document No. 39, 1998, the State Council) made new provisions with regard to the import channels of chemical fertilizers and prices: Sinochem was given the right of management of domestic trade in chemical fertilizers to appropriately increase agency channels for the import of chemical fertilizers. Apart from Sinochem, agency right of management for fertilizer import was awarded to the China National Agricultural Materials Production Group Co. (CNAMPGC). In 1998, the volume of DAP imported was 35% of the world's trading volume and accounted for 85% of agricultural demand for DAP in China in that year (domestic output was 420,000 t of P_2O_5 and the amount imported was 2.4 Mt of P_2O_5).

On 7 May 2000, the State Planning Commission issued the Circular about "Further Improvement of the Method of Management of Prices of Imported Chemical Fertilizer" by the Central Government according to which the implementation of government's fixed price on the DAP and compound fertilizers imported by the central government was changed to government's guide prices. That is, the State Planning Commission would add 1.7% consolidated operating difference to the delivery prices based on the actual cost of imports. The operating enterprises could, according to market supply and demand and using the standard delivery prices at the port as the basis, negotiate and determine a specific price within a 3% upward or downward fluctuation. The port delivery prices of chemical fertilizers imported by local authorities would be determined by the local department of commodity prices with reference to the above-mentioned method and in combination with the actual local conditions.

2. Trading and prices of phosphate fertilizers during the transitional period after joining the WTO

In 2000, in accordance with the relevant agreement on the accession of China to the WTO, there were changes to the policy of external trade of phosphate fertilizers. A tariff quota was implemented on the import of urea, DAP and compound fertilizers. The tariff for products imported within the quota was 4% while for products imported outside the quota a 50% tariff was imposed. The import of potash fertilizer was not restricted by quota. The "Interim Measures in the Control of Tariff Quota for the Import of Chemical Fertilizer" was implemented starting on 1 February 2002. Consequently, there was only a 1% drop in tariff which had little effect. According to the agreement on accession to the WTO, when the permitted quantity of several fertilizer types has been used up, there will be an appreciable impact on the domestic fertilizer market. The base number (year 2002) of the permitted quantity of imports within the tariff quota for chemical fertilizer was 9.4 Mt (urea, DAP and NPK compound fertilizer). By 2005, 12.6 Mt (urea, DAP and MOP) could be imported within the tariff quota which accounted for 14% of China's demand for chemical fertilizer in that year. The expiry of the transitional period after joining the WTO would actually be the opening of the chemical fertilizer market. In 2005, the total quantity of chemical fertilizers imported by China amounted to 13.8 Mt. The total quantity exported was 4.7 Mt. There was a net import of 9.1 Mt. Net exports of urea were 1.5 Mt. There was a net import of 1.0 Mt of DAP and 8.8 Mt of MOP.

After 2000, the operation of the few imported installations of large-scale high-analysis phosphate compound fertilizer gradually became normal. Output of DAP and NPK grew rapidly and this replaced part of the imported products. The quantity of import gradually decreased and prices started to go down. In addition, from 2001 to the present, great effort has been put in the publicity of Chinese brands of phosphate compound fertilizers at the production and marketing promotion fairs for high-analysis phosphate compound fertilizers that have been held annually. High-analysis phosphate compound fertilizers produced in China quickly opened and took a large share of the domestic market. In 2005, the annual import of phosphate fertilizers was reduced to 1.2 Mt of P_2O_5 (product quantity of DAP was 1.78 Mt and that of NPK was 2.3 Mt). Market share of DAP produced in China reached 71.1% and the self-sufficiency rate increased to 83% (an increase of 44% and 52% respectively compared with 2000). This put an end to the long-term dependence on the import of DAP. The volume of imports of NPK compound fertilizers from 1996 up to the present has basically remained around 2 Mt with minor fluctuations. After 2000, the actual volume of DAP and NPK imported had been lower than the quota quantity. The import quota increased but the actual volume of imports decreased. This indicated that after joining the WTO, phosphate compound fertilizers produced in China has better competitive power than imported phosphate compound fertilizers.

In recent years, the international phosphate fertilizer market has maintained relatively stable prices. The chief reason could be attributed to the relatively stable volume of imported phosphate fertilizers (volume of imported DAP account for 25-30% of the trading volume in the world). At the same time,

when the demand is weak, phosphate compound fertilizer suppliers in the international market reduce the supply of phosphate fertilizer through restricted production or shut down of plants to maintain a higher market price. Since 2004, in conjunction with the high international petroleum prices, transport of chemical fertilizer has gone up and CIF price has been increasing continuously (before 2002, ocean freight from the US port of Tampa to Chinese ports for DAP was US\$20 per tonne and in 2004 it was US\$48-54 per tonne).

During the same period, there was a similar trend in the price of domestic phosphate compound fertilizers. This was mainly due to the attention the central government was paying to the three problems in the agricultural sector (the *San Nong* problems) that further raised the status of fertilizers. However, due to increases in production costs (increase in the price of coal and electric power, cost of manpower, freight charges and input for environmental protection), there was a big increase in the prices of chemical fertilizers. From January to April 2004, six ministries and State Commissions enhanced the supervision and control with an effort never seen in the past. In order to protect farmers the following six measures were taken to restrict prices and increases were contained as a result:

1. A policy of preferential prices and taxes was adopted to encourage domestic production of chemical fertilizers.
2. Favourable freight charges were implemented to promote the circulation of chemical fertilizers. In December 2003, when rail freight charges were adjusted, it was clearly spelled out that favourable charges for electrical power used for the production of chemical fertilizers would not be adjusted. The policy of giving preferential prices to the chemical fertilizer industry will continue to be maintained. There would be a subsidy of RMB100 per t DAP produced domestically. Also the exemption from railway construction funds would continue and when rail freight charges were adjusted, it was clearly indicated that favourable freight charges would continue to apply for chemical fertilizers without any adjustment.
3. The measures of the utilization of financial and taxation policies to encourage the import of chemical fertilizers control of exports and increased domestic market supply was adopted. In 2004 there was a subsidy on imports of DAP of RMB100 per tonne. From 2 April 2004, tax refunds for the export of DAP were temporarily removed.
4. The price of imported chemical fertilizers was lowered. At the beginning of March 2004, the National Development and Reform Commission issued a document that stated clearly that the consolidated rate of difference in distribution expenses added to the import of chemical fertilizers by enterprises during the spring ploughing season would be reduced from 1.7 to 1.2 %. The port delivery price of imported DAP and compound fertilizer would be allowed to fluctuate downward and the execution of the 3% upward fluctuation was temporarily halted.
5. the supervision of chemical fertilizer prices was enhanced. Since 2005, the National Development and Reform Commission issued six documents that include the "Urgent Circular Concerning the Implementation of

Interference in the Exceeding Rise in Prices of Agricultural Production Materials such as Chemical Fertilizer" that required local authorities to adopt measures of interference at the appropriate time with regard to prices of Chinese-made chemical fertilizers that have not been listed in the price catalogue, port delivery prices of imported chemical fertilizers and the wholesale and retail prices of chemical fertilizers to truly enhance price supervision and reduce the price level. For prices already found in the catalogue, they should be checked and rectified.

6. Inspection of chemical fertilizer prices would be enhanced to encourage the implementation of the price policy. From December 2003, the National Development and Reform Commission planned and launched a nationwide special inspection of prices of agricultural production materials. Inspection and guidance teams were sent out to various places on a number of occasions to inspect prices of chemical fertilizers and the implementation of the relevant policies.

3.4.2.2 The effect of the export trade and prices on the development of the phosphate fertilizer industry

Prior to 1997, China's capacity to supply phosphate fertilizer was far from sufficient. Export volume was small, the major items of phosphate fertilizer exported were products with special characteristics such as SSP, TSP, and FCMP. After 1999, the strategy of "substitution by the manufactured products for similar imported products" gave good results and there was a remarkable increase in the output of high-analysis phosphate compound fertilizers. The export of phosphate compound fertilizer products grew year-on-year, particularly the export of DAP. In recent years, provinces with PR resources (Yunnan, Guizhou, Hubei) have been under pressure, to increase output, and from financial tightness during the off-season and by transport limitations. In addition, they are relatively close to the Southeast Asian markets and their products have definite competitive advantages. The volume of export has been increasing each year. Even after the removal of tax refunds for exports in 2005, the volume of exports of DAP, MAP, SSP (inclusive of TSP) and NPK still reached 718,000 t, 217,000 t, 841,000 t and 128,000 t of product respectively. Volumes of phosphate fertilizer exports and prices are shown in Table 3-9.

In 2006, supply exceeded demand in the phosphate fertilizer market resulting in a decrease in the volume of imports and an increase in the volume of exports. In 2006, the net import volume of phosphate compound fertilizer in China was merely 24,000 t (100% P_2O_5). 1.4 Mt of DAP was imported, more than 80% from the USA. The average import price was US\$275.9/t. 1.9 Mt of NPK was imported from Russia, Norway and other countries. The average CIF price over the year was US\$224.2/t. 786,000 t of DAP was exported, an increase of 9.5% compared with 2005. Exports of NPK were 195,000 t, an increase of 52.6% over 2005. 475,000 t of MAP was exported, an increase of 119.2% compared with 2005. The volume of export of TSP was 182,000 t, which was about the same as in 2005.

Table 3-9 Volume of exports of phosphate fertilizer and prices in China

| Fertilizer Variety | Year | Product Quantity of Export ('000 tonnes) | FOB Price (US\$/tonne) |
|--|---------------|--|------------------------|
| DAP | 1999 | 106 | 217.58 |
| | 2000 | 204 | 171.6 |
| | 2001 | 452 | 170.2 |
| | 2002 | 478 | 168.8 |
| | 2003 | 800 | 187.8 |
| | 2004 | 857 | 246.5 |
| | 2005 | 718 | 282.9 |
| MAP | 1999 | 39 | 225.9 |
| | 2000 | 92 | 173.7 |
| | 2001 | 95 | 191.2 |
| | 2002 | 126 | 213.7 |
| | 2003 | 126 | 252.7 |
| | 2004 | 151 | 265.0 |
| | 2005 | 217 | 329.4 |
| SSP (including TSP) | 1999 | 326 | 141.8 |
| | 2000 | 273 | 118.8 |
| | 2001 | 219 | 113.0 |
| | 2002 | 483 | 114.4 |
| | 2003 | 513 | 131.6 |
| | 2004 | 855 | 141 |
| | 2005 | 841 | 165 |
| Other Mineral Phosphate Fertilizers and Chemical Fertilizers | 1999 | 137 | 104.7 |
| | 2000 | 140 | 97.6 |
| | 2001 | 151 | 103.3 |
| | 2002 ~2003 | - | - |
| | 2004 | 230 | 90.15 |
| | 2005 | 161 | 113.5 |
| NPK | 1999 | 64 | 167.8 |
| | 2000 | 132 | 154.1 |
| | 2001 | 115 | 151.5 |
| | 2002 | 104 | 155.3 |
| | 2003 | 113 | 165.5 |
| | 2004 | 148 | 216.9 |
| | 2005 | 128 | 269.8 |

3.4.3 Raw materials and transport

3.4.3.1 Effects of raw materials and trends in the development on the phosphate fertilizer industry

PR, S and synthetic ammonia are raw materials used in large quantities in the production of phosphate fertilizers. China has plenty of P resources but they are not rich. Appropriate exploitation and utilization of PR will help to achieve the sustainable development of P resources and this has a

strategic significance to agricultural production and a healthy development of the national economy. China is short of S resources. In 2005, it imported 8.3 Mt of sulphur, accounting for 25% of the volume traded in the world. The degree of dependence on external S exceeds 50%. Coal and natural gas are raw materials for the production of synthetic ammonia. At present, the domestic market for raw materials is being driven by the international market, with prices rising continuously. For chemical fertilizer enterprises, they have entered an era of high costs. The raw material supply situation for the production of phosphate fertilizer in China is as shown in Table 3-10.

1. Phosphorus resources

Characteristics of PR

PR is the most important raw material in the production of phosphate fertilizer with 90% of the world's supply being used for various types of phosphate fertilizer. China's PR reserves are second only to Morocco. There are 16.8 Bt of resource reserves. Of this, there are 2.1 Bt of reserves, 4.1 Bt of foundation reserves and a resource quantity of 12.7 Bt. However, the reserves of high-quality PR with more than 30% P_2O_5 do not exceed 1.3 Bt. Even when medium grade PR with greater than 24% of P_2O_5 is included, PR reserves will not be more than 3 Bt. On the other hand, there is 15 Bt of low-grade PR reserves containing 14-24% of P_2O_5 . The resource reserves of the five provinces of Yunnan, Guizhou, Sichuan, Hubei and Hunan together account for 75% of the country's reserves. Besides, P_2O_5 rich rocks with greater than 30% are almost all concentrated in these five provinces.

PR in China belong to three types, sedimentary phosphorite (usually referred to as collophanite), metamorphic rock phosphorite and endogenic apatite. There is also the accumulative bird droppings type. Mineral deposits in China are mainly sedimentary phosphorite, accounting for about 80% of the total P resources throughout the country. The chief mineralogenetic epochs are the late Sinian period, the early Cambrian period and the late Devonian period. These mineral deposits are the main targets for exploitation and utilization. Metamorphic rock phosphorite and endogenic apatite mineral deposits are smaller in scale compared with the sedimentary type. The minerals are of a lower grade but are easier for beneficiation. The endogenic type has associated iron, vermiculite and graphite, which can be comprehensively recovered for utilization. At present, this type of PR is exploited in small quantities. However, there is inadequate geological prospecting for this type of P mine. The low and medium grades of collophanite in China have the following characteristics: the mineral particles are fine, tightly and closely embedded. There are relatively more harmful impurities, making screening more difficult and causing beneficiation costs to go up. Most of the mineral particles in medium-thickness seams are with inclining or slightly sloping rock formations. There are few mines suitable for large-scale and intensive exploitation. Again, this adds difficulty to mining. Technologically and economically, the foundation reserves that can be currently utilized make up only 24% of the total resource reserves. 76% of the resources are difficult to exploit for utilization. Furthermore there is a small quantity of pyrogenic apatite, the reserves of which

Table 3-10 Historical output of raw materials for the production of phosphate fertilizers ('000 tonnes)

| Year | Output of PR (30% P ₂ O ₅) | Output of Pyrite (35% S) | Output of Sulphuric Acid (100%) | Of Which | | | |
|------|--|-----------------------------|---------------------------------------|-----------------------------------|---------------------------------------|---|---|
| | | | | Production of Acid from Pyrite | Production of Acid from Sulphur | Production of Acid from Smel- ting Fume | Production of Acid from Phospho- gypsum |
| 1949 | | 20 | 40 | | | | |
| 1950 | | 100 | 69 | | | | |
| 1951 | 20 | 120 | 149 | | | | |
| 1952 | 80 | 550 | 375 | | | | |
| 1960 | 1420 | 3090 | 1330 | | | | |
| 1965 | 1580 | 3360 | 2340 | | | | |
| 1970 | 3940 | 3460 | 2914 | | | | |
| 1975 | 10180 | 5180 | 4847 | | | | |
| 1980 | 10730 | 5780 | 7643 | | | | |
| 1984 | 14210 | 8020 | 8173 | | | | |
| 1985 | 6970 | 6820 | 6715 | | | | |
| 1987 | 14870 | 10550 | 9830 | | | | |
| 1989 | 19980 | 12200 | 11526 | | | | |
| 1990 | 21550 | 12650 | 11968 | | | | |
| 1995 | 26540 | 16960 | 17767 | | | | |
| 1997 | 25090 | 17270 | 19910 | | | | |
| 1998 | 27090 | 14850 | 20510 | 13670 | 2090 | 4360 | 300 |
| 1999 | 20763 | 9413 | 21649 | 12066 | 4332 | 4998 | 248 |
| 2000 | 19370 | 9640 | 24550 | 11220 | 6180 | 6710 | 440 |
| 2001 | 21000 | 12630 | 27860 | 12360 | 8180 | 6880 | 432 |
| 2002 | 23000 | 9260 | 30520 | 12060 | 11120 | 6930 | 412 |
| 2003 | 24470 | 8710 | 33710 | 13030 | 12610 | 7520 | 547 |
| 2004 | 26170 | 10660 | 39950 | 14320 | 16240 | 8850 | 547 |
| 2005 | 30450 | 11460 | 46250 | 16120 | 19730 | 9810 | 590 |

are less than 100 Mt and apart from the Fanshan Mine in Hebei Province; the mineral is of low grade but easy for beneficiation. If accompanying minerals are utilized in the process of beneficiation, it can provide PR of medium and high grade for the production of phosphate fertilizer from acid.

At present, there are 241 P mines that are being exploited for utilization throughout the country; 136 are medium and large scale mines. As conditions of resources and the extent of exploitation are different, the mining of P is mainly concentrated in the three provinces of Yunnan, Guizhou and Hubei. The provinces of Sichuan and Hunan are the next in line. The output of PR from the five provinces mentioned account for 97% of the total production in China. The other provinces with P mines are Jiangsu, Hebei and Jiangxi. According to statistics in 2006, 123 enterprises of P mines in the country produced about 39 Mt, an increase of 22.3% over 2005.

Developments in the exploitation and beneficiation technology of PR from the establishment of the PRoC to the period of the 9th Five-Year Plan

From the initial stages of the establishment of the PRoC to the completion of the 7th Five-year Plan, mining, dressing, transport and marketing of P resources in China developed along the path of a planned economy.

Up to the 1970s, the industry used the crude rock directly, resulting in the SSP industry being forced to add a fourth-grade product of 12% P₂O₅. During the period from the 4th to the 6th Five-Year Plan (1970-1985), a programme was put forward to vigorously exploit the mines. However, locating P resources, formulation of development plans and the appraisal of PR were way behind the actual requirements. It was not until the end of the 6th Five-Year Plan that some actions were taken. After 1978, "the policy of fine materials" and "uniformity of raw materials" were proposed to enhance quality management of the mines, improvement of the method of mining, development of a new flotation agent, grading by scouring, application of the technology of heavy media separation, insistence on the combination of mining and dressing and synchronized construction. All these raised the

quality of PR. In addition, the phosphate fertilizer production departments were told to improve their technology and produce fertilizer according to the rock.

During the 7th, 8th and 9th Five-Year Plans, it was decided that the establishment of mines should follow the principle of "start with easy exploitation, open the rich mines first, operate the open air mines before going underground and select to work on the good mines in the region and in the whole country." A large amount of capital was invested during the period of the 7th and 8th Five-Year Plans (1986-1995) for mining construction. Big horsepower bulldozers for breaking up rocks were imported for open-air mining with the following techniques: front-end installation and loading, the underground anchor bar top protection trackless sublevel, open-stope technique, the long-distance pipeline transport and high-tensile mechanical belts for long-distance transport of crude rock. All these were advanced techniques of international standards. However, since the 9th Five-Year Plan, investments in mines for the chemical industry decreased and efforts on the promotion of advanced techniques were inadequate. At present, with the exception of a small number of newly built large mines whose major equipment can compare with the advanced level of the 1990s, most of the small entities and group mines have not even achieved mechanized production at the lowest standards. At the same time, a series of problems such as low prices, too many employees and heavy burdens still exist.

Level of technological exploitation and beneficiation

1. Methods of exploitation of PR in China are divided into underground and open-pit exploitation. Underground exploitation accounts for 60% of the total. Main underground P mines include those medium and large ones such as the Maluping and Yongshabei mines at Kaiyang in Guizhou Province, Yichang in Hubei Province, Jinhe and Qingping in Sichuan Province, Jinpin in Jiangsu Province, Jingxiangwangji in Hubei Province and Fanshan in Hebei Province. Medium and large mines representative of open-pit exploitation include the Puning Phosphorus Mine of the Yunnan Phosphorus Chemical Industry Group Co., Huangmailing in Hubei Province, Wengfu in Guizhou Province and the Jingxiang Dagukou Phosphorus Mine in Hubei Province. These mines account for 40% of the total production of PR.

2. The beneficiation process

Since the first 1.2 Mt/y large-scale flotation plant for meta-sedimentary PR – the Jiangsu Jinpin PR beneficiation plant was built and put into production in 1958, another 300,000 t/y medium flotation plant for magmatic PR was set up at the Maying Phosphorus Mine in Hebei Province in 1976. The establishment of these two flotation plants gave an indication that China had grasped the technique of beneficiation and enrichment of the apatite-type PR that is easy for separation. In 1986, the first 1.5 Mt/y large-scale flotation plant for the process of direct flotation for sedimentary phosphorite was built and put into production at the Jingxiangwangji Phosphorus Plant in Hebei Province. This enabled China to score a major break-through in the technique of beneficiation of collophanite which is difficult to separate by following the direct flotation technique, beneficiation enrichment processes

such as baking and digestion of sedimentary phosphorite, removal of earth by scouring, counter-direct (or direct-counter) flotation, and heavy-media process. Among these techniques, direct flotation, counter flotation, soil removal by scouring and heavy-media process have been successfully applied in industrial production.

As phosphorus resources generally contain MgO, Al₂O₃ and Fe₂O₃, the intergrowth of phosphorus minerals and vein minerals are close together, with fine granules embedded. Only the use of flotation can yield effective separation. Therefore, the flotation method was the most applied beneficiation method. The progress in the method of flotation enabled the policy of raw materials for the phosphate fertilizer industry to be transformed from "use whatever that is available" to "use of fine materials." It also provided guarantees of resources for China's phosphate fertilizer industry in the 1990s, particularly for the very rapidly developing medium and large scale high-analysis phosphate compound fertilizer enterprises.

Even though there was a remarkable break-through in the collophanite flotation technology, beneficiation costs were high. At present, domestic production costs of fine rock selected from medium to high-grade (28-30% P₂O₅) crude rock is RMB150-160/t. Production costs of fine rock selected from low to medium grade (20-24% P₂O₅) crude rock is RMB180-200/t whilst production costs of fine rock from low-grade (P₂O₅ < 20%) is above RMB250/t. In addition, investment in a flotation plant is high with poor economic benefits. Mining enterprises are, therefore, full of worries and adopt a wait-and-see attitude towards the construction of a flotation plant.

At present, Yihua has adopted the heavy-media process of beneficiation and has successfully resolved the earlier worldwide problem of producing DAP using collophanite. In order to effectively utilize the low to medium-grade PR of Yichang and to ensure the level of demand for high-grade PR by enterprises, it was planned to use heavy-media for beneficiation and the flotation process to establish a fine rock installation of 1 Mt/y. The selected grade will be 20-24% with heavy-media beneficiation attaining 28% and reaching above 30% after counter flotation. The installation is for AP production. Work started in May 2005 and the installation went into production in June 2006.

Levels of P mine exploitation and utilization

Compared with other countries, the utilization rate of P mine exploitation in China is relatively low. Viewed from the level of resource utilization, the rate of recovery of P resources can reach 95-98% in the USA and North Africa. After beneficiation, these resources can be almost fully recovered. The overall economic results of the mines are high. At the end of the 1980s, relevant departments in China took exploitation of P resources seriously. By utilizing loans from the World Bank and national foreign exchanges, in conjunction with exploitation of P resources, advanced mining equipment, production and management techniques were brought in from abroad and the level of utilization was raised tremendously. For example, at the Wengfu, the Puning and the Huangmailing Phosphorus Mines, recovery rates for open-air exploitation could reach and exceed 98%. At the Kaiyang Phosphorus Mine in Guizhou Province, recovery rates underground could

Table 3-11 Export of phosphate rock by China in 1995-2005

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|
| Volume of Export ('000 tonnes) | 960 | 1320 | 1660 | 2150 | 2420 | 3450 | 4910 | 3510 | 3560 | 3130 | 2110 |
| Export Price (US\$/tonne) | 370 | 410 | 430 | 420 | 410 | 360 | 320 | 330 | 350 | 390 | 540 |

also reach as high as 71.1%. According to results of a survey of sampled P mines organized by the Ministry of Land and Resources, on the average, the rate of recovery of P mines in China is only 60.8%. In the small mines, the rate of recovery is only about 30%. Compared with other countries, there is an appreciable gap.

Import of PR

The amount of PR imported by China is very small. Since 1999, the amount of imports each year has not reached 100 t. With the increase in the output of domestic PR, besides meeting the requirements of the chemical fertilizer industry and other industries, part of the domestic PR production can be exported, with the amount for export showing a significant increase.

Exports of PR from China mainly goes to countries in South Asia and in the Asia Pacific Region such as Vietnam, Indonesia, New Zealand and Bangladesh, and particularly India, South Korea and Japan. In recent years, owing to the fact that the PR exported is mainly rich rock with a P_2O_5 content $\geq 33\%$, some enterprises exploit the rich rock and abandon the poor rocks to raise the grade of rock for export. As a result this has caused a tremendous waste of resources. The sudden and great increase in exports gave rise to uncontrolled competition, causing export prices to slide in successive years. According to Customs statistics, prior to 1999, the export price of PR was above US\$40/t, but by 2003 it was only US\$35/t, causing a great loss to the interests of the country. In order to control large quantities of PR being exported cheaply, from October 2003, China abolished the 13% tax reimbursement for the export of PR. The system of advance verification of signatures and seals was implemented. In 2004, the volume of export of PR began to drop and the unit price of export increased. In 2005, the unit price reached the historical height of US\$54/t. In 2006, China imported 51,000 t of PR at a CIF price of US\$31.3/t, mainly from Vietnam and Egypt. The volume of exports was 951,000 t, a decrease of 53.4% compared with 2005, 97.3% heading to Japan and South Korea.

The phosphate fertilizer industry is a resource-dependent industry. Since the end of November 2005, the supply of raw materials has been tight and prices continue to rise. For example, in Yichang City of Hubei Province, in April 2006 the delivery price at Kengkou for 28% P_2O_5 PR excluding freight charges, was RMB190-210/t (compared with RMB80/t at the same period of the previous year), it was more than RMB400/t for 33% P_2O_5 PR and the upward trend continued. At the same time, prices of PR from Guizhou Province were also adjusted upwardly to different extents. At present, for phosphate fertilizer enterprises in provinces without PR, the price of purchased PR will be RMB400-500/t by the time it arrives at the plant. In recent years, phosphate fertilizer enterprises in provinces that lack P often reduced their production or shut

down due to the supply shortfall. In order to guarantee the sustainable growth of the phosphate fertilizer industry, China should enhance management, develop rationally, grade and utilize P resources that are plentiful but not rich.

2. Sulphur resources

The development of S resources in other countries went through three stages, the pyrite period, the natural gas period and the S recovery period. At present, apart from China, production in other S-producing countries in the world comes mainly from natural gas and S recovered from the process of refining petroleum, which account for 80% of the total S output. The various recovered S account for more than 98% of the total production. In China, the major raw materials for the production of sulphuric acid include pyrite, S, smelting fume and phosphogypsum. Compared with acid production with pyrite, acid production with S involves less investment. It is environmentally friendly and transport expenses are lower. Consequently, when the price of S is competitive, domestic production of acid with S is bound to continue to expand. Even though the production of recovered S continues to rise domestically, demand is growing even faster. For a long time to come, domestic production of S will not meet demand.

Characteristics of S resources in China

S resources in China include pyrite, associated pyrite, natural solfataras, S recovered from smelting fumes, petroleum and coal gas. In addition, small quantities of S are also recovered from synthetic ammonia plants and coking plants that use coal as raw material when they produce synthetic ammonia and gas.

Pyrite is the major source of S in China. In the production of sulphuric acid using pyrite as raw material China accounts for about 50% of the world output. China has 321 Mt of natural S reserves that are mainly distributed in the two mining areas of Zhujiazhuang, Tai'an City and Dawenkou, both in Shandong Province. They account for 99.2% of China's natural S reserves. Even though the natural S reserves of China are not low, the rock is of low grade, usually with about 10% S content. Storage and exploitation are not easy. Technologically and economically, they are not suitable for large-scale exploitation. Presently, the amount of exploitation is very small. The exploitation of S resources has the following characteristics:

1. For technical and economic reasons, natural S is basically not exploited. It can be neglected in the total amount of exploitation of S resources.
2. There is a shortage of oil and gas supplies in China. Domestic crude oil is mostly low-sulphur oil with less than 0.5% S. There are not many acidic natural gas fields with high S content, and these are mainly concentrated in the northeast region of Sichuan (the Sichuan Northeast Gas Project will add 1.5 Mt of S).

At present, China is capable of producing 1.8 Mt of S recovered from oil and natural gas per year. The actual amount of S recovered from oil and gas is 800,000-1,000,000 t/y. The proportion is small compared with the total amount used in China.

China is a big producer and consumer of coal. However, the use of high-S coal and S recovery is not encouraging. The S in the large quantity of coal consumed for thermal power generation is mainly recovered from the desulphurized gypsum. Currently, the coal chemical industry uses low-S coal as raw material, with only a small number of projects equipped with supporting installation for the recovery of S. In other cases, S is removed during combustion (production of calcium sulphate) and the quantity of S recovered is about 100,000 t/y.

3. China is rich in pyrite and associated S resources; and the non-ferrous metal industry is well developed. Over a long period of time, S was mainly produced from the exploitation of pyrite and associated S, recovery from the production of acid, and from the fumes of non-ferrous metal smelting.

For S resources, China has been depending on pyrite, non-ferrous metal by-product tailings and sulphuric acid as a by-product of smelting fume. From the 7th to the 9th Five-Year Plan (1986-2000) the State decided that S resources had to be properly exploited with enhanced management. While implementing the policy of fine materials, there should be integrated utilization of smelting exhaust and non-ferrous tailings and new channels of S resources should be opened. As domestic iron resources are in short supply and prices are high, natural and recovered S are relatively deficient. Over a long period of time, China has been depending on pyrite, non-ferrous metal by-product tailings and sulphuric acid produced as a by-product from smelting fumes.

Since the 10th Five-Year Plan, there has been great development in the production of sulphuric acid from S and dependence on imported S resources exceeded 50%. In the 1990s, world supplies of S exceeded demand. Prices gradually dropped and there was ample supply. This spurred the development of acid production from S, a system known as "sulphur roasting technique" for the production of acid. This relieved the tense situation of pyrite shortages. Installations of acid production from S guaranteed strong demand for phosphate fertilizers in the phosphorus-producing provinces of Yunnan, Guizhou and Sichuan and the strong demand for acid for non-fertilizer uses.

On entering the 21st century, large phosphate compound fertilizer production installations were being built in areas near phosphorus resources. As sulphuric acid is a highly corrosive liquid and a hazardous substance, it cannot be stored in large quantities over a long period of time and it is not suitable for long-distance transport. The speed of the establishment of pyrite mines in China cannot match the speed of the development of phosphate compound fertilizer. On top of that, the tight scheduling of domestic rail transport has yet to be resolved. Compared with plants producing acid from pyrite, plants for acid production with S are cheaper, freight charges are lower and they are more environment-friendly.

Consequently, all large sulphuric acid producing installations that are supporting the large phosphate compound fertilizer installations use imported S as raw material, resulting in dramatic increase in the demand and consumption of S. The S comes mainly from refining the imported high-sulphur crude oil.

In 2005, sulphuric acid production in China was 46.3 Mt. Imports were about 2 Mt and there was little for export. The apparent consumption of sulphuric acid was 48.2 Mt. Of this, acid consumption by high-analysis phosphate fertilizer was 44.0%, and consumption by low-analysis phosphate fertilizer was 21.3%. Consumption of acid by other chemical fertilizers was 4.0%, whilst acid for industrial use was 30.7%. Compared with the year 2000, output of sulphuric acid grew at an average annual rate of 13.5%. Acid produced from sulphur was 19.7 Mt, increasing at an annual rate of 26.1%, acid produced from pyrite was 16.1 Mt, increasing at an annual rate of 7.5%, acid produced from smelting fumes was 9.8 Mt, an annual increase of 7.9, and acid production by phosphogypsum and other raw materials amounted to 590,000 t, increasing at an annual rate of 6.0%.

During the 10th Five-Year Plan, increases in the output of sulphuric acid have mainly come from that produced with S. In 2005, China's capacity for S recovery was 1 Mt. It will reach 4.5 Mt by 2010. If the speed of consumption of crude oil and natural gas in China continues to increase by 5% after 2010, the quantity of recovered S in China will go up to 5.8 Mt. However, production of S in China has been unable to satisfy domestic market demands and China imported 8.3 Mt of S in 2005. It is estimated that by 2010, deficiencies in S will be 6.3 Mt and by 2015, the shortfall will be 8.6 Mt. This shortfall has to be met by imports. Due to severe shortage of S in China, the development of sulphuric acid industry has been hampered. China's dependence on external sources was at around 60%. Factors such as transport costs and bottlenecks have given rise to large quantities of structural surplus globally. From now on, the rate of increase in S production will be larger than the rate of consumption and the situation of supply exceeding demand will be maintained. As a result of the monopoly by international financial groups coupled with an increase in ocean freight, the price of imported S went up once more. The CIF price of imported S increased from US\$48/t in 1999 to US\$90-93/t in 2004 and US\$96/t in 2005. In 2005 Chinese imports of S accounted for about 30% of the S traded in the world. From 1998 to 2005, the volumes of S imported by China and the average CIF prices are shown in Table 3-12.

During the 11th Five-Year Plan, there will be big developments for sulphuric acid production. Dependence on imported sulphur resources will exceed 60%. In the first three years of the 11th Five-Year Plan, the sulphuric acid industry will continue to grow rapidly. According to incomplete statistics, there will be newly added capacity of 18.7 Mt of sulphuric acid in the three years. Net increases will be 7.4 Mt in 2006, 7 Mt in 2007 and 4.2 Mt in 2008. Increases in the capacity of sulphuric acid production is due to the development of the capacity of smelting of non-ferrous metals in the provinces of Gansu, Inner Mongolia, Jiangxi, Anhui, Yunnan and Shandong where large sulphuric acid installations of 500,000 t/y and 700,000 t/y have been built. In the next three years, the newly increased capacity of by-product sulphuric acid

Table 3-12 Volume of sulphur imported by China and the average CIF price from 1998 to 2005

| Year | Volume of Import ('000 tonnes) | CIF (US\$/tonne) | Ex-factory Price of Domestic Sulphur (RMB/tonne) |
|------|--------------------------------|------------------|--|
| 1998 | 937 | 48 | |
| 1999 | 1979 | 48 | 1020 |
| 2000 | 2730 | 55.8 | 825 |
| 2001 | 3380 | 40.9 | 673 |
| 2002 | 4092 | 45.7 | |
| 2003 | 4993 | 78.6 | 1022 |
| 2004 | 6766 | 89.8 | 1102 |
| 2005 | 8306 | 96.0 | 1097 |

from the smelting of non-ferrous metals will be 5-6 Mt. The second reason is the 800,000 t and 1 Mt installations of acid production with S that are built in the provinces of Jiangsu, Zhejiang, Yunnan, Guizhou and Hubei. The related newly increased capacity will be 10.3 Mt. The third reason is the establishment of 300,000 t and 400,000 t installations of acid production from pyrite in areas of pyrite production and from pyrite fine tailings. The related newly increased capacity will be 3.2 Mt. By 2008, the production capacity for the whole country may reach 73 Mt and by 2010, 75 Mt (Table 3-13).

From 2006 to 2010, sulphuric acid production in China will be mainly from S and smelting fumes. Some of the small installations of acid production from ore by smelting will be closed. There will be little expansion for acid production with pyrite. By 2010, the apparent consumption of sulphuric acid throughout the country will reach 66.3 Mt and of this, imported sulphuric acid will be 3 Mt.

According to forecasts by the International Fertilizer Industry Association (IFA), even though the output of AP in developed countries will maintain the existing level, AP will still show larger growth in developing countries and therefore, demand for S will also grow. This will have an effect on the S price. After going through many years of low prices at US\$30-50/t coupled with the excessive growth in short-term demand, there is an increase in ocean freight. Therefore, the price of S in international trade is going up. However, viewed from the overall trend, the supply will exceed demand and the international CIF price of S will generally fluctuate around US\$60-70/t.

3. Synthetic Ammonia

More than 70% of the production capacity of synthetic ammonia in China use coal coke as raw material but the tight supply of coal coke could not be fundamentally resolved in recent years. The price of coal coke is maintained at the present (2004) high level and even a small drop will be limited to the southwest region. The cost of production and price of synthetic ammonia will remain at a high level. Due to shortages of electric power, the majority of small nitrogenous fertilizer plants find it difficult to carry out production at full capacity and this will lead to increases in the production costs of synthetic ammonia and shortages in its supply which in turn will affect the production of MAP and DAP.

3.4.3.2 Effect of transport and trends in development on the phosphate fertilizer industry

The raw materials in China used for the production of phosphate fertilizers, such as PR, S, synthetic ammonia and other phosphate fertilizer products, show obvious differences in their regional distribution. This has made transport one of the important factors that affects the development of the phosphate fertilizer industry. PR is mainly concentrated in the provinces of Yunnan, Guizhou, Hubei, Sichuan and Hunan, and S resources that support the development of the phosphate fertilizer industry are mainly distributed in the provinces of Guangdong, Jiangxi, Anhui, Inner Mongolia and Shanxi. Places where there is a plentiful supply of P or S are usually without the supply of synthetic ammonia as a raw material. In addition, the main markets for phosphoric compound fertilizers are located in northeast, north and northwest China where there is no P, and in economically better-developed areas along the coast of Southeast China. At different stages of the development of the phosphoric compound fertilizer industry, transport has been a major factor which hampers the development of the industry.

1. The effect of transport on the development of the phosphate fertilizer industry during the period of the planned economy

Prior to 1990, under the guidelines of the planned economy, the phosphate industry established many SSP and FCMP enterprises in accordance with the principle of "emphasizing the market by taking into consideration the resources" and the strategic thought of "regional balance and balance within a province." Many SSP and FCMP enterprises were set up. With regard to major medium and large scale phosphate fertilizer enterprises, in particular, for those enterprises in provinces

Table 3-13 World output of elemental sulphur and forecasts: 2001-2008 ('000 tonnes)

| Year | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|----------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Frasch Mining | 1130 | 950 | 780 | 710 | 710 | 710 | 710 | 710 |
| Recovered Sulphur | 40620 | 42180 | 43520 | 45140 | 46120 | 47800 | 49660 | 50710 |
| Of this: Natural gas | 22710 | 23460 | 23730 | 24110 | 23880 | 24690 | 25870 | 26420 |
| Petroleum | 16730 | 17170 | 18070 | 18940 | 19640 | 20500 | 21080 | 21490 |
| Others | 1180 | 1560 | 1720 | 2080 | 2600 | 2600 | 2700 | 2800 |
| Total | 41750 | 43130 | 44300 | 45850 | 46830 | 48510 | 50370 | 51420 |

Note: Data for 2004 are estimated values; data for the years 2005-2008 are forecast values.

that required large quantities of fertilizer for agriculture, the S and P resources were supplied according to agriculture supporting plans. The transport departments guaranteed the transport of goods. The two provinces of Yunnan and Guizhou did not have a high level of fertilizer consumption. They were treated as major provinces of natural resources that supply PR to major phosphate fertilizer enterprises in the interior. In 1980 for example, phosphate fertilizer and PR that left Yunnan Province was about 6 Mt. However, because of the distance from the interior with poor transport conditions, the cost of transport were high, affecting the economic production of an enterprise. The rail transport department also came under pressure. Sometimes, stable production of an enterprise was directly affected.

2. Effects of transport on the development of phosphate fertilizer enterprises during the period of the market economy

In the course of switching to a market economy, some phosphate fertilizer enterprises faced the dilemma of having to shut down because they were far away from resources and there was no guarantee of the transport and supply of raw materials. Costs of raw materials were rising and there was no competitive advantage for the products. For enterprises close to resources, they were able to digest the resources available locally to reduce cost of production. Consequently, after the 8th Five-Year Plan, moving the phosphate fertilizer industry to areas with natural resources was expedited. As high-analysis phosphate fertilizer could cut down the expenses of packaging, storage and transport, following the 8th Five-Year Plan, the fertilizer industry was basically in accordance with the principle of combining rock and acid with fertilizer production, (proximity to place of production of raw materials) and establishing mainly high-analysis phosphate fertilizer production.

During the period of the 7th, 8th and 9th Five-Year Plans (1985-2000), State emphasis was on the exploitation of phosphorus mines in Yunnan and Guizhou as the cost of exploitation in Yunnan was two-thirds lower than those in Yichang, Hubei Province and investment in the exploitation of a 5 Mt-P mine could save more than RMB1 B compared with Hubei. In addition, to resolve the problem of transporting PR and phosphate fertilizers out, there was an investment of more than RMB4 B to accelerate the construction of the railroads linking Nanning and Kunming and linking Neijiang and Kunming and reinforcing old railroads for the expansion of capacity. When the Nanning-Kunming line was opened in 1992, the volume of phosphate fertilizers and PR that left the province of Yunnan during the period of the 9th Five-year Plan went up rapidly from 6 to 12 Mt. The new railroads have contributed much to the large-scale exploitation of PR and the development of the phosphate fertilizer industry.

Reserves of PR in Hubei Province amount to 1.8 Bt, which puts it in the third position after Yunnan and Guizhou. 90% of the PR is distributed in the northwest of Hubei including Yichang and Xingshan. As Hubei Province is located in central China and is closer to the phosphate fertilizer enterprises in the interior, it has the advantage of railway transport and cheap water transport along the Changjiang River. All these have made it the number one province for exporting PR.

During the 9th Five-Year Plan, the State made clear the policy of "linking the rock to fertilizer production" for the phosphate fertilizer industry and implemented the strategy of "substitution of fertilizer transport for rock transport." The objective was to optimize resource allocation and raise the overall economic outputs of an enterprise. The transport of high-analysis phosphate fertilizers that have a high nutrient content and added value, substituting for the transport of low-value raw materials, reduces the physical quantity being transported to meet agricultural demands.

However, at present, the large distribution of chemical fertilizers in markets throughout the country has aggravated the pressure on the transport systems. The main reason is the strong seasonality in the use of chemical fertilizer. Owing to the fact that differences exist in the crop varieties and the time of cultivation between northern and southern China, only marketing throughout the country can avoid the imbalance of "peak and off seasons" in the phosphate fertilizer industry and achieve a balanced situation of production and sale throughout the year to relieve enterprises of the pressure of capital and warehousing brought by marketing carried out only in the local market. The legacy of effects from the planned economy to the farmers is felt in their recognition of the traditional brands from other parts of the country that they have been using for years and their consumption practices. Phosphate fertilizer enterprises will not give up their traditional markets easily. This has now resulted in long-distance transport; tight schedules in the transport system create "bottlenecks" that limits the production and development of the phosphate fertilizer industry. In 2004, transport capacity which could be assured was only 40-60% of what was planned. Due to this inadequate transport capacity, transporting phosphate fertilizers and PR out of Yunnan and Guizhou was difficult and there was overstocking of products. Phosphate fertilizer enterprises located in provinces that lack PR had to reduce or stop production due to inadequate supplies of PR. Also, it led to fertilizer shortage in areas where fertilizer was inadequate. It could even lead to "scarcity of fertilizer."

3.4.4 Policies, laws and regulations implemented up to 2006

Subsidizing agriculture is a long-term policy taken by major countries in the world. In developing countries, supplying chemical fertilizer to farmers at a low price is an important policy of agricultural subsidy. Countries adopt different policies with regard to the link at which the subsidy should come in. China is one country that subsidizes agricultural produce. The government bears part of the subsidy for chemical fertilizer, for example, a price subsidy for imported chemical fertilizer, a subsidy for import tax, low product taxes (3-5%) for small and medium enterprises of chemical fertilizer and tax exemption for 3 years for small chemical fertilizer installations in the 1980s. In many provinces and cities, over a long period of time, financial subsidies were given to fertilizer enterprises that were running with a deficit. Prior to the 1980s, there was a policy of planned purchase and marketing by the State with regard to grains. Correspondingly, there was a stipulation for chemical fertilizers to be sold at low prices. As a result, the State also implemented the preferential treatment

of low prices for raw materials, driving power, transport and taxation with regard to chemical fertilizer production.

Subsequent to the 1980s, in order to maintain the stable development of agriculture, the State continued to extended part of the policy of preferential treatment and adjusted the policy of preferential treatment for the phosphate fertilizer industry. In addition, it adjusted part of the preferential treatment that supported the development of high-analysis phosphoric compound fertilizers.

At the end of 2006, the transitional period after joining WTO will come to an end. International chemical fertilizer enterprises will enter China in full force. Domestic fertilizer enterprises will come under pressure from the new competition. At the same time, during the 11th Five-Year Plan, China has to implement reform of the pricing management system for chemical fertilizer. Owing to the upstream raw materials becoming market-oriented, the tight supply of PR, transport and electric power supply will be aggravated. Meanwhile, the policy of preferential treatment will be gradually reduced until it is abolished. Therefore, during the period of the 11th Five-Year Plan, the phosphate industry will be facing severe challenges.

3.4.4.1 Taxation policy on phosphate compound fertilizers

On 20 July 2001, the Ministry of Finance and the State Administration of Taxation issued the notice of "Policy Concerning the Imposition and Exemption of VAT on Several Materials for Agricultural Production" according to which, compound fertilizers that use phosphate fertilizers, apart from DAP, potash fertilizers and tax-exempted chemical fertilizers as raw materials (the proportion of the cost of tax-exempted chemical fertilizers used for the production of compound fertilizer by an enterprise is higher than 70% of the total cost of chemical fertilizers in the raw materials) will be exempted from taxation.

In April 2001, the Ministry of Finance and the State Administration of Taxation issued the "Circular Concerning Exemption from Import VAT for Potash Fertilizers and Compound Fertilizers Imported under the Arrangements of the State Plan." The Circular required that from 1 January 2001, for potash fertilizers and compound fertilizers imported under the arrangements of the State planning, the policy of exemption from import VAT would continue to be executed.

3.4.4.2 Policy on energy and transport of materials for phosphate compound fertilizer implemented up to 2006

1. Energy policy

Electric power utilization for the production of small and medium chemical fertilizer enterprises enjoys preferential treatment. According to provisions of Document (*Ji Jiao Neng* [1996] No. 583) of "Circular of the State Planning Commission Concerning the Continued Collection of Electric Power Construction Fund during the Period of the 9th Five-Year Plan," electric power consumption of enterprises producing N, P, K and compound fertilizers under the production permit issued by the former Ministry of Chemical Industry should be executed as RMB0.02 per kw-hour lower than the

classified power price formulated by the various regions. The average price for electric power consumption by the chemical fertilizer industry is RMB0.33/kw-hour (RMB0.48/kw-hour for other industries).

2. Transport policy

Rail transport of chemical fertilizer enterprises enjoys the policy of preferential treatment. The Ministry of Railways issued the "Circular of Provisions for Charges Concerning Goods in Railway Transport to Which Chemical Fertilizer Freight is Applicable" executed 1 May 2000 and according to which the preferential treatment given to rail transport freight of chemical fertilizer enterprises would continue to be implemented. Subsequently, based on Document No. 39, the Ministry and Commission concerned issued relevant supporting policies for guiding and pushing the distribution of fertilizer towards the model of market economy. These policies include the further opening up of the management of chemical fertilizer prices, exemption from VAT for some materials for agricultural production and the continuation of the policy of preferential treatment for rail transport of chemical fertilizer. The rail transport freight for chemical fertilizer was RMB0.024/t-km, the maximum being RMB0.09/t-km (tonne-kilometre).

3.4.4.3 Expiry of WTO transitional period, adjustments of industrial policies and the effects on the phosphate fertilizer industry

During the 11th Five-Year Plan, implementation of new industrial policies will produce the following effects on enterprises and the industry.

1. The removal of the exemption from value-added tax (VAT) will push up the price of compound fertilizer by 6%

The chemical fertilizer industry has been enjoying the preferential treatment of exemption from VAT all along. The VAT is a kind of re-directed tax. Regardless of how long the industrial chain may be, in the end, the tax will be re-directed to the final consumer. Taking a certain product as an example, after the abolition of the preferential policy of exemption from VAT, the amount of VAT per tonne of product is calculated to be RMB137, equivalent to 6% of the existing price. The sales profit for compound fertilizers is only 5%. Therefore, if a profit rate of 5% is to be maintained then the selling price must rise by 6%. With the present high price of chemical fertilizers, how much the price can be raised or whether it should be raised at all, will depend on other factors as well – the price level of food, capability of the farmers to adapt, conditions of demand and supply of chemical fertilizer and the price of chemical fertilizer in the international market. If the rise in the product price exceeds a certain range, the volume of chemical fertilizer imports will increase and domestic enterprises will feel the impact of these imports.

2. Effects of the abolition of preferential treatment policy for transport of chemical fertilizers on the chemical fertilizer market

As the phosphate fertilizer industry is heavily dependent on N, P, K and S, and China is short of these resources their distribution is unbalanced causing the flow of large quantities

of both raw materials and finished products within the country. If, for example, we take a certain plant on the Bay of Bohai that markets 1.4 Mt of products in a year, the freight charges are about RMB56 M, covering most of the provinces except Tibet, Hong Kong, Macao and Taiwan. After the removal of preferential freight charges, if the market coverage remains unchanged, transport costs will increase by RMB35 M or 62.5%. If the overall transport cost is kept unchanged then the rate of market coverage will be greatly reduced. Therefore, the adjustment of the policy of preferential treatment for the transport of chemical fertilizers will have important effects on the profit of the chemical fertilizer enterprises.

3. Important effects of the abolition of preferential treatments to the price of coal, natural gas and electrical power on small and medium-size enterprises

As with the nitrogenous fertilizer industry, the phosphate fertilizer industry is a high-energy consumption business. Removal of the preferential treatment for coal and natural gas will have a big effect on the cost of production. To small and medium scale enterprises the effects may even be greater. As some small and medium scale enterprises are disadvantaged in terms of size, technology and resources, once the entire trade is pushed towards the market, many of the small enterprises will be eliminated due to competition. Only those with advanced technology, the advantage of scale and with low-energy consumption will be able to survive and grow.

4. The implementation of a subsidy for chemical fertilizer to the farmers will have direct effects on the success or failure of the reform in the policy of production and marketing

When the State abolishes the policy of preferential treatment for the fertilizer industry, it has, first of all, to ensure that the fund for a fertilizer subsidy to the farmers has been allocated and that the subsidy channel is smooth. If the subsidy is allocated, farmers will get the real benefit and their purchasing power will be raised. It will encourage them to grow more grains and this will have beneficial effects on the chemical fertilizer and agricultural production.

3.4.4.4 Proposed policy measures to be adopted by the State

In recent years, investment in the phosphate industry has been overheated. Production capacity has been increasing too fast and supplies exceed demand. The inability of the supply of raw materials to meet demand is gradually becoming obvious. It is proposed that the State should adopt the following policy measures:

1. Enhance the macro-economic control for the total amount of phosphate fertilizer. Repeated construction at low levels should be prevented and the system of approval for new projects implemented

For the construction of AP projects with a scale of more than 240,000 t/y [with related phosphoric acid unit of 120,000 t/y (P_2O_5)], they are to be approved by the National Development and Reform Commission. Projects that are below 240,000 t/y are to be approved by a local development and reform commission. In principle, the scale of newly built single series installations is not lower than 300,000 t/y (P_2O_5). Other newly

built single series installations in areas with resources are, in principle, not lower than 120,000 t/y (P_2O_5). The essence is to control the total volume of phosphate fertilizer and prevent repeated low-level constructions.

2. Improve the policy of preferential treatment for the phosphate fertilizer industry to prevent large increases in the price of fertilizer in order to cut down farmers' expenditure

There is no change to the present taxation policy on phosphate fertilizer products. That is:

- a. Apart from DAP, other phosphate fertilizer products will continue to be exempted from VAT. For tax exemptions on compound fertilizer produced in China, the tax-free raw materials used must be above 70% of the total cost. This limitation achieves the purpose of equal competition with imported products.
- b. Continue to implement preferential freight charges for the rail transport of chemical fertilizer and PR.
- c. Continue to implement preferential charges for electric power used for the production of phosphate fertilizers.

3. Strictly control the export of PR and increase customs duty and resource tax for the export of PR

High-grade PR that can be used directly for the production of phosphate compound fertilizers is being depleted. According to the present rate of exploitation, the high-grade rock will be depleted in slightly more than 10 years. At present, driven by partial and immediate interests, PR is still being exported. The export of PR (primary product) and the import of AP (product with high added value) is a loss to the national economy and resources. Even food security is threatened. The export of PR should be prohibited, as in America. A high customs duty and VAT should be imposed on the PR being exported.

4. The "Standards of Limitation of Harmful Elements in Chemical Fertilizer" should be introduced as soon as possible

The content of the heavy metal cadmium in PR in China is low, only 10% of that of rocks from Florida, USA and 3.3% of rocks from Morocco and Tunisia. Applications of fertilizer with a high content of cadmium will cause pollution to the soil and the environment, threatening the safety of man and livestock. In order to protect these in China, it is proposed that the "Standard of Limitation of Harmful Elements in Chemical Fertilizer," which has been formulated, be introduced as soon as possible. As a WTO barrier, this can control the import of PR and reduce the impact of imported phosphate fertilizer on the domestically produced.

5. Augment the geological exploration for PR, the technology of beneficiation and input for the establishment of mines

In China, the back-up resources of PR are severely inadequate. The Ministry of Land and Resources has one of those important rocks which cannot meet the requirements of national economic development after 2010. By 2010, the amount of PR required for phosphate fertilizer production will be about 50 Mt. Calculations by the China Chemical Mining Association show that, excluding rocks used for other P, the deficiency in PR will be 8-10 Mt. Consequently, enhancing the exploration for PR and expediting the establishment of P

mines requires immediate action. In order to rationally utilize low and medium-grade PR and guarantee the sustainable development of PR and the phosphate fertilizer industry, there must be an increase in the development of the technology of beneficiation and enrichment for low-grade PR .

6. Guarantee that phosphate fertilizer enterprises in P deficient provinces obtain the rock required for production

Relevant departments of the State should co-ordinate the supply of PR leaving the P-rich producing provinces of Yunnan, Guizhou and Hubei to guarantee that the needs of major phosphate fertilizer enterprises deficient in phosphorus

are met. A definite amount of commercial rock should also be supplied to existing phosphate fertilizer plants. Furthermore supplies of low and medium-grade PR required for the production of SSP and FCMP should be arranged.

7. Encourage departments of petroleum and natural gas processors to recover Sulphur

There is shortage of S resources in China. The State should encourage petroleum and natural gas processing departments to recover sulphur. Exempt domestically produced and imported S from VAT.

Chapter 4

Potassium (K) Fertilizers in China: Development and Outlook

Potassium (K) fertilizer is a basic fertilizer for crop production. It is common knowledge that soils in China are deficient in potassium (K). At the same time, K resources are seriously lacking. The way in which to resolve the “domestic bottleneck” in the supply of K fertilizer has become an important matter that concerns the sustainability of agriculture in China. In order to allow more people, particularly those working with agricultural resources, to understand the resources, the production and market of K fertilizer, an account on the development of K fertilizer over a period of 50 years is given below.

4.1 Development of potassium fertilizer products in China

4.1.1 A review of the history of the development of the K fertilizer industry in China

Looking back at the 50-year history of the development of the potassium (K) fertilizer industry in China, production was mainly achieved by utilizing chloride-type salt lake brines. With this method, the conversion of potassium chloride (KCl) to produce sulphate of potash (SOP), potassium nitrate (KNO_3) and potassium-magnesium (K-Mg) fertilizers only happened some ten years ago. The development of the Chinese K fertilizer industry can be divided into 3 stages: 1949-1977 being the first stage, 1978-1999 the second and 2000 onwards, the third stage.

The exploration for K minerals hardly existed before the liberation of China. After liberation, the whole country organized a large number of manpower and material resources to look for K minerals. In 1951, Professor Ge Fuxiang of the Faculty of Chemistry at Lanzhou University wrote to the Central Government requesting for the survey of the Qinghai salt lake resources. In 1956, the Chinese Government and scientists formulated the “Long-term Planning for the State’s Major Items of Science and Technology for 12 Years in China” which included the study of Chinese salt lakes. In 1957, the “Salt Lakes Scientific Survey Team of the Chinese Academy of Sciences” and the National Committee of Complex Expeditions was formed with the mission to look for K and B.

In 1955-56, when the Highway Office of the Transport Department of the Province of Qinghai was building the Dunge Road in Chaerhan Prefecture which cut across the Chaidamu Basin, they discovered the world-famous Chaerhan Salina. Road workers dug up some salt for their own consumption but found that it was a bitter and pungent salt which was not

edible. The salt was sent to the Northwest Geology Office for laboratory tests. Geologist Zhu Xia pointed out that Chaerhan was a large salt deposit with 10% of the layers containing 0.40% K. In 1956, the chief engineer of the Bureau of Geology and Minerals of the Ministry of Chemical Industry, Li Yue, an expert in salt mines, sent Zheng Jinping to follow the general investigation group to Dachaidan, Mahai and Chaerhan for observation. It was found that the K content at Chaerhan was 1.1% and there was the hope of finding more K. With Liu Dagang, a researcher from the Institute of Chemical Research of the Chinese Academy of Sciences as the team leader, Professor Yuan Jianqi of the Beijing Institute of Geosciences and Han Chenshi, a leader in the Committee of Complex Expeditions, Chinese Academy of Sciences as deputy team leaders, the salt lake survey team received orders to make another trip to Chaerhan of Qinghai Province in 1957. During that period, Zheng Jinping and Gao Shiyang discovered and appraised the K-containing carnallite and the K salt layer of the primary salt lake sedimentary carnallite. From then on, a new page in the history of China’s K salt began. In the autumn of the following year, more than 5,000 youths from more than 20 nationalities produced China’s first batch of K fertilizer – 953 t containing 50% KCl from primary carnallite from the vast and seldom-visited salt marsh using indigenous method. This was 100 years after the first exploitation of K salt in the world by the Germans in 1860.

Up to 1978, according to explorations by the Ministry of Geology and Mineral Resources, there were only a few places of proven K minerals. Reserves of KCl were not even 200 Mt. Compared with other countries, China is severely deficient in K resources, most of which come from salt lake brines. Output of KCl by 1978 was only 23,000 t. Cl-free K fertilizer such as SOP and KNO_3 was not even produced. This was far from meeting the requirements for increasing agricultural production. Therefore, the production and field trials of flue ash K was carried out in various parts of the country, particularly in the southern provinces.

In order to raise the self-sufficiency rate of K fertilizer, the National Development and Reform Commission (NDRC) issued a document in 1975 concerning the planning and exploitation of the Chaerhan Salt Lake in Qinghai. In August of that year, ten Ministries and Commissions, including the NDRC and the Ministry of Petrochemical Industry completed a report on the exploitation plan that proposed an annual production of 200,000 t of MOP in Phase I of the project and 800,000 t in Phase II. This was an indication of the great importance attached to the development of K fertilizer by the Chinese Government and the older generation of scientists specializing in K salts.

The characteristic of the first stage of development of the K fertilizer industry in China was a breakthrough, but work carried out during this stage was far from satisfying demands from agriculture.

During the same period, China began the second stage (1978-1999) of a difficult journey of searching for and producing K. On 1 August 1978, the NDRC issued a document giving its consent to the establish of the Qinghai K Mine. It was planned for a total annual capacity of 1 Mt of MOP. Phase I of the project would produce 200,000 t and Phase II, 800,000 t, at the Bieletan section. In 1986, the work on the Qinghai K Mine was officially started and its Phase I work was listed as a major project of the 7th Five-Year Plan. By May 1989, after three years of construction and one year ahead of schedule, the mine had been established. In October 1990, the second beneficiation plant, the main construction of Phase I development was declared operating and producing normally. After the 72-hour test run, it produced, on average, more than 500 t of K fertilizer. The Phase I project work went through a 10 year period of preparation and construction and China's production capacity for K fertilizer then reached 250,000 t or 10 times the production in 1978. The Phase I project mainly utilized the brines in Chaerhan Prefecture. 18 M m³ of brine were drawn every year by transporting the brines through channels.

In 1987 preparation for the construction of Phase II of the Qinghai K Mine began. In 1994 the appraisal "Report on the Feasibility Study of the Sino-Israeli Qinghai Potash Fertilizer Joint Venture Phase II Project" was completed and expounded. According to the report which complied with the national industrial policy, the establishment of the project was significant to the exploitation of the natural resources at the Chaerhan Salt Lake and the development of China's K fertilizer industry. Importing the Israeli technology of cool crystallization was appropriate. For the Phase II project, the brine was drawn from the Bieletan section of the salt lake by well drilling, different from the method used for Phase I. The annual volume of brine drawn was as high as 40 M m³. On 24 December 1996, the Phase II construction work on the Qinghai K Mine started operating at Golmud City. All early stages of Phase II work were completed according to the order of basic constructions for Phase II.

On 25 November 1998, the signing ceremony of the Joint Venture Contract of the Sino-Israeli Qinghai Potash Fertilizer Co. Ltd. was held at the Diaoyutai State Guest House. This project started in the 20th century and continued into the 21st century and would increase the production capacity of China's K fertilizer from about 300,000 t to more than 1 Mt/y. However, due to the Israeli's requirement of very harsh confidentiality over their cool crystallization technology and the exorbitant price demanded, the self-developed counter-flotation cool crystallization process was adopted for the Phase II 1 Mt project. Construction work began in 2001 and the project went into full production in 2004. Production capacity for MOP of the Yanhu Group was raised to 1.5 Mt/y. In 2006, it rose to 2.5 Mt. Taking into account the small plants around the Chaerhan Salt Lake, the present production capacity for MOP in China is above 2.5 Mt/y.

Production of SOP started late in China. It began in the latter part of the First Stage of the development of the K

fertilizer industry in 1992. Before the national meeting on SOP was called by the former Ministry of Chemical Industry, SOP was produced domestically in small quantities at the Wenzhou Main Chemical Plant by using alumite. Total output was not even 4,000 t. No production occurred in other regions in China. The total adjustment in the structure of the agricultural economy and the optimization of the composition of cultivation increased the demand for Cl-free K fertilizer.

Under this macroeconomic background, the Yunnan Phosphate Fertilizer Plant imported the Nissan Mannesmann technology and equipment. In September 1992, the first Mannesmann 10,000-class production plant was established in China. In 1994, the Tianjin Sulphuric Acid Plant imported one set of the Mannesmann technology and equipment from Mr. Chen Yiquan of Qing Shang Co., Taiwan through a joint venture. Another four sets were imported by the Tianjin Sulphuric Acid Plant with its own funds. Since then, the SOP industry in China has grown rapidly through the import of technology, the introduction of capital and development. At present, apart from Shandong Haihua which utilizes underground brines for the production of SOP, other producers utilize technologies using naturally occurring minerals as raw material, and by converting KCl through the Mannesmann and Glauber salt methods. The Mannesmann method has become the most mature and most applied production process for SOP in China. SOP from this method accounts for 70% of the agricultural SOP in the country. By 2006, the Qing Shang Co. of Taiwan has set up 60 Mannesmann installations on the Mainland either by sole proprietorship or joint ventures. With these, together with 2 sets using the Nissan method and a Chinese-made Mannesmann installation, China now has 180 Mannesmann installations with a total production capacity of 1.8 Mt. In addition to this, the Nanfeng Chemical Plant produces 180,000 t/y, Shandong Haihua, 20,000 t/y and Luobupo, 80,000 t/y. The actual production capacity has reached 2.1 Mt/y with an output of about 1.2 Mt. Demand for SOP has basically been met. Consequently, imports of SOP have been gradually decreasing in recent years.

The production of KNO₃ has a very long history in China. The market for agricultural KNO₃ began at the end of the 1980s to early 1990s. It was the initial stage of the policy of openness and reform. In order to raise the quality of tobacco and expand the export of high-grade cigarettes, KNO₃ was used in tobacco growing areas in Yunnan. At that time, KNO₃ enterprises in China produced mainly industrial grade KNO₃. The enterprises covered a wide scale range and production costs were high. Production plants, for agricultural use KNO₃ were set up after 2002. This production for agricultural use included products of the Third Stage of the K industry development in China. In order to open up and take a share of the market of KNO₃ for agricultural use, the biggest KNO₃ production enterprises of the world, Haifa Co. of Israel and SQM of Chile were selling their products at lower prices in China than in other markets. This limited the development of the KNO₃ industry in China.

Soon after the formation of New China, the double decomposition of sodium nitrate (NaNO₃) and KCl in order to produce NaCl as a by-product was used. Due to the short supply and high price of NaNO₃, by the early 1980s, these KNO₃ products were widely used only in fireworks

and firecrackers. With the onset of the “K supplementation project” in agriculture, to meet the needs of the market for agricultural KNO_3 , some enterprises which produced industrial KNO_3 originally utilized their existing advantage to carry out technical reforms to produce KNO_3 for agricultural use.

China began to use ion exchange for the production of KNO_3 with AN and KCl as raw materials. Ammonium nitrate as a raw material was cheap and easy to obtain and the scale of production could be large or small with small investment. After many years of improvement, this method became a major method of producing KNO_3 and it has expedited the production and application of KNO_3 products for agricultural use.

In the mid-1980s, China began using the re-circulation of double decomposition of AN and KCl to produce KNO_3 and AC. The process was simple and energy consumption was low. Besides, there was no pollution. The process caught much attention domestically. Presently, it is one of the major methods for the production of KNO_3 . In 2003, there were more than 20 enterprises of KNO_3 of various sizes. In recent years, with the active market for chlorine-free K fertilizer, many more production plants of agricultural grade KNO_3 with capacities of 10,000 to 70,000 t joined the market. Their method of production was mainly re-circulation of double decomposition. The total production capacity for agricultural KNO_3 at present is about 300,000 t/y. However, these double decomposition enterprises have inadequate resistance against market risks. Limited by the level of technology and equipment of double decomposition, it is difficult for production to increase in scale. The low industrial concentration does not allow the size effect to be felt.

China began the industrial production process of manufacturing potassium dihydrogen phosphate (KH_2PO_4) in the 1970s. The neutralization process is the more mature route. There are only a few domestic producers. The Wuhan Inorganic Salt Chemical Plant and the Zhejiang Provincial Chemical Industry Research Institute drafted the National Standard for Mono-potassium nitrate GB 1963-80. In 1980, the Hubei Provincial Chemical Research Institute and the Wuhan Inorganic Salt Chemical Plant jointly set up the first plant using the ion exchange method for the industrial production of 2,000 t annually. During this period, a few production enterprises led by the Wuhan Inorganic Salt Chemical Plant in co-ordination with the Ministry of Chemical Industry, the Ministry of Agriculture, Production and Construction Corps of the Chinese People's Liberation Army and the farms began the free promotion of field demonstration and the application of KH_2PO_4 in agriculture throughout the country. In the 1980s, China began developing a KCl manufacturing process. There were plants in Wuhan, Xuzhou and Lianyungang which used the double decomposition process for production. In the late 1980s, the Shanghai Chemical Research & Design Institute developed the direct production process for KH_2PO_4 and ammonium potassium phosphate by the wet-process phosphoric acid. A pilot production of 3,600 t/y was carried out at the Wuhan Inorganic Salt Chemical Plant. In the early 1990s, the Tianjin Chemical Research and Design Institute developed the decomposition process of KCl and monosodium phosphate. In 1992, the Shanghai Chemical Research &

Design Institute was responsible for drafting the standard for the chemical industry for mono-potassium nitrate HG 2321-92. In the late 1990s, the double decomposition process of KCl and MAP used by the Chemical Research Institute of Jiaozou University and the Jinyang Qinsheng Technological Development Co. was more representative domestically in China. In the 21st century, experiments on extracting KH_2PO_4 from seawater have been conducted. In addition, research in solvent extraction is also being carried out in China but with little effect. Currently, there are many enterprises which produce MAP domestically. However, there are few who exert definite influence in industries, agriculture, animal feed, food, pharmaceuticals and export.

Magnesium sulphate of potash (Mg-SOP) fertilizer is a new fertilizer type in China. There are two major companies producing it. One of them is the biggest Mg-SOP producing company in China – the Qinghai Citic Guo'an Technological Development Co. Ltd. with its “Guo'an” Brand. At present, the trial production of 300,000 t/y of Mg-SOP is operating normally. In 2006, the annual production and sale was more than 200,000 t. In 2005, in conjunction with field tests carried out in the various provinces, the company presented small packets of samples as a gift to farmers for testing in some provinces. After testing, many farmers wanted to buy and use the “Guo'an” Brand Mg-SOP. Market feedback is now very good and China is vigorously promoting the technique of prescribing the fertilizer to be applied after soil testing. China will push strongly for the development of prescribed, special purpose bulk blend (BB) fertilizer which is a favourable factor for Mg-SOP.

The second is the Guangxi Luzhai Main Chemical Fertilizer Plant which applies the new high-technology promoted by the State. It produces kalimagnesia using insoluble K ore. Currently it has achieved the scale of industrial production. The first batch of 2,500 t of “Xifeng” Brand of kalimagnesia has been put in the market and is much welcomed by the local farmers. The Luzhai Chemical Fertilizer Plant has now built a production plant with an annual production capacity of 300,000 t.

After 50 years of development, China's K fertilizer industry has become the seventh in the world that possesses an installation capable of producing 1 Mt. Self-sufficiency rates for K fertilizer has grown from nil to 21% in 2005. K fertilizer demand continues to grow. Current production capacity for MOP is about 2.5 Mt/y. Production capacity for SOP is 2.1 Mt. It is 600,000 t/y for kalimagnesia and 400,000 t/y for KH_2PO_4 . The scale of production is appreciable but limited by resources. It is very difficult for China to satisfy the demand for K fertilizer for agriculture. It is China's long-term strategic policy to depend on imports and to establish K fertilizer bases in neighbouring countries.

4.1.2 Types and characteristics of K fertilizer products in China

Since China started producing muriate of potash (MOP) at Qinghai Province's Chaerhan in 1958, K fertilizer grades sold into the Chinese market include the following:

1. Potassium chloride (KCl), also known by the name of muriate of potash, abbreviated as MOP. It appears mostly

as a milky white or slightly reddish crystal. It is non-transparent, hygroscopic and readily dissolves in water. It is a physiologically acidic and water soluble fast-acting fertilizer. K oxide (K_2O) contents range between 60%, 57% and 54%. There are both Chinese-produced and imported products with different packing specifications. The execution standard is GB 64549-1996. KCl is the main grade of K fertilizer and a basic fertilizer type with the best sale. Compared with other K fertilizer grades, its price is the lowest. Its K content is higher than other K fertilizer grades such as SOP and KNO_3 . With the exception of crops that repel chloride but prefer K, K is applied in the form of MOP and this application accounts for about 90% of K fertilizer.

MOP is suitable for field crops such as grains, cotton and flax. However, it is not suitable for crops that repel chloride such as tobacco. It leaves behind residual chloride ions in the soil and long-term use leads to an increase in the soil salinity index, causing calcium deficiency in the soil, soil hardening and acidification. It should be used with lime and calcium fertilizer.

2. Sulphate of potash or potassium sulphate (K_2SO_4) is abbreviated as SOP. It is an important Cl-free K fertilizer of excellent quality. It is also a compound fertilizer containing S and K. K_2O contents are 50%, 45% and 33% with corresponding contents of sulphur (S) at 2.5% and 1.5%. The execution standard in the past was HG/T 3279-1990. The new standard of SOP for agricultural use, GB 20406-2006 was officially implemented in March 2007. SOP is generally a white or light yellow crystal, weakly hygroscopic, does not harden easily and dissolves readily in water. As it does not contain chloride ions, it has a wide scope of application. In general, it is used for field and cash crops, such as sweet potato, sugar beet, tobacco, tea, citrus, grape and watermelon, which prefer K but repel chloride. It is also used in marine aquaculture. Its sale is next to MOP, but its price is higher than that of MOP. After application to the soil, K ions can be directly absorbed by plants. They can also be adsorbed by soil colloids. Besides raising crop output, the crop quality is also improved.

The residual sulphate radical ions left in the soil are a shortcoming. Long-term use of SOP easily leads to an increase in soil salinity, soil hardening and acidification. It should be used with lime and calcium fertilizers. Application of SOP is not suitable for paddy fields because the oxidation-reduction potential is low under flooded conditions and sulphate radical ions are easily reduced to sulphide which poisons the root system of crop plants and turns it black.

3. Potassium nitrate (KNO_3) has K_2O contents of 45-46%. It is an important and excellent K, N and chlorine-free fertilizer. It is the most suitable for plant absorption and efficient among all K fertilizers. It is a white or greyish white crystal and a two-nutrient compound fertilizer of N and K. As it does not contain chloride ions, it has a wide scope of application. In general, it is used for cash and field crops, such as sweet potato, sugar beet, tobacco, tea, citrus, grape and watermelon, which prefer K but repel chloride. At present, there is no national standard for agricultural KNO_3 . The national standard for agricultural KNO_3 submitted by the Shanghai Chemical Research and

Design Institute as a relevant organization was appraised at a meeting held in November 2004. However, due to various reasons, it has not yet been implemented. The standards currently used for KNO_3 are mostly enterprise standards. KNO_3 is combustible and explosive. Great care should be taken when storing or using it. The price is much higher than for MOP and SOP. Its advantages include a very low salinity index and are free of residual ions. The mass ratio of its N and K elements is 1:3 which is also the ratio of N and K in the nutrient absorption of various crop plants. KNO_3 has good water solubility. Besides being used for irrigation and top dressing, it can also be used for foliar spray. KNO_3 is generally indispensable in the preparation of nutrient solutions. It contains two (N, K) of the three major nutrient elements for plants, N, P and K. Total nutrient content is about 60%. Content of K (as K_2O) is 44-45% and N content is 13.5%. It is highly soluble and its effective components of K^+ and NO_3^- are quickly absorbed by plants. It is not volatile and is the best ingredient for liquid fertilizer, as it will not form sediments with other fertilizers. KNO_3 can be fully absorbed by plants and will not introduce chemical residues to the environment. KNO_3 does not absorb moisture or harden easily, which is convenient for storage and transport.

4. Potassium dihydrogen phosphate (KH_2PO_4) is also known as monopotassium phosphate. It appears mostly as a white crystal or grey powder. It has low hygroscopicity and is soluble in water. It is used mainly as a foliar fertilizer. As an excellent quick-acting compound fertilizer of P and K, it has high nutrient contents and is fully soluble in water. It contains 2% P_2O_5 and 34% K_2O and nutrients in the form of $H_2PO_4^-$ and K^+ can be fully absorbed by crops. It does not contain impurities and residues. As its salt value is extremely low, it is an ideal foliar fertilizer that is suitable for tobacco, horticulture, vegetables, fruits, flowers and both indoor and outdoor cultivations. It is also a good fertilizer for nursery and seedlings. Its low-concentration solution is often used for aerial roots and in the nutrient solution for soil-less cultivation. In other countries, it is used in the preparation of high-concentration compound fertilizers but the production cost and price are high.

5. Flue ash K is a by-product of the cement industry. Owing to the different raw materials, fuels, roasting operations and recovery processes used for cement production in the various plants, the K oxide contents of the flue ash K produced are appreciably different, from as low as 8% to over 20%. The main component is SOP whose content is above 90%. The execution standard for flue ash K is JC 216-80.

6. Kalimagnesia is a double salt with the mineral name of $K_2SO_4 \cdot 2MgSO_4$. It is a good chlorine-free fertilizer grade which contains SOP and $MgSO_4$. It can provide three nutrient elements: K, Mg and S simultaneously. Citic Guo'an has just gone into production and the product is already in the market. It contains 22% K_2O , 18% MgO, 22% S and 1.5% Cl. There is another kalimagnesia which is a by-product of the salt-making industry. By making use of the different solubilities of the salts in the course of concentrating the bittern, kalimagnesia is separated. As the natural conditions of the

various salt plants are different, the quality of kalimagnesia obtained differs. Most contain a definite amount of table salt with very high Cl content. It is also possible to produce kalimagnesia from non-soluble K ore by conversion through fusion. This product contains 8-10% K_2O , 10% MgO and does not contain chlorine (Cl).

7. *Biological K fertilizer* is a new type of agent for increasing production, that is, silicate bacterial fertilizer. It has two forms, one is in the form of grass peat, a black powdered solid that is moist, loose and contains 30% water, the other is in the form of a liquid that appears milky white, turbid with a mildly sour taste. According to information, the effect on yield increase by applying 1 kg of biological K fertilizer on 1 *mu* (= 0.0667 hectares) of land is about the same as the application of 15 kg of SOP, 15 kg of MOP or 30 kg of SSP. Besides, the biological K fertilizer nurtures soil fertility without causing pollution to the soil.

4.1.3 Problems with the quality of China's K fertilizer products and their solution

4.1.3.1 Existing problems

With the high market demand for K fertilizer, many K fertilizer plants have been built throughout the country. Some carried out conversion by dechlorination using MOP as the basic raw material. Some produce low-content K fertilizer by using local low-grade K ore. Based on local agricultural production requirements, some production plants supplement high-content K fertilizer with several types of microelements to produce a complex fertilizer. These K fertilizer plants have spurred the development of K fertilizer to a certain extent. However, they have also brought many irregularities that affect the overall quality of K fertilizer. The main irregularities are as follows:

1. MOP is passed off as SOP. K fertilizers use the K_2O content to express the level of their effective contents. Regardless of whether it is KCl or SOP, the method of analysis of K_2O content is basically consistent. Unlawful traders and small fertilizer plants purchase KCl of the same K_2O content and sell it as SOP. In particular, selling it as SOP with 33% K_2O , because according to the standards for SOP, K_2O content should not be $\geq 33\%$ and there is no specified amount of limit with regard to chloride.
2. MOP or KCl is sometimes sold as KNO_3 . At present, there is no national standard for agricultural KNO_3 . The method of testing the K_2O content in KCl and KNO_3 is basically the same, thus in the market there are many occurrences of passing KCl off as KNO_3 .
3. MOP or KCl is sometimes sold as KH_2PO_4 . In the standard for KH_2PO_4 it is stipulated that to be qualified for agricultural use, K_2O content $\geq 31.8\%$ and KH_2PO_4 content $\geq 92\%$. However, there is no requirement for a limitation of Cl content. The method of measurement of its K_2O content is the same for KCl. As a result, there are two scenarios in passing KCl off as KH_2PO_4 . In the first, KCl is passed off directly as KH_2PO_4 . In the second, the mixture of KCl and AP is passed off as KH_2PO_4 . The real KH_2PO_4 does not contain ammoniacal nitrogen but a micro quantity of Cl.

4. Dilute the K_2O content in the MOP, purchase high-content MOP and add raw materials such as $MgSO_4$, $CaSO_4$, calcium bicarbonate, rock powder and clay to produce powdered or granular fertilizer containing 20% K_2O , then call it by the fine-sounding name of "double-effect K fertilizer," medical K fertilizer, K-Mg-Zn- SO_4 , KH_2PO_4 type foliar fertilizer and new K-Mg-King. Analysis of these products reveals that they contain a large quantity of Cl.

4.1.3.2 Causes of occurrence

The root causes of the four types of fake products mentioned above are the following loopholes in the standardization of K fertilizers in China:

1. In the standards of K fertilizers, the K_2O content is always used to indicate the effective nutrient content while there is no specification of limit for the amount of chlorine for agricultural use. K_2O content is highest in KCl but its price is a third and two thirds lower than SOP and KH_2PO_4 respectively. Due to the big difference in prices and the difficulty in distinguishing whether it is KCl, SOP or KH_2PO_4 by the method of analysis for K_2O , and since there is no limit specified for the amount of Cl for the KNO_3 containing 33% of K_2O and KH_2PO_4 for agricultural use there are occurrences where KCl is passed off as SOP and KH_2PO_4 and when tested according to the standards, the K_2O content is found to comply with requirements.
2. The methods of testing and enterprises' technological indices or standards for KNO_3 are irrational. There is still no national or industry standard for agricultural KNO_3 . Presently, enterprises' standards are used for KNO_3 . When formulating their standard, some enterprises make use of the method of testing for KNO_3 content in the industrial KNO_3 standard (GB 1918-1986), that is, after measuring the K_2O content the KNO_3 content is calculated from the ratio between K_2O and KNO_3 . Because KNO_3 is a pure compound, its ratio of N and K_2O is fixed. Therefore, testing for pure KNO_3 using the method in GB 1918-1986 is feasible. However, it cannot be used to test fake KNO_3 . According to the method of testing in GB 1918-1986, from KCl containing 45% K_2O (not containing N) one can also get KNO_3 of 98% by calculation. In the standard of industrial KNO_3 , the chlorine content (calculated as NaCl) of qualified products is specified as $\leq 0.20\%$ while in some enterprises' standards for agricultural KNO_3 , there is no requirement for the specification of limits for the amount of chlorine or the range of limits is too wide (the chlorine content specified by enterprises for agricultural KNO_3 is $\leq 5\%$). For pharmaceutical K fertilizer, double-effect K fertilizer, multi-element SOP, K-Mg-Zn SO_4 and granular SOP, the standards of some enterprise are low, disorderly and poor.
3. In the standards, the moisture content is always set at $\leq 6\%$ for KCl. Nutrient contents are calculated on a dry basis. The K_2O content is raised artificially.
4. In the standard the K_2O content is low. The K_2O content in the standards of the majority of K enterprises is fixed at 20%, 34% lower than the minimum target for KCl. By mixing with rock powder and clay at less than RMB100 per t, and giving the product a fantastic name, its price is much higher than KCl with the same K_2O content. This

is obviously cheating the farmers and reaping staggering profits.

4.1.3.3 Countermeasures

1. For samples of non-KCl, carry out spot checks or authorized testing for chloride ion content. Adopt the method in the GB 6549-1966 < KCl > standard to determine the chloride ions in the samples. With regard to KNO_3 and KH_2PO_4 samples, apart from testing for chloride ion contents, content of $\text{NH}_4\text{-N}$ should also be tested.
2. Amend the current national and industry standards. In the explanation of the standard for KCl, though it is stated that qualified products are only applicable to SOP produced with alunite, product by this process contains a small amount of Cl. However, spot checks in the market will not be able to tell its production process so, requirements of a limit to the amount of Cl should be formulated according to the characteristics of the product by this process.

The chlorine content of $\leq 0.20\%$ for industrial grade products specified in the standard for KH_2PO_4 should be increased in accordance with characteristics of agricultural grade products.

Expedite the formulation of the national standard for agricultural KNO_3 . When formulating the standard, the following points should be taken into consideration:

- a. KNO_3 cannot be used to express the total nutrient which should be expressed separately as contents of K_2O and N.
- b. Attention should be paid to the ratio between K_2O and N. There should be co-ordination and consistency.
- c. There is no ammoniacal nitrogen in KNO_3 . If it contains $\text{NH}_4\text{-N}$, then it must be fake KNO_3 . Use Nessler's Reagent to test for $\text{NH}_4\text{-N}$ qualitatively. If $\text{NH}_4\text{-N}$ is present, the total N content should be determined by reduction first, then subtract the content of $\text{NH}_4\text{-N}$ determined without reduction and the final difference is the nitrogen content of the KNO_3 (nitrate nitrogen).

Formulate the method of determination of Cl content of various grades of K fertilizer and specify the limit for the amount of Cl. Check all fertilizers (for example, K fertilizer products with the words that say it includes SOP, KNO_3 , KH_2PO_4) and products whose names do not contain the words "KCl." Their Cl contents should comply with the stipulated requirements (if international or industry standards are executed, then requirements of these standards should be met first). K fertilizers that exceed the limit for the amount of Cl, the words "KCl" will be added to the name of the product.

4.1.4 Outlook for the development of K fertilizer products

Changes in market demand directly determine changes in product composition. This demand has two obvious characteristics; that is, increase in the concentration of nutrient components of the fertilizer and the co-existence of many types of nutrient components. In addition, change in the form of the fertilizer required by changes in the mode of cultivation is an important aspect to be considered in future products of K fertilizer. Consequently, K fertilizer products of different grades, many specifications and taking the form of a compound type will be in a better position to enjoy a bigger

market share. The K fertilizer industry will follow the trend of specialized product composition. With regard to KCl, SOP and KNO_3 , products that have a definite production in China, attention should be drawn to the following:

1. Enhance the work of the standardization of K fertilizers. Standards for production and quality of K fertilizer products such as agricultural KNO_3 and K-MgSO_4 should be formulated as soon as possible;
2. Vigorously develop new types/grades of K fertilizer that fit the special needs (for example, granular K-based fertilizer with consistent granular diameter) in order to adapt to advanced irrigation systems and the needs to mix fertilizers;
3. Put in efforts to expedite the augmentation of output of K-Mg fertilizer to enable the utilization of K resources to develop made-in-China K fertilizer as soon as possible;
4. Vigorously develop new products such as calcium silicate fertilizer, biological K fertilizer and K-Ca fertilizer;
5. Reform the conventional methods of fertilizer application. In the past, chemical fertilizer enterprises were of the opinion that methods of fertilizer application were something for the agriculture department and the farmers to worry about. The enterprises did not pay attention to this matter. From now on, chemical fertilizer enterprises have to positively take the initiative to survey, study and summarize the methods of fertilizer application. One way or another, they should make their products easy for the farmers to use in order to increase the utilization rate of their K fertilizer.

During the period of the 11th Five-year Plan, the product structure of the K fertilizer industry in China will be further improved. P and K rich high-analysis fertilizers will become major products in future. Apart from the above-mentioned types of K fertilizer and in order to resolve the problem of shortages of K fertilizer in China, there is the need to fully utilize compost made of stalks and flue ash potash, a by-product of the cement industry.

4.2 Technological development of China's K fertilizer industry

4.2.1 Technological processes and the development of the K fertilizer industry in China

Based on the main K fertilizer grades produced in China and by summing up the processes used in the domestic production of MOP, the more mature methods applied are shown in Figure 4-1.

4.2.1.1 Potassium Chloride (KCl) or Muriate of Potash (MOP)

Based on the industrial raw materials for the production of KCl, there are, mainly, three types or techniques of production. One uses the chloride-type bittern of Chaerhan Salt Lake as the raw material. The second uses solid K ore as raw material and in the third type seawater bittern is used.

China's utilization of K-containing bittern of modern salt lakes to produce KCl has a history of more than 50

| Solid potash ore as raw material | Potassium-containing salt lake bittern as raw material | Salt-making bittern & seawater as raw material |
|----------------------------------|--|--|
| Flotation method | Flotation (also called direct flotation) | Bittern method Zeolite method |
| | Bittern exchange (process #4 for short) | |
| | Counter flotation-cool crystallization method | |

Figure 4-1 Methods of domestic MOP production.

years. During this period processing techniques used for MOP included the flotation method (also known as direct flotation), speed-controlled decomposition crystallization of bittern exchange by Na removal (#4 Process in short) and counter flotation cool crystallization.

1. Chloride-type salt lake bittern as raw material

Flotation method

This method was developed during the later years of the 1960s by the Qinghai Salt Lake Research Institute of the Chinese Academy of Science in collaboration with the Chaerhan Potash Fertilizer Plant at that time. The method was officially put into industrial production in 1967. It was also the first KCl process flow, in the real sense, in the Chaerhan Prefecture. It is, to date, the most mature process flow. The principle of the flotation method (also known as direct flotation) is to make use of the difference in the solubility of KCl, NaCl and magnesium chloride to decompose the carnallite. Mg enters the liquid phase and by flotation, K and Na are separated. More accurately, this process should be called decomposition-flotation-washing technique. There are three stages in this process:

1. Cold decomposition – this is dissolution by adding water to remove the dissolved $MgCl_2$;
2. Flotation – flotation reagents of carboxymethyl cellulose, stearyl amine and oil No. 2 are added to carry out separation by flotation and to select KCl in four steps in a closed circulation;
3. Washing – add fresh water to wash off the residual NaCl. The composition of refined K should be 90% Cl, 1.15% NaCl, 0.63% $MgCl_2$ and 6% water content.

The advantages of flotation include low energy consumption, low cost, low volume of anti-corrosion materials used, simple operation of the process flow and high adaptability to the mass of the raw ore. Its shortcomings include; low recovery rates, small granule size and low quality. It is gradually being eliminated by international K plants. After years of technical reform and application domestically, the process has been gradually improved. With the decrease in good-quality carnallite resources that contains high $CaSO_4$ and earth to produce KCl, it is difficult for the agricultural K fertilizer to achieve the international standard of 54% (K_2O). For this reason, the China Bluestar Lehigh Engineering Corporation developed a new type of high efficiency $CaSO_4$ inhibitor, QM, to be applied on the cold decomposition flotation process to enable the KCl content of products to increase from 74.2

to 88.2% and the content of $CaSO_4$ to decrease from 16.7 to 7.3%.

Beginning in the mid-1980s, the Shanghai Chemical Research & Design Institute, the China Bluestar Lehigh Engineering Corporation (formerly the Chemical Mines Design and Research Institute of the Ministry of Chemical Industry) in Lianyungang and the Qinghai Salt Lake Group carried out research in counter flotation and cold crystallization. In the mid-1990s, the Phase II 800,000 t project of Qinghai Potash Fertilizer, whose preparation for construction had been going on for some time, decided to adopt the Israeli cool crystallization technology in the form of a Sino-Israeli joint venture. However, due to the Israeli requirement of very harsh confidentiality over their cool crystallization technology and the exorbitant price demanded, it did not materialize. As a result of this, the Salt Lake Group invested RMB13 M in 1994 to carry out further research and development on cool crystallization. After three years of effort, the technique of “counter flotation-cool crystallization” was successfully developed. In the 1990s, industrial tests were carried out to prove that the technique was feasible and by late 1990s, a 200,000 t production installation was established. The capacity was later expanded by 100,000 t. Operation was good and production was stable, with good results against the various targets. With development launched in the western part of China, the 1 Mt KCl production project of the Salt Lake Group also adopted this counter cool crystallization process, making the process the main production technique in Chaerhan Prefecture.

The counter flotation cool crystallization process is divided into three stages:

1. Stage of counter flotation– NaCl is removed to obtain low-sodium carnallite;
2. Stage of cool crystallization – there are actually two processes – decomposition of carnallite followed by precipitation of KCl;
3. Washing – water is added to remove residual NaCl.

There are two important reasons why this technique replaced the cold decomposition and flotation process and became the major process flow for the salt lake K industry: Firstly, the quality is able to reach around 95% and secondly, granule size of the product is big with good external appearance. These two factors narrowed the gap between salt lake K fertilizer and imported K fertilizer. The shortcomings of this process include the relatively complicated flow, making it difficult to operate, particularly the crystallization system. Furthermore, the rate of recovery is not very high.

Bittern exchange method

Both seawater and salt lake bittern have complex compositions. Based on the different major components, they are divided into the carbonate, sulphate and the chloride-type. In the course of evaporation and concentration of the bittern, the different salts precipitate when they reach saturation. While mixing the bitters of different concentrations, during the process of concentration, the common ion effect that causes the solubility of a certain salt to drop, reach saturation and precipitate, producing an effect similar to the use of heat energy to bring about evaporation, saturation and precipitation; the method is called bittern exchange. The Chaerhan Salt Lake is a typical

chloride-type salt lake. It has provided the natural conditions of bittern for utilizing this method. Firstly, the dry desert climate and strong sunlight have provided a huge amount of evaporation that allows the bittern to achieve maximum concentration by nature alone. Secondly, the pure chloride bittern has provided the natural condition required for bittern exchange – an over-saturated ion and highly concentrated bittern. Based on these two favourable conditions, the bittern exchange method in Chaerhan Prefecture began to develop and achieve a certain scale.

The bittern exchange method has long been practised in the coastal regions but its application in Chaerhan Prefecture went through a long road of exploration in the early days. Research and exploration in many aspects was carried out with regard to the phenomenon of salt crystallization produced by mixing bitterns of different concentrations in actual production in order to eliminate the harm brought by this phenomenon and the problem of attenuation of bittern channels caused by salt precipitation. A relatively good solution has yet to be found for these problems but it is known that vertical separation and mixing bitterns of different concentrations in the salt field invariably cause the precipitation of one type of salt. In 1988 the Chemical Mines Design and Research Institute of the Ministry of Chemical Industry in Lianyungang submitted a report on a technological project about “Production of Carnallite at the Salt-field by the Bittern Exchange Method.” This was implemented between 1990-1994 by building a salt-pond of 300,000 square metres at the salt lake, using old bittern (commonly referred to as F-point bittern) and mineralised water (commonly referred to as E-point bittern) for carrying out bittern exchange. The method used was to fill a bittern exchange pond with E-point and F-point bittern from two different salt-ponds at the same time according to ratio.

E-point and F-point. They are mixed artificially to precipitate carnallite with a lower Na content and this carnallite is used as raw material for the production of high-quality KCl by decomposition. This project achieved a certain success and was appraised by the State. However, in view of the fact that there existed a number of limiting factors in the application of this method, it was not possible to promote its application. Nevertheless, a series of data obtained have provided a reliable basis for the further development of this technique. During this period, the Chemical Mines Design and Research Institute used the bittern exchange method to conduct supplementary tests in the production of KCl of good quality in some installations. In addition, there were new breakthroughs in the application of speed-controlled decomposition of KCl. The new technique of “Making good-quality KCl from chloride-type K-containing bittern” by the method of “speed-controlled decomposition crystallization of bittern exchange by Na removal” was developed. This is the #4 Technique which was awarded the State patent for invention. This patent’s inventor was Cheng Zhong, a research worker at the Lianyungang Research Institute.

In 1991, the Scientific Research Institute of Qinghai Potash Fertilizer Plant did a great deal of laboratory work on how to utilize the bittern exchange method in actual production. Firstly, they carried out experiments on the technical conditions of low-sodium carnallite with old bittern and

mineralised water from which they obtained important first-hand information on the best bittern exchange ratio, time for bittern exchange and the rate of production. Subsequently, in accordance with market demand for refined salts, a project to produce high-purity NaCl by using the process of bittern exchange was started. Due to a change in the market, production of NaCl was switched to the production of low-sodium carnallite by the bittern exchange method. In 1994, the Chemical Mines Design and Research Institute in Lianyungang established a project and started a ten-thousand capacity KCl installation using bittern exchange that went into production in 1996. The original design of this project utilized mineralised water from a big salt-pond but due to the unstable quality of the mineralised water and restrictions on its supply, production fell short of the installation’s capacity. Subsequently, the two beneficiation plants of the Salt Lake Group were used to decompose the mother liquid as E-point bittern, generating a reliable source of bittern. The cost was greatly reduced and control of production was continuously stable. There was a great improvement in process control, production costs and product quality and at one stroke the enterprise became the most competitive, in the production of KCl, in the Chaerhan Prefecture with the simplest process, the highest quality and the best results.

In 1997, the Qinghai Salt Lake Group Co. taking into consideration the need to make up for the lack of grading of its products and the large quantity of decomposed mother liquid, instructed a science and technology company to establish a mutually supporting KCl project with the decomposition of the mother liquid. The science and technology company drew on the successful experience of the 10,000 t unit and the foundation data obtained from experiments in the past to design and build a project of good-quality KCl with an annual capacity of 40,000 t on its own. The project went into production in August 1998. Apart from the above-mentioned two projects in Chaerhan Prefecture, there is the 10,000 t bittern exchange workshop belonging to the Lanzhou Air Force (former the Lanzhou Air Force Potash Fertilizer Plant which is now annexed by the Golmud Cangge Potash Fertilizer Co., Ltd.) and the Bittern Exchange workshop at the Golmud Kalimagnesia Plant under construction making it possible for the total amount of KCl produced by the bittern exchange method to reach an annual production of 80,000 t.

The advantages are as follows:

1. In the bittern exchange method, E-point bittern can be exchanged directly for carnallite reducing the leakage of bittern in the salt-pond and increase the systematic rate of yield. In addition, the area of the carnallite salt-pond and the process of exploiting and transporting the ore are reduced thus, lowering the cost of production tremendously.
2. The yield and production per 100 t of E-bittern mother liquid by the bittern exchange method is slightly lower than the counter flotation process, but it is superior to the other two processes in other aspects. In particular, because of its low production cost, its economic advantage is rather obvious, with the gross profit equivalent to 1.5 times that of direct flotation, and 1.2 times that of counter flotation. The gross profit per tonne of product is equivalent to 1.4 times that of direct flotation and 1.3 times that of counter flotation.

3. The KCl product is of a high grade with big grains (granule size $\geq 0.3\text{mm}$), white in colour and the product grade can be adjusted at will between 93%-98% in order to adapt to the market. Therefore, the product possesses stronger market competitiveness.
4. Technical control of the process is simple and automatic control can be achieved.
5. Besides being an attached process of other techniques, this process can also exist as an independent technical system with strong adaptability.
6. The bittern exchange process makes full use of the natural energy source of the Chaerhan Prefecture and discarded resources to produce high-quality KCl. This is doubtlessly a new opening. If the utilization of finished liquid is resolved, its potential for development is tremendous.

The low recovery rate of the system is a shortcoming. For the promotion of installations for large-scale production, further economic proof is needed.

2. Solid K ore as raw material

In 1965, the first sylvite mine was discovered at Mengyejing, Simao region of Yunnan Province. To date it is the only enterprise in China that utilizes soluble solid K ore to produce KCl. The total reserves of KCl at this mine are about 6.6 Mt. The mine adopts the flotation method to produce KCl and once reached the production capacity of 6,000 t/y. After beneficiation, the grade of the fine K product obtained is between 90 and 97% and the recovery rate is between 50 and 70%. Based on the characteristics of the mine, the Shanghai Chemical Research and Design Institute carried out tests and research in the separation of KCl and NaCl using the thermal full-dissolution process. This provided essential data for the establishment of the plant. Table salt can be obtained by this method but problems of complex process flow and greater fuel consumption remain.

From 1970 to 1975, the former Chemical Mines Design and Research Institute in Lianyungang collaborated with the Yunnan Simao Potash Fertilizer Plant to carry out a pilot study using the flotation method to obtain 1,000 t of KCl per year from sylvite. However, this method had the problems of low yield and that the NaCl, after separation, is not edible and can only be used as an industrial raw material.

Recently, the Jiangcheng Taiyu Potash Fertilizer Co. Ltd. of Yunnan Province organized relevant experts who examined and appraised the "Report on the study of KCl production from difficult-to-dress sylvite at Mengyejing and minor tests on the study of process development of KCl from greyish green sylvite" undertaken by the Qinghai Salt Lake Research Institute of the Chinese Academy of Sciences. According to this group of experts, there are many substances which are insoluble in water and many types of impurities in the greyish green sylvite whose ore composition is complex and difficult to dress, a technical difficulty found everywhere in the world. Through its in-depth studies of earth removal and flotation technique, the Qinghai Salt Lake Research Institute provided technical indices, parameters and recommended flows in its study report. These provided the basis for technical designs for industrial demonstration installations with a scale of 10,000 t per year. There were important breakthroughs in earth removal from difficult-to-dress sylvite and the

flotation technique in which China attained the advanced level internationally. Subsequently, the Jiangcheng Taiyu Potash Fertilizer Co., Ltd. of Yunnan Province and the Qinghai Salt Lake Research Institute reached an agreement after consultations on an equal basis to jointly participate in the research and development project "Installation for the industrial demonstration of producing KCl from greyish green sylvite (poor ore) with a capacity of 10,000 t/y."

3. Seawater bittern as raw material Bittern exchange method

This technique was developed and improved based on the technology brought in from Japan by technical personnel of China's Ministry of Light Industry in the 1960s. This method uses bittern formed by concentration after the production of NaCl through the evaporation of seawater as raw material. In the course of concentration, KCl and magnesium chloride in the solution are separated to obtain artificial carnallite. KCl is then extracted. The technique of producing KCl using bittern in bittern exchange is a conventional and comprehensive utilization process widely adopted over the years by bittern chemical enterprises in China. At present, the output is small, of only about 30,000 t/y. With the rise in costs of energy, materials and manpower, the shortcomings of this technique for high energy consumption and low recovery rate, are becoming more obvious. The cost of production is obviously higher than the selling price. Scientists of salt formation have carried out many studies on technological reforms but have failed to resolve the problem of high-energy consumption of the original technique. Fuel costs take up about 50% of the total. The bittern exchange method made important contributions in resolving the issue of K for industrial use during the 1970s and 1980s.

The seawater zeolite method

During the period of 1975-1983, extraction of KCl from seawater by the zeolite method was proven to be technically feasible after extension test at the 100 t level and the 1,000 t pilot test. KCl produced was qualified in batches. However, problems of high energy consumption, high salt consumption and the low volume of effective exchange of zeolite have caused the cost of production of K to be higher than the market price, making further industrial production not possible.

4.2.1.2 Sulphate of Potash (SOP)

Since the 20th century, production methods for SOP have been emerging one after another, both domestically and in other countries. Some of the techniques are already mature and are in industrial production, others are at a stage of maturing but needs improvement. There have been breakthroughs for techniques that are at the stage of research and development. Methods of production for SOP can be divided into two main categories. One is SOP from natural K-containing minerals and the other is the KCl conversion method that produces SOP with KCl as raw material. The conversion method can be further divided into the thermal method and the wet method. The Mannheim method is the more typical thermal method whilst double decomposition is the more often applied wet method. Other methods include the AS ion exchange and salt-making bittern methods. Glauber's salt process is the

most typical among the double decomposition methods. Compared with other methods in China, this process has the advantages of the presence of resources, domestic production, large installations and achieving quick results with small investment. After more than 10 years of development, the methods of SOP production actually applied in China are shown in Figure 4-2.

| Production with potassium-containing minerals | Conversion of potassium chloride |
|--|---|
| Sulphate salt-type potassium-containing bittern (salt lake bittern process) | Mannheim process - Qingshang process - Nissan process |
| Alunite [KAl ₃ (SO ₄) ₂ (OH) ₁₂] | Glauber's process Ammonium sulphate process |
| | The "Dizhi" process Bittern process Seawater process |

Figure 4-2 Processes and methods of SOP production in China.

1. Production by using K-containing minerals

K produced from sulphate salt-type K-containing bittern

This method of K production in China is relatively new. The Xinjiang Luobupo Kali Salt Science and Technology Co. Ltd. and the Changsha Design and Research Institute of the Ministry of Chemical Industry used the bittern exchange method to regulate the onsite bittern systems at Luobupo and successfully produced high-quality high- K and low-sodium mixed K salt under the sun. The precipitation of K mixed salts in the course of evaporation is properly segmented, thus obtaining high-grade mixed K salts of magnesium and vanadium and mixed K salt of carnallite. In response to the absence of fresh water at Luobupo, a new endeavour to use specific bittern to decompose carnallite mixed K salt to produce KCl which complied with requirements for good-quality product in Category II of GB 6549-1966 Standard provided the necessary raw material for producing SOP on the site at Luobupo. The result of this research solved the problem of shortages of fresh water in Luobupo. It also enabled the yield of K from the raw ore of carnallite mixed K salt to be much higher than decomposition with fresh water. In line with local conditions in Luobupo, mildly brackish water is used to carry out bittern blending of leonite and KCl to produce good-quality SOP through the salt-field.

Results of technical and economic appraisal indicate that pilot tests on the production process of SOP using the hypo-type magnesium sulphate bittern from Luobupo, in Xingjiang Province was a right technological route with small investment and low costs. It is capable of yielding better economic benefits and the production technology and economic efficiency are feasible. Achievements are at the top domestically and it can be the basis for industrial tests and designs. Subsequently, the Changsha Design and Research Institute of the Ministry of Chemical Industry completed the feasibility study, scheme design and working drawings for a 20,000 t/y of SOP industrial test using the hypo-type magnesium sulphate bittern from Luobupo. This installation was built and went into production in 2004. In addition, the

Changsha Design and Research Institute also completed a feasibility study of 1.2 Mt/y capacity of SOP on behalf of the Xinjiang Luobupo Potash Science and Technology Co. Ltd. On 11 May 2006, work began on the process of producing SOP from hypo-type magnesium sulphate bittern used in the 1.2 Mt/y of SOP project. It is expected to be completed for production in 2009.

SOP produced from the comprehensive utilization of alunite

Since 1930, many countries launched research and technology developments on the comprehensive utilization of alunite. More than ten flow processes were put forward. Of these, the "reductive pyrolysis- alkaline" process developed in the former Soviet Union achieved industrial production. The Wenzhou Main Chemical Plant imported this technology and in the 1990s, the plant imported the water chemistry process from the former Soviet Union again. However, it was a financial failure and has been shut down.

Explanation of the flow: After breaking up the ore from larger to smaller pieces and sieved, the smashed pieces are fed into a leaching container. Circulation leaching using a caustic soda solution is carried out at a certain temperature. The leached liquid is concentrated by evaporation. After crystallization, the coarse potash, containing SOP and Na sulphate, is separated out. It is then purified by a three-stage substitution using KCl followed by crystallization, separation and drying to obtain the product of SOP. On cooling and salt precipitation, the mother liquid goes through steam concentration, crystallization and separation to extract NaCl. After separation of the coarse potash, silicon is removed from the evaporation mother liquid which is decomposed to give aluminium hydroxide. After baking, alumina is obtained. The decomposition liquid returns to the leaching process for circulation. After the alkaline leaching the mineral waste residue can be used as a supplementary building material.

2. KCl conversion method

Mannheim process

The Mannheim process is for the production of SOP, developed by a German chemist by the name of Mannheim Verein. It uses KCl and concentrated sulphuric acid as raw materials.

This method uses 98% concentrated sulphuric acid and KCl (about 60% K₂O, usually white) which react in the Mannheim furnace under 500-530°C for 2-3 hours to form solid SOP and gaseous hydrogen chloride. On cooling, the hydrogen chloride is absorbed in water to give the by-product of industrial hydrochloric acid.

The Mannheim furnace has the following four characteristics:

1. The diameter of the furnace directly determines the production capacity. Usually, the standard of production capacity is based on the daily production capacity of a single reacting furnace. Due to limitations of the manufacturing technology and materials, the largest Mannheim furnace in the world has a diameter of 6 m.
2. The rabble driven system is stable and reliable, thus guaranteeing that the reaction will be carried out continuously and steadily.

3. Materials must meet high requirements. The fire-resistant material used for the reaction chamber of the furnace must be resistant against high temperature, strong acid and wear and tear. The rabble arms must have strong mechanical endurance. Whether or not the material quality meets the requirements will directly affect the period of repair, maintenance and the service life of the furnace.
4. There is automatic temperature control and security protection system.

Merit: The agricultural SOP produced is of stable quality. It is easy to achieve the standard of excellent grades for agricultural SOP.

Shortcoming: This method is carried out under conditions of high temperature and corrosion and requires good resistance against these conditions. The period of continuous operation of the equipment is short, with relatively high maintenance and repair cost. Its heat efficiency is low and energy consumption high.

A hundred years of development and improvements all over the world has given rise to many Mannheim processes. There are two main types imported by China. One is the Nissan process Mannheim installation first imported by the Yunnan Phosphate Fertilizer Plant from the Nissan Corporation of Japan. Two sets were imported. As the improvements made by Japan on the furnace was mainly on automation, after being brought into China, the two installations suffered severe corrosion and imports were stopped. The other type was from Mr. Chen Yiquan of Taiwan who spent more than 20 years working hard to optimize the structure, materials, processing flow and organic solvent of Mannheim process. The original intermittent production became continuous with his improvements. In 1994, Mainland China imported the installation. In 1996, studies on the domestic manufacture of the imported equipment started in Shanghai. After years of study, China developed its own Mannheim process equipment for producing SOP. From 1997 to the present, many full sets of installations of Mannheim process) designed by the Chinese have been built.

Glauber's process

China is rich in Glauber's salt. Using the reaction between Glauber's salt and KCl to produce SOP is a method favourable for domestic production. For the past 20 years, China has been carrying out research and development on the technology of Glauber's process in the production of SOP. In general, this method adopts the process flow of "two-stage conversion and flush distillation," using KCl and Glauber's salt (main component being Na sulphate) as the main raw materials which react in the solution and, after concentration and separation, produces SOP. The entire production process of this method is carried out under normal temperature and pressure and closed circulation. There is no discharge of wastewater and no emission of waste gases. The technique is relatively mature and the reaction conditions are easy to control and operate. Production costs are lower and investment can be reduced. The installation can be easily augmented. The shortcoming is the high consumption of Glauber's salt. The plant should be located at a place rich in this.

The Shanxi Potash Fertilizer Co., Ltd. is the major plant using the method of conversion of Glauber's salt. Situated

in the eastern part of China, the location of the only large Glauber's salt mine, Jiangsu Hongze is utilizing its Glauber's salt resources as an advantage to have a joint venture with a Spanish company in setting up a 150,000 t/y installation. The Glauber's process has continuous production. Its equipment is domestically manufactured. There is automatic control and it is suitable for large-scale production. It is a domestic leader and is technically comparable to advanced international methods. The installation itself does not have special fixed equipment. There is no specific requirement in the choice of materials. Compared with the Mannheim process it has obvious advantages with regard to technical equipment and its investment is relatively much lower. SOP from Glauber's process does not contain free acid. It is a neutral and fully soluble K and S compound fertilizer suitable for various types of soils. This is more advantageous than SOP by the Mannheim process because the latter contains free acid and thus, is unsuitable for application on acidic soil.

Ammonium sulphate (AS) process

The Research Institute of Nanhua Co. began research and development of an AS process in 1988. In 1992, a 5,000 t/y SOP installation was built for the first time at Zhangjiagang. The Shanghai Chemical Research & Design Institute and the Hebei Engineering College successfully developed this technology. Due to difficulties in the supply of the raw materials, the ammonium sulphate (AS) process installations have a smaller scale. The production capacity is usually 3,000-5,000 t/y. At present, of the more than 10 AS - SOP process installations already built, the majority have stopped production due to shortages of raw materials.

The "Dizhi" process

Its development began in 1988 with the establishment of a 3,000 t/y advanced pilot installation in Shanyang. Subsequently, 10,000 t production installations were built in Shifang, Shandong, Yunnan and Guangdong. Owing to a number of factors, all have failed to realize normal production.

Bittern process

With the successful breakthrough in the key technique of separation of NaCl and SO₄ for producing SOP from bittern in the 1990s, a series of techniques for obtaining SOP from bittern were developed. Owing to different methods of separating NaCl and SO₄, these techniques can be divided into the flotation process, the spiral-flow process, the sifting process and salt precipitation at high temperature. Of these, the flotation process is applied by the 10,000 t SOP project at the Daqinghe Salt Field in Hebei Province. The spiral-flow bittern process has passed the appraisal by the Scientific and Technological Committee of Shandong Province and achieved industrial production in the Shandong Haihua Group with a capacity of 20,000 t/y of SOP. Technically, Haihua changed the two-effect evaporation to three-effect evaporation to enable the technique to reach an advanced level. This technique is composed of three parts – production of KCl from bittern, separation of wet salt by the spiral-flow process and the two-step conversion of MgSO₄ and KCl to produce SOP. Its characteristics include short production periods, simple equipment and technology, thorough separation and without

pollution. Using the technique of producing SOP from bittern to revamp a plant that produced KCl by the bittern process will markedly improve economic benefits. Haihua obtained appreciable economic results between 1995 and 1998. In 1998 it was awarded the National Invention Award. After 1999, with the domestic SOP market competition becoming fiercer, the price of SOP dropped from RMB2,000 to RMB1,500/t. In the application of this process, the production of every tonne of SOP consumes almost one tonne of KCl. This was clearly a shortcoming that led to reductions in plant profits. Consequently, the technique of obtaining SOP from bittern cannot be promoted on a large scale.

Seawater process

In order to reduce the cost of extracting K from seawater, during the period of the 6th and 7th Five-year Plan, science and technology personnel in China put in their best efforts to develop the "Process of extracting SOP from seawater and brine."

Comparisons of this technique with the extraction of KCl from seawater: the first is the use of cheap salt-field saturated bittern to replace brine as the eluant which reduces raw material costs. The second is the transformation of the product from KCl to the higher-priced SOP which raises the overall benefit of the technique. The third is the selection by preference of zeolite with higher capacity for K exchange. The fourth is the completion of the study of the theory of zeolite ion exchange. Small-scale tests and a 100 t pilot study on a K enrichment process were completed. From the initial economic analysis, due to inadequate market competitiveness of the cost of SOP, further improvements were needed for the process.

After the accumulation of the above-mentioned work, at the end of the 9th Five-Year Plan, the joint efforts of the Hebei University of Technology and other organizations successfully developed the "high efficiency and energy-saving technology in the extraction of SOP from seawater." In response to the key technical problem of high-energy consumption in K enrichment caused by the low effective exchange capacity of zeolite in the extraction of K from seawater, this process developed a superimposed bittern process that enabled the effective exchange capacity of zeolite to be increased threefold which greatly reduced the cost of SOP, thus, achieving an important breakthrough in the technology of extracting K from seawater. This technology passed the achievement appraisal conducted by the Scientific and Technological Committee of Hebei Province in January 2000. Examination and appraisal experts composed of academicians from the two academies in China unanimously affirmed that the technology was at the highest international level. This process showed extremely strong market competitiveness and good industrial prospects when compared with the sulphuric acid process, AS process, Glauber's process and the bittern process. At present, with the support given to an important science and technology project of Tianjin City, the 100 t pilot test of this process was successfully completed by the Changlu Haijing Group Limited of Tianjin City. It is ready for industrial production. This technology is particularly suitable for revamping and improving traditional sea salt chemical industries, thus it is getting support from the State

and the relevant local departments and catches the attention of departments in charge of trade. The Ministry of Science and Technology listed the "6,000 t/y demonstration and study project of high efficiency and energy-saving technology in the extraction of SOP from seawater" as an important scientific and technological plan to be tackled during the 10th Five-Year Plan in order to provide a reliable basis of design in the promotion of its industrial production.

4.2.1.3 Potassium nitrate (KNO₃)

There are three main types of production processes for KNO₃ in China, shown in Figure 4-3. One is the use of the double decomposition circulation process. The second is the ion exchange of AN and KCl and the third is the nitrite extraction method.

1. Double decomposition process

Sodium nitrate conversion process

| Double decomposition process (Conversion process) | Ion exchange process | Nitre extraction process |
|---|--|--------------------------|
| Sodium chloride conversion process | Ammonium nitrate and potassium chloride as raw | |
| Double decomposition & circulation process - Ammonium nitrate and potassium chloride as raw | | |
| Double decomposition & crystallization process | | |

Figure 4-3 Main methods of KNO₃ production.

The double decomposition process that uses NaNO₃ and KCl as raw materials is no longer a main method of production because the price of NaNO₃ is very much higher than AN. Besides, the KNO₃ produced is of poor quality and the sale of by-product NaCl is not good.

Double decomposition and circulation method

The earliest research into this technique began in the mid-1980s. Before the early 1990s, the double decomposition and circulation method was at the stage of laboratory tests and as industrial pilot projects. At that time, the scale of production using this method was very small, usually 500-2,000 t. The equipment was backward and operation was intermittent. Raw material consumption was high, each tonne of KNO₃ requiring 0.9 t of KCl, 0.95 t of AN and 6.5 t of steam.

From 1992 to 1996, after a number of industrial practices and optimization improvements of the technique, the scale of production was raised to 5,000 t/y. Consumption of raw materials was greatly reduced. This method was promoted to more than ten enterprises throughout the country. However, many technical problems existed in the process which restricted its application on a large industrial scale. The major problems were:

1. The rate of conversion by the reaction was low, generally only about 45%. The large volume of the raw materials solution which did not react in circulation led to

correspondingly high-energy consumption and operation expenses.

2. The use of sleeves and coils in the cool crystallization of KNO_3 and ammonium chloride (AC) gave rise to severe deposition.
3. There was serious corrosion of the evaporation equipment. The single-effect evaporation was used and this consumed a large volume of steam.
4. A link-suspended basket centrifuge was used for product separation and this required more manual labour.

The Yueyang City Potash Scientific Research Institute systematically studied the technology of KNO_3 production by the method of double decomposition and circulation. Studies were carried out on the augmented industrial production by which a series of technical difficulties were resolved. They successfully established and put into production 11 sets of installations of agricultural and industrial KNO_3 , with production scales generally being 20,000-30,000 t/y. The actual production capacity exceeded the designed capacity.

This technology has the following main characteristics:

1. It uses a specially made, highly efficient and non-deposition heat exchanger as external cooler for the cool crystallization of KNO_3 and AC. Compared with the existing sleeve or coil cooling being used domestically, it does not have the problem of deposition and the effect of heat transmission is increased by 2-4 times. It saves energy consumption and investment by 50%. The land area occupied is also reduced. According to what we know, this technique is the first of its kind in China and elsewhere.
2. There is no need to install a stiffing device by using a unique technique, a specially made separation device that operates continuously to separate the KNO_3 and AC. Compared with other domestic organizations that use stiffing device with a volume of ten cubic metres, the investment is lower and the technique, simpler. Besides, the effect of separation of KNO_3 and AC is good.
3. The use of an advanced prescribed technique and the addition of an accessory ingredient in the circulating mother liquid to increase output, which enabled the unit volume of mother liquid to produce the maximum amount of product. At the same time, the consumption of raw materials is close to the theoretical level with each tonne of agricultural KNO_3 consuming 98% of the KCl at 0.8 t, 99.5% of the NH_4NO_3 at 0.8 t and 0.6 t of agricultural AC as by-product. For the production of every tonne of agricultural KNO_3 , only 1.5 t of evaporated water is needed. In other domestic organizations, for every tonne of agricultural KNO_3 , nearly 3 t of evaporated water is required. This is the core technology unique to the Yueyang City Potash Scientific Research Institute.
4. Based on requirements, products of different qualities can be produced through the adjustment of the technique. In general, the agricultural KNO_3 is controlled at $\text{K}_2\text{O} \geq 44.5\%$, $\text{N} \geq 13.8\%$, $\text{Cl} \leq 1.0\%$ and $\text{H}_2\text{O} \leq 1\%$. For agricultural AC, it is controlled at $\text{N} \geq 23.5\%$, $\text{K}_2\text{O} \leq 3.0\%$, $\text{H}_2\text{O} \leq 2.5\%$. Further purification can produce industrial KNO_3 with the product quality achieving the excellent grade by the GB/T 1918-1998 Standard, that is, $99.4\% \leq \text{KNO}_3 \leq 99.7\%$.

5. There is no environmental pollution. It is a green technique. The production flow is short with production in closed circulation.
6. Investment is small and the scale can be large or small. To build an installation with an annual production of 15,000 t of KNO_3 , requires an investment of about RMB7 M.
7. The equipment is simple. The flow is short. The technology is completely mature and reliable for large-scale industrial production. Production costs are low with good economic benefits.

Among the numerous methods of producing KNO_3 , the double decomposition of KCl and AN has the advantages of being technically outstanding with low investment and low cost and is developing fast. The majority of KNO_3 plants in China adopt this method. The more typical domestic production plants include Yichun Tengda Chemical Industry Co., Ltd. in Jiangxi Province, Lianda Chemical Industry Co., Ltd. in Zhejiang Province, Wotewei Chemical Industry Co., Ltd. in Yunnan, Jinye Fertilizer Co., Ltd. in Huanan Province, Xinghuo Chemical Industry Co., Ltd. in Qinghai Province and Xiangtan Chemical Plant in Hunan Province.

2. Method of purification of nitre

The method of purification of nitre uses the method of extracting KNO_3 from nitre ore. In 1986 a nitre mine, considered relatively rare both in and out of China and easy to exploit, was found in the Uzongbulake Prefecture in the province of Xinjiang. On survey, the highest K content in the nitre ore of the region reached 14%. The reserves convert into more than 5 Mt of pure KNO_3 . A pilot workshop with an annual output of 2,000 t was built in the Turpan Prefecture of the Xinjiang Autonomous Region. In the process, after breaking up the nitre ore, the broken pieces are added to the dissolving tank where the ore is dissolved by direct heating with steam and stirring, with the temperature maintained at 50-60°C. When the ore is completely dissolved, clarification is carried out in the settling tank. The clear liquid is sent to the evaporation tank for stirring and evaporation. When the solution is concentrated to 45°Bé (Baumé scale) and the temperature is at 120°C, large quantities of NaCl and Na_2SO_4 are precipitated. Based on the content of NaNO_3 in the liquid phase and in order to increase the production of KNO_3 , KCl is added accordingly. The precipitated NaCl and Na_2SO_4 are filtered and removed. The filtrate is sent into the crystallizer to precipitate out KNO_3 crystals. After rinsing with water there is one re-crystallization.

After years of production exploration, a salt lake development company in Hami City grasped a technique of producing KNO_3 and NaNO_3 from nitrate-type bittern. They successfully resolved the technique of setting up a salt-field in a small dry salt lake and the technique of the separation of bittern minerals by natural exposure to the sun. These are required in the production of NaNO_3 and KNO_3 by using nitrate salt-type bittern. The cost of constructing the salt-field and the cost of production of KNO_3 and Na nitrate are lower than other methods.

The Turpan Gongqi Company adopted this method and built up a production capacity of 20,000 t/y. Compared with other production processes, this method has the advantages of a short process flow, a simple production method, low

costs, good-quality product, and stable quality and easy to organize production on a large scale.

3. Ion exchange process

The production of KNO_3 by the ion exchange process also uses AN and KCl as raw materials. Usually, cation exchange resin is used as the exchange medium, enabling the K and NH_4 ions in the purified solution of AN and KCl to carry out ionic exchange through the action of the cation exchange resin, thus, obtaining KNO_3 and AC solutions separately.

The major advantages of the ion exchange process include separation of salt products, high purity of the liquid after completion of exchange, and a first grade industrial product is obtained after direct evaporation, cooling and crystallization. The cost of raw materials is low, the equipment is simple, investment is small, the process can be operated continuously unit consumption of raw materials is low and the utilization rate is high. Major shortcomings include the high cost of evaporation because after completion of exchange the concentration of KNO_3 solution is low and the volume to be evaporated is large. The problem of equipment corrosion is difficult to solve. Production of KNO_3 using the ion exchange process has its limitation. Because of this, after years of practical experience, the Wentong Potash Group in Shanxi Province successfully developed independently the "high-efficiency energy-saving ion exchange process."

Compared with the original ion exchange process, the following competitive advantages are obvious:

1. There is optimization of the aspect ratio of the ion exchange column. In the ion exchange column with optimized aspect ratio, concentration of the KNO_3 solution in the finished liquid is increased by about 20%.
2. The period of exchange is shortened from 12 to 6 hours. Each period saves more than 30% of rinsing water.
3. The overall concentration of AC solution in the liquid on exchange completion is raised by more than 15%.

The actual production capacity of a single installation has exceeded 20,000 t. The installation has successfully adopted an evaporator of multi-effect titanium material for the evaporation and recovery of AC. By using the high-efficiency ion exchange process, the Wentong Group has built an installation with a production capacity of 200,000 t/y.

4.2.1.4 Potassium dihydrogen phosphate (KH_2PO_4)

The technique for the preparation of KH_2PO_4 was studied at the beginning of the 18th century but it wasn't until the mid-1960s that various countries began in-depth studies on the theoretical foundation and technology in the process of its production. As a result of the confirmation of the fertilizing effect of KH_2PO_4 , various methods of preparation were developed. In summary, the methods of KH_2PO_4 production used in China are shown in Figure 4-4.

1. Neutralization process

In the neutralization process, reaction is carried out directly between phosphoric acid by furnace process and potassium hydroxide or potassium carbonate. The pH value of the neutralization solution is controlled at 4.2 to 4.6, thus obtaining a saturated solution of KH_2PO_4 . Characteristics of the neutralization process include short process flow, a mature

| |
|---|
| Neutralization process |
| Organic extraction process |
| Double decomposition |
| Ion exchange process |
| Direct method (without industrial production) |

Figure 4-4 Methods of potassium dihydrogen phosphate production in China.

technology, little equipment needed, high quality of product, low energy consumption and low investment. Shortcomings include the high cost of production by using the phosphoric acid by furnace process and K as raw materials and difficult to use in agriculture. At present, throughout the country, the production capacity of KH_2PO_4 accounts for over 90% of the total production capacity.

2. Organic extraction process

Here, wet-process phosphoric acid and caustic K are used as raw materials. The organic solvent dibutyl sulphoxide is used to extract phosphoric acid, enabling 50-60% of the phosphoric acid to enter the organic phase. After separating the water, an aqueous solution of caustic soda is used to carry out counter extraction, making pure phosphoric acid to transform from the organic phase to the aqueous phase to generate KH_2PO_4 .

A great deal of research has been conducted on the extraction process, both in China and other countries. There have been reports on the use of different extracting agents for production. These include *n*-butanol, organic amine, melamine, dibutyl sulphoxide and trioctylamine-cyclohexane-isoamylol. This method has the merits of being a simple process, low energy consumption, mild conditions for reaction and cyclic utilization of the organic solvent. However, the organic solvent is expensive and consideration must be given to its recovery for utilization. Production investment is too high and the process causes environmental pollution. In China, there are relatively more plants that use an organic solvent extraction process to produce KH_2PO_4 . Annual production ranges from 1,000 to 3,000 t, and 5,000 to 30,000 t. The technique is getting better and in comparison with the neutralization process, the cost of production can be reduced by about 25%.

3. Ion exchange process

Through styrene cation exchange resin, KCl solution is used to adsorb K^+ in the solution. Ammonium dihydrogen phosphate solution is then made to exchange ions through resin to give a KH_2PO_4 solution. After concentration, cool crystallization, centrifugal separation and drying, the final product is KH_2PO_4 . The crystallization mother solution returns to the section of concentration to be reused.

Domestically, the Hubei Chemical Research Institute was the organization that developed the ion exchange process for the production of KH_2PO_4 . In 1980, this institute was conferred the State Invention Award for the development of the ion exchange process for the production of KH_2PO_4 . In Huangmei County and the Wuhan City Inorganic Chemical Plant, the institute carried out pilot tests of 500 and 1,000 t/y,

respectively. Based on examination on the cost of production, it was a third lower than the neutralization process at that time. With regard to product quality, $\text{KH}_2\text{PO}_4 > 98\%$ was noted. At present the Tianjin Binhai Fuli Chemical Plant uses the ion exchange process to produce KH_2PO_4 and has a production capacity of 1,000 t/y.

4. Double decomposition process

Reaction between phosphoric acid and ammonium bicarbonate gives rise to ammonium biphosphate which then reacts with KCl to generate KH_2PO_4 . This process does not emit the three wastes. Its production cost per tonne can be RMB1,600 lower. Compared with the extraction process and the ion exchange process it can be RMB1,000/t lower. However, product quality is not comparable with the neutralization, extraction and ion exchange processes and can only be used in agriculture. Currently, Jiaozuo University is carrying out technology transfer of a 6,000 t/y production capacity using the double decomposition process.

Presently, a domestic plant which uses the KCl double decomposition process for the production of KH_2PO_4 is at the Runjia Dongfang Chemical Industry Co., Ltd in Xuzhou which has a production capacity of 1,000 t/y.

4.2.1.5 Potassium magnesium sulphate (K-Mg-SO_4)

Beginning 1980s, based on the foundation of scientific research results by the Salt Lake Research Institute of the Chinese Academy of Sciences, Zhongxing Guo'an Co. used the intermediate product of carnallite in the production of KCl and the rich, natural anhydrous Glauber's salt in Chaidamu Prefecture as raw materials and after 20 years of hard work they came out with their own mature production process. Their core technology is among the leaders internationally. The overall technological content of the project attained an advanced level internationally.

Production processes for K-magnesium phosphate include bittern exploitation from the salt lake, tedding on the salt-field, mixed K salt as raw material, double conversion (Na and Cl removal), drying and forming granules and automatic packing.

4.2.2 Important technological breakthroughs and inventions in the K fertilizer industry

With regard to over 50 years development and production of the K fertilizer industry, China has achieved many important technological breakthroughs and inventions such as the Cl free K fertilizer. A few important technological breakthroughs and inventions with milestone effects in the K fertilizer industry of China are briefly described below.

4.2.2.1 Process #4

In the middle and later years of the 1980s, the Chemical Mines Design and Research Institute of the former Ministry of Chemical Industry (the China Bluestar Lehigh Engineering Corporation) developed the newly patented technique of "Making good-quality KCl from chloride-type K-containing bittern by the method of speed-controlled decomposition crystallization of bittern exchange by Na removal" which included the new idea of removing Na before Mg, unlike

the conventional way. By the skillful use of crystallizers with specific structures, crystallization products of Na oxide and the generated KCl are separated. This process is a uniquely created K fertilizer technique with good prospects. It is different from both the flotation process commonly used in and outside China and the cool crystallization process developed by the Israelis. It is a new technique with Chinese characteristics that resulted from the research and development work conducted by China's scientific personnel in accordance with the conditions in China and the characteristics of the Qinghai Salt Lake and after years of experiments at the site. It is different from conventional techniques and the relevant department named it as "Qinghai Potash Process #4."

Test results have proved that this technique is totally feasible. The results passed the appraisal of senior experts named by the Ministry of Chemical Industry in December 1993. In June 1994, it was awarded the national patent. The first person named in this patented invention, Cheng Zhong, is a research worker in the Lianyungang Chemical Mines Design and Research Institute of the former Ministry of Chemical Industry. In 1999, he was conferred the Class II Scientific and Technological Achievement Award by the National Petrochemical Bureau. In 1997, the Qinghai Salt Lake Group went further and built the Dongfang Quality KCl Experimental Plant with an annual capacity of 40,000 t. This plant has been producing continuously and steadily for more than 10 years, turning out KCl products of excellent quality for industrial and agricultural uses.

Taking into consideration the characteristics of the resources at the Chaerhan Salt Lake in Qinghai Province, the present technique uses bittern at the salt field as raw material. Inside the processing plant, by way of bittern exchange and Na removal, low-Na carnallite is directly produced. This has avoided the complex work process of tedding large areas of salt-field carnallite, exploitation, transport and selection. In particular, there is no longer the need to use expensive equipment such as the hydraulic mining boat, greatly reducing investment in infrastructure and the cost of production.

Bittern exchange in a container is carried out under conditions of artificial control. It can effectively regulate the quality of bittern and conditions of reaction in the exchange. This has avoided the effects of natural factors which are difficult to control in the process of tedding at the salt-field over a large area. This has also effectively ensured the stable quality of carnallite. Separation and Na removal are carried out by the difference in the crystal size from the crystallization using artificial carnallite and mineral impurity NaCl to obtain low-Na carnallite of a higher-grade of KCl, thus, simplifying subsequent processing without having to add any flotation chemical to obtain high-grade, good quality KCl. This has also avoided pollution of the environment and salt lake resources by the use of chemicals. The scope of application of the product is also widened. Low-Na carnallite with mass ratio [$m(\text{KCl}):m(\text{NaCl})$] > 5 have crystals of uniform size and good quality. Besides being a raw material for obtaining good quality KCl, it is also the best raw material for obtaining metallic magnesium by electrolysis. All these have important significance with regard to the comprehensive development and utilization of salt lake resources in Qinghai Province.

4.2.2.2 Counter flotation – cool crystallization process

The “Counter flotation–cool crystallization process” is a K fertilizer production technique developed by the Qinghai Salt Lake Group Ltd. by combining the Israeli cool crystallization technique on the basis of counter flotation of process #4. The technique concerned has been successfully applied in the Salt Lake Phase II 1 Mt-project. It was conferred the National Patented Invention Golden Award.

Since testing and going into production in March 2004, the 1 Mt K fertilizer project in Qinghai, the new technique of “Counter flotation–cool crystallization process” developed by the Qinghai Salt Lake Industrial Group has been operating and producing normally and steadily for more than two years. The average daily product quality of K fertilizer is above 95%. Based on design requirements and conditions of production, the 1 Mt K fertilizer project can reach, in 2006, the production capacity of 1 Mt. Together with the original 500,000 t production capacity of the Salt Lake Industrial Group and the production capacity of the Group’s small-scale production areas, the Qinghai Salt Lake Industrial Group can, in 2006, provide at least 1.5 Mt of high-grade K fertilizer products.

4.2.2.3 Production of SOP using hypo-type $MgSO_4$ bittern

The initial amount of deposits of the $MgSO_4$ hypo-type bittern K ore found in Luobupo in 1995 was verified to be 250 Mt. However, over a long period of time, there was no technology for the production of K fertilizer for agricultural use.

At the “2004 National Scientific and Technological Award Presentation Meeting,” the project “Research in the Development and Utilization of Potash Resources in Luobupo Prefecture” led by the China Bluestar Changsha Design and Research Institute was conferred the Class I National Science and Technology Progress Award. There was a breakthrough in the technology for the application of K in China. “The Environment Report for the Potash Fertilizer Project at Luobupo Potash Base with Annual Production of 1.2 Mt” was also examined and approved by the State Bureau of Environment Protection. Relevant departments of the State agreed to carry out the exploitation of the K ore mine at Luobupo. With this, the strategy of K application in China was fully launched.

The project “Research in the Development and Utilization of Potash Resources in Luobupo Prefecture” adopted the process of SOP obtained from hypo-type $MgSO_4$ bittern and this marked the beginning of this technology in China and made China one of the few countries in the world capable of utilizing salt lake bittern to produce SOP.

At present, major foundation work for the 1.2 Mt K fertilizer project at Luobupo in the Xinjiang Autonomous Region which includes the exploration of resources, tests on the technique, geological prospecting, prospecting of clay resources and water resource prospecting have basically been implemented. Construction began on 25 April 2006. By 2009, a world-class SOP fertilizer production base will be born at Luobupo.

4.2.2.4 Production of agricultural KNO_3 by the high efficiency ion exchange method

As the biggest KNO_3 producing enterprise in China and after years of practical production and meticulous research, based on the original ion exchange method, the Wentong Potash Group developed a process for producing KNO_3 which is suitable for the conditions in China and with its own characteristics - high efficiency ion exchange method. The use of this method has the following advantages:

1. There is advantage in terms of energy. The Wentong Group is located at an energy chemical industry base where it can make use of cheap, good quality, coal resources. Each tonne of KNO_3 consumes 0.3 t of coal and the energy cost is RMB30-40. By using steam, from boilers after combined heat and power generation, to carry out evaporation and concentration of the solution, the energy cost of the product is reduced by 80%.
2. There are advantages in the supply of raw materials. The company has built a base for liquid AN as raw material. It is piped directly to the workshop producing KNO_3 . Each tonne that arrives at the plant costs RMB1,000 which is RMB400-600 lower than those plants without their own AN installation built. Another important breakthrough in KNO_3 production technique is the use of the KCl produced by the Qinghai Salt Lake Group to produce KNO_3 nitrate. This further reduces the cost of KNO_3 products.
3. There is the advantage of AC recovery. The AC solution discharged in the course of ion exchange production can be recovered as a part of the process. This is a breakthrough with regard to equipment. Industrial AC can be successfully produced this way. This is a unique domestic technique which saves energy, protects the environment and achieves the requirement of no discharge of wastewater in the course of production, thus complying with environment protection requirements.
4. There is the advantage in terms of scale. The scale of KNO_3 production is 200,000 t/y, the largest KNO_3 producing enterprise. Domestic market share is above 50%.
5. There are advantages in granulation. The Wentong Group now has the production capacity of 40,000 t of granular KNO_3 . The granulometry range is 0.5-3 mm. The granulation technique is the first in China and is in a leading position internationally. This has solved the problems of product storage, transport and the requirement for agricultural KNO_3 fertilizer to be released slowly.

4.2.2.5 Chinese made equipment for the production of Mannheim process SOP

To import the Mannheim production process equipment capable of producing 10,000 t requires an investment of about RMB30 M, which is a huge investment. Therefore, research into the domestic manufacture of production equipment for Mannheim process SOP has an important significance in spurring the development of SOP production in China. The earliest to be engaged in this aspect of work was Professor Liu Renmin of Liaocheng University. Professor Liu led a group in designing and manufacturing the new type of roasting reacting furnace for the improved Mannheim process which successfully resolved the problem of anti-corrosion materials against high temperature and strong acid of high

concentration. This was a key step for the domestication of the technology and equipment for the production of SOP by the Mannheim process. In response to the technical problem of continuous raw material injection and production, sulphuric acid and KCl distributing devices were designed to achieve continuous raw material injection and production and to raise product quality. Research workers also improved the heat supply system to the Mannheim furnace, changing the original supply from heavy oil combustion to hot coal gas supply from a coal gas furnace, to reduce cost. In response to the high temperature of the hydrogen chloride discharged from the reaction furnace which contains a certain amount of SO_2 , they even designed a heat exchanger and S remover. Through technical reform, heat exchange and S removal can be carried out simultaneously, thus ensuring the high quality and high rate of absorption of hydrochloric acid. Resulting from the solution to the above-mentioned key technical problems, SOP production equipment by the Mannheim process was developed. The quality of the SOP products reached the target of internationally high-class products.

The Mannheim process production installation, with its entire set of equipment designed in China was set up in more than ten companies that include Liaocheng Lufeng Potash Fertilizer Co. Ltd. of Shandong Province, Dalian Ruize Chemical Plant and Panjin Yongxing Chemical Industry Co. Ltd. Investment for the entire set of production installation was only 20% of the imported equipment. The payback period of the project is 2.2 years.

Compared with SOP production equipment in other countries, its outstanding features include low investment and simple operation. A national patent has been applied for this set of equipment, with patent number is ZL 01 2 43499.X. This "Technical Development of 10,000 t agricultural SOP" has passed appraisal by the experts and was conferred the Class II Science and Technology Spark Award by Shandong Province and the Class I Liaocheng City Award.

4.2.3 Outlook for the technological development of the K fertilizer industry in China

The experience in the development of salt lakes for almost 50 years has proven that the counter flotation-cool crystallization process is the technology, which should be promoted and improved upon in the future, for the production of excellent quality KCl from chloride-type salt lake bittern. Process #4 is also an innovative technology which must be advocated and vigorously promoted for producing KCl from salt lake bittern.

Owing to the strong demand for Cl-free K fertilizer in China, there has been the rapid development of SOP, KNO_3 and K-Mg fertilizer industries in the past 10 years. From nothing at the beginning, they have become important industries with appreciable scale in terms of production capacity. They have made their contributions to the national economy and agricultural production. However, from the review above we can see clearly that, due to development without proper order over many years, many obvious problems have arisen. Examples include the very small scale of production, the absence of unified planning in the regional distribution of production capacity, the low quality of business operation, development and innovation of production technology and the

sustainable development in terms of resource utilization. On the other hand, with continuous scientific and technological development and the arrival of the era of knowledge economy, movement is fast towards the integration of the global economy. Coupled with its accession to WTO, China's economy is now integrated with the world economy to a large extent. In addition, as China is implementing the strategy of grand development for the western part of the country, the socio-economic background for the development of Cl-free K fertilizer industry will be changed totally. New development trends which are favourable to the adjustment of industrial and product structures have emerged.

After more than ten years of rapid development, the production technology of the SOP industry in China has experienced importation, absorption, digestion and self-innovation, establishing a development path with special characteristics. In this aspect, the gap with the rest of the world has been narrowed in respect of the production technology of SOP. At the same time, the scale of the SOP industry has expanded. This has laid the foundation for self-innovation and development in the future. It can be seen, from the current conditions of the technological development of SOP, that domestic production techniques with autonomous intellectual property rights which comply with the characteristics of China's K resources have emerged. Examples include the technique of obtaining SOP by using sulphate-type salt lake bittern, the technique of obtaining SOP by using salt-making bittern and the preparation of SOP from mixed salts and KCl. These techniques represent hope for the future development of the SOP industry in China. They are also a basis for China's SOP industry to participate in the global competition.

A technique which should be developed in the future is another new Glauber's salt method SOP – technique for the production of excellent quality SOP by decomposition crystallization with controlled speed. This technique has achieved key breakthroughs based on the foundation of the conventional technology. It makes use of the basic principle of the conversion of Glauber's salt and KCl to generate SOP. By applying the relevant phase diagram and the theory of decomposition crystallization with rate determination, the improved liquid phase constitution point G is ingeniously selected to be the dosing point. Glauber's salt and KCl are treated inside the reactor which is equipped with internal circulation crystallization and grading installations to enable material reaction, crystallization grading, separation of impurities and mother liquid circulation to be carried out synchronously. A new technique is used to treat the mother liquid. After direct evaporation of the mother solution, by-product NaCl of the highest quality will be obtained. As the process flow is greatly simplified, the cost of processing is, to a large extent, reduced. Purity of the main product of SOP can be above 98% and the chloride ion content is less than 0.5%, which comply with technical indices of industrial grade SOP. In 1995, this technology was examined and listed as an important scientific and technological achievement by the NDRC and the former Ministry of Chemical Industry and went through technical appraisals. In 1997 it was approved as "achievement in high and new technology" by the province of Jiangsu and was listed as a programme to be seriously tackled

in the 9th Five-Year Plan. It was, for a time, promoted as the leading technology in the production of SOP in China.

In 1998 a demonstration installation of SOP with a production capacity of 50,000 t a year was set up in the Lianyungang Zhonghau Potash Centre. It was responsible for testing the installation which was successfully run in August 2000 and more than 1,000 t of excellent quality SOP was produced. Due to various reasons, this technology did not go into industrial production. The technology had two breakthroughs. Firstly, granulation of SOP is speed-controlled crystallization. Granules are large and of good quality. Secondly, the NaCl recovered by evaporation through bittern exchange is of good quality and can achieve 99.9%, a top grade product internationally. Further studies on its industrial production have to be carried out, in the hope that it will become a SOP production process of Glauber's salt method.

With respect to agricultural KNO_3 , the techniques which should be developed are high efficiency ion exchange, double decomposition circulation process and double decomposition crystallization process.

As for K-dihydrogen nitrate, the new technique of producing K-dihydrogen nitrate directly with sulphuric acid and KCl as raw materials has not been applied to industrial production in China. This process was first announced by the *Geerding* Fertilizer Company of Ireland at the technical meeting of the International Fertilizer Industry Association (IFA). The method is generally regarded as a relatively economical way of producing K-dihydrogen nitrate. On this basis, the Israeli Rotem Company adopted the direct flow method and in 1987 applied for a technological patent in the US. A pilot trial was carried out in 1988 and in 1990 an industrial scale installation was built. It went into production in August 1993. The new technique made use of cheap phosphorus ore, sulphuric acid and KCl, not the expensive phosphoric acid and K-hydroxide in the existing process. Thus, the production cost of K-dihydrogen nitrate was only RMB2,000/t. It is estimated that in the next 5 years, the application of K-dihydrogen nitrate in agriculture and industries will increase rapidly and domestic enterprises and research units should expedite and put in more effort in the development of low-cost production technology – the direct method. They may do so by import or cooperative development to resolve technical difficulties as soon as possible so as to realize its industrial production in China and in order to spur the development of a K-dihydrogen nitrate industry.

4.3 Development of K fertilizer enterprises in China

4.3.1 A survey of the development of K fertilizer enterprises

4.3.1.1 KCl Enterprises

The establishment of Chaerhan Potash Fertilizer in Qinghai Province in 1958 marked the beginning of K fertilizer enterprises in China. Growth in recent years has been spectacular. There are more than 50 K fertilizer enterprises.

More than 30 of them are at Chaerhan Salt Lake. Data indicate that from 2000 to 2003, the annual output of KCl averaged about 1.4 Mt. In 2004, owing to the establishment and trial production of the 1 Mt K fertilizer project in Qinghai, output shot up to 2.3 Mt. In 2005, output of KCl was 2.6 Mt. In the Chaerhan Prefecture of Qinghai Province, apart from the largest Qinghai Salt Lake Group, using the Qinghai-Tibet Railway as the line of division; to the east of the railroad there are more than 30 local enterprises producing KCl. They include the Golmud Hanhai Group, the Chaidamudi Mine and Chemical Plant, Qinghai Golmud Jinxin Potash Fertilizer Co. Ltd., Qinghai Dachaidanqingda Potash Fertilizer Co. Ltd., Qinghai Mangyaxingyuan Co. Ltd. and Golmud Qingfeng Potash Fertilizer Co. Ltd. The scale of production is 1 Mt of KCl per year. The production technique is mainly the cooling decomposition – flotation process.

4.3.1.2 SOP Enterprises

From 1992, SOP projects were established one after another. According to incomplete statistics, there are more than 130 SOP enterprises, including those already set up, being set up (including expansion) and planned-to-be set up. In 2005, plants of the Mannheim process which include those of Qingshang, Nissan and those built by China numbered 150. In 2006, 14 sets of Qingshang installations were planned. In this way, Qingshang Mannheim installations will number 60 and Mannheim installations in China will total 180 sets. The main enterprises are the Migao Group and the Qingshang Group of Taiwan. Together with Glauber's method, plants for producing SOP from magnesium sulphate hypo-type bittern used by Shandong Haihua and Xinjiang Luobupo Potash Science and Technology Development Co. total production capacity of domestic SOP is more than 2 Mt. The actual annual output is 800,000-900,000 t.

The Mannheim process is the main method of SOP production in China but those that achieve the benefits of scale number less than ten. The small-scale operation is limiting the international competitiveness of the SOP industry. The very formation and survival of these small SOP-producing plants originated from the lax K fertilizer policy and serious shortage of SOP output in China. However, following changes in the external conditions of survival for SOP production, a large number of plants which lack the benefit of scale will have to face new adjustments and reorganization. With the help of policy and the power of marketing, they will have to carry out the reorganization of stock resources. This will be the route to be taken by SOP plants in China in order to raise their competitiveness.

4.3.1.3 KNO_3 enterprises

There has been great progress in agricultural grade KNO_3 in the past 2 to 3 years. The total production capacity in China is close to 300,000 t/y. The chief production plants include Yichun Tengda Co. Ltd. in Jiangxi Province (annual production of 25,000 t for the production installation of double decomposition process, expanded to produce 50,000 t/y in 2007), Wentong Potash Group Co. with an installation producing almost 80,000 t/y of agricultural grade KNO_3 by the ion exchange process (total production capacity of 200,000 t/y of industrial and agricultural grade KNO_3 ,

specifically producing agricultural grade or industrial grade depending on market conditions); the Migao Group with a 60,000 t/y double decomposition installation, Yunnan Wotewei Chemical Industry Co. Ltd. with a 75,000 t/y production installation and Hunan Jinye Fertilizer Co. Ltd. with 20,000 t/y of KNO_3 . In recent years, many regions in China have been working out plans to build new plants for the production of agricultural KNO_3 or expand their existing installations. There are about 50 enterprises producing KNO_3 in China, most of them applying the double decomposition method of production.

4.3.1.4 Potassium dihydrogen nitrate (KH_2NO_3) enterprises

China has 40-50 plants producing KH_2NO_3 and it is the world's largest producer and consumer. China's production capacity is 340,000 t/y with an output of 178,000 t/y. The province of Sichuan has a production capacity of 220,000 t/y. Output is about 70,000 t/y in Hubei Province and 17,000 t/y in the province of Yunnan.

The total sales volume of KH_2NO_3 in 2005 was 5,700 t (referring to small packets of 50-1,000g, not including bulk sale). Some agricultural enterprises do not produce KH_2NO_3 but purchase from outside in bulk and pack the fertilizer under their own brands. The sales volume is estimated to be within 1,000 t. There are enterprises that produce foliar fertilizers which buy KH_2NO_3 to be used as ingredients of P and K. The volume of consumption is estimated to be around 1,000 t. There are some large farms of agricultural crops which use KH_2NO_3 in bulk with the volume of consumption estimated at 2,000-3,000 t. The total volume is about 10,000 t. In 2006, the estimated sales volume will reach around 21,000 t. Therefore, the actual volume of consumption of KH_2NO_3 by agriculture is not large.

4.3.2 History of development and prospects for major K fertilizer enterprises in China

4.3.2.1 Qinghai Salt Lake Industry Group Ltd.

Qinghai Salt Lake Industry Group Ltd. is a representative enterprise in the production of KCl using chloride-type salt lake bittern in China. The history of development of K fertilizer enterprises in China is mostly the history of the development of salt lake groups. They are currently the largest KCl production enterprises in China. Close to 70% of the KCl in China comes from the salt lake group companies. Salt lake groups are the weather vanes of the development of K fertilizer industry in China.

In 1956, research and development of salt lake resources was listed in "Long-term planning of important science and technology over a period of twelve years" in China. Scientific research personnel and volunteers for the development of western China were organized and stationed at the Chaerhan Salt Lake. Under circumstances where production, living conditions and technology were less than ideal, the Chaerhan Potash Fertilizer Plant (currently the Eastern Workshop of the Qinghai Salt Lake Group Co. Ltd.) was established in August 1958. In that year, 953 t of K fertilizer was produced using the indigenous method. This broke the record of hitherto zero production. From here the curtain was raised

on the K fertilizer industry in China. Preparatory work for Phase I of the Qinghai K fertilizer project began in 1975. Construction began in 1986. In 1989, construction was completed and the project went into production. In 1986, 1990 and 1993, the feasibility study reports for domestic sole investment and Sino-Israeli joint venture for Phase II of the project were completed. In 1996 and 1997, the parts to be designed by the Chinese; bittern collection, bittern transport, salt field and discharge of used bittern and the initial design and construction drawings for its supplementary supporting constructions were completed. In October 2000, the NDRC approved the construction of one of the ten important projects among the first batch of projects for the grand development of the western part of China – the Phase II KCl project of the Salt Lake Group with an annual capacity of 1 Mt. The project was completed in October 2003. In 2004, tests on the 1 Mt project went smoothly and in that year, turned out 550,000 t of 96% product. Currently, the Salt Lake Group has six subsidiaries with shares directly or indirectly under its control, three fully owned subsidiaries, four branch offices and one subsidiary of share participation. There is a technology centre at the national level. Employees number 5,000. Up to the end of 2004, the total assets of the entire group reached almost RMB5 B. In 2004, output of K fertilizer by the Salt Lake Group broke the one million mark for the first time. It produced 1.1 Mt of KCl. At present, the Salt Lake Group's K fertilizer industry has a production capacity of 1.5 Mt. It has established a system which is complete with research and development, production and business operation, logistic services, construction and installation. The Group has trained and built up a construction and development team with a high degree of professionalism. With an increase in the capability to explore and expand potential production capacity and utilize resources, the capacity of the K fertilizer installation of the Salt Lake Group reached, by the end of 2005, 1.8 Mt/y. By 2010, it will reach 2 Mt/y.

The short and medium-term development strategy of the Salt Lake Group is to establish large projects with the advantages of local resources, advanced and mature technology, large market volume, good development prospects and strong competitiveness through the combination of natural gas and salt lake. The Group aims at the promotion of profound development of salt lake resources and their comprehensive utilization. In 2004, the confirmed Phase I project construction was the establishment of installations with annual production of 60,000 t of K hydroxide, 72,000 t of KCO_3 , 100,000 t of PVC, 330,000 t of urea and the construction of a heat supply system with a capacity of 7.5 Mt that completes the production network. In January 2006, the Qinghai Salt Lake Potash Fertilizer Co. Ltd. announced its three principle projects in the erection of a heat supply centre, the expansion of the capacity of the railroad line for special purpose and the establishment of a 200,000 t installation for the production of KCl by the direct flotation process. These three projects were meant to increase the production of K fertilizer and transport capability. The total production capacity reached 1.8 Mt in 2006.

During the period from the 11th Five-Year Plan and the 12th Five-Year Plan, the Qinghai Salt Lake Industry Group will invest RMB10 B to get the "salt lake one million-tonne

K fertilizer comprehensive utilization project” started and vigorously develop and utilize the salt lake resources of Chaerhan Salt Lake.

In the course of history spanning almost 50 years, important events that have taken place in Salt Lake Group are: Firstly, was the successful development of the counter flotation-cool crystallization process with autonomous intellectual property rights and its successful application in the Phase II salt lake project with a capacity of 1 Mt/y. The second was the successful application for “renowned brand of China” for its “Salt Bridge” brand of KCl and the third was the successful research and development of the hydraulic mining boat.

4.3.2.2 Migao Group

The Migao Group represents the production of agricultural SOP by the Mannheim method in China. Its main products are KNO_3 , SOP, AC and HCl. The Group has set up four plants: Sichuan Migao, Guangdong Migao, Liaoning Migao and Shanghai Migao. There are plans to expand in southeast China and the central part of north China.

At present, the company has annual production capacities of 140,000 t of agricultural SOP, 168,000 t of HCl, 60,000 t of KNO_3 for agricultural use, 50,000 t of AC containing K and 200,000 t of H_2SO_4 . The actual output KNO_3 for agricultural use, will be topping the list among enterprises of the same industry throughout the country. Migao Chemical Industry (Shanghai) Co., Ltd. is the fourth largest-scale chemical plant invested in and built by the Migao Group in China. It is estimated that construction will be completed in September 2007. When the plant goes into production, it will help the Migao Group increase its annual production of industrial and pharmaceutical grade HCl by 96,000 t and the production of high-purity SOP by 80,000 t.

4.3.2.3 Tengda Chemical Industry Co. Ltd. in Yichun City, province of Jiangxi

Tengda Chemical Industry Co. Ltd. in Yichun City, province of Jiangxi which represents enterprises for the production of KNO_3 by the double decomposition method, was the earliest organization in China to develop the technique of producing KNO_3 by double decomposition. It is a large production enterprise of industrial and agricultural grade KNO_3 . Since its formation six years ago, it has become an important chemical industry enterprise in Jiangxi Province. In 2003, it was recommended as an executive director organization in the petrochemical trade of Jiangxi Province. It was the first batch of honest and trustworthy enterprises in Jiangxi Province. The Jiangxi Branch of the China Agricultural Bank awarded it with the “AAA” credit grade. It was commended by the Association of Chinese Chemical Industry enterprises as an enterprise whose product quality can be trusted. It was awarded ISO 9001:2000, making it an enterprise certified by the International Organization for Standardization (ISO). Its motto is Quality, Honesty and Creditability. The “Yuanzhou” Brand of industrial and agricultural KNO_3 produced by the company is the only product in the country where the main content of KNO_3 is $\geq 99.7\%$.

4.3.2.4 Wentong Potash Group Co., Ltd.

The Wentong Potash Group is an enterprise representative of agricultural KNO_3 production by the ion exchange method. The predecessor of Wentong Group was the Wenshui County Chemical Plant in Jiangxi Province (in 1993, the name was changed to the Shanxi Potash Plant). In 2001, the Headquarters of the Group was moved to Shanghai. It now has its production base in Jiangxi Province but makes Shanghai its marketing centre. It is a large group-company with centralized management of its production, supply, sale, manpower, finance and materials. It is the largest KNO_3 production enterprise in China and has become a large enterprise group with diversified investments, large-scale production and international business operation with scientific management. Its production capacity is 200,000 t/y, of which 80,000 t is agricultural KNO_3 .

The KNO_3 production technique of Wentong is the high efficiency energy-saving ion exchange process developed and improved constantly by the enterprise itself. The new process of “ion exchange method” was conferred the Class I Scientific and Technological Progress Award by the province of Jiangxi. Wentong Group was the pioneer in replacing imported KCl with that from Qinghai Salt Lake to reduce product costs. Through their research, the Group had successfully produced the granular KNO_3 product that resolved the caking problem. AC solution of medium and high concentration is recovered directly for the production of AC products. Technical advantages create an advantageous industrial chain. The Wentong Group is able to adjust its industrial structure according to market changes. The Group is further enhancing its cooperation with the Qinghai Salt Lake Industry Group so as to make full use of the technological advantage of the Wentong Group and the advantage of resources of the Qinghai Salt Lake Industry Group. For synthetic ammonia, the by-product of Phase II work of the project on the comprehensive utilization of KCl from Golmud in Qinghai Province, the K fertilizer of Qinghai Salt Lake Industry Group and the establishment of a 200,000 t installation for agricultural KNO_3 using the ion exchange method, initial work of the project has been fully launched. According to estimates, the cost per tonne of agricultural KNO_3 will be RMB800-1,000 lower than the cost of product from the existing installation of the Wentong Group. The product will have obvious competitive advantages.

4.3.2.5 Xinjiang Luobupo Potash Co. Ltd. invested by the State

Xinjiang Luobupo Potash Co. Ltd. invested by the State is a representative enterprise for producing SOP from MgSO_4 hypo-type salt lake bittern. Set up in September 2000, the company was reorganized a number of times. Currently, its stocks are controlled by the National Development and Investment Company, the biggest investment holding company in China. The other shareholders are the Bureau of Geology and Mineral Resources Prospecting and Development, Xinjiang Uygur Autonomous Region, the Xinjiang Beyin State Assets Business operation Ltd. and the Changsha Design and Research Institute of the Ministry of Chemical Industry. The registered capital was RMB540 M. Total assets amounted to RMB690 M. The place of registration is Kuerle City in the

Xinjiang Autonomous Region. The principle business activity of the company is to produce SOP and KCl by working on the natural bittern resources at Luobupo.

Since the formation of the company and by relying on its own scientific and technological strength, absorbing the experience and lessons learnt by both domestic and foreign enterprises in the development and processing of salt lake bittern, through small-scale tests and pilot tests, the company managed to develop a world-class processing technology with autonomous intellectual property rights. The company was conferred several awards that include the Class I National Scientific and Technological Progress Award. An application has been made for the State Patent. On 1 July 2003, an experimental plant for the annual production of 20,000 t of SOP was built. Currently, 21.6 km² of salt field has been established, giving a production capacity of 100,000 t. Construction work on the largest SOP project in the world—the Luobupo Project - capable of producing 1.2 Mt/y of SOP began in April 2006. It will be complete for test production at the end of 2008.

4.3.2.6 Shanxi Potash Fertilizer Co., Ltd.

Shanxi Potash Fertilizer Co., Ltd. is the Chinese representative for the production of SOP by the Glauber's salt method. The Shanxi Potash Fertilizer Co. Ltd. is a joint venture SOP-producing enterprise formed jointly by the Nanfeng Chemical Industry Group and the China Tobacco Company. The company produces as much as 180,000 t of SOP. It has a unique production technique, it adopts the "Glauber's salt method" with some improvements developed on its own. It is a technique considered as advanced in the world and leading in the country. It was conferred the Class I National Scientific and Technological Progress Award for the year 2003. The raw material, natural Glauber's salt, is obtained from the Yuncheng Salt Lake. Glauber's salt is rich in micronutrients such as B, Fe, Mg, Ca and Zn. It does not contain free acid and the content of chloride radical is extremely low.

4.3.2.7 Qingshang Chemical Industry (China) Investment Co., Ltd.

Qingshang Chemical Industry (China) Investment Co., Ltd., is the representative of the production of agricultural SOP by the Mannheim method by the Qingshang Company of Taiwan in Mainland China. Qingshang Chemical Industry was set up in Kaohsiung, Taiwan in 1970. The pioneer of the company, Mr. Chen Yiquan imported the German Mannheim method for the production of SOP. He worked very hard to overcome many problems. He carried out a series of improvements to the imported equipment to perfect the Mannheim production technique. He was able to achieve stable and high production, low consumption and long periods of operation. As China lacks K fertilizer production technology, Mr. Chen Yiquan was keen to introduce his SOP production technology to Mainland China, where cheap and good-quality SOP can be produced to reduce dependence on imports. Driven by economic reform, the Qingshang Company built the first SOP production line using the Mannheim process on Mainland China in 1994. This laid the foundation of the SOP industry in China. Subsequently, Mr. Chen Yiquan built 60 Mannheim installations by joint venture or independently in places

which include Shanghai, Panjin in Liaoning Province, Lunan in Shandong, Qingdao in Shandong, Foshan in Guangdong, Kaifeng in Henan, Guangzhou, Xiamen in Fujian, Zhunyi in Guizhou, Chengdu in Sichuan and Zhuzhou in Hunan. The total SOP production capacity of Qingshang Chemical Industry in Mainland China has reached 600,000 t/y and the production capacity for HCl is 720,000 t.

4.3.2.8 SOP Plant of Shandong Haihua Co., Ltd.

The SOP Plant of Shandong Haihua Co. Ltd., uses underground bittern to produce SOP. It is situated to the northwest of Weifang City which is nicknamed the world's capital of kites. Weifang City is located to the northeast of Shouguang City, China's largest vegetable production base. To its north is the Cailai Bay on the Sea of Bohai. There is a rich supply of underground bittern. The production technique used is double decomposition of MgSO and KCl. The technology used is the original creation in the country and at a leading level internationally. It was conferred the Class II New Product Award by the Gunagdong Economic and Trade Committee, Class II Scientific and Technological Progress Award conferred by the China Light Industries Association and the Class III National Technical Invention Award. Its fixed assets amount to RMB56 M. Designed production capacities are as follows: 20,000 t/y of SOP (granular and powder forms), 10,000 t/y of Mg-KSO₄, 15,000 t/y of *Hailei Shuichong* fertilizer and 86,000 t/y of magnesium chloride.

4.4 Important events in the technological development of K fertilizer and some of the technical experts and entrepreneurs

Looking at the 50 year history of the K fertilizer industry in China, Yuan Jianqi, An Pingsui, Li Xiaosong, Cai Binghua and Li Gang are among those who have contributed to the brilliant development of the industry in China. The domestic production of Process #4, counter flotation-cool crystallization process, high efficiency ion exchange process and the Mannheim process and equipment for SOP, and the new technique for producing SOP from the bittern of Lupbupo Salt Lake are techniques that were born in China. The 1 Mt per year Phase II MOP project of the Qinghai Salt Lake Group was successful at its first trial; work commenced on the construction of the SOP project with a capacity of 1.2 Mt/y at Luobupo, Xinjiang; the first K fertilizer project to go abroad started work on the 50,000 t/y KCl demonstration project in Vientiane, Laos and the production capacity of 200,000 t/y of KNO₃ achieved by Wentong are important events for the K fertilizer industry of China. We could have written a lot more on these people and events but due to limited space, we have selected just a few for our description.

4.4.1 Important events

4.4.1.1 Establishment and production of the million-tonne KCl project of the Qinghai Salt Lake Group

At 3 in the morning of 27 October 2003, the one million-tonne KCl project of the Qinghai Salt Lake Group built with production technology developed completely in house was

completed and tested with injection of raw materials. The test was a success. It was a dream realized for people in the K fertilizer industry after half a century. With an investment of RMB2.6 B, the Qinghai million-tonne KCl project is one of the ten construction projects of the grand development of western China that is the focus of people throughout the country. Work on the engineering construction began in May 2000. The project is under construction. It adopts the counter flotation-cool crystallization production technique, flotation agents, the technique of hydraulic mining boat and automatic control technology at world-class levels developed by engineering and technical personnel of the Salt Lake Group on their own initiatives. In addition, more than a thousand tests were made to improve, optimize and perfect the mining and transportation of bittern, production technology and automatic control systems to enable the entire production system to become simpler and smooth with better automation performance to greatly increase product quality and production capacity.

4.4.1.2 China's biggest overseas K fertilizer project – commencement of work on the Laotian Potash ore project

In January 2006, the biggest project in the economic cooperation between China and Laos – work on the development of a 50,000 t/y good-quality KCl demonstration project with K from the Vientiane Plain in Laos was officially started. The Yunnan Sino-Laotian Mining Development and Investment Co. Ltd. was fully in charge of the development of this project. The company is joined by the Yunnan Provincial Geological Mining Company and the Yuntianhua Group to form a cooperative body. Besides, Tianjin University, Chongqing Industrial Equipment Installation Group and the Yunnan Construction and Engineering Group with the technological standards and the strengths in research were attracted to the project. The commencement of work on the Vientiane project was an important event in the history of K fertilizer industry development in China. It was the first time the Chinese geological and mining department participated in a foreign project by going through the entire process that started with risk prospecting and system technology tests before a large-scale mining enterprise was established in the end. It will have significant effects on the optimization of domestic deployment of mineral resources and improvements to the present condition of K shortage. This project is also a life project that is the embodiment of painstaking labour and wisdom of the Chinese government and people.

The course of its development is as follows: In November 2000, leaders from the two countries signed the agreement in principle with regard to the prospecting and development of K in the Vientiane Basin. On 10 July 2001, the agreement of a feasibility study was signed in the Laotian capital of Vientiane. This marked the official commencement of the biggest mining project under the strategy of “going abroad” implemented by the Department of Geology and Mining. In November 2004, the “Agreement on the Exploitation and Production of the Vientiane Basin Potash Mine in Laos” was officially signed and the “Investment Licence and Mining Licence” awarded by the Laotian government were obtained. The Yunnan

Sino-Laotian Mining Development and Investment Co., Ltd. obtained the exploitation rights authorized by the Laotian government on 78 km² of land with 860 Mt of K reserves and 30 years of mining rights (which can be extended twice upon expiry, each extension being 10 years).

The Laotian Vientiane Basin is adjacent to the province of Yunnan, China. The potash-containing area is close to 2,000 km². Initial prospecting proved that in the two selected areas, the verified reserves amounted to 100 Mt with prospective reserves at 13.4 Bt of KCl. The reserves are considerable. As the Laotian government has given China the right to exploit for 50 years at no charge, it is China's biggest offshore K fertilizer production base. This can be implemented in three stages: Firstly, complete the construction of the demonstration work for the annual production of 50,000 t of good-quality KCl which was approved by the NDRC and put it into production. This is to provide the base reference for the construction of the production installation with annual production of 1 Mt of KCl. Secondly, in accordance with provisions of the agreement on the development of K salt signed with the Laotian government, build up the million-tonne production installation in 5-8 years. Thirdly, under the prerequisite of stable production of the installation for an annual production of 1 Mt KCl, build another installation which can produce more than 3 Mt of KCl a year. This project will change the present situation where China depends mainly on imports for agricultural K fertilizer. The project will also become China's main K fertilizer production base outside China.

4.4.1.3 Commencement of work on the 1.2 Mt SOP project at Luobupo, Xinjiang

On 25 April 2006, construction work on the 1.2 Mt/y SOP project of Luobupo Potash Co. Ltd. of the State Development and Investment Company began in Luobupo in the Xinjiang Autonomous Region. This is an important milestone in the development of the K fertilizer industry in China. Total investment in the project is about RMB4 B. With the Industrial and Commercial Bank of China taking the lead, together with the Agricultural Bank of China and China Merchants Bank, loans amounting to RMB2.6 B were extended to the project. At present, 100 km² of salt field has been established, giving a production capacity of 100,000 t of K fertilizer. This has laid the sound foundation for the establishment of the 1.2 Mt/y SOP project. The project is expected to be fully completed and go into production in 2009. To date, Luobupo is the biggest sulphate-type K-containing bittern deposit discovered in China. Currently, there are three K deposits found to have a total area of 10,000 km² with industrial reserves of 243 Mt. K oxide, are about twice the size of the Chaidamu Basin in Qinghai Province, presently the largest K fertilizer production area. It is 67% of the country's industrial reserves. It is the only existing and verified super large K deposit site. Currently, China's production capacity for SOP is only 2.1 Mt and most of this is conversion product with a higher cost of production. The “process of obtaining SOP by utilizing the K-containing bittern at Luobupo” is unique in the world and the installation is the first of its kind. The cost of production is tremendously reduced. It is more suitable for sale in the Chinese market.

4.4.1.4 The establishment of the Wentong Salt Bridge Company

In early 2003, Shanxi Wentong Potash Group Company and Qinghai Salt Lake Industry Group jointly invested RMB400 M to set up the Shanxi Wentong Salt Bridge Compound Fertilizer Co. Ltd. at the Baijinbao Chemical Industry Park, Luliang Prefecture, Shanxi Province. On 10 March of that year, work on a project to produce 50,000 t/y of agricultural KNO_3 and 50,000 t/y of KCO_3 was started. This marked the entry into the business of agricultural KNO_3 of the largest enterprise in China – the Wentong Potash Company. Due to market demands, production line for two products can be made to produce just one product. The company made full use of the technical advantage of Wentong, the advantage of coal resources in Shanxi Province and the advantage of 200,000 t/y of direct flotation KCl resources from the newly built installation of the Qinghai Salt Lake Group to produce synthetic ammonia with its own anthracite. From synthetic ammonia, AN is produced. Finally, agricultural KNO_3 is produced by Wentong's own high efficiency ion exchange process by using middling coal and coal gangue generated from local coking to have a combined heat and power production. The power generated is used to operate the installation while the steam is used in chemical production, thus forming a coal-power-chemical industrial chain. This has obvious advantages in the cost and scale of production. It has also enhanced the market competitiveness of agricultural KNO_3 . The establishment of the Wentong Salt Bridge Company is an important milestone in the developmental history of agricultural KNO_3 in China.

4.4.1.5 The biggest agricultural KNO_3 producing company using the double decomposition method in China went into production

On 18 April 2003, the Yunnan Wotewei Chemical Industry Co. Ltd. was formed. It is the biggest enterprise in China which uses the double decomposition method to specialize in the production of agricultural KNO_3 . The Yunnan Wotewei Chemical Industry Co. Ltd. made use of the KNO_3 and compound fertilizer installations of the People's Liberation Army Fertilizer Plant as its foundation to bring in capital from private enterprises in the eastern parts such as the Yunnan Petrochemical Group Co. Ltd., the Yunnan Province Development and Investment Co., Ltd. the Yunnan Province State Assets Operation Co. Ltd., the Wuxi Zhongxing Biochemical Engineering and Manufacturing Co. Ltd. and the Kaiyuan Jiehua Investment Management Co. Ltd. These companies jointly contribute funds to set up the company, which built an installation capable of producing 50,000 t/y of KNO_3 , which together with the original production capacity of Jiehua of 25,000 t of KNO_3 brought the total production capacity to 75,000 t/y. When pressures were off market supply of agricultural KNO_3 , another issue was the possibility of extending and applying the production technique of double decomposition circulation. Wotewei has plans to gradually increase the scale of production to 100,000 t/y in accordance with demands from the international and domestic markets.

4.4.1.6 Phase I “Guo'an Brand” K-MgSO_4 went into operation

The Phase I 300,000 t/y K-MgSO_4 production line of the Guoan Qinghai Xitai Jinaier Salt Lake was finally put into trial production in the third quarter of 2005. Operation was normal and it achieved the designed production capacity in 2006, with production and sales of more than 200,000 t. At present, Guoan has drawn up plans to expand the production capacity of K-MgSO_4 at Xitai Jinaier Salt Lake in Qinghai Province to 1 Mt/y. The Phase II K-MgSO_4 production line is presently in intensive preparation. The Qinghai provincial government has given its support to the Qinghai Guoan Xitai Jinaier Salt Lake comprehensive development project in many ways. In order to ensure the transport of the Xitai Jinaier Salt Lake K-MgSO_4 and other products, the Qinghai provincial government changed the route of national highway 315. In the past, the highway passed through Dachaidan, Yuka, Nanbaxian and Yiligou to Huanggualiang. A new route linking Lucaoshanso with Huanggualiang via the Sebei Gas Field, Xitai Jinaier Salt Lake and Yiligou was constructed. The national highway along the new route will pass through the the Xitai Jinaier Salt Lake region. At present, foundation construction of national highway 315 has basically been completed. This will create favourable conditions for the development of Qinghai Guoan Salt Lake and the transport of products out of the region.

4.4.1.7 The recognition of the “Salt Bridge” trademark of the Qinghai Salt Lake Group as a renowned trademark of China

In 2002, the “Salt Bridge” brand of the Qinghai Salt Lake Group was recognized as a renowned trademark of China. This marked the true rise of China's K fertilizer enterprises, with great improvement in product quality. The “Salt Bridge” trademark was officially registered in 1983. However, output was only several tens of thousands t/y at that time. The KCl content was only 60-85% whilst water content was more than 10%. Confronted by increasing imports of K and increasing pressure from competition, the Qinghai Salt Lake Group was determined to radically raise product quality and change product image. In 1997, on the basis of having successfully operated the new technology of “counter flotation-cool crystallization,” the company achieved a big rise in product output and quality. The company has totally changed its former state of backwardness. In 2001, salt lake KCl output reached 500,000 t and the grade of KCl was raised from the original 90% stability to more than 95%. The ratio of grade I product was raised from the original 70% to about 90%. In addition, with cooperation and support from the agricultural technology extension department, the Salt Lake Group threw in close to 10,000 t of their products free of charge to set up demonstration points for contrast tests between the “Salt Bridge” Brand KCl and several imported K fertilizers. These were carried out in more than 200 villages, 108 counties and 18 major K consuming provinces. In 1997, after a long period of contrast tests, a book, compiled by relevant agriculture experts and technical personnel from the Salt Lake Group entitled “Demonstration of Contrast Tests on Fertilizer Effects between China's Qinghai “Salt Bridge” Brand KCl and

Imported K Fertilizers,” was published. In conclusion, with equal amounts of nutrient input, the “Salt Bridge” Brand KCl was comparable with the imported K such as the Canadian red K and the Russian white K but “Salt Bridge” Brand KCl was slightly more economical than imported K. Excellent production technology and publicity coupled with constant improvement of before, during and after-sale services, the “Salt Bridge” Brand KCl has become a representative made in China K fertilizer.

4.4.1.8 Formation of the K industry branch of the Inorganic Salt Industry Association of China

From 28 February to 1 March 2006, the Potash Branch of Inorganic Salt Industry Association of China was officially formed in Pudong, Shanghai. This was an inevitable result of the rapid development of the K industry and the expedited course of globalization. The formation of the K industry branch was aimed at integrating the industry’s resources and enhancing the industry’s cohesion, besides assisting government departments to improve macro-administration of the industry. It also safeguards legal rights of enterprises and provides services in the overall interests of the industry. The formation of the Potash Industry Branch of Inorganic Salt Industry Association of China was a major event that concerned the vital interests of every enterprise engaged in the K fertilizer trade and business operators. It will play a role in the technical reform of enterprises, formulation of quality standards, product appraisal, protection of intellectual property rights, anti-dumping with regard to trading and prices of K products domestically and abroad, coordination of import-export trade of K_2O , self-discipline of the industry and the promotion of sustainable, stable and rapid development of the entire industry.

4.4.2 Some of the technical experts and entrepreneurs

4.4.2.1 Representative figure in the development of the technique in obtaining KCl from salt lake bittern – Li Xiaosong

In 1994, Li Xiaosong was conferred the title of Advanced Science and Technology Worker by the Ministry of Chemical Industry. In 1996, he was conferred the honorary title of “The Ten Outstanding Youths.” In 2000, he was appraised as national model worker and in 2005, as a national outstanding science and technology worker. Li Xiaosong participated in or led the organization of important research projects that included “Study on the analytical and test methods of bittern,” “Study on deep water salt field tests,” “Study on the comprehensive utilization plans for salt lake resources,” “Study on obtaining bischofite by the salt field method and enrichment of boron and lithium,” a science and technology project to be tackled in the 7th Five-Year Plan and “Study on evaporation tests of Chaerhan Salt lake bittern.” Of these, “Study on low-sodium salt process” won the Class II “Five Minor Achievement Award” conferred by the Qinghai Committee of the Communist Youth League. The “Study on the production of bischofite by the salt field method and enrichment of boron and lithium” was appraised by experts to be advanced by world standards. The patented technology

of counter flotation cooling evaporation invented, with him as the leader, is considered at an advanced level by world standards. In 2001, the study was conferred the Gold Award for Patented Invention by the State and the World Intellectual Property Offices. These research achievements have made tremendous contributions to the development of the Qinghai Salt Lake Company and the K industry of China. In 1996, Li Xiaosong proposed to revamp Phase I project works using the process of counter flotation cooling evaporation. In May 1998, counter flotation cool crystallization technical reform of a 200,000 t KCl workshop was achieved according to schedule, resulting in increased product quality, stable granulation and increased recovery rates. This marked a new milestone in the reform of China’s K fertilizer technology because the Chinese managed to overcome technical problems in the production of K fertilizer by depending on their own strength. In November 1999, Li took the lead in manufacturing China’s first hydraulic mining boat with its manufacturing price RMB50 M lower than the imported hydraulic mining boat.

4.4.2.2 Representative figure in the production of industrial and agricultural KNO_3 by the double decomposition method in China – Cai Binghua

Cai Binghua is currently the chief engineer of the Yichun Tengda Chemical Industry Co. Ltd. in Jiangxi Province. He is associated with outstanding achievements in the history of development of technology and production of industrial and agricultural KNO_3 in China. In 1985, when Cai Binghua was the director of the Turpan Prefecture Chemical Plant in Xinjiang Autonomous Region, he was the first to develop an advanced technology for producing KNO_3 by utilizing the double decomposition of KCl and AN. More than 20 years have passed and the technique has developed to become the technique with which to produce stable industrial and agricultural KNO_3 with the maximum nutrient contents that China is able to produce. For this, Mr. Cai Binghua won many honours of invention. The technique has merits that include good-quality product, low energy consumption and high efficiency. It has become a technology for which the people of Tengda own its intellectual property rights. Other techniques are simply not comparable.

4.4.2.3 Representative figure in the production of agricultural KNO_3 by the ion exchange method in China – Li Gang

Li Gang is the Chairman of the Wentong Group. Under his leadership, new products such as calcium nitrate, calcium-ammonium nitrate (CAN), granular KNO_3 and granular KCO_3 were developed. There are more than ten new products which were manufactured for the first time in China. The new technique of AC recovery was established. They have thoroughly resolved the difficulty of environment protection in the development of the industry. These are leading products and techniques in the country. They have laid a strong foundation for the development of the K industry in the Wentong Group and throughout the country. Li Gang was awarded “Science and Technology Entrepreneur of Shanxi Province,” “National Outstanding Enterprise Administrator” and “National Outstanding Entrepreneur in Light Industries.” He was a National May Day Medal Winner.

4.4.2.4 Representative figure in the production of SOP by the Glauber's salt method in China – Cheng Fangqin

The project “Study on the Key Technology for the Production of SOP by Glauber's Salt Method and Its Industrial Application” was completed under the charge of Cheng Fangqin. It was conferred the Class II National Scientific and Technological Progress Award. It attained international standard. It was a tremendous contribution to the development of the domestic SOP industry. The breakthrough in the technique of SOP production with Glauber's salt method laid the foundation for the construction of Asia's biggest installation for the industrial production of SOP in China. In October 1999, construction of a K production line with a capacity of 10,000 t/y was completed and went into production. Theoretically, the achievement established that at a temperature of 120°C and in a state of over saturation, there is fractional crystallization and salt precipitation. Also, the evaporation crystallizer and the full back mixing flow reactor were developed. These allowed the effective separation of NaCl as a by-product in a system where many salts co-exist. This overcame the international problem experienced, in not having a by-product when using the double decomposition method. In terms of design, the project presented a closed circulation new technique which has continuity, automation and without the “three wastes.” These enabled the recovery rate of K to exceed 95%. Consumption of KCl is close to the theoretical level. It has opened up, internationally, a new path for obtaining SOP by Glauber's method.

4.4.2.5 The leading figure responsible for China's K fertilizer output attaining the million-tonne level – An Pingsui

In the 40-year history of the development of the Chaerhan Salt Lake, the Chairman cum General Manager of the Group, An Pingsui was the key figure to lead the company in turning from deficits to profit and helping China in achieving an historic breakthrough in the output of K₂O. Under his leadership, the Salt Lake group is growing strongly. He puts fund management as his most important task in enhancing the control over newly increased bank loans. He strictly implements the marketing strategy of payment before delivery of goods and, through the use of price leverage, the marketing mechanism adapts to the needs of market economy. In 1988 the production and marketing and loan recovery rate reached 100%. This was achieved with the price of KCl being adjusted twice. The average unit price was RMB67 per tonne higher than in 1997. The system for contracted responsibility of second-ranked organizations was revamped and collection of repayment was done with assets. This has further transformed the mechanism of operation. Deficits of secondary companies dropped from 60% in 1997 to 25% in 1998, and in 1999, only one secondary company was in deficit. Adjustments were carried out on the major business operators halfway through. According to the system for contracted responsibility, a secondary organization determines the total amount of wages based on output, quality and sales turnover. A secondary organization is permitted and encouraged to break away from the current system of wages on the basis of a particular job, widely implement distribution methods such

as piecework wages, time wages, the quantitative approach and contractual posts. The level of income is linked to labour achievement. There is the enhancement of corruption-free construction and loopholes in management are blocked. Work outside the plans is cleaned up vigorously and three system reforms were launched: Gradually adjust the train of thought on development by emphasizing planning, building, production and business operation of KCl. The pilot test for SOP was terminated in time to establish a 40,000 t bittern salt installation with mature technology and raising the capacity of the installation to 90,000 t. With regard to ore utilization, K companies consume the fine ore, the science and technology sector take the tailings and crude ore goes to ternary companies. Intensification of K resources in the business operation is gradually formed. Besides the three technical routes of flotation, cool crystallization and bittern salt are also established and this has filled the gap of not having high-grade K fertilizer faced by the Group Company. In 2000, at the time when work on the expansion of capacity and technical reform of the 400,000 t project was basically completed, construction of the new 1 Mt KCl project was confirmed. In order to guarantee smooth progress of the project, there was a strengthening of responsibility, standardization and operation according to procedure. A command post was set up for the project. Management of construction was executed in three separate levels: decision-making, management and the execution level. Responsibilities and authorities were clearly spelled out with mutual coordination and control. The chief-in-command reports to the board of directors. The project manager reports to the chief-in-command. The management model of owner-supervisor-construction enterprise was executed. In 2006, a comprehensive utilization project with a 1 Mt capacity was started.

4.5 Comparison between China and K fertilizer industries overseas

4.5.1 Analysis and comparison of competitiveness

4.5.1.1 Resources

From the point of distribution of K resources, the reserves in China are mainly concentrated in the Chaidamu Basin of Qinghai Province and Luopupo Prefecture of Xinjiang Autonomous Region, accounting for 96% or more of the total reserves in the country. These are geographically remote locations and transport is a problem. The K is of low grade with high integrated and associated components. Bittern mines are the main K mines in China. There is little solid potash. Contrary to the world K situation, bittern K mines in China account for more than 98%, while solid K merely accounts for about 2%. Mineral deposits are mainly the modern salt lake type. 98% of K resources in the world come from solid K deposits formed before the 4th epoch while K deposits in China are mainly inland salt lake type mineral deposits formed in the 4th epoch.

4.5.1.2 Scale

At present, the Salt Lake Industrial Group is the sole enterprise of MOP of any appreciable size, the rest produce less than 100,000 t/y. Small scale of production, relatively backward management and production technology, high consumption of raw materials and public utilities, low quality of product and remote production locations have resulted in the relatively weak competitiveness of China's MOP in the international market.

4.5.1.3 Production technology and equipment

In other countries where carnallite is the raw material in the production of MOP, the advanced cool crystallization technique for K fertilizer production is adopted. In China, in the past years, the flotation technique was mainly used for MOP production. The flotation method has the shortcomings of small granule size and product of low grade. In recent years, the cool crystallization method has been gradually used to reform the process of flotation. After the reform, there has been an increase in product quality but a gap still exists when compared with other countries. Owing to the inadequate major equipment input and research in the production of K fertilizer, main components of the filter, the high efficiency concentrator and the hydraulic mining boat and other key equipment must be imported. With respect to control in K fertilizer production and management, the gap with advanced enterprises in other countries is even bigger.

Currently, there are many methods of producing SOP in China but the conversion method is the main one. The cost of production is high and the scale small. It is generally thought in other countries that the scale of economic production should be more than 40,000 t/y but the majority of SOP production in China is below the scale of economic production. The overall production level is low. Even with the application of the Mannheim process from Japan and Taiwan, the technique is still relatively backward. It can be seen that China does not have any advantage in the SOP production technique.

4.5.1.4 Product quality and services

K fertilizers from Canada, Israel and the USA are superior to K fertilizers from Qinghai in terms of quality, grade, external appearance and fertilizer efficiency. The successful development and application of counter flotation-cool crystallization technique by the Qinghai Salt Lake Group in recent years has brought big improvements in the quality and grade of the Qinghai "Salt Bridge" Brand KCl with the external appearance changed from powder to granules. Unfortunately, compared with "foreign fertilizer," particularly with the red K fertilizer from Canada, there is still a definite difference. Apart from the Salt Lake Industry Group, there are still more than 30 small plants that adopt the conventional cool decomposition-flotation process to produce K fertilizer. For this type of small plants, the difference in grade, quality and external appearance in the MOP compared with foreign fertilizers is even greater. In other countries, the major raw material used for the production of MOP is sylvinite. In China, carnallite is the raw material and the product contains Mg. This helps in the conversion of protein and the absorption of N and P. This is also the reason why the production of K fertilizer in China has a definite market advantage. Furthermore, when

China produces its own K fertilizer, continuous supply can be guaranteed and prevents the many problems that accompany a one-time supply in a large quantity. Therefore, it is appropriate to develop our own K fertilizer industry and there is future for this development.

4.5.1.5 Cost

There are two major factors that determine the cost of producing KCl.

The first is the extent of automation of production and the degree of maturity of the technology. At present, the major K fertilizer producing countries adopt the counter flotation-cool crystallization production technique. This technique has a relatively long history of application in other countries. In Qinghai, it has only just been successfully developed. The Phase II 1 Mt/y project carried out test production as recently as March 2004, therefore, in terms of technology, K fertilizers are more mature in other countries than Qinghai K fertilizers. As for the degree of automation, the USA, Canada and Israel are far ahead of Qinghai.

The second is resources. In major K fertilizer producing countries such as Canada, Israel, Germany, Russia and Belarus and even Thailand, their K resources are mainly ancient sylvite. In China, K is from the Cenozoic Era. Conditions of exploitation are poor and the grade of K resources is low (bittern K oxide has content of 0.9%-1.9%). Ancient K exists in the form of K ore sedimentation. Reserves are concentrated and of high grade. Technical difficulties and the costs of exploitation are lower than for Qinghai Salt Lake potash.

On the whole, the above two points determine the cost which is higher than the production cost of imported K fertilizer. According to estimates, the production cost per tonne of KCl in Canada and Israel is not even RMB300 whilst that for Qinghai is RMB400-600. In other words, production cost of Qinghai is about 50% higher than "foreign K fertilizer." The cost per tonne of transporting the Qinghai K to the market place would be below RMB800 and according to calculations the cost per tonne of transporting imported K fertilizer to domestic ports would not be lower than US\$100. Thus, it can be seen that, in terms of transport cost, domestic K fertilizer has a slight competitive edge over imported products.

4.5.1.6 Brand names

Foreign K fertilizer (mainly the red K fertilizer from Canada) has been the subject of advertising in China to establish brand image. Since the 1990s, Canadian K fertilizer producing enterprises have been carrying out publicity through measures like popularization of science (for example, giving lectures on this in "Balanced Fertilizer Application" on China's Central Television) and media advertisements, resulting in the Canadian red K fertilizer becoming widely known. Qinghai K fertilizer was relatively late in launching this sort of marketing work. As a result, its brand is less known in the market than the Canadian fertilizer.

4.5.1.7 Comprehensive utilization of technology

Among the salt lakes being developed, sylvite is better utilized but research and development work on integrated and associated ores has stagnated. The lack of a comprehensive

utilization technology has affected the comprehensive economic results of the K fertilizer industry.

4.5.1.8 Transport

With the rapid growth in the amount of K fertilizer applied, the fertilizer industry is taken more and more seriously by the State. However, the industry is limited by inadequate resources. On top of this, the resources are mainly distributed in remote places where natural conditions are poor, such as the Chaerhan Prefecture in Qinghai and the Luobupo Prefecture in Xinjiang Autonomous Region. The total amount of resources and the conditions of transport have limited the normal development of the K fertilizer industry in China. The world is rich in K resources of a high grade. Reserves of K in China are not even one-thousandth of the world's total K reserves. Remote geographical locations, poor exploitation conditions and lower grade K resources have all contributed to the degree of difficulty in the production of KCl in China.

4.5.2 Comparison between China and Israeli counter-flotation-cool crystallization technique

1. The domestic Chaerhan Salt Lake bittern resources and the Dead Sea bittern resources are both chloride-type bittern. However, in the two bitters, the ratios of quantity and number of the various chloride components are different and coupled with differences in climatic condition, the characteristics of minerals of the carnallite precipitated are different.
2. In the case of the Dead Sea Company, after collecting the carnallite ore from the salt field and sieving, 30% of the salt field carnallite goes to counter flotation while 70% of the crude ore low-sodium carnallite goes directly to cool crystallization. In the case of Chaerhan, with carnallite from the salt field of the lake, it is not possible to obtain low-sodium carnallite by sieving. 100% of it has to go to counter flotation, thus, increasing the production cost.
3. In the Israeli cool crystallization process, stirring is at the bottom but in China's counter flotation-cool crystallization process, stirring takes place at the top.
4. With regard to the production of carnallite ore from a dry salt field, large-scale production is not possible due to limitations of the salt field area and the control of cost. Of the salt collected from a dry salt field, more than a third of the carnallite ore has very high Na content and the counter flotation reagent has no effect on this and the use of the cool crystallization process does not yield good results.

4.5.3 Comparison of Cl-free K fertilizer grades

Cl-free K fertilizer grades in China and in other countries do not differ much. The major varieties are always SOP, KNO_3 , K-MgSO_4 and KH_2PO_4 in very small quantities. The difference lies in the fact that among these Cl-free K fertilizer grades some large foreign K fertilizer producing companies develop new grades which are more suitable for specific needs. For example, the French SCPA Company employed the Mannheim method to produce SOP which accounted for 25% of the sales volume in the world. In order to overcome the occurrence of neutralization reaction between CaCO_3 and excess H_2SO_4 to produce residual CaSO_4 that is hard to

dissolve at the later stage of the Mannheim technique, making it unsuitable for solution irrigation, the company developed a kind of soluble SOP product with the name of SoluPotasse. This product is 100% water soluble. The granules are smaller than 0.3 mm. At 20°C, solubility reach 99%, dissolving at a rate much faster than ordinary SOP, making it more suitable for fertigation (fertilizer application through the irrigation system). The technique for manufacturing this type of SOP product is to completely remove the stage of neutralization reaction from the Mannheim process. In this way, the SOP produced becomes clearly acidic with a pH value of just below 3. This level of acidity is suitable for the absorption of nutrients by crop plants. It also helps to prevent the blockage of nozzles by Ca sediments and algae. Practical experience proves that by using this type of soluble Cl-free K fertilizer in fertigation, citrus and grape production, is higher than when using ordinary SOP.

Great Salt Lakes in the USA produces many types of industrial and agricultural grade SOP in both soluble and granular forms. K+S of Germany also developed a water-soluble SOP product "Hortisul" to be used specially for fertigation and foliar spray. It is applied by dissolve it in water and, after filtering, feeding it into the irrigation system or adding it to the sprayer.

The KNO_3 fertilizers produced and sold by the Israeli Dead Sea Industries Co. Ltd. covers almost all the grades, ranging from granular fertilizers which can be applied directly to the field to liquid fertilizer used in high-class irrigation systems.

1. Granular fertilizer is suitable for use in the field, broadcasted accurately by machine or used with other fertilizers (such as urea, ammonium biphosphate) to make blended fertilizer. The merits of this fertilizer, made by prescription, include its low cost, flexible adjustment of its nutrient combinations and convenient application. It is reckoned that this type of granular K fertilizer would have better prospects in China.
2. The relatively large standard crystalline granules makes this grade of fertilizer suitable for direct application in the field, by machine or manually. It can be applied even under windy conditions.
3. The small granules of the fine powdery granular type enable it to be rapidly and fully dissolved. It is particularly suitable for use in clear liquid fertilizer and the industrial production of SOP. It is also suitable for use in the processing and production of granular PK, NK and NPK compound fertilizers.

Israel is a model in the technology of fertigation. More than 65% of the K fertilizer is applied through advanced irrigation systems. The liquid K fertilizer applied in the irrigation, FERTI-K is a pure white KCl with a potassium oxide (K_2O) content not lower than 61%. It can dissolve rapidly with a very low content of insoluble impurities (less than 0.08%). It has almost no chemical reaction with the irrigation water and ions of other nutrients. This type of K fertilizer will not block up drippers or filters. It is very suitable for drip, spray and fine spray irrigation systems where it is dissolved in a fertilizer pond. The dissolved liquid-state fertilizer is directly applied through a fertilizer application pump. In the field, farmers can conveniently mix this type of special-purpose K fertilizer with

urea, AS, AN, KH_2PO_4 and other soluble fertilizers to prepare various types of limpid liquid fertilizer.

4.6 The external environment in the development of the K fertilizer industry in China

4.6.1 Characteristics of China's K resources and transport of K fertilizers

Since the discovery of the Chaerhan Salt Lake K ore in 1956, Mr. Yuan Jianqi has conducted systematic research and proposed that the Qinghai Chaidamu 3rd Epoch has no relation at all with seawater and the modern salt lakes and put forward the theory of "Mountain Basins" that opened a new page in the development of K in China.

According to the summary of Xuan Zhiqiang, the Qinghai Chaerhan Salt Lake is the largest in scale. The distribution of soluble K resources in China is shown in Table 4-1.

Salt lakes are divided into four types, namely K chloride-type, K sulphate-type, K nitrate-type and K carbonate-type. From the above description and analysis, it can be seen that the Chaerhan Salt Lake of Qinghai Salt Lake Potash Fertilizer Group is the KCl type. The Xitai Jinaier Salt Lake invested by Citic Guo'an is a magnesium sulphate hypo-type salt lake. K deposits in China are mainly the modern salt lake type. K ores are mainly bittern ores with little solid K ore. Bittern potash ore accounts for more than 98% of the total while solid potash ore makes up only about 2%. This is the direct opposite of K resources in the world. 98% of the world's K resources were formed in the solid K deposits before the fourth period while K deposits in China are mainly continental salt lake-type deposits of the fourth period. In addition, K reserves of China are mainly concentrated in remote areas like the Chaidamu Basin of Qinghai Province and Luobupo of Xinjiang Autonomous Region. The verified K reserves at Chaerhan Salt Lake of Chaidamu Basin are 370 Mt. The verified amount of resources in Luobupo Prefecture is 250 Mt. These account for 97% of the total reserves.

The mineralization conditions of K resources in China are poor. There is little possibility of finding large-scale K deposits in the near future.

97% of the K resources are concentrated in regions of the provinces of Qinghai and Xinjiang where infrastructure is lacking. The KCl of the Salt Lake Group and other small production plants of KCl, and K-MgSO₄ plant of Citic Guo'an and the 1.2 Mt Luobupo SOP project which will go into production in 2009 are all distributed around the Chaerhan region in Qinghai and the Luobupo Prefecture in Xinjiang. However, K fertilizers are used throughout the country. The rapid growth in the amount of K fertilizer used now involves the problem of transporting K fertilizer from Qinghai and Xinjiang all over the country. Transport problems are well known to everyone and have always been an important bottleneck in the rapid development of K fertilizer in China.

The K fertilizer industry is receiving more and more attention from the State. The State has begun putting in a great deal of manpower and material resources to carry out infrastructure improvements. Implementation of the emergency construction of the double-track Xining – Geermu section of the railway should be the best measure that the State has taken in improving the K fertilizer transport of Qinghai Salt Lake. Once construction of the Xining – Golmud section of the double-track railway is completed, transport in the entire Golmud region will be greatly improved. Be it freight charges, forwarding time or railway wagon, the Chinese government gives its support by way of its policies. It is believed that the external transport of Qinghai K fertilizer will be greatly improved.

4.6.2 The K fertilizer market in China

4.6.2.1 K fertilizer consumption

Since the commencement of K fertilizer use in China, demand has grown. Consumption has been growing every year, due particularly to the wide spread publicity and promotion of application for Canadian red K fertilizer after 1992. Both the Chinese government and the farmers gained new knowledge on the effects of K fertilizer. With the implementation of agriculture departments' "K supplementation project," the

Table 4-1 Distribution of soluble potassium resources in China

| Name of Basin | Main Strata | Characteristics of Main Components | Scale and Achievements |
|--------------------|---|---|---|
| Chaidamu Basin | Third & fourth system and modern stratum | K-magnesium salt deposits, carnallite, rich in bittern | Exceptionally big ore field |
| Luobupo Basin | Third system, carboniferous series | Bittern rich in K, boron, sodium, halite, Glauber's salt | Big, and exceptionally big ore fields |
| Xizang Salt Lake | Fourth period continental stratum | Halite, carnallite, K-magnesium salt deposits | Numerous small fields |
| Sichuan Basin | Triassic system | K-rich bittern, miscellaneous bittern-containing rocks, K-magnesium salt deposits | Liquid-state potash ore estimated at 437.4 billion cubic metres |
| Eerdosi Basin | The Ordovician system (the two provinces of Shaanxi and Shanxi) | K-containing halite, gypsum (rare in the world) | The sylvite basin centre has been found |
| Yunnan Simao Basin | Old salt chamber | Red but non-edible potash | Medium-size solid potash deposit |

demand and consumption of K fertilizer became more vigorous. From 1980 to 2005, K fertilizer consumption increased progressively with the average rate of increase at 11.9% as shown in Table 4-2.

Table 4-2 Potash fertilizer (K₂O) consumption in China: 1980-2005 ('000 tonnes)

| Year | Consumption Volume | Year | Consumption Volume | Year | Consumption Volume |
|------|--------------------|------|--------------------|------|--------------------|
| 1980 | 386 | 1992 | 1960 | 2000 | 3765 |
| 1985 | 804 | 1993 | 2123 | 2001 | 3996 |
| 1986 | 774 | 1994 | 2348 | 2002 | 4224 |
| 1987 | 919 | 1995 | 2685 | 2003 | 4380 |
| 1988 | 1010 | 1996 | 2896 | 2004 | 4673 |
| 1989 | 1205 | 1997 | 3220 | 2005 | 6858 |
| 1990 | 1479 | 1998 | 2457 | | |
| 1991 | 1739 | 1999 | 3656 | | |

According to forecasts by the Ministry of Agriculture, based on growth in the consumption of K fertilizer in recent years, the demand for K fertilizer in China for the period 2010-2020 are shown in Table 4-3. By 2010, total demand for K in China will be 8.2 Mt. Of this, demand for agricultural K is 7.5 Mt. Based on the Ministry of Agriculture's forecast and the output of K fertilizer of 2.6 Mt in 2005, there will be a theoretical shortfall of 4.9 Mt of K fertilizer by 2010.

Table 4-3 Demand forecast for K fertilizer during the period 2010-2020 ('000 tonnes)

| Year | Total Potash | Agricultural Potash Fertilizer | N : P ₂ O ₅ : K ₂ O |
|------|--------------|--------------------------------|--|
| 2010 | 8220 | 7510 | 1 : 0.4 : 0.25 |
| 2015 | 10370 | 9500 | 1 : 0.4 : 0.30 |
| 2020 | 10540 | 9580 | 1 : 0.4 : 0.30 |

4.6.2.2 Market supply

1. Development and outlook for domestic production

It is common knowledge that due to the shortage of soluble K resources in China and their concentration in the undeveloped western regions that include Qinghai and Xinjiang, the development of production of K fertilizer is greatly hampered. KCl in China is mainly produced by the flotation technique and the counter flotation-cool crystallization production process developed domestically. They are able to give products with purity above 95%. Through its own development, China's K fertilizer technology carries its own characteristics. The standard for domestic production technology has been raised appreciably. In recent years, K fertilizer production in China has been growing rapidly. In 2003, the 1 Mt project of the Qinghai Salt Lake Group went into production. Output increased from 36,000 t in 1990 to 1.2 Mt in 2004, an average

growth rate of 29%. The rate of fulfilment by the domestically produced K fertilizer increased from 2% in 1990 to 21% in 2004. In 1999, total production of K fertilizer in China was merely 0.8% of the world's total production. This increased to 4.5% in 2004.

Limited by resource conditions, MOP production plants of a certain scale are mainly concentrated in the Chaerhan area in Qinghai Province. The Salt Lake Group Company is the biggest K fertilizer-producing enterprise in China. At present, its annual production capacity is close to 1.6 Mt. Together with the 30 or so small K -producing plants in the region, China's total production capacity of MOP is 2.6 Mt (product quantity). Statistical data on the output of MOP production in China are shown in Table 4-4.

Table 4-4 Historical production of of MOP in China: 1986-2006 ('000 tonnes K₂O)

| Year | Muriate of Potash | Year | Muriate of Potash | Year | Muriate of Potash |
|------|-------------------|------|-------------------|------|-------------------|
| 1986 | 18 | 1995 | 168 | 2001 | 420 |
| 1990 | 36 | 1996 | 150 | 2002 | 510 |
| 1991 | 120 | 1997 | 192 | 2003 | 624 |
| 1992 | 114 | 1998 | 210 | 2004 | 1242 |
| 1993 | 108 | 1999 | 222 | 2005 | 1560 |
| 1994 | 144 | 2000 | 378 | 2006 | 3100 |

Note: To avoid repetition, output of K fertilizer is counted only once.

Currently, there are 120 enterprises producing potassium sulphate (SOP) with a capacity close to 2.1 Mt (product quantity). In 2004, annual production of SOP in terms of product quantity was 1.2 Mt.

In recent years, the development of KNO₃ production has been relatively rapid. There are close to 50 enterprises which produce KNO₃ with their production capacity reaching 350,000 t/y. In 2004, the output of KNO₃ in product quantity was 280,000 t.

For more than ten years, the growth of Cl-free K fertilizers such as SOP and KNO₃ has been relatively fast. Their production capacity has been increasing progressively during the 14 years from 1990 to 2004 by 30% and 20% respectively. From almost zero production, China has become a big producer of SOP and KNO₃. Production techniques for SOP and KNO₃ are close to or have attained world advanced standards. Major production techniques are by the conversion of KCl and sulphuric acid and nitrate. Production capacity and output of SOP and KNO₃ are shown in Table 4-5.

Table 4-5 Production capacity and output of SOP and KNO₃: 1980-2006 ('000 tonnes in K₂O)

| Year | SOP | | KNO ₃ ¹ | |
|------|---------------------|--------|-------------------------------|--------|
| | Production Capacity | Output | Production Capacity | Output |
| 1980 | 2 | 1 | 13 | 9 |
| 1985 | 4 | 2 | 15 | 10 |
| 1990 | 15 | 10 | 18 | 11 |
| 1995 | 40 | 25 | 23 | 19 |
| 2000 | 400 | 320 | 30 | 22 |
| 2001 | 500 | 400 | 53 | 26 |
| 2002 | 550 | 450 | 79 | 44 |
| 2003 | 600 | 560 | 110 | 79 |
| 2004 | 650 | 600 | 220 | 123 |
| 2005 | 1800 | 700 | 450 | 300 |
| 2006 | 2080 | 800 | 450 | 350 |

¹ KNO₃ is mostly industrial grade product and it was only in recent years that people began using it in agriculture, particularly in tobacco cultivation. Taking 2004 as an example, the production of KNO₃ for industrial use in that year was about 120,000 t (product quantity).

2. Imports

There is, in China, a large gap between demand and supply in the K industry. In order to guarantee the stable supply of K fertilizer, imports of K fertilizer are increasing every year. Each year, about 80% of the K fertilizer consumption must be imported. Among all the mineral resources in China, K is the resource with the highest ratio of dependence on external supply. Table 4-6 shows the history of import of KCl by China.

Table 4-6 Historical import volume of KCl during the period 1981-May 2006 ('000 tonnes)

| Year | Import Volume | Year | Import Volume | Year | Import Volume |
|------|---------------|------|---------------|------|---------------|
| 1981 | 840 | 1990 | 2010 | 1999 | 5200 |
| 1982 | 700 | 1991 | 2530 | 2000 | 5990 |
| 1983 | 860 | 1992 | 2330 | 2001 | 5120 |
| 1984 | 900 | 1993 | 1900 | 2002 | 6650 |
| 1985 | 380 | 1994 | 2850 | 2003 | 6230 |
| 1986 | 530 | 1995 | 3860 | 2004 | 7180 |
| 1987 | 1680 | 1996 | 3470 | 2005 | 8830 |
| 1988 | 2040 | 1997 | 4630 | 2006 | 7053 |
| 1989 | 1160 | 1998 | 5110 | | |

From Table 4-6, it can be seen that since 1981, Chinese imports of K fertilizer has always been on the trend of rapid rise. For ten years, from 1981 to 1990, a total of 13.1 Mt of KCl was imported, that is, on average, 1.3 Mt/y. From 1991 to 2000, 44.1 Mt was imported or 4.4 Mt/y on average. From 2001 to 2005, the import of KCl was 34.0 Mt, averaging 6.8 Mt/y. In 2005, the amount imported was ten times that of 1981, a net increase of 8 Mt. In the recent five years, imports

have been increasing sharply. China has truly become a major world importer of K fertilizer. It has, thus, become a target for major exporters.

From Tables 4-7 and 4-8, it is obvious that owing to the fact that SOP and KNO₃ are second operation K fertilizers, with the continuous improvement in the production technique for Cl-free K fertilizer and the continuous increase in standards, domestically produced Cl-free K fertilizers have taken the major share of the domestic market. This has resulted in the reduction of import of SOP and KNO₃. This is also in line with the country's macro-control objectives.

Table 4.7 Historical changes in the import of SOP in China ('000 tonnes K₂O)

| Year | SOP | Year | SOP | Year | SOP |
|------|------|------|-----|------|-----|
| 1990 | 362 | 1996 | 210 | 2002 | 150 |
| 1991 | 357 | 1997 | 314 | 2003 | 165 |
| 1992 | 281 | 1998 | 265 | 2004 | 85 |
| 1993 | 360 | 1999 | 99 | 2005 | 102 |
| 1994 | 309 | 2000 | 96 | | |
| 1995 | 2378 | 2001 | 130 | | |

Table 4.8 Historical changes in the import of KNO₃ in China ('000 tonnes K₂O)

| Year | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|------------------|------|------|------|------|------|------|------|------|------|
| KNO ₃ | - | - | - | 21 | 49 | 26 | 28 | 32 | 5 |

4.6.2.3 Market price

From 2003 to 2005, the domestic K fertilizer market experienced an earth-shaking change. Whether it was the price trend or market demand-supply relationship, great changes occurred. Regardless of whether it is in China or in the world, the K fertilizer market is different from other products. The distinction lies in the fact that the resources are concentrated in a few countries and regions while demand is spread all over the world. Viewed from resource reserves, although supply exceeds demand, from the point of transport and supply channels in some countries and regions, smooth supply of the commodity is truly a problem. This is also the reason why in the past two years, there has been much fluctuation in the market price of K fertilizer and supply was a little tight. Table 4-9 shows the historical changes in the import prices of KCl and Cl-free K fertilizers (calculated according to average CIF prices).

Summarizing the import volumes and amounts according to the time periods, table 4-10 below shows that the average CIF price per tonne of KCl during the 10-year period from 1981 to 1990 was US\$117.9. From 1991 to 2000, the average price was US\$116.5. For KCl imported during the period of 2001 to May 2006, the average CIF price was US\$151.5 (the exchange rate used in the table is RMB8.28/US Dollar). It can be seen that from 1981 to 1990, the import price of KCl was on a downward trend. From the 1990s all the way through to 2002, the import price of KCl was relatively stable, fluctuating between US\$112/t and US\$120/t, with an average

Table 4-9 Historical changes in the import price of KCl

| Year | CIF (US\$/tonne) | CIF (RMB/tonne) | Year | CIF (US\$/tonne) | CIF (RMB/tonne) |
|------|------------------|-----------------|------|------------------|-----------------|
| 1981 | 171.79 | 1422.46 | 1994 | 107.58 | 890.80 |
| 1982 | 150.12 | 1242.98 | 1995 | 113.47 | 939.53 |
| 1983 | 111.14 | 920.25 | 1996 | 112.20 | 929.03 |
| 1984 | 115.45 | 955.89 | 1997 | 115.06 | 952.71 |
| 1985 | 122.41 | 1013.52 | 1998 | 118.59 | 981.89 |
| 1986 | 102.47 | 848.48 | 1999 | 117.10 | 969.62 |
| 1987 | 94.41 | 781.69 | 2000 | 119.45 | 989.00 |
| 1988 | 112.72 | 933.31 | 2001 | 116.48 | 964.47 |
| 1989 | 125.13 | 1036.05 | 2002 | 115.58 | 957.00 |
| 1990 | 112.30 | 928.85 | 2003 | 118.62 | 982.17 |
| 1991 | 124.22 | 1028.54 | 2004 | 161.00 | 1333.08 |
| 1992 | 121.55 | 1006.45 | 2005 | 206.00 | 1705.68 |
| 1993 | 114.46 | 947.70 | 2006 | 192.00 | 1589.78 |

of US\$115.95/t. Even though Russia and Canada raised their CIF prices, because of the relatively stable petroleum price and the drop in shipping costs, the price of KCl arriving in China did not change much. In addition, there was a small difference in the CIF price of KCl imported from Russia and Canada. In 2002, the average CIF price from Russia was US\$114/t whilst the average from Canada was US\$122/t.

Table 4-10 Historical changes in KCl imports at different periods

| Period of Time | 1981-1990 | 1991-2000 | 2001-May, 2006 |
|-----------------------------|-----------|-----------|----------------|
| Import volume ('000 tonnes) | 1,311,850 | 4,409,480 | 4,288,350 |
| CIF (US\$/tonne) | 117.94 | 116.51 | 151.5 |
| CIF (RMB/tonne) | 976.50 | 964.68 | 1,255.36 |

However, from 2003, the average price of imported KCl reached a turning point. Starting from this point, K fertilizer prices experienced an earth-shaking change that broke 10 years of stability. By 2005, the average import CIF price of KCl reached RMB1,705.7/t (US\$206/t). The price of domestic KCl changed with the import price. In recent years, import price of SOP and KNO₃ have also been gradually increasing as shown in Table 4-11.

From the analysis of demand and supply above, owing to the fact that K fertilizer is a type of fertilizer for which China lacks the resources, almost 70%-80% of the K fertilizer must be imported each year. This is the cause of price fluctuation of K fertilizer. There are two major causes which affect the price of K fertilizer in China, the supply/demand relationship and shipping costs.

Firstly, from the point of supply and demand, in 2006, consumption of K fertilizer in China exceeded 10.5 Mt while output was only about 3.1 Mt (deducting the partial output from the conversion of KCl to SOP). Imports had to be above 7 Mt. Based on K fertilizer development plans and conditions

Table 4-11 Price of imported chlorine-free K fertilizers in recent years

| Year | Name of Product | Import Quantity ('000 tonnes) | Amount of Import (Million US\$) | Import Price (US\$/tonne) |
|------|-------------------------------------|-------------------------------|---------------------------------|---------------------------|
| 2002 | KNO ₃ used in fertilizer | 58.7 | 14.91 | 254.0 |
| | SOP | 302.4 | 50.60 | 167.3 |
| 2003 | KNO ₃ used in fertilizer | 62.9 | 15.85 | 252.1 |
| | SOP | 332.8 | 56.56 | 170.0 |
| 2004 | KNO ₃ used in fertilizer | 72.5 | 19.20 | 265.0 |
| | SOP | 168.6 | 30.02 | 178.0 |
| 2005 | KNO ₃ used in fertilizer | 11.1 | 3.48 | 314.9 |
| | SOP | 189.6 | 43.31 | 228.4 |

of K resources in China, even though there will be some increase in the production capacity in the next few years, it is very difficult to make up the deficit of more than 7 Mt. Moreover, increases in the area of cultivation of cash crops and the emphasis on product quality by the people will lead to an increase in the use of K fertilizer. The promotion of the technique of fertilizer application according to prescription after soil tests will encourage the development of compound fertilizer and will also increase the recommended quantity of K fertilizer, thus increasing demand. This situation has determined the long-term problem of supply falling short of demand. Dependence on imports for K fertilizer will continue for a long time to come. Prices will remain high where there is market demand thus, the price of K fertilizer will remain high in China.

Secondly, from the point of shipping, due to the centralized production of K fertilizer and its global consumption, circulation of K fertilizer can only be realized through international trade. In general, China adopts the strategy of following the CIF price of imported K fertilizer for pricing its domestic K fertilizer. However, the FOB CIF price of imported K fertilizer depends on international K fertilizer prices and shipping costs. When shipping costs double or increases several times, their ratio to the purchase price of K fertilizer will grow larger and larger. In recent years, changes in shipping costs and the shipping market have become important factors which affect the purchase price of K fertilizer in the major consuming countries. International shipping market rates began to rise in September 2003 and reached unprecedented high points in February and December 2004. It was also in these two years that a radical change in the supply-demand relationship took place in the international K fertilizer market. Consequently, driven by a huge increase in shipping costs and high international prices, the price of domestic K fertilizer went up. As a result, the development of the domestic K fertilizer market has shown greater momentum.

Spurred by skyrocketing prices on the international market, domestic KCl prices went up from the ex-factory price (Qinghai, 90% KCl) of RMB900/t in 2002 to RMB1,750/t

in May 2006. Import prices even went up to RMB1,950/t. In July 2004, the market dropped suddenly, followed by an uncontrollable increase. In a few months, the price difference reached RMB400/t. In the past two years, the price of K fertilizer has reached its historical height.

As the quantity of imported K fertilizer occupies an important position in the Chinese market, for many years the price of domestic K fertilizer have been changing according to changes in import price. Taking KCl as an example, historical changes in the price of imported KCl are the same as the changes in the price of domestically produced KCl. Monopoly of resources enjoyed by the Salt Lake Group has determined its independence in fixing the price of salt lake KCl. After an upward adjustment of RMB10/t at the end of March 2006, there was another overall upward adjustment. The price of crystallized KCl increased by RMB40/t and powdered KCl by RMB50. At present, the price for 62% crystallization is RMB1,790/t and RMB1,730/t for 60% crystallization.

Owing to the fact that, in China, most of the SOP and KNO_3 is obtained through the conversion of KCl, with the price of KCl raw material soaring, the price of SOP and KNO_3 also rise rapidly. At present, the price of SOP is about RMB2,300/t, a rise of RMB700/t compared with 2002. The present price of KNO_3 is about RMB3,700/t, an increase of RMB400/t compared with 2002.

4.6.3 Policies, laws and regulations

4.6.3.1 Value-added tax (VAT) preference for K fertilizer by the Ministry of Finance and the State Administration of Taxation

In 1995, the Ministry of Finance and the State Administration of Taxation issued a notice concerning the VAT on K fertilizer products:

1. With regard to the VAT imposed on the links in the production chain of K fertilizer, the policy of tax payment followed by refund was implemented in 1995.
2. The VAT on the production and sale of K fertilizer products unpaid by the Qinghai Potash Fertilizer Plant in 1994 was exempted but there was no refund of the VAT already paid in 1994.
3. The specific method of tax payment followed by refund with regard to the VAT was implemented by the Finance Ministry's offices of special finance supervisor at the various places and was executed in accordance with relevant provisions of the document "(94) *Cai Yu Zi* No. 55." The policy of "tax payment followed by refund" for VAT is a preferential taxation policy given to specific trades adopted by the State to increase local supplementary tax income, expedite fund turnover of enterprises, enhance the vitality of enterprises and promote local economic development.

4.6.3.2 Exemption from VAT of K fertilizer and compound fertilizer importations

After joining the WTO, China implemented the tariff quota administration with regard to the import of chemical fertilizer. Customs tariffs for chemical fertilizer imported within the tariff quota are much lower than the tariff rate for chemical fertilizer imported outside the tariff quota. Besides, the amount of tariff quota will be increased progressively

every year for five years. For example, in 2004, the amount of quota for urea was 1.3 Mt. It was 1.8 Mt in 2005 and 3.3 Mt in 2006.

Large quantities of imported chemical fertilizers will certainly have an impact on the domestic fertilizer-producing enterprises. However, the "Notice of Exemption of Import VAT concerning Arrangements to Import Potash Fertilizer and Compound Fertilizer within State Plans" (*Cai Shui* [2001] No. 76) from the Ministry of Finance and the State Administration of Taxation stipulates that from 1 January 2001, for K fertilizer and compound fertilizer imported under the arrangements within State Plans, the policy of exemption from VAT on the links of importation will continue to be executed. In view of the fierce competition in the domestic chemical fertilizer market, there are some people who wish to have the above tax exemption policy abolished. In order to fulfil the undertaking for joining the WTO, the Ministry of Finance and the State Administration of Taxation issued, on 14 December 2004, the document of *Cai Shui* [2004] No. 197 concerning notification of problems relevant to VAT on K fertilizers according to which, with the relevant registration certificate or proof of tariff quota, exemption from import VAT for imported chemical fertilizer will continue.

4.6.3.3 The government made clear the policy of preferential transport for chemical fertilizers

On 30 June 2004, the NDRC and the Ministry of Railways of the PRC jointly issued a document that clearly stated the policy of preferential transport for chemical fertilizers, including K fertilizer.

4.6.3.4 Change in the mode of the imposition of K fertilizer VAT by the Ministry of Finance and the State Administration of Taxation

The Ministry of Finance and the State Administration of Taxation issued the document of *Cai Shui* [2004] No. 197 with the following contents: "Beginning from 1 December 2004, with regard to the K fertilizer produced and sold by chemical fertilizer enterprises, exemption from VAT shall be changed to tax imposition followed by refund. The specific method of refund shall be handled by the Ministry of Finance in accordance with provisions of Document (94) *Cai Yu Zi* No 55.

4.6.4 Analysis of the influences on the domestic K fertilizer industry and the outlook

From the above statistical data and analyses of demand, output, import volume and market price, the market space for K fertilizer in China is rapidly magnified. In 2003, owing to the importance the State had given to agricultural development and food production, the volume of K fertilizer applied has been increasing faster than before, at the rate of about 6% per year on the average. In 2004, in order to expedite agricultural development to increase food production and farmers' income, China implemented a series of policies to benefit the farmers and greatly encouraged them to cultivate their land with more enthusiasm. Farmers' inputs into their crop production were raised appreciably. This also spurred the fertilizer industry of China to grow faster, particularly the

compound fertilizer industry. The demand for K fertilizer was also growing faster. At the same time, the rapid development of China's economy also caused the rapid development of the K processing industry. In the days to come, the increasing trend in the consumption of K fertilizer will continue.

The volume of imported K fertilizer in China is increasing every year. In the long term, China's demand for K fertilizer will still grow at the rate of 10% a year. Combining the present production capacities in China and to ensure abundant supply of K fertilizer domestically, apart from continuously increasing the production capacity, more work has to be done to gain access to more K fertilizer resources. It needs to establish K fertilizer bases in other countries. China must adhere to the principle of having an international market and a domestic market and two sources of resources. Studies must be done on the consumption/demands of its major competitors which include the USA, Brazil and India and on the long-term development strategy of the major countries and enterprises of K fertilizer production in order to guarantee security and abundance of China's long-term supply.

In recent years, the areas of K-deficient soil continue to expand. Agriculture departments have realized the seriousness of being deficient in K and they have been promoting the idea of "supplementation of K" throughout the country. The demand for K fertilizer by agriculture is growing rapidly. This has provided a good opportunity for the K fertilizer industry. In addition, with the development of agriculture in China, relatively large changes have occurred with regard to the composition of cultivation of agricultural crops. Cultivation of economic crops expands very rapidly. Even though the area under the cultivation of tobacco is shrinking, quality requirement for tobacco is becoming more stringent. This has to be guaranteed by special-purpose fertilizer, which means higher demand for the structure of K fertilizer grades.

The large gap in the demand-supply of K fertilizer has attracted great attention from some enterprises. This has given a big boost to the development of the K fertilizer industry in China. K fertilizer production is experiencing a good time hitherto unknown. All domestic K fertilizer production plants are working hard to produce at full stream. Large international and domestic investment companies are taking a positive view of the K fertilizer industry in China. One hears incessant news about cooperation to exploit K resources in Qinghai and Xinjiang and the production of K fertilizer. The Phase II 1 Mt/y K fertilizer project of the Qinghai Salt Lake Industry Group was successfully tested at one stroke under such favourable market conditions and gradually went into production. The 200,000 t flotation KCl installation, for which its subsidiary ternary company holds shares, will go into production in the third quarter of 2006. Total production in 2006 has reached 1.8 Mt. At present, the production capacity of the KCl installation of the Salt Lake Group is 1.7 Mt/y and it is striving to attain 2 Mt in one or two years. The State Development and Investment Company began to set foot in the K domain as early as September 2000. It set up the State-invested Xinjiang Luobupo K Co. Ltd. with a register capital of RMB540 M. The 1.2 Mt SOP project began construction work in April 2006. It will be completed and will go into production in 2009. Within five years it will become the largest SOP production base in China. In 2006, production

capacity for KCl has broken the 3 Mt mark to reach 3.1 Mt. This enables China to become the fifth K fertilizer producer in the world, after Canada, Russia, Belarus and Germany. The domestic K fertilizer industry is already on the fast track of development!

4.7 Suggestions and prospects for the development of the K fertilizer industry in China

Looking back on and analysing the development of the K fertilizer industry in China, there are many unfavourable factors in the development of domestic K fertilizer enterprises but at the same time, there are opportunities hitherto unknown. The ratio of 2:10 Mt describes the true picture of the serious imbalance in domestic supply over total demand for K fertilizer in China. To ensure that China's agriculture continues to grow steadily in the 21st century, the K fertilizer industry will have to depend on domestic K resources and the huge domestic market and make full use of domestic and international "dual resources and two markets" to achieve a K resource supply system that is relatively stable and able to meet domestic agricultural requirements. The outlook for the future development of the K fertilizer industry in China can be summarized in the following points:

4.7.1 Importance attached to the prospecting and exploitation of bittern K deposits

Train and nurture a professional team to engage fully in the survey and study of K resources. Enhance the geological prospecting of salt lakes rich in K and work out development plans to guarantee the provision of follow-up resources. Emphasize research on the prospects of ancient K mineralization in basins where oil and salts co-exist. Persevere in the implementation of simultaneous prospecting for oil and salt (K) and formulate supporting policies and technical measures. At the same time, carry out reconnaissance surveys and the appraisal of K resources in the few K containing basins (such as the underground bittern in Sichuan, the basins of Luobupo and western Chaidamu). Pay attention to looking for K in the western Yunnan Province.

4.7.2 Expediting the establishment of domestic K fertilizer production bases in China

Even though China is extremely poor in soluble solid K resources, it is relatively rich in salt lake K resources. The KCl industrial reserves at the salt lake in the Chaidamu Basin amounts to 136 Mt, the second largest K-containing salt lake in the world. In the next 10 years, China's biggest K fertilizer production base will be built in the Chaidamu Basin with production capacity of 3 Mt of KCl. Apart from the Chaidamu Basin in Qinghai Province, large K resources have been found recently in salt lakes in Luobupo of the Xinjiang Autonomous Region and in Zabuyechaka in Tibet. Construction work has started in Luobupo to build a SOP project with a capacity of 1.2 Mt/y. It will go into production in 2009 and will develop a production capacity of 1.2 Mt/y according to initial

estimates. Therefore, in the next 10 years, the existing Chinese production capacity, coupled with the proposed new capacity, will give an estimated total capacity of about 4.2 Mt. This will be able to meet 30-50% of the forecasted demand for K fertilizer.

4.7.3 Active and sound promotion to establish bases of K fertilizer production and supply overseas

After years of difficult exploration by relevant departments of the State with the local authorities and enterprises of neighbouring countries with resources, a common view was arrived at – carry out risk-bearing prospecting for K resources in the neighbouring countries and establish an independently developed K fertilizer base to overcome the shortage of K fertilizer supply in China. At this juncture, the best choices are Thailand and Laos. These two neighbours have rich K resources and hope to cooperate with China in prospecting and developing them. Currently, China's cooperation, particularly with Laos, has achieved substantive progress and it is hoped that the State will give further support to its policies, funding, and external constructions with regard to the development of the Laotian Vientiane K resources. The next will be Russia and countries of Central Asia rich in K resources. These countries can be China's second echelon in carrying out prospecting and exploitation of K resources. It is suggested to develop K resources of Thailand and Laos first and after gaining experience, decide whether or not to exploit the K resources of Russia and Central Asia. We should strive for the establishment of an offshore production capacity of 3-4 Mt/y of KCl to meet 50% of demand for K fertilizer during the corresponding period.

4.7.4 Purchase shares or holdings of foreign companies that own K mines

Integration of the world's economy is progressing ever faster. This provides good opportunities for Chinese enterprises to compete in the international K resource market. Share participation in foreign K fertilizer-producing enterprises will have partial control or even right of control to prevent the demand for K fertilizer in China being influenced by other countries. This will allow a stable supply of K fertilizer products in the Chinese market. This is the path with the minimum risk and is also the easiest to implement.

Looking at the present international K fertilizer production and market, share participation in foreign K fertilizer-producing enterprise is completely possible. An example is the Israeli Dead Sea Potash Fertilizer Company which, in 1997, acquired control of a Spanish KCl producing enterprise with a production capacity of 1 Mt/y with nearly US\$300M, thus enabling its international K fertilizer market share to be raised further and allowing Dead Sea Potash Fertilizer to further occupy the European market. With regard to the issue of purchasing the stock equity of foreign K fertilizer-producing enterprises, in recent years, relevant departments and companies in China have been exploring with relevant K fertilizer companies. An example is taking up shares in the 2 Mt K fertilizer project in the *Udon* District of Thailand by the

Canadian Asia Pacific K Fertilizer Company. Another example is Russia's *Shangkamu* Mine, which has been exploited for over 50 years. Russia has contacted the relevant department in China, hoping to jointly invest in the construction and reform of the mine. These examples show that it is feasible for share participation in foreign K fertilizer-producing enterprises to build production capacity of 3-4 Mt/y in 10-15 years.

4.7.5 More aggressive investment in the exploitation and utilization of insoluble K resources

China has a shortage of soluble K resources. However, reserves of insoluble K resources (such as alunite, K feldspar, nepheline and miscellaneous bittern rocks) are enormous, with higher grades (average content of K_2O above 10%). However, due to reasons of technology and economics, they have not been exploited for utilization. With socio-economic development and the fast-increasing demand for K fertilizer, exploitation and utilization of insoluble K ores will become possible. At present, in view of the development of the technique of biological production of K fertilizer from insoluble K resources, it is now possible to have large-scale comprehensive utilization of insoluble K resources in China. It is suggested that the relevant departments increase their input in the exploitation and utilization of insoluble K resources to make up for the severe shortage of soluble K resources in China.

4.7.6 Implementation of large-scale operations

Expanding the scale of production to achieve the most economical operational scale is the most fundamental way to reduce production costs and increase product quality. Taking the Salt Lake Group as an example, when its production scale expands from the original 600,000 to 1 Mt/y, the production cost drops about 5% compared with the original level. If the production scale is expanded to 1.5 Mt/y, then the cost can be reduced by about 15%, that is, a drop of more than RMB100 for each tonne. If the cost is at this level, compared with imported K fertilizer, the disadvantage in production cost of Qinghai K fertilizer is lowered. Increasing the level of intensification of Qinghai's K fertilizer industry is the most effective answer to the challenges brought by joining the WTO. At this juncture, the most important thing is to take the Salt Lake Group as the reference. Strengthen the production scale of the Salt Lake Group and at the same time, prepare follow-up K fertilizer resources for large-scale exploitation. For other new K fertilizer-producing enterprises, put forward the requirement of scale. An enterprise that fails to reach the proper scale has to be blocked by making it go through production licence applications, tax levies and mining licences.

Many enterprises are still using the "flotation process" to produce K fertilizer. Production by this technique is high-cost, product is low-grade, with unstable quality and its appearance and fertilizer efficiency are far inferior to products of the "counter flotation-cooling crystallization process." Although KCl produced by the flotation technique still has a market domestically, with China's accession to WTO and the long-term effects, this type of production technique should

be quickly eliminated. Encourage large-scale K fertilizer-producing enterprises to become a shareholder with their technology and the transfer of technology with compensation to transfer their advanced K fertilizer production techniques to small and medium K fertilizer-producing enterprises. Enterprises that fail to meet requirements of technology and product quality are given a time limit in which to revamp and if they fail, they will be asked firmly to stop production and merge, thus raising the overall technical level and product quality of the K fertilizer industry in Qinghai and raising its competitiveness in the market.

4.7.7 Unified brands of K fertilizer

In an attempt to lower the cost of marketing and raise the level of awareness for their K fertilizer, Qinghai K fertilizer should have only one or a few unified brands to prevent competition between groups and their possible destruction. We can consider having a big enterprise with a well-known brand to transfer its brand (OEM^{*} production model) to the small and medium enterprises. An enterprise or plant receiving the brand name must accept the supervision and technical guidance from the enterprise possessing the brand name. Production is in accordance with the technological standards of the brand name owner. Products will be marketed with a unified brand name. The owner of the brand name charges brand utilization and management fees. A well-known enterprise may become a shareholder through intangible assets like technology and brand name, share replacement and becoming a shareholder by cash injection. Through share participation or equity control in the small and medium enterprise, a K fertilizer-producing enterprise group with a larger scale is formed. In this respect, we can follow the example of Yunnan Baiyao (*a medicinal powder*). Yunnan Baiyao used to be produced by more than 20 factories resulting in group competition and non-unification of product quality and standards. Consequently, Yunnan Baiyao lost all its reputation in the market throughout the country. For this reason, in the mid-1990s, the Yunnan Provincial government designated that the “Yunnan Baiyao” Brand should belong to the Yunnan Pharmaceutical Factory. Other enterprises are authorized by Yunnan Pharmaceutical Factory to produce Yunnan Baiyao under its brand name. As a result, Yunnan Baiyao won back its former glory after the 1990s.

4.7.8 Emphasis on comprehensive development

Apart from KCl, K fertilizers also includes SOP, KNO₃ and KH₂PO₄. From a long-term point of view, market demand for SOP and KNO₃ is growing very rapidly. At present, the annual demand exceeds 2 Mt. Domestic output is still unable

to meet domestic market demand. The strategy for K fertilizer development during the 11th Five-Year Plan is “to strive for a one-third self-sufficiency rate for KCl. Secondary processed grades, which include SOP, KNO₃ and KH₂PO₄, will have a foothold in the country.” In the preceding paragraphs (refer to in Table 4-7 and Table 4-8), it can be seen, from a reduction in the import volume of SOP and KNO₃ in recent years, that this strategy has basically been achieved. In future, one of the key issues is to have breakthroughs in the production technology. In view of the slow progress in self-development, with regard to improvement in technology, we should insist on following the path of import, digestion and absorption. Secondly, we have to go for intensification. The scale of production of a single enterprise should be at least 50,000 t and above. The mistake of having small, scattered and disorderly enterprises which caused China so much pain should never be repeated. Thirdly, carry out integrated production of KCl, SOP or KNO₃ to further reduce the cost of production. If the above three points can be achieved, competitiveness of China’s SOP and KNO₃ industry will be greatly increased.

4.7.9 Enhancement of studies on soil K

The K providing ability of different soils and the effective conditions of the application of K fertilizer used in combination with other fertilizers in order to reduce K fertilizer losses to the minimum and increase the efficiency ratio and economic benefits so that limited resources can bring the biggest possible economic benefits, should be known. Research into the cycle of K element in the crop-soil system should be enhanced and attention should be paid to the application of organic fertilizers and return of straw to the field.

4.7.10 Perfecting the distribution and management systems of chemical fertilizers

The system of distribution and management of chemical fertilizers so that the limited K fertilizer is used in areas that need it most and on crops that give the highest economic benefits should be perfected.

4.7.11 Strengthen the standards system and ensure the quality of K fertilizer

Standards are the basis of quality. Without high standards there is no high quality. Revise the existing international standards and standards within the trade. Expedite the work of formulating national standards for agricultural KNO₃ and SOP.

4.7.12 Enhancement of publicity and recommendations of KNO₃, KH₂PO₄ and K-Mg fertilizer

Production plants and departments of agricultural resources should enhance publicity and recommendations of KNO₃, KH₂PO₄ and K-Mg fertilizer. Help farmers to gradually know these fertilizers. Next, production plants and departments of agricultural resources should improve communication.

^{*} OEM: Abbreviation for Original Equipment Manufacture.

Strictly speaking, OEM is just authorized production, a kind of sub-contract manufacture. The brand name producer does not manufacture the product directly but by making use of the “core technology” in its hands, it is responsible for the design and development of new products and controls the marketing channels. Processing will be carried out by other enterprises. A manufacturer that takes up the processing mission is called an OEM manufacturer and what it produces are OEM products.

Besides establishing the relationship of supply and demand, they should also establish a relationship of close cooperation with regard to technology and capital. In every village within a definite area, determine one or a number of plots of sample land for special fertilizer application for its rapid promotion.

4.7.13 Adopt measures to protect salt lake resources

Seriously execute the laws and regulations of the State concerning mineral resources. Insist on putting an end to disorderly excavation and exploitation that exist in the

development of the Qinghai Salt Lake. An administrative organization with authority should be established to improve the supervision and control of the utilization and protection of resources with regard to potash-producing enterprises. In particular, centralized management should be adopted for key links in bittern collection and discharge. With regard to K resources to be exploited, there must be valid reasons for the scientific bittern collection and appropriate discharge to be carried out. There must be follow-up monitoring and supervision to prevent new incidents of disorderly excavation and exploitation.

Chapter 5

The Development and Prospects for Compound Fertilizers in China

5.1 The development of the compound fertilizer industry and industrial technology

5.1.1 Definition of a compound fertilizer

5.1.1.1 Definition and stipulation of nutrients

According to international standards, the three nutrients of N (N), phosphorus (P) and potassium (K) in fertilizers, such that, for a fertilizer containing at least two of those nutrients with the quantities labelled will be referred to as a compound fertilizer. In addition, single nutrients and total nutrients in the compound fertilizer are calculated in terms of the contents of nitrogen (N), phosphorus pentoxide (P_2O_5) and potassium oxide (K_2O).

5.1.1.2 The matching form

The way to express the nutrients in a compound fertilizer is according to N, P_2O_5 and K_2O arranged in that order. The nutrients are to be written in the form of “N- P_2O_5 - K_2O ” referred to as the matching form, with the contents of nutrients expressed in Arabic numerals.

For example:

1. “17-17-17” indicates N, P_2O_5 , K_2O contents are 17% each, a compound fertilizer of three elements with total nutrient content of 51%;
2. “17-17-0” indicates that contents of N and P_2O_5 are 17% each, a compound fertilizer of two elements with N and P and total nutrient content of 34%;
3. “17-0-17” indicates that contents of N, and K_2O are 17% each and it is a compound fertilizer with two elements of N and K with a total nutrient content of 34%.

5.1.2 Present state of compound fertilizer development in China

China started the application of compound fertilizers in the 1950s. It became accepted by the farmers after a long period of time. In 1970s, on average, the amount of compound fertilizer

applied each year was about 273,000 t (of pure nutrients) which was 2.2% of the total amount of chemical fertilizers applied. In the mid 1980s, the use of compound fertilizer grew rapidly. The amount applied in 1990 was 3.4 Mt, accounting for 13.2% of the total amount of chemical fertilizers used. In 1995, it was 6.7 Mt, accounting for 18.7% of the total amount of chemical fertilizers used. In 2000, the figure was 9.2 Mt or 22.1% of the total amount of 41.5 Mt of chemical fertilizers consumed. By 2005, the amount of compound fertilizer applied throughout the country was 12.3 Mt or 25% of the total amount of almost 49 Mt of chemical fertilizers consumed (Table 5-1).

Production of compound fertilizers in China started late but development was relatively fast. Currently, there are more than 4,000 enterprises all over China that have obtained a licence to produce compound fertilizers. Actual annual production is more than 6,000 t (product quantity). Chinese-made compound fertilizer is gradually becoming the main product with competitiveness. In 2004, China's volume of imported chemical fertilizer was less than the volume imported in 2003. The volume of DAP imported was 2.6 Mt, decreasing yearly by 14.3%. There was also a decrease in the import of NPK. China even exported 147,500 t of three-nutrient compound fertilizer in 2004, an increase of 30.5% over 2003. Even though the compound fertilizer industry in China achieved good results, there are many problems that require urgent solution. Over the years, the amount of compound fertilizer application and the rate of recombination of fertilizers increased continuously. However, the extent of recombination of fertilizers in China is lower compared with advanced countries. The production and amount of bulk blended (BB) fertilizer applications, among compound fertilizers, are also relatively small. The proportion of BB fertilizer is only about 10% of the total amount of N and P fertilizers. Due to its instability, it does not have a good reputation among farmers.

Table 5-1 Consumption of compound fertilizers and their ratio to total chemical fertilizers used in China: 1981-2005

| Item | 1981 | 1985 | 1990 | 1995 | 1997 | 1999 | 2005 |
|---|-------|--------|--------|--------|--------|--------|-------|
| Amount of chemical fertilizers used ('000 t) | 13349 | 17758 | 25903 | 35936 | 39809 | 41250 | 48975 |
| Amount of compound fertilizer used ('000 t) | 566 | 1796 | 3416 | 6708 | 7978 | 8800 | 12250 |
| Ratio of compound fertilizer to chemical fertilizer % | 4.24% | 10.11% | 13.19% | 18.67% | 20.04% | 21.33% | 25% |

5.1.3 Classification of compound fertilizers

5.1.3.1 Classification according to production process

1. Formation compound fertilizer

This refers to compound fertilizers synthesized or produced through chemical means. It has two main types as follows;

One type is the two-nutrient compound fertilizer synthesized through pure chemical reactions. The main grades are as follows:

1. Nitrophosphate: In general, the total nutrient content is 40%. The N: P₂O₅ ratio includes the 1:1 type and the 2:1 type;
2. Diammonium phosphate (DAP): Contains 18% N, 46% P₂O₅, with the total nutrient content at 64%; (18-46-0)
3. Monoammonium phosphate (MAP): In general, the N content is 10-12%, P₂O₅ content is 45-51% and the total nutrient is 55-60%.

As the N:P₂O₅ or N:K₂O ratio of the two-nutrient compound fertilizers are inconsistent, some advanced countries stopped using it for direct application. It is mostly used as a raw material for processing bulk blend fertilizers. At present, the MAP produced in China is mostly used as a raw material in mixing fertilizers.

The other type of formation compound fertilizer is the three-nutrient compound fertilizer. Its production is made up of a chemical reaction and mixing process. The main raw material is phosphoric acid, and ammonia is added for reaction. K fertilizer is then added for mixing. On concentration, it becomes a three-nutrient compound fertilizer. Reaction of phosphoric acid with ammonia is a chemical process and the addition of K is a physical mixing process. This production technique is also called the slurry process. Usually the medium and large enterprises use this type of technique. Only high-analysis fertilizers are produced. Compound fertilizers imported from abroad such as 15-15-15, 16-16-16 and compound fertilizers produced by domestic large enterprises adopt this technique. The compound fertilizer produced by this type of process is generally referred to as “*fuhe* fertilizer” by the Chinese.

The main advantages of this type of compound fertilizer are as follows:

1. Nutrients are evenly distributed and uniform in every granule. Errors seldom occur. Therefore, it is easy to achieve the content of single nutrient and the total nutrient content;
2. Physical conditions are good. Granules are of even size with strong resistance against pressure. The surface is bright and smooth. The granules do not break easily during storage and transportation. They do not form lumps easily. Fertilizer quality can be guaranteed.

2. Mixed fertilizers

Domestically, dry powder is used for granulation, that is, powdered fertilizers are used (if granular fertilizer such as urea is used, it has to be crushed in advance). Granulation is carried out after physical mixing. The production scale is generally not large when this process is adopted. Annual production by a small enterprise is less than 10,000 t. Large enterprises produce only 50,000-100,000 t, most of them

producing only 10,000-30,000 t. The nutrient concentrations of the fertilizer produced are relatively low with total nutrients between 25 and 35%.

Mixed fertilizers in other countries are mainly BB fertilizers, usually formed by mixing granular N, P and K fertilizers. However, the granule size and density of the P, P and K fertilizers that are mixed must be the same; otherwise there will be separation that leads to nutrient unevenness that affects fertilizer efficiency. The fertilizer can be mixed and packed according to the farmer's requirement at the time of selling.

5.1.3.2 Categorization according to uses

1. General compound fertilizer

In China, fertilizers with same nutrient content of N, P₂O₅, K₂O are referred to as general fertilizers. Examples are 15-15-15 and 16-16-16. As this type of fertilizer can be used on various types of soils and crops, they are also called “the fool's fertilizer.” General fertilizer is easy to apply but there is an obvious disadvantage, that is, the proportion of nutrients has no specific target. When this type of fertilizer is used in the south, there is wastage of P. If it is used on wheat fields in the north, it may cause wastage of K.

2. Special purpose compound fertilizer

Determination of fertilizer composition for special purposes is based on the nutritional requirements of a crop. Compound fertilizer is used mainly as a base fertilizer and N fertilizer is used mainly for topdressing; thus, ratios of P and K should be the main consideration in the composition.

1. Type of crop

Different crops require different nutrients. Crops can be broadly divided into the P-loving and K-loving crops. P-loving crops are oilseeds. Examples are rape, soybean, sunflower and leguminous forage grass. K-loving crops include melons, fruits, vegetables, tea, potatoes, tobacco and sugar-producing crops.

2. Type of soil

Fertilizer composition is prescribed based on the characteristics of fertilizer application to the soil in a region, the farmer's practice of fertilizer application and results of experiments at the various places. At present, soils in southern China are deficient in K while soils in northern China are deficient in P.

As fertilizers with special purpose take into consideration the crop and the soil, it works with a target. As a result, with the same total nutrient content of 45%, the effect of a fertilizer with special purpose is generally better than a general fertilizer.

5.1.3.3 Classification according to nutrient state

Currently, compound fertilizers in the domestic market are broadly divided into the following categories:

1. Urea-based compound fertilizer. It is made mainly by spraying urea solution and granulation.
2. Nitrate (NO₃)-based compound fertilizer. It is made by adding K during the production of NP fertilizer. It contains NO₃-N, suitable for use in northern China where rainfall and temperature are low. It is particularly suitable for

vegetables and fruit trees. Imported compound fertilizers are basically of this type.

3. Sulphur (S) -based compound fertilizer. This refers to the source of K in the fertilizer, which is SOP, and is suitable for crops that are sensitive to Cl.
4. Chlorine (Cl) -based compound fertilizer. In this fertilizer, either K or ammonium chloride (AC) is the source of K or N or both (also referred to as double-chlorine fertilizer).

5.1.3.4 Classification according to nutrient proportion

Usually, compound fertilizers with N, P₂O₅ and K₂O contents higher than 20% are referred to as high-N, high-P or high-K type.

1. High-N compound fertilizer

High-N compound fertilizer is used in once-only fertilizer applications and top-dressing. Once-only fertilizer application is mainly as a base fertilizer for the spring maize crop in Northeast China and as a base fertilizer for wheat crop in the provinces of Shandong and Hunan. The main fertilizer grades include Sakefu 28-9-11, 26-10-12 and 25-13-10. In northern China, many farmers cultivate their summer maize crop without applying the base fertilizer. Instead, they apply fertilizer once only at the seedling stage. Therefore, high-N fertilizer is used mainly on the summer maize, wheat and cotton crops as topdressing. The main fertilizer grades produced by the Shijiazhuang Lianjian Chemical Industry include:

| | | |
|--|----------|----------|
| 28-6-16 | 30-5-15 | 30-10-10 |
| 32-6-12 | 32-0-18 | 34-0-16 |
| 35-5-10 | 25-10-10 | 28-9-9 |
| the Sakefu | | |
| 20-10-10 | 24-16-6 | 25-10-5 |
| and the Jiaji | | |
| 25-13-17 and 24-8-11 (especially for vegetables) | | |

2. High-P compound fertilizer

High-P compound fertilizer is divided into special purpose fertilizer for soils and special purpose fertilizer for crops. The special purpose fertilizer for soils target areas where readily available P is low and for soils that are partially saline. The main fertilizer grades for wheat, maize and cotton on such soils include 15-27-8 and 13-20-12. Special fertilizers for crops are mainly used as seed fertilizers for spring maize in Northeast China and for rape and legumes. The main fertilizer grades include 16-18-12, Sakefu seed fertilizer 10-15-5, 12-23-5, special purpose fertilizer for legumes 15-23-10 and special purpose fertilizer for soil 15-25-5 and 15-20-10.

3. High-K compound fertilizer

In order to satisfy the requirements of cash crops for quality and yield, many manufacturers developed high-K compound fertilizers to be used as a base fertilizer and as topdressing for fruit trees, garlic, tobacco and vegetables. These fertilizers must meet the high requirements of solubility, external appearance and colour. Some fertilizers even have progression agent such as humic acid added. The main grades include; 15-15-20, 18-6-24, 15-10-20, 20-5-30, 10-6-24, 16-8-20, 16-10-24, 15-10-20 and 12-8-20.

4. P-K type compound fertilizer

China's soils in most regions are generally N deficient. In recent years, yield increases by the use of K have been obvious. At the same time, domestic processes for increasing the P content in compound fertilizers such as melt granulation, rotary drum granulation and rolling granulation process are encountering difficulties. The ratio of N and K compound fertilizers is high domestically. Grades found in the market include 16-0-40, 20-10-20, 18-9-18, 14-12-14, 18-8-14 and 20-5-30 (for fruit and vegetables topdressing).

5. N-P compound fertilizer

In China, farmers in most regions favour the use of DAP. Based on their own production techniques, some manufacturers developed the N-P compound fertilizers which contain little or no K. Examples are made-in-China and imported DAP, Tianji NP (27-11-0), P-K NO₃ (22-9-9, 22-9-6), Sakefu 16-16-8, 18-18-8, Shuanglian 10-10-5, 16-18-8 and 18-16-8.

6. Balanced compound fertilizer

Because the production technique required for balanced compound fertilizers is not high, performance of product is stable and its application is wide. This fertilizer is taking up the main share in the market. The main grades include 15-15-15, 16-16-16 and 17-17-17. It is produced by every manufacturer.

5.1.4 Production techniques and products of compound fertilizers in China

5.1.4.1 Compound fertilizers by the rolling granulation process

This is a major method for producing compound fertilizers domestically and overseas. Based on the different granulation equipment used, the method can be divided into disc granulation, rotary drum granulation and double-blade mixing granulation. The first two methods are widely adopted by compound fertilizer production plants. The technique is mature and the quality is reliable.

1. Basic principle

The basic principle in the rolling granulation process is that fertilizers formed should be of definite pellet fineness (particle size) with the granules formed by cohesion with the aid of the liquid phase of the fertilizer salts. With further help from an external force, motion is generated among the cohesive pellets. Mutual squeezing and rolling enable the pellets to become inseparable and form granules.

2. Characteristics of production

Characteristics of flow: Firstly, as production by the rolling granulation process involves the formation of pellets from powdered, dry and mixed materials with the help of the liquid phase and mechanical action, there is no occurrence of chemical reaction in the entire flow. This is the most outstanding characteristic of this product. Secondly, the process flow of production is relatively long and requires independent installations for sieving, granulation, drying and cooling.. Thirdly, there is a wide range of choices for N, including urea and MAP. However, since high-analysis

liquid ammonia and phosphoric acid cannot be used as raw materials, it is difficult to produce compound fertilizers with high nutrient contents.

Merits and shortcomings: The rolling granulation production process is relatively simple without the restriction of heating and application of pressure, thus, stability of the products can be controlled. The technique is mature with low investment and simple operation. However, since there is no chemical reaction in the process of granulation, and granule formation is dependent on liquid phase cohesion only, granule strength is weak and the product easily turns into powder and forms lumps.

5.1.4.2 Compound fertilizers by the slurry method

1. Basic principle

During the production of compound fertilizers by the slurry method, all or most of the materials that go into the process of artificial granulation are in the form of slurry. The slurry is generated by the reaction of nitric acid, phosphoric acid or H_2SO_4 with ammonia and pellets are formed after the processes of granulation and drying. When categorized according to raw materials, the compound fertilizer can be divided into the ammonium sulphate-ammonium phosphate (AS-AP) series, the ammonium nitrate-ammonium phosphate (AN-AP) series and the urea-ammonium phosphate (U-AP) series.

2. Characteristics of production

Characteristics of flow: Firstly, slurry is formed by neutralization reaction through ammonia and phosphoric acid and this is more complicated than the granulation method. Secondly, there is a wide range of raw materials used, such as urea, MAP or DAP in the liquid or solid form. Solid raw materials have to undergo molten state treatment. Thirdly, flow of the AZF (Toulouse, France) slurry method is complicated, however, products are flexible. Various types of compound fertilizers can be produced. The highest N content of NPK products can reach about 30%. However, the process flow of potassium bisulphate is fixed with a set formula.

Merits and shortcomings: Production flow is complicated with a high level of automation that allows precise control of the intrinsic quality of products. There are also many types of products. In addition, the pipe reactor can also be used to save energy consumption. Due to the complicated operation, the cost of production is high and requires high quality raw material (particularly phosphoric acid). Compared with other production methods it is difficult to raise the N content in the potassium bisulphate technique during the process of the slurry method. It is, therefore, difficult to produce high-N type compound fertilizers.

3. The AS-AP series of compound fertilizers

The series of compound fertilizers formed by AS and AP have low hygroscopicity. They are slightly acidic and have the effect of improving alkaline soils. They have unique fertilizer effects on tea and sugar cane and are suitable for many types of soils and crops. In the mid-1970s the pipe reactor successfully developed by International Fertilizer Development Center (IFDC), using ammonia to neutralize phosphoric acid and H_2SO_4 , was first applied to the production of the AS-AP series

of compound fertilizers. This method has been widely used for the production of compound fertilizer in China. Raw material wet-process phosphoric acid (less than 40% P_2O_5) is added to the tail gas system for washing the drum ammoniation and granulation device and the gyratory dryer-gyratory cooling cylinder, draw out tail gas containing ammonia and dust. The washing acid obtained is heated by the acid pre-heater and, after measurement, is added to the pipe reactor. After measurement, H_2SO_4 is added from the other end of the reaction tube. Liquid ammonia and a small volume of water are added from the end of the reaction tube. When the acid and the ammonia are circulating at high speed in the channel, they mix rapidly and produce a reaction. The heat of reaction enables the material temperature to rise above the boiling point of the liquid material. Steam produced causes the material in the tube to be in a state of pressure of 0.3-0.4 MPa (megapascal). The high temperature increases the solubility of AP and the concentration of the raw material phosphoric acid can be slightly higher. This means a decrease in the volume of water that enters the production system with the phosphoric acid and an increase in the ratio of water brought in by the materials to be evaporated using the heat of neutralization reaction. The amount of drying of granulation materials from the pipe reactor technique is obviously lower.

4. AN-AP series of compound fertilizers

The production of AN-AP series of compound fertilizers is mostly by the addition of a concentrated solution of AN to the pre-neutralization device of the phosphoric acid and ammonia reactor, or by the addition of a concentrated solution of AN into the drum ammoniation and granulation device. Together, the concentrated solution of AN and the AP slurry from the pre-neutralization device undergoes granulation in the ammoniation and granulation device. A small number of plants neutralize the mixed nitric and phosphoric acid by using ammonia with the N-P slurry generated reverting to form granules, or K is added to make N-P-K compound fertilizer. Solubility of AN is high and granulation by AN-AP is a typical slurry granulation process.

In the late 1960s, both the Dutch company (Stamicarbon) and the Norwegian company (Norsk Hydro (now Yara)) developed the technology of molten mass tower spraying granulation. There was an increase in the ratio of tower granulation design in AN-AP and NP fertilizer plants. In this type of technology, the slurry of neutralized AN or NP is concentrated to more than 96%. The concentrated slurry is sent to the top of the granulation tower by pump. In a stirring trough that mixes rapidly, the slurry and the added fine-powder K and fine-powder returning charge are mixed. The slurry is sprayed down from the top of the tower through a revolving sprinkler and solidified to form granules in the air stream. PEC of France vigorously promoted its granulation technique with "spherodizer" in its production of NP fertilizer and AN-AP series of compound fertilizers. It is called the gunite granulation technology in China. This technology was applied to the production of AP by the American Chemical and Industrial Corporation at the beginning of the 1950s. PEC of France used the same method in the production of NP by low-concentration carbonisation.

AP by the slurry concentration process was used in the former Soviet Union. Production of AP in Romania also used this method to form granules of AP and dry them. The Tongling Ammonium Phosphate Plant in the province of Anhui and scores of other Chinese AP plants of slurry concentration process use this method to establish operations of slurry granulation and drying. In the process of gunite granulation and drying, the slurry containing 15-30% is sprayed and spread into a foam. "Screen barrier spraying" or "curtain spraying" is formed when the foam meets the solid returns charge in the drum and the K salt particles falling as a material screen. Hot air for drying blows in from the front end of the drum, from the direction of the gunite. The pellets get coated as they move to the centre of the drum after going through many circulations and spraying. Water from the coated material evaporates rapidly. The products discharged at the end of the drum have obviously increased in granule size. The granules are rounded, full and hard. The water content of the discharged material can meet the pre-determined requirement by controlling the rate of flow and temperature of the hot air. The moisture content permitted in AN-AP series of compound fertilizer and NP is less than 1.0%.

5.1.4.3 Compound fertilizer in granulation tower of concentrated solution

Melt-granulation is a special process of the slurry granulation technique. With progress in the production technology of compound fertilizer, the technique of melt-granulation has gradually evolved into an independent method for the production of compound fertilizer.

1. Basic principle

Characteristics of the melt-granulation process include the high-temperature molten state of the material, the very low water content and direct spraying of the mobile melt into the cooling medium. During cooling, the material solidifies to become spherical pellets; or the mobile melt is sprayed onto the particles of the return charge inside the granulation machine so that it is coated on the surface of the fine particles or forms pellets that comply with the requirement. Evaporation or concentration of solution involves energy consumption. However, with regard to the utilization of energy, it is far more effective than dried pellet products. Besides, in certain production processes, the heat of reaction can be utilized fully to evaporate the water partially or fully. In the common granulation processes, the dryer is usually the most bulky and the most costly equipment in the granulation plants. In the melt-granulation process, however, no drying is required. This saves investment and energy consumption. The technology of manufacturing compound fertilizer by the method of melt-granulation was first applied in the production of MAP, AN-AP and urea-AP. In these methods of production, K or other solid substances can be added to produce pellet form NPK compound fertilizers. According to the different ways of granulation, the process of manufacturing compound fertilizer by melt-granulation can be divided into:

- the tower spraying granulation process
- the oil-cooling granulation process
- the bi-axial granulation process

- the drum granulation process
- the gunite granulation process
- the pan granulation process
- the steel band granulation process

2. Characteristics of production

Characteristics of flow: Firstly, raw materials such as urea and AN are turned into the molten state. Liquid urea from the urea plant can be used directly. The key to production is the making of congruent melting. Secondly, compound fertilizers containing 25% or more N can be produced with ease but the source of N can only be urea or $\text{NO}_3\text{-N}$. It is difficult to change the N source in the same installation. Thirdly, the process of drying is not necessary. It is energy saving. Externally, the product appears rounded, full and unique.

Merits and shortcomings: The product has a good external appearance. It does not form lumps easily and is attractive to consumers. Drying equipment is not needed. This saves cost and energy consumption. It is very convenient for the production of high-N type compound fertilizer. In the case of products of compound fertilizer by the method of tower granulation, due to its own restrictions, product specifications are limited. In general, compound fertilizers of high-P type and with nutrient content below 42% cannot be produced. Furthermore, the biuret content of urea is high in a molten state at above 100°C.

5.1.4.4 Bulk blend (BB) compound fertilizers

1. Mixing of powder fertilizers

Mixing powders was the early process in manufacturing compound fertilizer. After weighing the basic fertilizers according to proportions, mixing is carried out in a simple container. Before mixing, the base fertilizers are crushed into small pieces to be sieved with about mesh 6. Caking often occurs in storage for mixed powder fertilizers. In the early days, discarded materials or lime was added to improve the physical properties of the fertilizer. In addition, many factories carried out mixing after "curing" to allow the completion of chemical reaction and reduce caking. Currently, powder BB fertilizers are relatively rare in the market.

2. Mixing of pellet fertilizers

Raw materials for mixed pellet fertilizers are in the form of granules of similar sizes. Materials used are urea, AC, AN, MAP, DAP and MOP. Usually, in the production of mixed pellet fertilizers, the pre-treated raw materials enter the isolated storage vessels. They are then weighed separately by a weighing installation before entering the mixer. The technical requirement of BB fertilizer is that pellets must be of the same sizes.

3. Characteristics of production

Characteristics of flow: As there is no heating, moisturizing and drying, the production flow is simple with little environment pollution. The efficiency rate of raw materials is high. The course of processing is simple and operation is easy. Nutrient matching is flexible and it can satisfy the requirements of various types of batch production. Annual production of the plant is generally at 5,000 to 30,000 t.

Merits and shortcomings: Merits include simple production, simple equipment, flexible nutrient matching, and good adaptability, suitable for various production scales, minimum investment in construction and a high production-investment ratio. However, the method relies much on the raw materials, particularly large pellets of urea and of K fertilizer. The degree of separation is high for products from a poor process.

5.1.4.5 Granulated compound fertilizers by the extrusion method

The production of compound fertilizers is mainly by pan and drum granulation. In recent years, some fertilizer plants adopted the method of granulation by extrusion in the production of NPK products. In its granulation process, mechanical action is used to apply pressure on the materials. Granules are formed from the perforated plate of the mould by extrusion. The product particles are of cylindrical shape and some are irregular. The particle diameter depends on the model of the extrusion machine, varying up to a few millimetres. With regard to the scale of production by the extrusion granulation method, depending on the fertilizer compound and purpose, there is much flexibility in the equipment. The flow is short without returning pellets. Investment is low. There are two types of granulation by extrusion: one is granulation by thrust and the other, granulation by rolling. In granulation by thrusting, the water content of the materials fed is usually 5-8%. After extrusion, a cylindrical product is obtained. On cooling, the water content of the product obtained is lower than 5% and the percentage of granulation is about 85. In granulation by rolling, the water content of materials fed can be lower, at 0.5-1.5%. The ribbon-shape material resulting from extrusion is broken, sieved to obtain a product of cube-shape or with edges and corners. As moisture content of the product is low, there is no need for drying.

Investment in the extrusion method is usually about one-fifth of the granulation method. This method is more suitable for the granulation of compound fertilizers from materials that are heat-sensitive (urea and AP) and water-sensitive (ABC and AC). Restriction by mould ability of the raw materials is a disadvantage and the types of products produced are less than the granulation method. There are many domestic manufacturers of extrusion machines that come in many types. However, the single machine has a small capacity. Equipment maintenance and repair costs are high. Processing of spare parts is tedious. This method is more suitable for manufacturers with mechanical processing capability. It is not suitable for relatively large scale industrial production. In addition, the granules produced from this method are not round, and the diameter of the fertilizer particles ranges from 1-4 mm which is not suitable for mechanical application.

5.1.5 History of the development and characteristics of compound fertilizers in China

The development of compound fertilizers in China began with the AP industry. In 1966, the Nanjing Chemical Industry Co. built a DAP plant capable of producing 30,000 t/y. This marked the official commencement of the compound

fertilizer industry in China. The 50-year history of compound fertilizer in China can be roughly divided into two stages described below.

5.1.5.1 Preparatory stages in the development of high-analysis compound fertilizers technology

In the early 1950s, when high-analysis chemical fertilizers and compound fertilizers were introduced worldwide, the Shanghai Research Institute of Chemical Industry manufactured and carried out pilot tests on wet-process phosphoric acid, thermal phosphoric acid, MAP, DAP, NP and TSP with good results. In the 1960s, production plants of NP, wet-process phosphoric acid and DAP were set up. In 1966, Sinopec the Nanjing Chemical Industry Corporation built the first industrial production plant capable of producing 30,000 t of DAP/y. This opened the first page in the history of AP production in China. The Shanghai Research Institute of Chemical Industry also jointly launched an agricultural evaluation test on the NP by the freezing method between 1976 and 1983. This was China's first large-scale nationwide test that yielded nearly 600 test data and laid the foundation for the subsequent development of compound fertilizers. The second test was carried out between 1980 and 1983. The national chemical fertilizer-testing network carried out studies on the fertilizer effect of compound fertilizers and the techniques of application. In March 1982, Zhang Kaiyan of the Institute of Planning and Design of the former Ministry of Chemical Industry and Liu Gengling of the Chinese Academy of Agricultural Sciences (formerly Director of the Institute of Soil Science and presently an academician of the Chinese Academy of Engineering) proposed and later chaired the "Discussion on the Problems of Development of Compound Fertilizer (Bulk Blend Fertilizer) in China" held in Beijing. It was proposed that they should learn from the advanced experience in foreign countries in order to develop the production and application of BB fertilizers (subsequently standardized to "compound fertilizers"). The third test occurred between 1983 and 1986. The National Science and Technology Commission organized and carried out the project of "Research on types of high-analysis compound fertilizer, technique of their application and secondary processing technology." Detailed studies were carried out on the fertilizer efficiency of compound and single fertilizers; fertilizer efficiency of compound fertilizer grades with different nutrient forms; fertilizer efficiency of powder and granular compound fertilizers and techniques of application of compound fertilizers. Between 1986 and 1991 the Chinese Academy of Agricultural Sciences and Shanghai Research Institute of Chemical Industry took the lead in launching the project "Study on the techniques of applying bulk blend fertilizers." A total of 355 test results were obtained. These results filled the gaps with regard to the fertilizer efficiency of bulk blend fertilizers, methods of field evaluation of nutrient separation and permissible limits for nutrient errors. Further studies were also carried out on the evolution of fertilizer efficiency of the different types of compound fertilizers and the rate of water solubility of P elements in the compound fertilizer. Studies on the techniques of production and application methods opened a new chapter in the production and application of compound fertilizer in China.

5.1.5.2 Stage of rapid development of compound fertilizer

1. The development of compound fertilizers using wet-process phosphoric acid and ammonia as basic ingredients

Medium and large AP plants were set up with their own advantages and imported technology. There were 11 AP plants, including:

- Tongling Chemical Industry,
- Dahua Group,
- Sino-Arab Chemical Fertilizers Company Limited,
- Guixi Chemical Fertilizers and
- Honghe Phosphate Fertilizers

Small and medium P fertilizer plants were built through China's research and development, such as the 73 plants built by utilizing the slurry concentration process on dilute AP that produce 30,000 t annually and the two AP plants that produces 60,000 t annually.

2. The utilization of many types of basic fertilizers in the development of compound fertilizers

Starting in 1979, the Shanghai Research Institute of Chemical Industry developed the production techniques by adopting the granulation process for many types of compound fertilizers such as;

- urea-SSP series
- urea-AP series
- AC-SSP series
- AC-AP series
- AN-SSP series

Before 1990, China adopted the granulation method that produced compound fertilizers in pellets. The plants were small and medium scale.

3. The rise of large-scale enterprises of compound fertilizer

After the 1990s, due to the impact of imported compound fertilizers and the policy reforms on agricultural resources by the State, state-owned large P compound fertilizer enterprises adjusted their policies and started producing high-analysis compound fertilizers on a large scale. The Sino-Arab Chemical Fertilizers Co. Ltd., in 1999, led in producing various types of compound fertilizers for special purposes. Other companies such as:

- Shandong Luxi Chemical Industry
- Yunnan Honghe Phosphate Fertilizer Plant
- Shandong Hongri Group
- Sichuan Shifang Yingfeng Industries and
- Hubei Yangfeng Group

switched to the production of high-analysis compound fertilizers. Enterprises throughout the country that had obtained the licence to produce compound fertilizer totalled 2,240 in 1990. The annual production capacity was 30 Mt.

After the 1990s, with the new market, compound fertilizers made considerable progress. From the low-analysis and single matching products in the 1980s, compound fertilizers developed into many types of high-analysis products. From the product composition of the AP series and the NP and FCMP series, it developed to include compound fertilizers of many processes and forms that included the granulation method, the AS-AP series, the AN-AP series, melt-

granulation and bulk blend fertilizers. By the end of 2005, production capacity for DAP in China already reached 9.6 Mt (product quantity). Based on the 75% level of operation of plants in 2004, calculations show that by 2006, the actual output of DAP will be around 7 Mt (product quantity). The total consumption of compound fertilizers in 2003 and 2004 reached 11.1 Mt (pure nutrient) and 12.0 Mt (pure nutrient) respectively. They accounted for 25.1% and 25.9% of the total volume of consumption of chemical fertilizers in those years. In 2005, the NPK (three-nutrient) compound fertilizer output, in terms of product, was 17.1 Mt, with an annual increase of 33.7%.

5.1.5.3 Characteristics of technical development

Essentially, the process of producing compound fertilizers involves breaking up the single raw materials separately (melt) followed by formulation of combinations of raw materials (including the choice of fillers and additives in defined proportions), mixing, granulation, drying, cooling, sieving and packing. The core of compound fertilizer production is granulation. Once the granulation process and equipment have been confirmed, the preparation of and matching the combination of materials prior to granulation and drying, cooling and sieving required after granulation can then be determined.

After more than 10 years of continuous exploration in the production of compound fertilizers, from the conventional production techniques, with specific requirement of output and technical index of a product and the supply of raw materials, classification of the granulation process includes mainly:

- granulation method
- slurry method
- melt-granulation method, mixing, extrusion
- granulation by coating

The various types of production processes co-exist at different periods of development of compound fertilizers but each has its own emphasis.

Based on the different periods and the main characteristics, the development process can be divided into four stages;

1. The first stage was in the 1980s during which the various regions developed small-scale production of compound fertilizers with an annual production of about 5,000 t. Products were mainly large pellets from extrusion and strips from rolling. There were also plants that granulated potassium phosphate before mixing it with urea. However, due to a number of shortcomings, there were only a small number of plants that used this method of production.
2. The second stage was from the late 1980s to the early 1990s. Production plants with a capacity of more than 10,000 t were set up to produce mainly pellet-form fertilizers. Disc granulation and drum granulation equipment was used for production. These two methods have both advantages and disadvantages. The disc granulation method is more direct. Once the angle of inclination and the speed of revolution are stabilized, operation is easy. The long process flow is its shortcoming. The method occupies more space and workers have to labour harder. Granule formation is only possible with the addition of a binder. The disc granulation method is suitable for the production

of compound fertilizers with an annual output of 10,000 t or less. The drum granulation method was first used in the production of compound fertilizers with an annual output of more than 10,000 t. Its merits include a smaller space requirement and less manual labour for the workers. However, the steam contains 40-50% moisture and it is difficult to calculate the water content of materials. Besides, workers must be experienced. In the second stage, the three-nutrient compound fertilizers with total effective nutrient content of $\geq 25\%$ were produced.

3. The third stage was in the late 1990s. With progress in agricultural development, high nutrient concentration compound fertilizers were required. In general, a total effective NPK nutrient content of $\geq 40\%$ was needed. In many regions, symptoms of soil deficiencies of elements required in medium amounts, such as Ca, Mg, and S began to appear. Requirements of agricultural production could not be met with only macro-elements of N, P and K. At this juncture, a large group of enterprises that produced high-concentration NPK (three-nutrient) compound fertilizers appeared. Most of these enterprises used the granulation process, the slurry process, the melt-granulation process and granulation by coating.
4. The 21st century entered with the fourth stage. The development of compound fertilizers progressed in leaps and bounds. Concentration of compound fertilizers is increasing. With developments in the technique of balanced fertilizer application, enterprises have begun to develop the technology of producing fertilizers for special purposes. At this juncture, BB fertilizers come to the fore. This further increased the nutrient content of compound fertilizers. At this time, techniques of producing organic-inorganic compound fertilizers and controlled (slow) release compound fertilizers also surfaced.

5.1.6 Technical innovation of compound fertilizers in China

There are many techniques for producing compound fertilizers in China. They include imported techniques and China's own innovations from research and development. At present, the most widely used techniques are improvements based on imported technology which are applicable to conditions in China. In the improvement of techniques for producing compound fertilizers, China relies on technological progress: the simplification of process flow, raised equipment strength, reduced consumption of materials, flexible handling of stock assets, development of the potential to multiply production, implementation of a rolling development and following the path of expansion at low cost. These will enable China's products to become competitive and change the situation of having foreign compound fertilizers dominate the Chinese market. For technological reforms, enterprises producing compound fertilizers and institutes of design in chemical industry made full use of their advantages and talents to develop a series of processes and techniques with autonomous intellectual property right.

The reforms carried out on the French AZF compound fertilizer process by the Sino-Arab Chemical Fertilizers Co. Ltd. is an example of success in the autonomous reform of an

imported process. In the original design, the slurry in the pipe reactor of the dryer easily causes the copy plate of the dryer to be scarred and this shortens the production cycle. The Sino-Arab Chemical Fertilizers Co. Ltd. proposed the removal of the pipe reactor in the dryer and replaced phosphoric acid with MAP. The feasibility of the revamp was substantiated by scientific calculations. Through pilot tests of the production plant, the best production parameters were determined and the technical development was finally successful, resulting in tremendous economic and social benefits. In order to raise output and reduce energy consumption of the original design, the mode of ammonia supply was revamped. The liquid ammonia coming from the piping entered the process workshop to supply the pipe reactor. This raised production greatly and reduced energy consumption. The changes on the imported AZF process made by the Sino-Arab Chemical Fertilizers Co. Ltd. were the first on the same type of production installation internationally. The annual production capacity of the plant increased from 480,000 to 700,000 t. In addition, a second set of AZF-process production plants was set up independently. This became an example of carrying out reform on imported technology and turning it into a domestic technology.

Large chemical fertilizer enterprises in China already possess the ability to carry out research and development in production technology. Their production processes have attained an internationally advanced level. For example, through its own research and development, the Shandong Hongri Group was able to develop the technique of S-based NPK production by removing Cl in the raw materials in the course of production. This has greatly reduced the cost of production. Fertilizer produced by this method is very competitive on the international market. To develop this technique, after much hard work and detailed investigation, the Hongri Group decided to produce three-nutrient (NPK) compound fertilizer in its AP plant. After repeated trials, they developed a new method to produce a S-based NPK compound fertilizer with HCl as a by-product by utilizing the low-temperature conversion of KCl in the AP plant. This method makes use of the direct reaction between KCl and concentrated H_2SO_4 followed by mixing with wet-process phosphoric acid. After neutralization with liquid ammonia, direct gunite granulation is carried out. The compound fertilizer products have K-AS, SOP and AP as their major components. This method directly combines the production of SOP and the production of N-P fertilizer. The process, which has broken the traditional way of using SOP as the source of K, produces the N, P and K fertilizers separately, crushes and mixes them according to proportions, bonds them, granulates and dries. The process flow is greatly shortened and the cost is reduced. At present, the annual production capacity for compound fertilizers by this process has exceeded 7 Mt. The compound fertilizers produced are very competitive in the international market.

In the development of compound fertilizers, the high impurities in the P ore restrict the development of P compound fertilizer. In order to fully utilize the Chinese P ore with high impurities and to reduce investment and cost, the Sichuan Yinshan Phosphate Fertilizer Plant and Chengdu University of Technology, in the early 1980s, jointly developed

the technology of MAP production by the slurry method. This technology shows high adaptability to the different grades of P ore. Furthermore, consumption of steam can be reduced by almost half. This method has greatly raised the production capacity of high-analysis P compound fertilizers in China and improved the composition of P fertilizer products. Currently there are more than 80 production plants all over the country that adopt this method. The original designed production capacity of these enterprises of 30,000 t has been increased to produce 60,000-80,000 t/y or more. In the slurry method, after dilute phosphoric acid has been neutralized with ammonia, slurry is obtained after concentration. This avoids the difficulty in concentration due to excessive impurities in the dilute phosphoric acid. This is the main difference between the slurry method and the traditional production process. The production of AP uses the gunite granulation machine and the ratio of internal returning charge is reduced from (3-4):1 in the traditional method to (0-0.5):1. This saves a great deal of investment and cost. It also eliminates the bottleneck that has been hindering the development of compound fertilizers. In 1988, this technology was conferred the Grade I National Scientific and Technological Progress Award and was considered one of the eight major scientific achievements during the period of the 6th Five-Year Plan. In 1995, it was again conferred the National Key Scientific and Technological Achievement Award. This is worth mentioning because it was the first time in the history of China's chemical fertilizer industry development that an R&D project twice won an award at the national level.

As a raw material for compound fertilizer, phosphoric acid production becomes the most important limiting factor. The Shifang Chemical Fertilizer Plant and others developed the technology of poly-crystals. A phosphoric plant capable of producing 15,000 t P_2O_5 per year using different ores can raise its output to 25,000 t of P_2O_5 a year with poly-crystals. If measures to remove heat are added, output can be further increased. This enables the limits of selection of P ores in the production of phosphoric acid to be extended. The Yunnan Phosphate Fertilizer Plant developed a technique to increase phosphoric acid production from 40,000 to 75,000 t/y of P_2O_5 . Volumetric capacity of the extraction trough reached 2m³/t of P_2O_5 per day. The rapid phosphoric extraction technique of the Jiangsu Hongda New Technology Development Plant allowed it to more than double its phosphoric acid output of 15,000 t without increasing the volume of the extraction and nitrification troughs. Owing to the more than doubled increase in the ability of phosphoric extraction the processing capacity that followed was also doubled. This raised the economic performance of the enterprise.

5.1.7 Outlook for technology and product development of compound fertilizers

5.1.7.1 Characteristics of compound fertilizer development in advanced European countries and the USA

1. Higher complexity of nutrients

In recent years a downward trend in the consumption of chemical fertilizer has been observed in advanced countries

such as Spain, Britain, Italy, France and Germany. However, fertilizer application per unit area is still relatively high at 143.9 kg/ha ($N+P_2O_5+K_2O$) which is second only to China (246.3 kg/ha). The complexity of nutrients in compound fertilizers continues to increase. According to statistics in 2000, for the chemical fertilizers consumed in the above mentioned countries, the average inclusion rate of N, P and K was 21.0%, 87.5% and 67.4% respectively. The level of inclusion of N is lower than P and K fertilizers in some crops, especially field crops, since most of the P and K fertilizers are applied as base in the form of compound fertilizer. Some N fertilizers are also used as single fertilizer for topdressing to further regulate and control the supply of nutrients from the compound fertilizer. This indicates that in order to meet crop nutrient requirements at different stages of growth, the compound fertilizer must be applied in coordination with single fertilizers to provide a "set meal." Even though the inclusion rate of chemical fertilizer nutrients must be raised continuously, it does not mean higher is better. Over a long period of time, it is not necessary or possible for the fertilizer nutrients inclusion rate to reach 100%.

2. The ratio of bulk blend (BB) fertilizer in compound fertilizers is increasing

Bulk blend (or BB) fertilizers refer mainly to high-analysis dry granular blended fertilizers in bulk. They have a low production cost and high nutrient concentration (the total nutrient content may reach 57-59%). Nutrient ratios can be regulated and controlled according to soil and crop characteristics. The standard for fertilizer application is further improved with BB fertilizers thus; BB fertilizers have been growing rapidly in developed countries. In the US, both bulk chemical and liquid fertilizers are growing annually. At the end of the 1990s, sales of bagged solid chemical fertilizers dropped to 10% of the total. Chemical fertilizers in bulk and liquid fertilizers rose to 50% and 40% respectively. 10-15% of BB fertilizers are in bags to suit wet and rainy regions, home gardens, ornamentals, lawns and for export. With the development of mechanical application techniques and of irrigation, liquid and compound fertilizers took a large proportion of the market, accounting for 37.8 and 16.2% respectively. At present, there are about 8,000 BB fertilizer plants in the US that account for 90% of the secondary processing fertilizer plants. On average, the annual amount of processed fertilizer produced by each plant is about 3,000-5,000 t.

3. Establishment of an agrochemical services system in the production, marketing and consumption of compound fertilizers

Currently, almost all developed countries have an established agrochemical services system that integrates fertilizer production, marketing and after-sales services to the farmers, guided by science and technology. This system has played an important role in the development of compound fertilizers, particularly BB fertilizers. For example, the American IMC-Agrico Company has its own secondary fertilizer processing plant, a marketing network and a system of scientific fertilizer application services for farmers. Manufacturers of BB fertilizers obtain chemical fertilizers with uniform granules,

that do not form lumps easily, as raw materials for making BB fertilizers. They recommend BB fertilizer formulations according to soil test results and the views of experts. Within the limits of a 24-40 km radius, commercial fertilizers and tools for fertilizer application are supplied directly to the farms. In the system of agrochemical services, the production, marketing and application of fertilizer form a beneficial interactive mechanism with interdependence and mutual improvement. China, however, has yet to see an enterprise with such a system.

5.1.7.2 Comparison of industrial technology and standards of China's compound fertilizers with those in advanced countries

The structure of chemical fertilizer products in China is irrational. Besides the irrational ratios of N, P and K, single nutrient fertilizers and low-analysis products dominate. The average nutrient content is 27%. There is a large gap compared with the average level of 40% in other countries. Compound fertilizers account for only 25% of the total volume. Henceforth, China will increase the production of compound fertilizers and special-purpose fertilizers and reduce the production of single fertilizers. China should promote tertiary processing to produce granular BB fertilizer in small batches but with many grades.

The present development in Europe and the US includes compound fertilizer with secondary and microelements. According to statistics, compound fertilizers sold at fertilizer distribution stations in the US contain about 25-30% secondary and micronutrients. Owing to the relatively unstructured market in China and the fact that China started late, compound fertilizers mainly contain the three macroelements N, P and K. Secondary and micronutrients are seldom taken into consideration.

In other countries, there are also compound fertilizers with mixture of pesticides. In Japan, this may reach about 20%. In China, due to policy and technology limitations, only a small quantity of fertilizer is combined with pesticides. According to patent reports in foreign countries, 80% mancozeb (4.5 kg/ha) and metalaxyl-maneb (4.5 kg/ha) are used to treat tomatoes and they are mixed with urea-ammonium nitrate (UAN) solutions. With 10mm of rainfall, the efficacy against *Phytophthora* five days later is as high as 80.3%, with only 15% infection. In contrast in experiments where pesticides were not mixed with the UAN solution, the efficacy against *Phytophthora* was only 8.5% and the rate of infection 31.7%. It can be seen that fertilizer has an obvious effect in increasing the efficacy of a pesticide. When pesticides and fertilizers are mixed, besides the physical and chemical interactions, there is also synergy between bioactivity and biological effects. Research on the pesticide-fertilizer relationship has significant meaning with regard to coordination, labour savings and encouraging increased production and efficacy. In the early 1960s, Japan developed fertilizers mixed with pesticides. The key factor was to synchronize the period of fertilizer application (and amount of fertilizer applied) with the period of pesticide application (and quantity of pesticide applied) and pesticide safety. To solve this problem, there was, over the following 20 years a tremendous change in the situation of fertilizers mixed with pesticides. The pesticides mixed with

fertilizer were herbicides and insecticides. Later, Japan also developed fertilizers mixed with fungicides. Isoprothiolane and fertilizer for ear development of rice plants were mixed to produce the dual-effect of preventing rice blight and raising the degree of ripeness of rice grains.

Countries in Europe establish their compound fertilizer complexes with large units of AP and NP as its foundation. European countries and Japan already have processed compound fertilizers with 80-85% P_2O_5 , 85-90% K_2O and 35-45% N. The USA has rapidly developed granular AP and produces it as a BB fertilizer to facilitate transport. 58% of the compound fertilizers sold and 40% of all chemical fertilizers are granular BB fertilizer. The USA is the country that uses the most liquid fertilizers, accounting for 15% of all compound fertilizers. In China, however, the volume of liquid fertilizer applied is small. The area of land under cultivation is large in China. Differences in human factors, geography and cultivation in the various regions determined that the AP, AN-AP and urea series, supplemented by other types of compound fertilizers are the major compound fertilizers.

5.1.7.3 Outlook for technological development

1. Development of drum granulation by ammonia conversion

When the traditional granulation process by ammoniation uses phosphoric acid and ammonia as raw materials to produce DAP, the phosphoric acid is added to the tail gas washing system to recover the small amount of ammonia and dust carried in the tail gas of the pre-neutralization device, the drum ammoniation granulation device, the dryer and the cooling device. With the concentrated phosphoric acid that enters the pre-neutralization device, they undergo neutralization reaction with ammonia and are sent to the distributor of the drum ammoniation granulation device for granulation. If a set of K measuring and charging up equipment is added into the granulation device in the process, NPK compound fertilizer can be produced. In China, the Jiangxi Guixi Chemical Fertilizer Plant, the Yunnan Yunfeng Chemical Company, the Nanjing Chemical Industry Group and Dalian Dahua used this technique to establish AP plants that produced 240,000 t (200,000 t of NPK compound fertilizer). These plants operated normally after they had been put into production.

Currently, the ammoniation drum granulation process with a pipe reactor added is a more advanced process. Urea or AN enters the production system directly in the molten or solid form with K added at the same time. Compound fertilizers of many grades can, therefore, be produced. Phosphoric acid and sulphuric acid enter the cross-shape pipe reactor simultaneously and react with ammonia. The melt generated by the reaction is sprayed into the drum granulation device and granules are formed together with the returning charge and other raw materials. Phosphoric and H_2SO_4 are added from the washer to recover the ammonia and dust in the tail gas that escapes from the drum granulation device and the dryer. They are then heated by the acid pre-heating device. After measuring, they are added to the pipe reactor. At the same time, liquid ammonia and a small amount of water are added from the end of the cross-shape pipe reactor. The acid and ammonia mix passes through the pipe reactor at

high speed and, after reaction, the resultant liquid is sprayed inside the granulation device to form granules. During the production of NPK compound fertilizers, measured K is added to the drum granulation device together with the returning charge. The Sino-Arab Chemical Fertilizers Co., Ltd. in Qinhuangdao imported the AZF process from France. Since its initial production in 1991, the operation has been operating well. Up to August 2006, it has produced 10Mt of NPK compound fertilizer.

2. Development of MOP products by low-temperature conversion

In the early 1990s, the Shandong Hongri Chemical Industry Group (former the Shandong Linyi Chemical Plant) took the lead in developing the technology for manufacturing S-based NPK compound fertilizer by low-temperature conversion of KCl. In 1988, a new demonstration plant that could produce 200,000 t annually of S-based NPK compound fertilizer was built. After it was put into production, it operated well. It was rapidly promoted throughout the country. In the province of Shandong alone, annual production capacity of about 2.5 Mt was achieved. According to incomplete statistics, the total annual production capacity of S-based NPK compound fertilizer plants utilizing the technique that are built and under construction throughout the country, is about 6 Mt. In this technique, hot 98% concentrated H_2SO_4 reacts with MOP to generate a solution of potassium bisulphate. This solution is immediately mixed with dilute phosphoric acid after which it enters the pipe reactor together with gaseous ammonia for ammoniation reaction. The slurry generated is sent to the gunite granulation dryer for granule formation and drying. Inside the gunite granulation device, the materials undergo internal grading, crushing and returning charge. Granular material that meets the standard enters the cooling device and after cooling by air it is sent to the packing machine after which finished product of S-based NPK compound fertilizer is obtained. On cooling, the hydrogen chloride gas formed from the reaction between concentrated H_2SO_4 and KCl becomes HCl after absorption of water. The HCl is a by-product. The major characteristic of S-based compound fertilizer made from MOP conversion is that the extraction of phosphoric acid does not require concentration. It saves investment and energy consumption. However, due to the presence of potassium bisulphate in the mixed acid, the neutralization process is a lot more difficult than the straightforward ammoniation process. This is a shortcoming of the method. Furthermore, in the process of neutralization, impurities present in phosphoric acid undergo a series of chemical reactions and form non-water soluble compounds and insoluble phosphates. The silicon in the phosphoric acid may form silicon oxide gel. The formation of gel will seriously affect the viscosity of the slurry.

The chloride radical content in the S-based NPK high-analysis compound fertilizer is one of the major indices that measure the product quality. The main technical index that affects the chloride radical content is the rate of conversion of MOP used as raw material. Theoretically, the balanced conversion rate of MOP can be above 99.0% but is very difficult to achieve this in actual production. The conversion rate of MOP should be determined based on the product quality

requirement. With regard to products of $N:P_2O_5:K_2O$ (mass ratio) = 15:15:15, the content of chloride radical has to be controlled at below 2% and the conversion rate of MOP must be above 84%. The major factors which affect the conversion of MOP include quality, concentration and volume of H_2SO_4 acid used, the temperature and time of reaction.

3. Development of the process of molten mass tower spraying granulation

Domestically, the process of molten mass tower spraying granulation is used mainly in the production of urea-based high-analysis compound fertilizers. This process makes use of the characteristic of the ability of molten urea, MAP and KCl to form compounds of low eutectic point. After heating the powdered MAP, MOP and additives, they are added to the molten urea. By reaction, an NPK congruent melting mass with good mobility is generated. It is then sprayed into the granulation tower through a special nozzle. In the course of descending, the liquid drops gradually cool and solidify to form granules. After separation of the granules by sieving, materials on the sieve are sent back to the crushing device to be crushed once more. Materials that pass through the sieve are sent to the heating device to be re-mixed, and sprayed for granulation.

Another method is to spray the molten mass into mineral oil for it to cool and solidify to form spherical granules without having to use a big and tall granulation tower. This reduces investment and simplifies the flow. There is a very small amount of oil adhering to the surface of the granules. By treating them with powder, caking can be prevented. In the market, there are already enterprises that combine oil cooling granulation and tower spraying granulation to develop the "total melting and freezing crystallization (low tower) granulation method" whose production cost is 80% less than the oil cooling method and 30% lower than the high tower method.

5.1.8 Problems in the industrial development of compound fertilizers and strategies to resolve them

5.1.8.1 Existing problems in the compound fertilizer industry

1. Production technology of compound fertilizer is relatively backward

With respect to the type of fertilizer, production techniques, manufacturing equipment, fertilizer formulae, product quality and the standards of service, there is a big difference between China and the developed countries. With regard to fertilizer types and grades, a fertilizer distribution station of an agricultural cooperative in the Saga Prefecture of Japan produces more than 800 types or grades for specific uses whilst a compound fertilizer plant in China produces few or little more than ten types. Some even produce just a single formula over a long period of time. It is difficult to talk about applying fertilizer formulation according to soil and crop. Some apply fertilizer blindly, resulting in wastage of N, P and K resources. This becomes an added burden to farmers.

2. Inspection and management of compound fertilizer products are inadequate

In recent years, local authorities have improved the inspection and management of compound fertilizers quality with spectacular results. For example, the fertilizer station in Jiangsu Province inspected 1,323 fertilizer products in 1991 and only 57.8% passed. The passing rate of compound fertilizers was only 50%. For products that failed to meet the standards, the Industrial Commercial and Standards Departments, together with other relevant departments, took measures to carry out investigations and gave the producers a time limit to make improvements. This resulted in a financial loss of more than RMB30 M. Besides protecting the interests of the farmers, it also safeguarded the lawful rights and interests of the manufacturers and ensured the quality of fertilizers. It also promoted the healthy development of compound fertilizers and the technique of fertilizer application according to the right formula. However, many local fertilizer quality inspection and management organizations are still not operating efficiently. Their operating systems are inadequate. Some manufacturers produce and market products that fail to meet the standards and there are even fake products. This is disastrous for the farmers and jeopardizes the reputation of the technique of fertilizer application according to formula and the compound fertilizers. It has also seriously affected the development of compound fertilizers.

3. Series of standard services of compound fertilizers is low

The series of services for compound fertilizer production, their circulation, secondary formulation and use are the main components of modern services (including products of the chemical industry such as chemical fertilizers, pesticides and agricultural films). Due to the collapse of the agricultural, industrial and commercial departments over a long period of time, the production, sale and use of chemical fertilizers has disintegrated. The market mechanism is far from adequate. Many difficulties are encountered in the serialized, scientific and quantitative agrochemical services. The requirements for the development in agricultural production and farmers' demands cannot be met.

At present, a system of agrochemical services of high standards has not been formed in China. To a large extent, this has restricted the development of the compound fertilizer industry. For a long time, the task of guiding the farmers on the proper application of fertilizers was left to the department promoting agricultural techniques at the different levels, particularly the agricultural extension stations at the county level. Since the 1990s, most of the agricultural service bodies at the basic level exist only in name. According to the investigation by random sampling carried out in 2002 in 28 counties in seven provinces and seven regions, the rate of increase in the input of funds by the State for agricultural extension stations at the county level was 14.1% lower than the average rate of increase of the national finances. Only 23% of the extension stations had technical extension projects. Funds used on technical extension accounted for only 10% of the total funding.

In developed countries, intensive cultivation is practised. In the US, for example, a farm owner has about 400-600 ha of farmland. In China, individual farming is practised. The

land area that each farming household has is only a few *mu* (1 *mu* = 0.0667 hectares) to tens of *mu*. The very scattered farming households and farmland make it very difficult for the recommendation of fertilizer application on specific farm plots. Farmers are reluctant to bear the relevant expenses on the technical extension in exchange for a thin profit. Since the opening up of the fertilizer market in China, the heavy responsibility of agrochemical services fall on the shoulders of manufacturers and traders. In recent years, many companies engaged in fertilizer production and marketing launched the work of agrochemical services. They include some big companies that are rather well known. For example, Sinochem Fertilizer carries out planned training for the compound fertilizer plants over which it has controlling shares or in which it holds participation shares and staff of their internal marketing system. Sinochem Fertilizer broadcasted lessons on the knowledge of fertilizer application and provided free telephone advice to farmers. During the period of peak farming activities, staff members would go the farming communities to conduct lessons on the promotion of science and guide the farmers on fertilizer application. The farmers welcomed all these initiatives. In the course of establishing the system of agrochemical services on the production, sale and use of fertilizers, staff of Sinochem Fertilizer cooperated with the academy of sciences and institutes of higher learning. Through application of fertilizer according to soil tests, specific guidance on fertilizer application is given to the farming households and the right conditions are created for them. In short, establishing an agrochemical service system of high standard within the Chinese culture is a necessity for the development of compound fertilizers and for the development of agricultural production. In this respect, there is still a long way to go for the enterprises of chemical fertilizers in China.

4. The poor market environment seriously interferes with normal business operations

The overall quality of chemical fertilizers is not good. Problems with the quality of compound fertilizers are outstanding. Results of investigations by the Consumers' Association of China indicate that farmers who are satisfied with the assessment of the quality of chemical fertilizers make up 46% and those whose assessment of fertilizer quality is "ordinary" or "average" makes up 46%. Those who are not satisfied with the quality of fertilizer constitute 8%. It can be seen that the quality of chemical fertilizers is still unable to satisfy most of the farmers. As the cost of faking compound fertilizers is lower and the secret reduction of nutrient contents is relatively easy, some illegal producers and business operators produce and sell fake and low quality fertilizers, violating the interests of the farmers. In summary, the quality of chemical fertilizers and false publicity cannot satisfy the majority of those surveyed and this has become an important problem faced by farmers during their purchase of fertilizers.

Secondly, local protectionism has seriously obstructed the development of the chemical fertilizer market. To safeguard narrow-minded local interests there is mutual obstruction and containment between departments and local authorities. This has affected the distribution enterprises in the expansion of their sales networks and hindered the formation of a large nationwide circulation organisation. According to many

chemical fertilizer enterprise chains, when they set up direct selling points at different locations within a province, even though their Head Office has obtained authorisation for business operations recognized by the State, they still have to apply for local authorisation in order to set up an independent corporate unit. In some places, the law enforcement department carries out forced laboratory tests on the quality of chemical fertilizers sold locally during the period of high demand. The laboratory tests take a long time in order to block chemical fertilizers from other places coming into the local market. Some places simply make it clear that products from elsewhere are not allowed to come in.

5.1.8.2 Diversity of compound fertilizer types

The development of compound fertilizers with special purpose, special uses, diversification, combination of pesticides and fertilizers and the objective of long-lasting efficacy should be appropriately expedited. There should be the incorporation of pesticide services and choice of multiple-component fertilizer types for once-only fertilizer application in line with local conditions in order to raise the efficiency rate of fertilizers, reduce costs, increase economic benefits and actively develop and promote special-purpose fertilizers in the liquid form. Examples are liquid ammonia fertilizer for direct application, fertilizer of the suspension type and the clear liquid type. Also, launch the work of developing and promoting coated granular fertilizer and raise the production capacity as soon as possible to increase production output from 15 to 20 Mt in 2005.

5.1.8.3 Carry out the development of compound fertilizer technology according to resource conditions in China

The development of compound fertilizer depends on the production of its upstream products. Quality and quantity of raw materials directly affect the development of compound fertilizers. China is already completely self-sufficient in N fertilizer with some surplus for export. It is also self-sufficient in P fertilizers. China is short of K and depends mainly on imports. However, in 2000, a huge K deposit was discovered at Luobupo. The verified deposits amount to 250 Mt. If the Luobupo K mine can be fully developed, the pressure from the import of K fertilizer can be greatly reduced.

Fortunately, enterprises and scientific research organizations in China have developed and reformed a series of production techniques for the local minerals and this has been a driving force in the vigorous development of China's fertilizer industry.

For example, in the mid-1950s, anthracite replaced coke in the manufacture of synthetic ammonia as raw material. This is a contribution to the utilization of rich anthracite resources, expansion of raw material sources for N fertilizers and creation of good conditions for expediting the development of China's N fertilizer industry. At the end of 1964, Design Institute No. 1 of the former Ministry of Chemical Industry proposed the scheme of "manufacturing synthetic ammonia with coal as raw material, using the three-catalyst purification process." This won the attention of the leadership in the Ministry of Chemical Industry and the support of the NRDC. In October 1966, the third stage expansion work at the Shijiazhuang

Chemical Fertilizer Plant as a test unit of the three-catalyst purification process in the manufacture of synthetic ammonia was completed and put into production. The success of this technique boosted the confidence of many Chinese technical personnel in the development and establishment of the N fertilizer industry through self-reliance. Subsequently, there were further new achievements. Examples include the manufacture of synthetic ammonia by the conversion of dry gas from the coking of 10% olefin hydrocarbon to steam, the manufacture of synthetic ammonia by the conversion of coke oven gas to steam and the manufacture of synthetic ammonia by the catalytic partial oxidation of refinery gas. By using these scientific research achievements, a number of medium N fertilizer plants that used oil, gas and coal as raw materials were built.

In P fertilizer production, there were four grand technical achievements of research and development that included the production of AP by the slurry process, the S-based compound fertilizer technique, the technique of combined production of H_2SO_4 and cement with phosphogypsum and the technique of rapid extraction of wet-process phosphoric acid. With these, the difficulties encountered in the course of P fertilizer production were basically resolved. This enabled China to achieve the development of domestic P fertilizer plants.

However, there should be continuous efforts to improve techniques in compound fertilizer production that suit agricultural demands and technical reforms in China. These include high tower granulation, low tower cooling granulation, changing granulation to ammoniation (pipe reactor) and oil cooling. Enriching the types of compound fertilizer products in China and raising the competitiveness of enterprises of compound fertilizer are key points in the future development of compound fertilizer.

5.1.8.4 Enhancement of research on the basic application of compound fertilizer

Influenced by a planned economy in the past, enterprises were concerned only with production but not marketing. The production of compound fertilizers lacked suitability and targets. With the introduction of the market economy, enterprises faced the farmers directly. They were able to develop compound fertilizers based on demands by the farmers and agriculture. Raw materials and energy are no longer directly allocated by the State unlike in the past. Enterprises have to tackle problems for raw materials and energy through their own technical innovation. Enhancing research on the application of compound fertilizer and increasing the value of fertilizers have become the most important techniques for compound fertilizer enterprises.

Due to the division of labour between the departments, the industrial production of fertilizers and their agricultural application were separated. This caused the agriculture department to conduct more research with regard to fertilizer efficiency, methods of application and plant nutrition. Owing to their inability to enter the domains of fertilizer production and marketing, many results of research lacked targets and it was difficult to transform them into actual products. On the other hand, efforts of industrial production departments were put mainly into process innovation and technological

adjustments. They were unable to get involved in the mode and method of fertilizer application and the agricultural property and character of fertilizers. All these have resulted in the separation of production and use of fertilizers as shown by the inadequate basic research on compound fertilizers. This is mainly illustrated by the following:

1. At present, simple fertilizer is being targeted by agricultural research in China without considering the synergistic effect between NPK in compound fertilizers;
2. In industrial production, consideration is focused on the simplification of techniques and optimization of costs. Cost is also the priority in the choice of raw materials with little thought given to the form of nutrients;
3. Production enterprises use industrial standards to inspect if the products are up to standards. There is almost no consideration given to the physical and chemical properties that affect nutrient absorption by plants such as the strength and size of nutrients in the granules, the speed and strength of nutrient release and the speed of granule dispersion;
4. There is inadequate research into the physical and chemical characteristics of compound fertilizers used in agriculture to support application technology and there have been many mistakes in fertilizer application.

5.1.8.5 Expedite the adjustment of the industrial structure

Overall, the small and medium fertilizer enterprises in China are relatively backward in terms of technology and equipment. Energy consumption is high and new technology to carry out reforms is needed. In the past, the so-called technical reforms referred to expansion of equipment and increase in production. This was actually a form of low standard expansion. Reform of an old enterprise must be carried out by combining adjustments in raw material and product structure, achieving energy savings, increasing output, appropriate marketing of products and raising economic benefits. Many old chemical fertilizer enterprise plants face the problem of low efficiency equipment. Therefore, they have to adopt new techniques, improve equipment parts, advance purification and heat recovery measures to raise the efficiency of their plants and not to expand blindly.

5.2 Enterprises of compound fertilizers in China and their products

5.2.1 Present status and characteristics of enterprises

5.2.1.1 Conditions of enterprises

Compound fertilizer producing enterprises in China (including those owning or are applying for a production licence) number about 4,000. In 2005, the production capacity was about 60 Mt in product quantity with an actual annual production at about 10 Mt. There are already some famous brands and some enterprises with a definite market share. Examples include:

- Yunnan Honghe Phosphate Fertilizer Plant

- Jiangxi Guixi Chemical Fertilizer Co., Ltd.
- Yunnan Phosphate Fertilizer Co., Ltd.
- Shanxi Huashan Chemical Industry Group
- Shandong Lubei Main Chemical Plant
- Guizhou Xifeng Chemical Fertilizer Plant
- Sichuan Shifang Yingfeng Industries Main Office
- Shandong Hongri Group
- Luyuan Chemical Industry Co., Ltd.
- Shandong Luxi Chemical Industry Group
- Xiyang Group

All of them have their total cost lower than the CIF cost of imported compound fertilizers. Another example is the 480,000 t AP or 600,000 t NPK compound fertilizer plant, a joint-venture involving China, Tunisia and Kuwait called the Sino-Arab Chemical Fertilizers Co., Ltd. In 1998, its annual production reached 720,000 t. Its production capacity for NPK compound fertilizers reached 200,000 t by 2006. This has an important effect in raising the quantity of compound fertilizer and the efficiency of chemical fertilizer application in China.

5.2.1.2 Product characteristics

For years, the chemical fertilizer industry in China operated under the system of a planned economy where products were monopolized by the agricultural resource departments. Chemical fertilizer enterprises only produced product and were basically without autonomy in management. Enterprises had little self-accumulation and were heavily burdened. With more profound reforms and changes in the social environment, the following three changes in the chemical fertilizer system emerged.

1. With the sluggish sale and lowering of prices of chemical fertilizers in 1997, chemical fertilizers have entered a buyer's market from a seller's market lasting many years.
2. Taking the promulgation of Document *Guo Fa* [1998] No. 139 as a marker, the system by which business operation of chemical fertilizer enterprises was monopolized by the agricultural resource departments over the years has come to an end. The management system of the State on the circulation of chemical fertilizer has been changed from direct control to indirect management. Chemical fertilizer enterprises enter the market directly. A mechanism of competition has been introduced to the domain of chemical fertilizer circulation.
3. The structural adjustments in agriculture increased remarkably. New demands were raised on the composition of chemical fertilizer products. The market for single N fertilizers produced by N fertilizer enterprises was facing a big challenge. Demands for scientific fertilizer application and agrochemical services by the farmers were fast increasing.

After the 1990s, under the new market form, compound fertilizers have been growing by leaps and bounds. Products have switched from low-analysis and single forms to high-analysis and diversified types. From the AP series, NP and FCMP series, compound fertilizers of multiple process and multiple forms such as the granulation process, AS-AP series, AN-AP series, melt granulation and bulk blend fertilizers have been developed.

5.2.2 Prospects of development

5.2.2.1 Prospects of development for enterprises

Basically, chemical fertilizer enterprises in China depend on State investment and bank loans to get established. Large investments are involved and the capital structure is simple without much vitality. In recent years, some enterprises have been listed and implemented on the stock exchange. However, the ratio of such enterprises is very small. There were small chemical fertilizer plants that sought breakthrough by revamping proprietary rights and achieved reorganization through diversification of ownership rights. This brought vitality to the enterprise and increased economic benefits. The State encouraged breakthroughs in the original business and distribution areas for N, P, K fertilizer enterprises. They were encouraged to head for the integration of business operations such as production, supply and internal and external trading. The State encouraged mergers of enterprises and joint reorganization. Using assets as the link, it gradually nurtured large fertilizer industry groups with international competitive power. By 2010, China strives to have 20 large enterprise groups that control 50% of the fertilizer output throughout the country. Besides, there should be two or three large enterprise groups that exert some influence internationally.

5.2.2.2 Prospects of product development

1. High-N single application fertilizer

Studies show that it is very difficult to resolve the problem of single application fertilizer with the existing compound fertilizer production processes. Lying at the core is N fertilizer. When the proportion of N fertilizer applied is high, crops grow too luxuriantly at the early stage. For crops with longer growth periods, such as winter wheat in the north, applied fertilizer is no longer available at the later stage of growth. According to research results, for clayey soil, or crops with shorter growth periods, such as the second rice crop in the south and the summer maize in the north, single application fertilization can be practised. For sandy soil and crops with a long growth period, single application is not feasible in general. The best method of fertilizer application is the development of BB fertilizers which combine slow release and quick-acting fertilizers, that is, the usual NPK three-nutrient compound fertilizer mixed with slow release N fertilizer. Examples are the one time 24-16-6 fertilizer and the 25-10-5 of humic acid series for wheat and the single application 28-10-10 fertilizer for maize grown in the Northeast (referred to as "One time bombardment" by farmers in the Northeast) launched by the Agricultural Service Department of the Sino-Arab Company.

2. Compound fertilizer for topdressing

Fertilizers applied during the plant growth period are commonly referred to as topdressing. In the past, farmers applied single fertilizers for topdressing, in particular, on field crops. In recent years, in response to the habit among farmers of topdressing, many compound fertilizer plants have produced types of fertilizers for this purpose. Examples include 30-5-5, 25-5-10, 20-10-10 (in the year 2002), 24-10-6 (in 2003) and some high-N topdressing fertilizers for ornamentals.

3. Completely soluble fertilizer

There are usually different ways to use completely water-soluble fertilizers. These are soil irrigation, foliar application, drip irrigation and soil-less cultivation. The diversity of its formulation and the flexibility of use enable it to be widely applied in agricultural production. Application by water flush fertilizers or fertilizers for fertigation (please refer to www.ferinfo.com.cn) and drip irrigation are more common. Highly soluble and non-granule forming fertigation fertilizer is used mainly for vegetable production while the development of drip fertilizer is based on the requirement for the promotion of drip irrigation techniques.

Products of fertigation are mainly in the form of powder and aqueous solution. Others are in a cream form and a small number are granular. Products are mostly packed in bags of a few thousand grams to 10,000 grams. They are used mainly for winter topdressing in greenhouses. Fertigation fertilizers can be classified according to different indices. Based on chemical properties and nutrient constitution, it can be classified as organic nutrient, organic-inorganic combination and the micro-nutrient types. Depending on application and the targeted crops, it can be classified as broad-spectrum, vegetable, fruit tree type and the special-purpose fertilizer for special economic crops. In the powder form, the nutrients content of macro elements is mostly 30-40%. Many types contain humic acid or amino acids. A small number are labelled with secondary and micronutrients (1-5% micronutrients). Local fertigation fertilizers are concentrated in the provinces of Shandong, Liaoning, Guangdong and Jiangsu. Unfortunately, there are fake products on the market. Indices lack standardization and to date, there are no relevant State trade standards. At present, Liaoning and other provinces are establishing local standards for fertigation fertilizers. Some enterprises even treat fertigation fertilizer as an independent product to distinguish it from compound fertilizers and foliar fertilizers. Its characteristics include quick dissolution and fast acting with comprehensive nutrition. Humic acid with fertigation fertilizers from Aojia, for example, in 15-5-20, $N+K_2O \geq 30\%$. These fertilizers are divided into leafy vegetable, fruit vegetable and SOP types. They contain secondary and micronutrients.

For the drip irrigation method of fertilizer application, a micro-dripping system is used. Fertilizer is added accurately and uniformly applied to the root system or near the leaves according to the nutrient requirements at different stages of crop growth and climatic conditions. The fertilizer is directly absorbed and utilized by the plants. Fertilizer application by drip irrigation is an effective method of quantitative supply of water and nutrients to the plants and the maintenance of a suitable amount of water and nutrient concentration. In China, the drip irrigation technique is spreading from the arid to the semi-arid regions. The technique has developed from the main intention of saving water to increase production through fertilizer application, temperature regulation, crop protection and improvement of the environment for plant growth. Requirements of the drip method of fertilizer application are as follows: owing to the fact that the nozzle diameter used in drip irrigation is about 0.4-1mm, liquid fertilizer or quick-dissolving fertilizer must be used. The major compound fertilizer type in China is not completely

soluble due to the raw materials and limitation of production technology. Therefore, development and promotion of the drip irrigation technique to save water and increase the rate of fertilizer efficiency requires the development of suitable highly soluble NPK compound fertilizers. In 2005, output for drip irrigation fertilizers reached around 200,000 t in the province of Xinjiang whilst the actual volume of production and sale was only 30,000-35,000 t.

4. Organic-inorganic compound fertilizer

Organic-inorganic compound fertilizer refers to compound fertilizers that use organic matters such as animal droppings, animal and plant remains, humic acids, charcoal from burnt grass and oil shale as raw materials. After a fermentation and decomposition treatment, inorganic fertilizer is added to produce organic-inorganic compound fertilizer. Since 2000 organic-inorganic compound fertilizers have become "newcomers" in many domestic exhibitions and the twice-a-year trade fairs. They are becoming more popular. Animal droppings cause water pollution in the US and European countries. They are a major factor in nitrate and phosphate salt enrichment. The area of arable land and the area under perennial crops is only 75% of that in the US. However, the number of chickens bred and the number of pigs and cattle on hand are 2, 6.9 and 1.1 times more respectively. Pollution to the environment caused by livestock droppings is more serious in China than in the US. According to a report carried on the *xinhuanet*, in 1999, the amount of livestock droppings generated was about 1.9 Bt, 2.4 times more than the amount of industrial solid wastes. Livestock breeding has become China's big source of pollution. Returning the organic fertilizer material to the farmland directly or after treatment, and bringing inorganic fertilizer to the source of organic manure to regulate the nutrient ratios, or transporting the organic manure to the inorganic fertilizer plant to process them into organic-inorganic compound fertilizer, has become a new trend in the development of fertilizer production.

In 2000 the overall target in the production of compound fertilizer was: carry out research to resolve problems concerning processes and equipment in the production of compound fertilizer in order to obtain the most optimized energy consumption, low investment and high output in the production process.

5.3 Compound fertilizers and agrochemical services

Agrochemical service is a product that results from the development of agricultural chemistry and modern agriculture up to a certain stage. Its basic concept is, with chemical fertilizer products as the centre, farmers and cultivated land as service targets, apply the ideas of systems engineering with theories of agricultural chemistry, organize and regulate the production, marketing and application of fertilizers scientifically in order to raise the economic, social and ecological benefits of chemical fertilizer to the maximum and increase the productivity of agricultural labour. The improvement and the level of perfection of the agrochemical services system and the standards of services

are important indices that reflect the level of development and modernization of agriculture in a country.

Most of the compound fertilizer enterprises today operate simply on production and sale. With the formation of a buyer's market domestically and the fiercer international competition brought about by the accession of China to the WTO, enterprises of the simple produce and sell type will not be able to adapt to the new trend at all. Under the current fertilizer market where supply and demand are basically balanced, the market of agricultural resources will see a comprehensive competition that involves many aspects including quality, prices and agrochemical services. Farmers' demand for chemical fertilizers will not only depend on product quality and commodity prices but also on high expectation in agrochemical services. Consequently, compound fertilizer enterprises have to enhance their market competitiveness to ensure their sustainable development. They must find breakthroughs in their agrochemical services.

5.3.1 Systems of agrochemical services of compound fertilizer enterprises overseas

Research on new types of compound fertilizers is the foundation on which enterprises can continue to develop and agrochemical service is the key to the realization of profits and raising the influence of brand names of the enterprises. Agrochemical service is also the direct reflection of an enterprise concern for the consumers and society and its contribution to social values. In other countries, many large fertilizer enterprises have gone through decades, if not nearly a hundred years of development to expand, amidst fierce market competition, to occupy a certain market share. Their brand names are well known and the acceptability of their products is high. According to in-depth investigations and studies of the research and development and agrochemical services of major large fertilizer enterprises in other countries, such as BASF (Germany), Cargill (US), Canpotex (Canada), IMC (US), CSBP (Australia) and Norsk-Hydro (now Yara-Norway), these enterprises have the following common features that form their advantages and styles:

1. There is emphasis on research and development. They have independent R & D organizations and agricultural research bases;
2. They have a complete system of agrochemical services;
3. They emphasize the establishment of brand image and increase the influence of their brands through continuous R & D and agrochemical services.

Figure 5-1 shows a basic model of how fertilizer enterprises in other countries provide agrochemical services. From the figure, it can be seen that the general manager is responsible for the entire chemical fertilizer enterprise. The enterprise is a complete system where production, marketing and market development are an integral whole. The Market Development Department of the fertilizer-producing enterprise carries out fertilizer promotion and publicity through fertilizer efficacy experiments, on-site exchanges and demonstrations. Subsequently, the farm owner will be guided on scientific fertilizer application through the expert system. Soil tests provide data on the amount of effective nutrients in the soil which are essential for recommendations on fertilizer

application. At the same time, the central laboratory of the fertilizer enterprise is responsible for soil tests, supervision and control of fertilizer quality. Through fertilizer tests and expert systems, the Market Development Department obtains information about the types and amount of fertilizers required in the market and works out product formulations. Together with research results from the New Product Development Office, the Department works out the integration of formulation and the production process and hands it over to the office of the chief engineer. Compound fertilizers required by the market will then be manufactured. Fertilizers produced by the Production Department are delivered to the Marketing Department and Market Development carry out promotional demonstrations. In this way, fertilizer formulations are continuously developed and improved, enabling the entire enterprise to become more relevant to agriculture production requirements at various places. Aside from occupying a place in the market, there is continuous expansion of the market share.

The predecessor of Mosaic, an important business department of Cargill Company, the Cargill Crop Nutrition Department, has employees in many countries world wide. They are engaged in Cargill's agrochemical services, marketing promotion and training. In recent years, Cargill has invested a total of more than US\$400 M in the development of new technology, improvement of plant equipment, increase in

production efficiency, guarantee of employee safety and improvement of environmental quality. These investments clearly improved the quality of Cargill's fertilizer products and the supporting services. These investments and measures fully prepared the company, materially and technically, for entering the Chinese market. In addition, through the tactic of strong implementation of agrochemical services, in a span of more than ten years, the company has taken a certain share of the Chinese market.

To open the market in China, Canada's Canpotex, with the aid of the Canadian International Development Agency (CIDA) and the Potash and Phosphate Institute of Canada (PPIC), launched, in 1983, the Sino-Canadian fertilizer agricultural projects. With initial projects in the provinces of Zhejiang and Hunan, it expanded to 31 provinces (cities and autonomous regions). They involved a full range of cooperation at various levels in plant nutrition and scientific fertilizer application. Much has been done in the application of basic and technical research, introduction of new technology, academic exchange, propaganda and education and nurturing of talents. Demonstrative tests have been established throughout the country. The company has achieved huge economic benefits and established its brand image.

The major business of CSBP of West Australia is the production and supply of compound fertilizers (they also

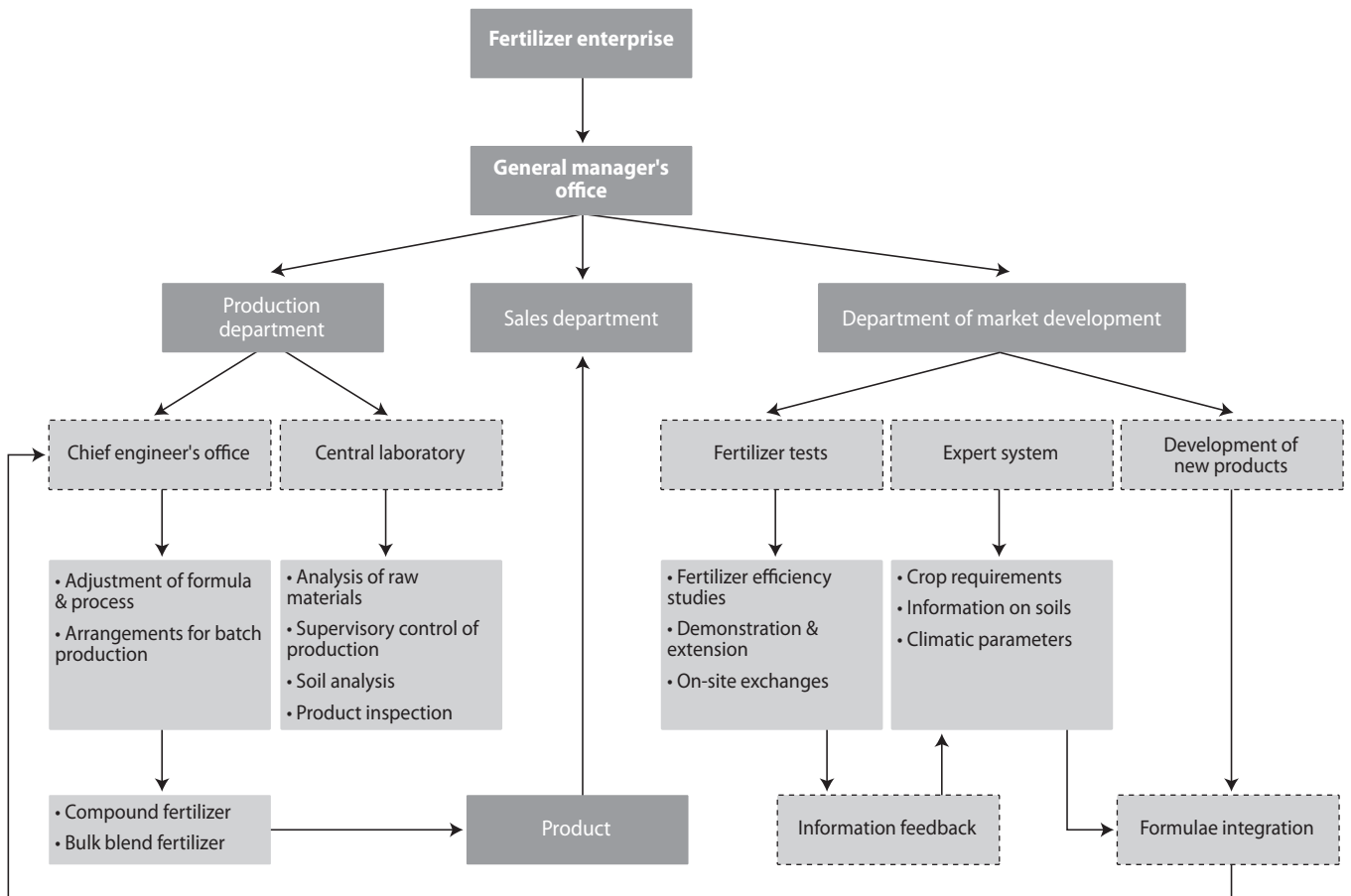


Figure 5-1 Model of agrochemical services of a foreign fertilizer enterprise.

have urea, MOP and SOP). The company has developed or imported a total of seven product series that are suitable for different regions and different crops for their business operation. The development of its range of fertilizer products originated from the results of a large number of field experiments and research. In order to develop fertilizer types and nutrient formulations suitable for different locations, from results of field experiments and research over a century, and through the production and import of chemical fertilizers to suit requirements, CSBP has played an important role in the agricultural production of West Australia. Between 1967 and 1970, CSBP initiated the national soil fertility research programme. They carried out a series of field tests in West Australia which continued for a period of ten years. The results were used in the improvement and verification of soil test services. These effective services have enabled the company to steadily occupy the fertilizer market in Western Australia.

In order to expand its fertilizer market, the Department of Chemical Fertilizer of Norsk-Hydro was separated from the Head Office. On 25 March 2004, the department was officially registered as a new chemical fertilizer company called Yara. The Hydro Agriculture Research Centre, set up in Germany by Yara, formulated the detailed service programme for guidance in technical decisions by farmers with a website. With the help of this service programme, farmers are able to determine the best quantity of fertilizer to apply and use fertilizer with high efficiency.

The enterprises mentioned above promote their production and sale through agrochemical services. When they devote themselves to agrochemical services, they bring a good brand image and bigger profits to their companies.

5.3.2 Development of agrochemical services in China and their difference from foreign models

5.3.2.1 History and background of development

China has a high population density with a small per capita land area. The standard of education and dissemination of science and technology is low, making it more difficult to promote agricultural technology. At present, the agrochemical service is a relatively weak link in domestic production and business operation of chemical fertilizer industry. Over a long period of time, China was under the influence of a planned economy. In addition, there was inadequate supply of chemical fertilizer in the past and malpractices existed in the distribution system. It was a general phenomenon for enterprises to emphasize production and neglect marketing and services. Compared with services in areas such as the light industries, textile and domestic electrical appliances, service in fertilizer enterprises was at its infant stage.

The first agrochemical service centre in China was set up in the Ji County Chemical Fertilizer Plant in Hebei Province in 1980. Due to the serious wastage after the application of the main fertilizer product of ammonium bicarbonate (ABC) at that time, the company promoted the method of "one time base application" to the farmers. Following this method, farmers were able to achieve better results in increasing their production. However, for the next 10 years, despite the promotion of agrochemical services by the State, results were

disappointing. It is encouraging that after the joint efforts of the Chinese government, technical personnel in agriculture and the many fertilizer enterprises, agrochemical services have made great progress. In the 1990s, with the gradual opening up of the fertilizer market, China began advocating and pursuing agrochemical services. The former Ministry of Chemical Industry set up the Office of Agrochemical Services to give guidance on agrochemical services to the fertilizer industry throughout the country. At the same time, a national compound fertilizer collaboration network was formed. The network convenes a meeting each year to exchange experiences with regard to scientific fertilizer applications and agrochemical services. Confronted by market competition that is becoming more intense, many enterprises are aware of the importance of agrochemical services to their own development. Today, almost all of the medium and large P compound fertilizer production enterprises have established an agrochemical service centre and have made great efforts to develop special-purpose fertilizers and to disseminate scientific practices.

5.3.2.2 The present situation and features

Agrochemical service in China can be divided into two types. One is the responsibility of the agriculture department. The agriculture department decides the amount and types of fertilizer to be used according to requirements of scientific fertilizer application. The marketing department then organizes the sources of fertilizer and supply to the farmers. In this practice, production, supply and sale are separated. Farmers usually purchase their fertilizers according to their own knowledge with less than satisfactory results.

In the other type of agrochemical service, enterprises producing or marketing fertilizers are responsible. Central to the agrochemical service is the sale of fertilizer. This type of service has its shortcomings too. Some enterprises are only able to provide single fertilizers or compound fertilizers with fixed formulations. They are unable to supply fertilizers of different formulations. A model of agrochemical services that suits the conditions in China is shown in Figure 5-2.

Launching agrochemical services is one of the favourable measures for domestic chemical fertilizer enterprises to compete with their foreign counterparts. The effective development of agrochemical services is then a more practical issue. Overall, there are many forms and a good variety of services. To sum up, we can look at the following aspects.

1. Launching of agricultural investigations and carrying out soil analyses

Conduct surveys of the local soil and crop types, areas of cultivation and the level of output of agricultural crops. The key is the farmer's process of fertilizer application (including the application method, the quantity, variety and the period/time of application), common diseases, insect pests and other problems encountered in agricultural production. Through surveys, conditions of the local agricultural development are readily grasped which provides the basis for the collection of typical soil samples. The soil analysis provides an understanding of the physical and chemical properties of the soil in different regions. This facilitates the provision of a basis for the application and use of fertilizer according to formulation.

2. Fertilizer application based on soil tests and provision of guidance to farmers

As regions vary from each other, soil conditions in different regions are rather complex with relatively large variations. Therefore, the department of agrochemical services should provide guidance on fertilizer application to the farmers according to the pattern of fertilizer requirement of the crops. This will enable the farmers' method of application to be more standardized and scientific.

3. Training of sales personnel and farmers as technical personnel

A good enterprise should be equipped with a good sales team. Therefore, the department of agrochemical services should emphasize the training of its sales personnel. Through training, they can understand the performance, functions and formulation of a number of compound fertilizer products and knowledge of crop nutrient requirement pattern. They will be able to respond knowledgeably to enquiries from farmers on the purchase and application of compound fertilizers. This will further promote the sale of products. Through follow-up services provided by the sales personnel on fertilizer efficiency, information about market needs will be mastered immediately. Users' reactions are gathered and dealt with immediately to explain the use of a fertilizer. Furthermore, the success of the extension of agricultural technology is inseparable from the active participation, as technical personnel, by a large number of farmers. A large number of farmers trained to be technical personnel will bring outstanding achievements in the extension of agricultural technology and the pace of agricultural development will be tremendously enhanced. The provision of essential training for farmers will enable them to practise what they have learned. Besides, by raising the farmers' knowledge of scientific cultivation, the influence of technology will be better extended. In addition, the cost of the extension of agricultural technology can be greatly reduced.

4. Establishment of experiment networks on fertilizer grades/types and their efficiency in the field

On the basis of soil tests and a wide range of experiments on special formulations fertilizer application programmes are

provided for the users with regard to soil, crops and climate. A network of experiments is established throughout the country. Make immediate modifications to formulations in line with local conditions and suit the remedy to the case. Through the setting up of demonstration plots, a system to promote new products can be established. At the same time, a system of fertilizer efficiency feedback by the users is built.

5. Give lectures on agricultural knowledge and conduct necessary training for farmers

With the development of agriculture heading towards high quality and high efficiency, farmers' need for advanced technology is becoming more urgent. Agrochemical service personnel should go down to the agricultural villages to disseminate agricultural knowledge to the farmers by giving lectures, providing technical advice, distributing reports on fertilizer application in advance and guiding farmers on the rational application of fertilizer. The many services of agricultural knowledge can be of practical help to farmers in order to resolve problems that arise in the course of fertilizer application and crop cultivation.

6. Development of new products to guarantee fertilizer quality

Whether or not an enterprise has vitality depends on its ability to innovate. An enterprise without innovation is bound to perish. Apart from technical factors, product innovation carries the most weight of all forms of innovations. The agrochemical service centre should take up the mission of product innovation. Through the various types of field experiments, an agrochemical service organization can guide the manufacture of a series of special-purpose fertilizers for crops, carry out extensive tests and demonstrations and popularize fertilizer application. Management of new product developments must be enhanced. Establish complete technical file materials and emphasize their regular study. Develop new products according to market needs. The content of product files should include product planning, application forms for the development of new products, formulations and tables of components, tables of changes, sales regions and quantities, data on tests and demonstrations, problems reported by users, manuals, publicity materials (flyers, banners, discs,

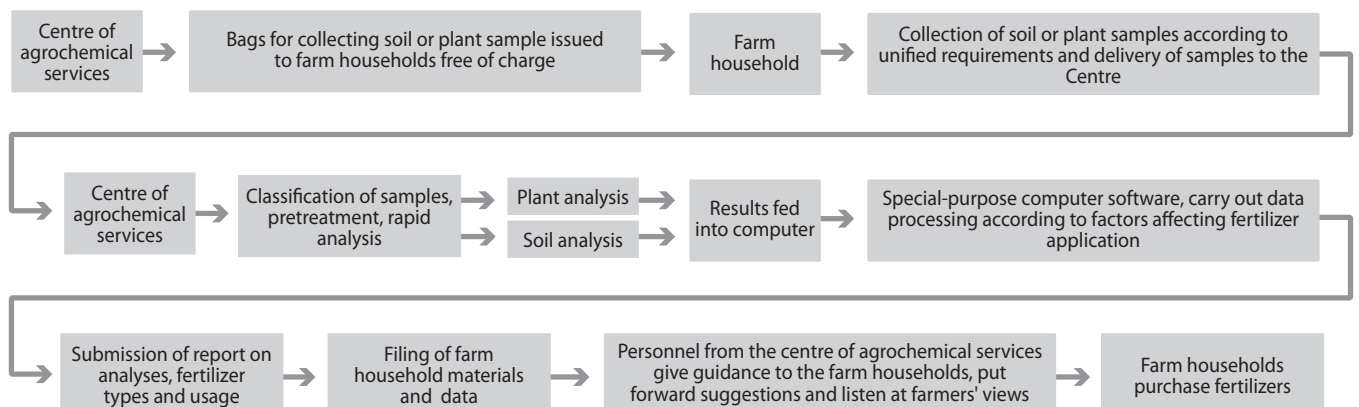


Figure 5-2 Flow of agrochemical services in some Chinese companies.

photographs), quality inspection certificate and design and changes in packing materials.

7. Have a complete system of agrochemical services to enhance contacts with agricultural resource departments

With the scale of agrochemical services continuing to expand, a complete system of agrochemical network service is becoming more and more important. Being informed is the trend of development in the present society. The computer fertilizer application command system is a major aspect of the balanced fertilizer application. Currently, precise fertilizer application in developed countries is achieved through satellite positioning and computer control. The computerized fertilizer application command system is a branch of artificial intelligence. It makes use of simulated plant nutrition by the computer and experts in the domain of fertilizer application, both with the technical ability to tackle problems in fertilizer application and capable of providing solutions of a high standard to the various specific and actual problems. Knowledge is the core of the system of guidance. Information provided by data, formulations, methods and experience can be regarded as knowledge. Knowledge on fertilizer is expressed as systematic knowledge and put into the knowledge storehouse before using it to answer questions raised by users through inference and interpersonal interactive interface. The agrochemical centre of a fertilizer enterprise can set up service stations in the villages and towns of the various counties and cities. Each service station establishes demonstration farming households and test bases in a few villages. Contacts with departments of agricultural science, technology and resources are to be enhanced in order to be able to make use of their data and materials, reduce repetitive efforts and raise the efficiency of agrochemical services. Furthermore, some large enterprises may even strengthen their contacts with research institutes or the universities and have cooperation and exchanges with them on aspects of new agricultural technology. In this way, the company can have access to the soil fertility data at the various places without carrying out soil analyses. This shortens the duration of research and manufacture. The company can also make use of the good marketing network of agricultural resource departments to speed up the sale of the company's products and establish a good reputation for the products.

5.3.2.3 Differences with foreign models

1. Differences in organization

Agrochemical services of enterprises in other countries are distributed to independent departments such as the market development department, the central laboratory and the production department which are all under the management of the General Manager's Office. Domestically, mostly special agrochemical service departments are set up. All agrochemical activities revolve around the agrochemical service centre of the company as the nuclear centre.

2. Items of service are different

In foreign enterprises, besides soil analyses, the central laboratory also carries out supervisory control on production, analysis of raw materials and product quality inspection. The

central laboratory in domestic enterprises, on the other hand, mainly carries out external soil and plant analyses, nutrient monitoring, fertilizer application based on soil testing, publicity and provision of guidance. They also administer and guide laboratories at a lower level but do not participate in production management.

3. Nature and mode of service are different

Services extended to farm owners by foreign enterprises are not free. Such services are of a large scale and, to a large extent, involve machines. Domestic agrochemical services are provided free of charge. Areas of cultivation are large and conditions of cultivation are more complex.

4. Distinction of expert system

Foreign enterprises usually have their own experts. In domestic enterprises, with the exception of company experts, they also employ experts at the various levels from all over the country.

5.3.3 Prospects of development of agrochemical services

On joining the World Trade Organization (WTO), products of agricultural resources (chemical fertilizer and other) were gradually decontrolled. The chemical fertilizer industry now faces tough challenges. The present main business operation has undergone great changes. Individual operation and direct sale by enterprises occupy important positions. Circulation is much reduced. Services required in the course of fertilizer production, marketing and consumption are rapidly increasing. This requires the establishment of a totally new network of agrochemical services, making full use of the advantages of the department of extension of agricultural technology, the enterprises and business operators and the establishment of a scientific and operational mechanism for the agrochemical services suitable for market needs. It is only with the full-course service of fertilizer production, marketing and utilization that the market and users are won over and the extension of new technology and new fertilizer products will show greater vitality.

5.3.3.1 Existing problems in the agrochemical services of enterprises in China

1. Due to inadequate funds and manpower input in agrochemical services, the service system is incomplete

In developed countries, expenditure for agricultural technology extension is usually 0.6-1.0% of the total output value in agriculture. In many developing countries, they may be about 0.5%. However, in China, such expenses are less than 0.2% and even lower than per capita expenses. Due to an inadequate budget and other reasons, some agricultural technology extension departments are being pushed to the market. Some are even auctioned or abolished. In addition, failure of the extension department to link up with departments of scientific research and education as a whole means the extension network is incomplete. All these are restricting the progress in the work of extension of agricultural technology.

2. Quite a number of small- and medium-scale compound fertilizer enterprises are still not well informed about these services and, very often, agrochemical services exist in form only

This is a common failure in providing agrochemical services. Much publicity is on the many types of products whilst little guidance and service on the use of fertilizer is given to the farmers. Scientific formulations, balanced fertilizer applications and the development of agriculture are simply out of the question. This situation is caused by inadequate awareness on the part of the enterprises which are still stuck in the era of planned economy. They are only concerned about production, sale and economic benefits without giving consideration to services before and after sale to the consumers. Many enterprises are not aware that service actually translates into production, sales and benefits. Most enterprises emphasize only low prices and products in their publicity and neglect the work of agrochemical services such as specific guidance in fertilizer application.

3. In the present chemical fertilizer market, misleading advertisements and publicity are made by enterprises

Such advertisements and publicity mislead farmers causing an increasing occurrence of crop yield reductions and total crop failure. This also has a direct relationship with the poor agrochemical services provided by the enterprise. Furthermore, the chemical fertilizer industry is in a period of transition. The mechanism of operation of agrochemical services and network effectiveness has to be further enhanced. When the operation is left to a few in the enterprise, it is not possible to bring the functions of the distributors and the local agricultural technology personnel into full play. There is an absence of the smooth circulation of information. All these have, to some extent, restricted and limited the more extensive and profound development of agrochemical services.

4. Knowledge and the level of education among farmers is relatively low and their ability to absorb new knowledge and new things such as balanced fertilizer application is poor and this has directly affected the quality of agrochemical services

In many places and enterprises in China, due to the less than ideal environment and poor wages, some agrochemical service departments find it difficult to attract well qualified people. This, coupled with the employment of non-professional people has resulted in an extension team with, on the whole, poor knowledge. These personnel are in the low level departments for a long time without any opportunity to improve their knowledge through training and further studies. They are not familiar with new techniques in modern agriculture and are incompetent in operation. Furthermore, there is too much of division of labour among personnel in the agrochemical services. Most of these personnel have a narrow range of knowledge and it is difficult for them to fit in to the present market economy and the diversity of high-efficiency agriculture. Their services and guidance given to farmers are inadequate.

5.3.3.2 Prospects of agrochemical services by enterprises

1. Establishment of the system for agrochemical services

Enterprises of compound fertilizers must take agrochemical services as the nucleus to carry out systematic and comprehensive innovations in the sequence of; determination of formulation – small-scale test – verification – extension – re-verification – formulation adjustment. This is to establish a good development model for a compound fertilizer industry that is scientific, highly efficient and environmentally friendly. That is, on the basis of mastering the fertilizer efficiency from a macroscopic perspective, a system of modern agrochemical services that include “determination of regional formulation by soil, special-purpose nutrients for crops, adjustment of nutrients through tests and demonstrations, production pilot test before optimization and training by experts” is achieved.

The major contents include verification, adjustment of formulation, tests, demonstration contents and methods for extension, research, application, establishment and management of expert systems during extension.

The method, basis and factors for reference in the determination of the formula of a compound fertilizer

There should be a comprehensive consideration of the pattern of fertilizer absorption, nutrient characteristics, fertility retention and nutrient supply ability of regional soils and regional climatic factors. These, in combination with long-term field fertilizer trials and indices of soil nutrient measurements, will determine the formulation for the fertilizer products. Analyses were chiefly on the mechanisms of determination of special-purpose fertilizers for crops and regional common fertilizer formulation.

Determination of parameters of pilot production and enterprise control indices and changes in development

This includes the best technical parameters in the quantitative analysis of products with different formulation, standards of enterprise control and the functions and application of fillers and auxiliary materials.

Verification, adjustment of formulation and tests, contents of demonstration and methods of extension

Summarize the programme of field tests used for formulation adjustments and high-efficiency demonstration methods. Summarize the train of thought in formulation adjustment.

Establishment of an expert network

Summarize the coordination, management and organization by experts and propose a training scheme for farming households and distributors.

Research on key technologies to raise brand value by using the theories of plant nutrition (basis of security and high efficiency)

2. Technical model of agrochemical services

Fertilizer application according to formulation based on soil tests by an enterprise

Fertilizer formulation based on soil tests and scientific fertilizer application forms the core of agrochemical

services. It is the key to the achievement of balanced fertilizer application. The condition of soil nutrients must be known. Input of N is appropriately reduced according to the recommended fertilizer application based on the method of comprehensive and systematic appraisal of soil nutrients and the technique of balanced fertilizer application. Increase the application of P and K fertilizers and the secondary and micronutrients so that the supply of various plant nutrients is balanced and rational. The yield and quality of crops will be raised. Wastage and adverse effects on the environment caused by excessive fertilizer application will be reduced. The formation, development and perfection of fertilizer application according to formulations based on soil tests by an enterprise is gigantic progress in the study of soil fertility and the science of fertilizer application.

The technique of fertilizer application according to formulation is based on soil test results, field experiments and patterns of fertilizer requirement of crops for agricultural production. In combination with organic fertilizers, propose the quantities, combinations and ratios of N, P, K, secondary and micronutrients. A suitable method of scientific fertilizer application should be adopted at a suitable time. Understanding the links in the technique of fertilizer application according to formulations based on soil tests is helpful in promoting the technique. This technique includes mainly the five core links of "soil tests, formulation, fertilizer preparation, supply and guidance in fertilizer application."

a. Field trials

Field trials are a fundamental way of obtaining information on the best amount of fertilizer to apply for various crops, the best period and method of application. It is also the technique of selection and verification of soil nutrient tests and the fundamental link in establishing a system of indices for fertilizer application. Through field tests, it is possible to optimize fertilizers applied to crops with different units of application, ratio of allocation of basic fertilizer and topdressing and the period and method of application. Establish the correction factors for soil nutrients, the quantity of nutrients supplied by the soil, the fertilizer requirement parameters and the rate of fertilizer efficiency. Establish a model and provide the basis for fertilizer applications according to region and fertilizer formulation.

b. Soil test

Collect soil samples and measure the contents of organic matter, pH value, N, P, K, Ca, Mg and the essential micronutrients in order to understand the condition of soil fertility. It is one of the important bases for determining fertilizer formulations.

c. Production according to formulation

Fertilizer formulation is the core of fertilizer application based on soil tests. Through results of field tests and soil nutrient data, divide the regions into different areas of fertilizer application. In addition, based on similarities and differences in climate, topography, soil and system of cultivation, propose the formulation of fertilizer application for different crops in combination with the views of expert. In order to ensure the accuracy of fertilizer formulation, the risk of batch production of formulated fertilizer and its application over a wide area

should be reduced to the minimum. At each unit of sub-region, there should be three treatment areas of fertilizer application according to formulation, traditional fertilizer application by farm households and the blank area without fertilizer application. The effects of formulated fertilizer on increasing yield are contrasted by using the local major crops and their main cultivated varieties as targets of study. The formulation used for fertilizer application is verified and perfected and the technical parameters of fertilizer application according to formula based on soil tests are improved.

The implementation of the fertilizer formula in the fields of farming households is important in upgrading and popularising the technique of fertilizer application according to formulation based on soil tests. At present, different regions have different models. Of these models, the one with market-oriented operation, factory production and network management has the best market potential. This model suits the present condition in China where farmers have low awareness of science and technology and a small scale of cultivated land.

d. Fertilizer application demonstration

In order to encourage the implementation of the technique of fertilizer application according to formulation based on soil tests in the field, besides having to resolve the difficulty encountered in the market-oriented operation of the technique, the farmers must be able to see the actual effects with their own eyes. This is the "bottleneck" that restricts the extension of the technique. We should, therefore, establish demonstration areas for fertilizer application according to formulation based on soil tests that create windows and establish examples for the farmers. This will fully demonstrate the effects of such fertilizer application.

New model of agrochemical services – precision fertilizer application

China has the largest quantity of fertilizer application in the world. However, the efficiency rate of chemical fertilizer is very low, 30-35% for N fertilizer, 10-20% for P fertilizer and 35-55% for K fertilizer. Nutrient elements of large quantities of fertilizers that are not absorbed and utilized by the crop pollute the soil, the environment and the atmosphere through fixation, adsorption, runoff and denitrification. Backward behaviour such as the careless application of fertilizers, both extensively and excessively, have resulted in harmful substances in some crops exceeding standards, poor crop quality and environmental pollution. This has seriously affected food safety which is very unfavourable to the international competitiveness of agricultural products after China's accession to the WTO. Consequently, the vigorous development of fertilizer application with precision in China's crop cultivation is something new entrusted to the agrochemical services. It is also the road that must be taken by China to achieve agricultural modernization.

Precision agriculture is an engineering system that integrates high, new and applicable technologies defined by the needs of actual application in agricultural development and the comprehensive development of agricultural technology in China. It covers all techniques in cultivation, irrigation, fertilizer engineering, information technology and

agricultural plastic films that can directly increase the level of agricultural production. Precision agriculture is an organic unification of two concepts (indices) of “refined quality” and “accuracy.” Its characteristics and intensions include new and refined measures in agricultural production, precise amounts of agricultural inputs, precision in the operation and management of the process of agricultural production and the nurturing of the fertility of agricultural resources.

In the main precision agriculture includes six technical links or technical systems namely; seed engineering (including biological and mechanical engineering), precision sowing, precision fertilizer application, precision irrigation, regulation and control of the state of crops and precision harvesting. The technique of precision and balanced fertilizer application currently requires a special active promotion in China. It is an important component of precision agriculture. The good quality of fertilizer is the basis of precision fertilizer application. The “accuracy” in the joint operation of agriculture, agricultural machinery and information is the soul of precision fertilizer application. Precision fertilizer application coordinates the relationship between inputs and outputs. It uses minimum input in exchange for good quality and highly efficient output, reducing imbalanced and excessive application to the minimum. The cost of fertilizer application and pollution are reduced to a minimum. Besides the scientific replenishment of soil fertility and the accurate regulation and blending of nutrients required by the plants, precision fertilizer application also supplies the nutrients according to the pattern of crop growth and nutrient requirement at the right time and in the right amount. The contribution of precision fertilizer application to yield increase of crops is about 40-60%. In short, the development of a system with Chinese features that supports precision agricultural technology in the future is an important developmental direction of scientific fertilizer application for China. To transform China’s agriculture from the blind and extensive type to precision agriculture, from high-input but low-output type to the precise input, good quality and low consumption type is doubtlessly the ideal choice.

5.3.3.3 Coordination between the enterprise’s agrochemical services and the public extension welfare technology

Fertilizer application according to formulations based on soil tests is a public welfare. In other countries, it is an essential part of fertilizer sales services and is mostly implemented by fertilizer suppliers. In China, due to a number of reasons, the concept of scientific fertilizer application has been spreading rather slowly. Enterprises’ knowledge on agrochemical services is far from adequate. Under such circumstances, the government must initiate fertilizer application based on soil tests. In the past two years, the government continued to put in more effort with regard to such application. Financial subsidies increased from RMB200 M in 2005 to more than RMB500 M in 2006. In this situation, many enterprises are moving with the times and actively participating in fertilizer application based on soil tests. However, how and in what form should the enterprises participate to get more subsidies for participating in fertilizer application according to formulation based on soil tests have become the focus of every enterprise.

These financial subsidies are mainly used in technical training of staff, soil laboratory tests and fertilizer tests. The agricultural department, on the other hand, is responsible mainly for asking enterprises to participate in this form of application and for supervising them. The government adopts measures to lead and push for the participation of enterprises with the final objective of getting enterprises to spontaneously provide the service of fertilizer application based on soil tests to the farmers. The main objectives of fertilizer application according to formulation based on soil tests is firstly to raise the farmers’ consciousness of scientific fertilizer application and secondly, to bring into play the enthusiasm of the enterprises in spontaneously developing the service. Fertilizer application according to formulation based on soil tests will never be a profit-making job. Instead, it should be a cost of sales service that an enterprise must invest in.

With the fertilizer application according to formulation based on soil tests, supported by financial subsidies, some local authorities come up with extension models where the department of agricultural technology extension carries out soil tests and fertilizer formulation, and the enterprise produces the fertilizer according to this formulation. The extension model does have positive contribution at the early stage of the work. When the work goes deeper, establishing its own complete system of agrochemical services and providing complete soil test services to the farmers while selling good quality formulated fertilizer, it will enable the fertilizer-producing enterprise to become the principal player in promoting fertilizer application according to formulation based on soil tests. This is a new, historical, mission that society has entrusted to the enterprises. In addition, an enterprise should increase its input with regard to agrochemical services. This type of input will not affect its profit. On the contrary, it will build a huge intangible asset for the enterprise since it has established a good image among the users. This will give impetus to the enterprise to grow further.

5.4 The external environment in the development of the compound fertilizer industry

5.4.1 Characteristics of the compound fertilizer market

5.4.1.1 Competition between the product of a well-known brand and the products of less known or inferior brands

Currently, a market economy means brand economy. As a well-known brand is widely known and influential, it becomes the first choice for consumers. A product of a well-known brand is always above products of other inferior brands in terms of sales volume and price. At present, in the compound fertilizer market, the price of product of a well-known brand is RMB30-50 higher than products of inferior or less known brands. In other words, if the fertilizer output of an enterprise is 500,000 t, its increase in profit in a year brought by its brand effect may reach about RMB20 M. However, due to their small scale, some small fertilizer enterprises grow slowly and

the brand consciousness is generally not strong. To a certain extent, this has limited the development of the compound fertilizer industry.

5.4.1.2 Competition between good and low quality products

As the level of farmers' education is generally not high, their ability to distinguish fake fertilizer and poor quality is low. It is still not possible to eradicate local protectionism. Currently, in the compound fertilizer market, fake products and poor quality are not uncommon. The appearance of fake and poor quality products has seriously damaged farmers' interests besides severely disrupting market order. It has also brought great impact on the distribution and marketing of good quality compound fertilizers.

5.4.1.3 Competition between special-purpose and general purpose fertilizers

A special-purpose fertilizer is a specially made fertilizer according to growth characteristics of a crop and the local soil characteristics. It is made for a good reason. It is easy to use. The fertilizer effect continues over a long time with great cultivation gains. It is the fertilizer that is most welcome by farmers and has the best development potential. However, chemical fertilizer enterprises in China generally do not pay enough attention to special-purpose fertilizer. Most of the fertilizer plants produce fertilizers for common use. Products lack characteristics. Farmers do not identify with the products. This is also the main reason why the market competitiveness of many fertilizer enterprises is not strong.

5.4.1.4 Competition between organic and inorganic fertilizers

Currently in China, inorganic fertilizer application is larger, at more than 50 Mt. Although inorganic fertilizers have contributed tremendously to agricultural production in China, excessive application will produce many negative effects such as hardened and impervious soil, soil acidification, pollution of underground water and deterioration in quality of fruits and vegetables. As the direction of development of modern fertilizers and important supplements, organic-inorganic (organo-mineral) compound fertilizers have emerged, as the market requires. Viewed from market demand and trends of development, there is much market room for organo-mineral compound fertilizers.

5.4.1.5 Competition between high-analysis and low-analysis compound fertilizers

Looking at the developmental history of chemical fertilizer in China, low-analysis fertilizers have been playing the main role. For example, in the case of NPK compound fertilizer, the sales volume of fertilizer with 25-35% concentration is larger than fertilizer with concentrations higher than 45%. With the development of modern agriculture, people came to realize that compared with low-analysis chemical fertilizer, high-analysis chemical fertilizer have the advantages in storage, low transportation cost and fertilizer application. In the long run, the replacement of low-analysis fertilizer with high-analysis fertilizer will definitely be the trend of fertilizer development. With the present low food prices, the purchasing power of

farmers is not strong and the price of low-analysis fertilizer is relatively low. Furthermore, farmers are influenced by their habits of fertilizer application in the past and other factors. Therefore, low-analysis fertilizer will still have a certain market share in the future.

5.4.1.6 Competition between local and foreign products

During the period of planned economy, the policy implemented by the State on chemical fertilizer enterprises was "unified purchase and sale." To facilitate transport and management, the government department usually divided the market into areas within the vicinity of the enterprises in which they would sell their products. This market became the most stable market of the enterprises. With the continuous extension of reform in the system of chemical fertilizer distribution, the market barrier was broken down. Foreign products poured in. The share of the local market dropped dramatically for many enterprises. For local manufacturers to effectively resist the impact of foreign products and to ensure that their "market at the doorstep" was not lost, the advantage of proximity and the short distance of transport was the key. They should vigorously develop the model of direct delivery by which the manufacturer's own products are sent directly to the various villages, even to the farmer's house, to allow the manufacturer to firmly dominate the market.

5.4.1.7 Competition between Chinese made and imported fertilizers

Owing to the fact that farmers prefer, for a long period, imported chemical fertilizers, they have had an obvious advantage over fertilizers made in China. For the same product, price per tonne of imported fertilizer is often tens or even hundreds of RMB higher than fertilizers made domestically. With China's accession to the WTO, there will be more and more imported chemical fertilizers finding their way on to the market and competition between those made in China and imports will be more intense. Domestic chemical fertilizer enterprises must realize the severity of this problem and vigorously strengthen fundamental research related to compound fertilizers and seriously study the advantages and disadvantages of imported compound fertilizers. They should work hard to increase the scientific and technological content of domestically produced compound fertilizers and should put in more effort to agrochemical services and strive for the establishment of domestic brands for locally produced compound fertilizers. It is through this way that local fertilizers will be able to compete with imports.

5.4.2 The future, and prospects for the compound fertilizer market in China

The switch from single fertilizers to compound fertilizers has become an important mark that symbolizes the level of development of a country's chemical fertilizer industry and the level of its agricultural development. At present, the output of compound fertilizers in China is merely 25% of the total output of chemical fertilizer. This is way below the level in developed countries. Based on this, the agriculture sector of China has proposed that in the next 10 years, China will

continue to regulate the composition of chemical fertilizers, expedite the development of the compound fertilizer industry, and increase the proportion of compound fertilizers to 50% by 2010.

For the next 5 to 10 years, increasing the output of compound fertilizers and increasing the rate of recombination will be one of the main tasks in the development of China's fertilizer industry. Looking at the overall development of compound fertilizers in China, both opportunities and challenges await the compound fertilizer market. The details are as follows:

5.4.2.1 The compound fertilizer market has a great developmental potential but some problems exist

China's compound fertilizer market has tremendous potentials but two problems exist. First is the slow pace of development. In 2000, total consumption of chemical fertilizers was 41.5 Mt and consumption of compound fertilizer accounted for only 22.1%. From 1995 to 2000, the ratio of compound fertilizer consumption to the total fertilizer consumption increased by a mere 4%. On average, the annual increase was less than 1%. Second, the ratio of imported compound fertilizers is rather high in certain regions. Imported compound fertilizers account for more than 50% of the total consumption of compound fertilizers, even if prices of imported compound fertilizers are much higher. In 2001, in the fertilizer market of Southern China (the provinces of Guangdong, Guangxi and Hainan), the Ship Brand of Norway's Yara, the Lion-Horse Brand of Germany's BASF and the Star King Brand of Finland's Kemira are popular among users despite their market selling price of RMB2,200-2,300/t. The same 15-15-15 locally produced compound fertilizer can only sell for RMB1,700-1,900/t.

The slow pace of compound fertilizer development is related to the scale of agricultural operations, financial conditions in the agricultural villages and operational benefits of agriculture in China. Under conditions where supply and demand are balanced in China's fertilizer market, the fact that high-price imported compound fertilizers are still able to command a large share in the Chinese market is something for the Chinese to consider. It cannot be denied that imported compound fertilizers have the advantages of brand effects and better product quality that enable them to remain strong. Chinese producers always say that Chinese made compound fertilizers are as good as imports. In reality, in terms of external appearance, prevention of hardening and solubility, Chinese-made compound fertilizers are inferior to imports. More important is the difference in fertilizer effect. To add salt to the wound, management of the fertilizer market is not standardized in China and farmers have been duped many times. Thus, in some economically more advanced regions, farmers would rather spend more money to purchase and apply imported "fertilizer that sets their minds at rest" for use in high value crops. China must learn from the foreign fertilizer business operation. Domestic large enterprises should work out their strategies in raising product quality and build up their own brands. Administrative and law-enforcement departments should handle matters impartially, take strong measures against fake and inferior products and standardize the fertilizer market. In summary, the market

potential for domestic compound fertilizer is tremendous but it is not easy to do a good job.

5.4.2.2 Compound fertilizer products must be diversified and enterprises must regulate product composition in time

Due to different practices in fertilizer application in different places and regions, requirements for the nature of completely soluble compound fertilizers are also different. First, high solubility of fertilizers is a product requirement. The application of rapidly dissolving and quick-acting fertilizer shortens the time interval of each harvest. Early harvest and high yields bring high benefits. The active development of fully soluble drip irrigation fertilizers is also a new requirement for product diversification. With the continuous development of water-saving agriculture, the drip irrigation technique will be gradually extended. Drip irrigation fertilizer is an indispensable part. Research and development of slow release fertilizers is one of the important measures in reducing nutrient loss, increasing the fertilizer efficiency rate and environment protection. However, the cost of developing and producing slow release fertilizers is high. The pressing matter at the moment is to actively look for markets, carry out research and development on low cost, good quality slow release fertilizers. In addition, development of various types of special-purpose fertilizers for specific crops and organic-inorganic compound fertilizers are also important ways to adapt to the needs of the compound fertilizer market and to ensure product diversification.

5.4.3 Trading and prices of compound fertilizers

In recent years, overall prices of compound fertilizers have been on the rise and the trend is for continuous price increases. Compared with low-analysis, prices of high-analysis compound fertilizers rise at a faster rate. According to data in 2005, the average price per tonne of 25% concentration compound fertilizers increased by RMB20-40. Some increased by more than RMB60. In the case of high-analysis compound fertilizers (45%), the price per tonne rose by RMB80-150. Some even exceeded RMB200. In 2006, the average price per tonne of 25% compound fertilizer is RMB760-920. In some cases, it is higher than RMB950. The average price per tonne of 45% chlorine-containing compound fertilizer is RMB1,450-1,600. It is more than RMB1,650 in the higher cases. The average price per tonne of 45% SOP compound fertilizer is RMB1,700-1,850. It is RMB2,200 for the more costly ones. In 2005, prices of Chinese made compound fertilizers dropped while prices of imported compound fertilizers remained the same. The annual average price of Chinese made low-analysis compound fertilizer was RMB928/t, an annual decrease of 2.7%. The annual average price of high-analysis compound fertilizer was RMB1,546/t, decreasing 6% annually. The annual average price of imported compound fertilizers was RMB2,004/t. There was neither an increase nor decrease. Looking at the trend of prices of compound fertilizers for the whole year, fluctuation in the prices of low-analysis compound fertilizers was not big. Prices of high-analysis compound fertilizers can be roughly divided into two stages.

One is the stage of rapid price drop where prices fell rapidly at the rate of about 10%. The other is the stage of stable price where prices basically remained stable with relatively small fluctuations. Prices of imported compound fertilizers can be roughly divided into 3 stages. The first is the stage of rapid price drop where prices fell rapidly at a rate of about 12%. The second is the stage of stable prices where they remain stable at about RMB1,980. The third is the stage of rapid rebound at which prices rose quickly.

Raw materials – chemical fertilizer production – grain production – grain price is a chain similar to the food chain type. When changes occur in one of the links, it is bound to cause a strong reaction to the entire chain. The continuous rise in the prices of chemical fertilizers is an effect of the fast increase in the cost of raw materials such as coal, electric power, natural gas and petroleum. Rapid economic developments cause a shortage of resources which brings benefits to resource-rich provinces. However, this caused the production costs to remain high and these enterprises have no choice but to raise their ex-factory prices. In addition, the increase in grain prices and grain subsidy has encouraged farmers to produce more and this caused a great increase in the demand for chemical fertilizers. Hoarding is also a factor that causes price increase. More importantly, international prices, which has always been lower than the domestic market price, continued to rise from the previous year. This has led to chemical fertilizer enterprises vying to export, resulting in a sudden short supply in the local market.

The continuous rise in the price of chemical fertilizers has greatly offset the hope brought by increases in grain price. To a great extent, it has affected farmers' enthusiasm to cultivate more. The reduced enthusiasm of farmers to purchase fertilizer affects the relationship of supply and demand of the entire fertilizer market. The management of fertilizer enterprises by the government is different from the past because the regulation and control of fertilizer prices will involve electric power and a number of other departments. Facing the present market economy which has presently gained much momentum, the State finds it difficult to intercede with the

help of administrative measures as it does in controlling grain prices. Furthermore, the fertilizer business is an open market now in China. Main sales channels no longer exist. Therefore, the continuous climb of fertilizer prices presents a tough test to fertilizer enterprises.

Raw materials for the production of compound fertilizers have certain requirements and standards. Main raw materials for N include mainly, urea, AC and AN. The main sources of P include mainly, SSP, TSP, FCMP, MAP, DAP and NP. K fertilizer has many types that include SOP, MOP, KNO_3 , KCO_3 , and FCMP- KNO_3 ; however, the most commonly used raw materials in the production of compound fertilizers are KCl and AS.

The compound fertilizer industry is, in itself, an industry with thin profits. This is mainly due to the cost of raw materials accounting for the major part of the entire cost of operation. Coal (or natural gas) and electric power supply, account for about 60% of the production cost. Therefore, price fluctuations of energy sources (coal and natural gas) and electric power supply will produce important effects on the production and business operation of the chemical fertilizer industry. From the middle of 2004, fertilizer prices went up on all fronts. Price increases for a large number of fertilizers were striking. Increases for urea and ABC reached 6% and 16% respectively. Price increases for K fertilizer reached above 15%. Increase of MAP even exceeded 20%. Thus, adjusting the formulation accurately at an appropriate time depending on prices of raw materials and achieving the best economic benefits while guaranteeing the supply of quality products and increasing the accuracy of ingredients has become the key technique in the study of formulation of compound fertilizers. In order to achieve the lowest cost, an ideal formulation system will have to fully analyse and determine the effects that fluctuating price has on formulations. It is then possible to search for more information to provide services in the design of a formulation and quickly respond to market changes. It is by this way that enterprises will remain strong in an intensely competitive market.

Chapter 6

The Development and Prospects of New Fertilizer Types in China

For a long time China's chemical fertilizer development was entirely focused on conventional N fertilizer (from low-analysis ABC to high-analysis urea). In recent years, high-analysis P and K fertilizers came into the picture. The trend of development for conventional types of chemical fertilizers followed the mainstream of development in the world, which is, emphasizing on high-analysis and compound fertilizers. Since the 1980s, total production and amounts of application of N fertilizers have been increasing continuously. However, the rate of N fertilizer efficiency is low. With the development of high-analysis N and P fertilizers, low-analysis N fertilizers such as ABC, AS and minor components (secondary nutrients such as S and Ca) and low-analysis P fertilizers have been replaced by high-analysis N and P fertilizers, resulting in the problem of micronutrient deficiency in the fields. Consequently, there are new developments which modern intensive agriculture has with regard to the chemical fertilizer industry. These are slow/controlled-release (S/CR) N fertilizers which are totally water-soluble and in liquid forms with secondary/trace nutrients. For the past 20 years, research and development for new types of fertilizer has been centred upon these two areas.

Application of slow/controlled-release nutrients and the supplementation of secondary and micronutrients through the non-root path has brought about a revolution in fertilizer use. Research and development for new types of fertilizers such as the slow/controlled-release ones centred on the high efficiency rate of plant nutrients is now an international hot spot in research and development of new types of fertilizer. During the key period of plant growth, the use of non-root tissues such as plant leaves to absorb and utilize nutrient materials and fertilizer application outside the root zone to supplement secondary and micronutrients are to achieve the objective of improving plant nutrition.

Since the 1980s, the development of foliar fertilizer products, in response to different plant nutrition requirements, is fast becoming a hot spot in the research and development of new types of fertilizer in China. With the development of intensive and large-scale cultivation, the traditional agriculture using mainly organic manure has been broken. The commercialization of organic fertilizer is also an important aspect in the research of new types of fertilizer. In the development of organic fertilizers, researchers can increase the commercial quality of the fertilizer by adding readily available nutrients or bacterial groups and bacteria that release P and K in soil. This type of active organic fertilizer and organo-mineral compound fertilizers are having an impact on people's traditional idea of fertilizers. Besides, the various types of fertilizers containing plant growth

regulators, growth hormones, beneficial active substances and secondary and microelements are flooding the market. As these new materials have different functions and are called different names (or brands) which are rather confusing, and for their different fertilizing effects, people have a hard time understanding them.

In view of the complexity of the research domain for new fertilizer types and their restrictions by resources, this chapter gives an account of the production technology, enterprises, products and the consumption market of new fertilizer types from the angle of foliar fertilizer and slow/controlled-release fertilizer (S/CRF).

6.1 Technological development of the slow/controlled-release fertilizer (S/CRF) industry

The production technology for the new fertilizer industry came mainly from research institutions and the R & D platforms of fertilizer industries. However, in China, the technology comes mainly from research organizations. This is because after the mid-1970s, domestic fertilizer enterprises adopted imported technology for the production of the major chemical fertilizers. There was inadequate input from the science and technology in China for the development of new products. As a result, the development of new fertilizers is relatively weak. In 2000, some domestic enterprises and investors started to pay attention to the development of new fertilizers. Development of production technology for new fertilizers is gradually being launched in some research organizations and agriculture universities, particularly in agricultural research institutes which mainly conduct research on fertilizer effects.

6.1.1 Characteristics of the technological development of the S/CRF industry in China

The research and development of new fertilizer technology started late in China with two major characteristics. The first is tracking international technology for the development of new fertilizers and second, combining the fertilizer requirements for sustainable development of intensive agriculture. As early as the 1930s, from the N fertilizer production using synthetic ammonia, European countries and the US, made use of the newly introduced technology of organic synthesis and developed organic N fertilizer grades with slow-release functions. These include urea-formaldehyde and isobutylidene di-urea. In the 1960s, high

polymer technology was rapidly applied in the research on coated fertilizer and they developed controlled-release fertilizer (CRF) products coated with alkyds and phenolics. In the 1970s, research on controlled release N fertilizers such as polyolefin coated urea was undertaken. During this period, due to the low level of development of fundamental industries such as iron and steel and machineries, and industries of organic synthesis and organic polymerisation, China was not involved in the industrial development of new fertilizers. The conventional fertilizer industry was mainly developing the production of low-analysis N fertilizers. There were no high-analysis fertilizers such as urea. The development of compound fertilizers began in the late 1980s, with modern significance, when China began to research new fertilizer technologies. In general, these technologies lacked a high level of industrialization, with slow commercialization.

6.1.1.1 History of development

The earliest research on S/CRF techniques in China can be traced back to the end of the 1970s when ABC coated with FCMP and the long-lasting ABC was developed. Due to an economic blockade by the international community, domestic N fertilizer production, at that time, mainly used synthetic ammonia to prepare ABC. As ABC volatilises easily, its fertilizer efficiency is very low. This spurred researchers to consider coating measures to control this volatilisation in order to extend its fertilizer effect. For this purpose, the research team headed by academician Li Qingkui of the Nanjing Institute of Soil Science of Chinese Academy of Sciences began to conduct studies on inorganic coated fertilizer by coating ABC with FCMP. First, they turned the ABC into granules. Then, they applied powdered FCMP to the granule surface. By adding H_2SO_4 , the FCMP powder and the ABC granules were stuck together. After the 1980s, research on S/CRF was carried out extensively and some research organizations explored and carried out studies on this type of coated fertilizer. Individual units even carried out pilot production. A group led by Professor Xu Xiucheng of the Faculty of Engineering at Zhengzhou University developed the inorganically coated fertilizer where compound fertilizer was coated with citrate-soluble phosphate fertilizer. This coated compound fertilizer was abbreviated as CCF and its trade name was Luxecote. In 1986, the Guangzhou Nitrogen Fertilizer Plant developed coated urea. In 1985, Beijing University of Chemical Technology began screening for coating materials of degradable resin. They also developed SRF with urea-formaldehyde resin as a coating agent. The Lanzhou Institute of Chemical Physics of the Chinese Academy of Sciences chose to use a few biodegradable organic polymer materials (such as urea-formaldehyde resin, polyvinyl urea phosphate, polyvinyl acetal) in their experiments as coating materials. They succeeded in manufacturing coated urea. The Hunan Provincial Plastics Research Institute developed polyvinyl alcohol – starch coated fertilizer. In the 1990s, studies on using high polymer materials as coating materials became more widespread. These studies were mainly centred on the screening and application of thermoplastic coating materials and coating techniques. The Beijing Academy of Agricultural and Forestry Sciences, the Shandong Agricultural University

and the China Agricultural University carried out more profound and systematic research.

Even though research and development of SRF started late in China, its growth has been relatively fast. Up to 2002, the number of published patent applications concerning S/CRF in China reached about 30. The techniques of slow effect included the following types: first, stable N fertilizer of the conversion-inhibiting type; second, long-lasting ABC with the addition of various stabilizing agents; third, the technique of urea paint-coating; fourth, inorganic or organic polymer controlled-release materials and coating technology.

Concrete progress in research of various research units is as follows.

From the late 1960s to the early 1970s, the Nanjing Institute of Soil Science of Chinese Academy of Sciences successfully developed granular ABC, long-lasting ABC coated with FCMP and long-lasting urea. However, there was no large-scale production.

After years of research, the Shenyang Institute of Applied Ecology of the Chinese Academy of Sciences perfected the stabilizing and synergistic reaction on urea by urease inhibitor, hydroquinone (HQ) and nitrification inhibitor, dicyandiamide (DCD) and applied them in the production of SRFs. The institute developed long-lasting urea, synergistic agents of N fertilizer and achieved theoretical and technical innovation. The technology was worth promoting.

Also, the Plant Nutrition and Resources Research Institute of Beijing Academy of Agricultural and Forestry Sciences successfully developed new types of coated S/CRF. The urea and compound fertilizer coated with zeolite was awarded the National Invention Patent and the Certificate of National New Product for 1996, the City Level Scientific and Technological Progress Award and Grade I City Promotion Award. The controlled slow-release coated urea passed the experts' appraisal in 1997. In addition, the Institute developed China's first set of processing equipment for coating urea by spraying. Through regulation of the coating material, the rate of release of the fertilizer in the soil can be controlled to a certain extent. One time fertilizer application is enough for many types of crops without the need for topdressing. This simplified the procedure of fertilizer application, allowing sowing and fertilizer application to be carried out simultaneously, greatly reducing agricultural labour and increasing the rate of productivity.

Shandong Agricultural University successfully developed a series of coated CRF with the rate of nutrient release varying from 2 to 12 months. Its core technology is coating material and corresponding additives. Through the adjustment of formulations it is possible to set the size of apertures of the coating to control the release of nutrients (Zhang Min, Yang Yuechao, Wan Lianbu, 2004). Nutrient release of CRFs is mainly limited by temperature and water content. Adjustment to the time of release and the peak period of release can be made in accordance with the crop requirement.

The College of Resources and Environmental Sciences of China Agricultural University achieved success after eight years of research.

1. The College developed the compound moulding material mainly of polymers that has the effect of controlled-release. The material is degradable by light and heat and is also bio-

degradable. They also set up and improved the processing equipment with boiling bed coating tower as the nucleus, thus, establishing the "POCF" coating technique and the corresponding technical rules.

2. The College developed the online testing method for S/CRF in China and the corresponding judging standards. This has provided the scientific basis for quality control on the production line and comprehensive assessment of products.
3. Based on research in the commodity character of coated fertilizer, soil agro-chemistry, agricultural character, environmental and economic benefits, the college established a comprehensive appraisal system for S/CRF. This has important theoretical and practical significance in the proper development of S/CRF in China.
4. Based on nutritional patterns of crops, the college designed corresponding controlled-release parameters (initial rate of dissolving out, rate of differential dissolving, period of release). Through the optimization of coating materials and coating technique, the college developed special coated CRF for vegetables, lawns, flowers and maize, with their costs of production lower than similar products in other countries.

The Institute of Pedology and Fertilizers of the Hunan Provincial Academy of Agricultural Science used natural polymers such as cellulose for coating fertilizer and developed CRF with a degradable coating and a special CRF for rice plants. The technique of precision fertilizer application for rice, the traditional method of fertilizer application, is replaced by one time fertilizer application in full amount. In this way, the application of N fertilizer on per mu (= 0.0667 hectares) of rice crop can be reduced by a third.

The Institute of Pedology and Fertilizers of the Guangdong Provincial Academy of Agricultural Science showed originality in utilizing plant compound coating materials for controlled-release and the application of mixed spreading and new adhesive coating techniques.

The Luxecote Phosphate Compound Fertilizer Technological Research and Extension Centre of Zhengzhou University developed the SRF-Luxecote. The nucleus is water-soluble N fertilizer such as urea. Many types of inorganic plant nutrient substances (such as ammonium-magnesium phosphate) are used as coating layers. All components of the coated fertilizer are plant nutrient substances. Luxecote SRF was awarded the patent of invention by China and the US aside from the conferment of the Grade III National Technical Invention Award, making it a high and new technology product recognized by the State. Since 1995, the product has been exported to the US, Australia and Singapore. A production line with an annual capacity of 100,000 t was set up in China and the US.

Organizations in China which carry out research and development of SRF include Beijing University of Chemical Technology (polymer-coated compound fertilizer), Tsinghua University (coated urea, coated compound fertilizer), the Institute of Chemical Metallurgy, Chinese Academy of Sciences (lignin SRF), Beijing Institute of Landscape Gardening and Beijing Chemical Engineering Research Institute (phenolic resin coated compound fertilizer), Huanan Agricultural University (scrap-coated SRF), Shanghai

Academy of Agricultural Science (mineral-coated SRF), Zhejiang University (urea coated with polymer), Institute of Magnetized Fertilizer, Northeast University, China (clad poly-magnetized fertilizer specially for lawns), Research Institute of Lanzhou Petrochemical Co. (high-strength slow release urea), Jilin Normal University (inhibiting type SRF), Institute of Geology, the Land and Resources Department of Hunan Province (meerschaum long-lasting fertilizer).

These achievements of research and development indicate that research on SRF in China has made bigger forward strides. A small number of SRF products developed have attained the quality standards of similar products in other countries. It is believed that the objective of industrial production of SRF in China can be gradually achieved. However, in order to further reduce the production cost of S/CRF, production must be expanded and its application to the agricultural land must be extended as soon as possible. Of course, there is still a great deal of in-depth R & D work that must be systematically carried out.

6.1.1.2 Technological characteristics and innovation

The initial objectives of S/CRF production were: firstly, to control the volatilisation of ammonia in ABC; secondly, to control the release of water-soluble N fertilizer, which is chiefly the processes of ammonization and nitrification of urea to reduce loss, with the objective of increasing the utilization of N fertilizer. The technical characteristic is the use of fertilizers as coating material to reduce cost and without secondary pollution. With regard to the coating of an inorganic fertilizer with another inorganic fertilizer, the earliest technique was the use of citrate-soluble phosphate fertilizer for coating ABC, first applied by academician Li Qingkui of the Nanjing Institute of Soil Science of the Chinese Academy of Sciences. Even though the technique was not used for large-scale production, its characteristics were inspiring to others. Subsequently, Professor Xu Xiucheng of the Faculty of Engineering at Zhengzhou University developed the inorganically coated fertilizer, which, if viewed from the angle of compound fertilizer technique or the slow-release urea technique, the characteristics were distinctive and the fertilizer was the first of its kind internationally. For this reason, this technical achievement was conferred the Grade III National Invention Award. It was also recognized by patent authorization bodies overseas. Together with the sulphur-coated urea (SCU) of the US, they were models for inorganically coated SRF.

After the mid-1980s, chemical engineering type research organizations launched more research into new SRF. These techniques were represented by Professor Xu Hechang of Beijing Chemical Technology University. After systematically studying the composition of the coating materials of other countries, he developed the processing technique for urea-formaldehyde resin SRF. The Lanzhou Institute of Chemical Physics of the Chinese Academy of Sciences also explored the techniques of film formation by polymerisation reaction in the laboratory. These studies basically follow the international track of film formation through reaction in the production of CRF. Seen from the perspective of similar research in the world, there was no technical innovation. The technique itself was far from perfect and there was no industrial production.

Looking at the international development trend in recent years, the technique of film formation through reaction in the production of CRF has been extensively looked into. The technique has primarily demonstrated its tremendous potential. It requires expertise on organic polymerisation, chemical technology, chemical machinery and plant nutrition to jointly carry out research and development to have some chance of success. At present, the China Agricultural University is dedicated to the establishment of a platform for research in CRF.

Since the 1990s, based on comprehensive considerations of theories and techniques of fertilizer application, many local research organizations in plant nutrition and fertilizers recognized the obvious advantage S/CRF has with regard to the nutrient supply to crops. They were conscious of the great potential that the development of S/CRF had in terms of environment protection and energy saving. This generally enhanced work in the research and development of techniques of S/CRF production. The trend of development had one obvious characteristic in that this type of R&D was started mainly in agricultural research institutes and agricultural universities. The technology adopted by these research organizations was mostly granular fertilizer coated with an organic polymer material. An early example was granular fertilizer coated with natural organic polymer materials developed by Zheng Shengxian, a research worker at the Hunan Provincial College of Agricultural Science. Later, Beijing Academy of Agricultural and Forestry Sciences, Shandong Agricultural University and China Agricultural University adopted the technique of using polyolefin resin for coating granular fertilizer and developed a technique for S/CRF production. Hunan Agricultural University and Hunan Agricultural Science College also developed many types of production techniques for S/CRF.

Organic synthetic N fertilizers with micro-solubility were developed in China, by chemical industry scientific research and chemical industry production enterprises, from urea-formaldehyde condensate products. However, their effects were not significant. Internationally, as early as the 1940s, research into this type of fertilizers had already started in the US, Germany and Japan. There were many types, such as urea-formaldehyde (UF), urea acetaldehyde and isobutylidene diurea (IBDU). However, these types of SRF grew very slowly. China did not launch similar research work for increasing the stability of N fertilizers. Another technical path was the stabilized N fertilizer – addition of nitrification inhibitor or urease inhibitor to control transformation by micro-organisms after the chemical fertilizer had entered the soil to extend the fertilizer effect of N fertilizer. This type of technique has been carried out by many research organizations in China. The most outstanding was the Institute of Atomic Energy of the Chinese Academy of Agricultural Sciences and the Institute of Applied Ecology of the Chinese Academy of Sciences.

Research work in techniques of S/CRF production is now progressing quite rapidly. People are exploring the various technological paths. Nearly 30 applications for national patent have been made. However, the level of industrial production of these techniques is generally not high. Points of innovation are not sufficiently outstanding. Originality is lacking and level of commercialization is not high.

6.1.1.3 Experience and lessons learned

Research in techniques of S/CRF production has gone through a period of 20 years in China. There are reasons for all the events that have taken place. In summary, the technical research was able to adapt with the conditions of the country at that time. Fertilizer products with practical value of utilization were developed according to the actual conditions. However, effects of the technology were not put to full use. Experience dictates that whilst tracking international research, China should link existing problems of production and utilization in the fertilizer industry in order to develop new fertilizers with practical value for application. The lesson learned was that the level of research was rather low. Research work lacked system and depth. Innovative research for new fertilizers required the overlapping studies of a number of subjects and the cooperation of research workers from different disciplines. Otherwise, it is very difficult to integrate the results and become a research achievement with high technological content. Research inputs, in particular manpower, for new fertilizer researches by the enterprises are inadequate. There have been very few techniques with originality. Commercialization is slow and follow-up research is lagging behind.

6.1.2 Breakthrough in production technology and important inventions

The S/CRF development techniques in China are mainly expressed as fertilizer coated by fertilizer, coating by polymer and coating with natural organic matter. Here, China's development of SRF with organic coating is worth mentioning; from the initial technique of ABC coated with FCMP, developed by the Nanjing Institute of Soil Science of Chinese Academy of Sciences, to the granular ABC and granular urea coated in citrate-soluble phosphate developed by the Faculty of Engineering at Zhengzhou University. These techniques are used in industrial production with some of the products exported to the US, Japan, Australia and Southeast Asia. These techniques combine P and N fertilizers effectively. While delaying the rate of release of N fertilizer, it also effectively makes use of low-grade phosphorus ore. With the shortage of high-grade phosphorus ore increasing, there is still plenty of room for development. Even though this technique was developed in the 1980s to suit the social conditions of China of the 1970s, 20 years later, from the point of view of comprehensive utilization of low-grade phosphate resources, its advantages were once more felt. Unfortunately, this technology is still inadequate to achieve the required international standards for CRF.

For the past 20 years, with the rapid development of the organic polymerisation industry, the search for various polymer materials used in making controlled-release film on the surface of fertilizer granules has been the focus of international research. On this technical path, many types of high polymer coated fertilizers were developed domestically. The main technique is the fluidised bed spray coating. The fluidised bed CRF coating technique has been developed. This technique is able to effectively control the period of release of fertilizer nutrients. Characteristics of nutrient release can be set in advance - the straight-line-type model or the S-type

model. There is the possibility that the speed of nutrient release from the fertilizer matches the pattern of nutrient requirement of the target crop. This is the best situation. Unfortunately, the current cost of production and technical stability, does not completely meet the desired target.

6.1.3 Important events in technological development and the technical experts

In the search for S/CRF technology, many research workers put in painstaking efforts. They include academicians and old experts with foresight and sagacity who participated in the formulation of development plans for S/CRF. There were academicians who led in the implementation of these scientific research plans. They also include a large number of young and middle-age research workers who were engaged in specific research work. Here, we give a brief account of some experts who have made specific contributions to the technical development of S/CRF.

Regardless of how you look at it, the research work of academician Li Qingkui of the Nanjing Institute of Soil Science of the Chinese Academy of Sciences in the 1970s on the coating of ABC with FCMP was certainly the beginning of research on S/CRF. The output of ABC increased from 10,000 t in 1961 to 8.4 Mt in 1989, a great contribution to the fertilizer industry in China. Of course, there were problems too. In the course of production, usage, storage and transport, the product absorbed moisture and hardened easily. It was not resistant against heat and moisture and could be lost through volatilisation. The industry was compelled to propose ways of improving it. Granulation of ABC and coating with FCMP fertilizer was one of the methods thought of. For this reason, academician Li led a research team to begin his tactical work on fertilizer coated in another fertilizer. His idea was already a type of slow-release technique. This raised the curtain for research in S/CRF in China.

In the course of his research in the utilization of phosphorus ore resources, Professor Xu Xiucheng of the Faculty of Engineering at Zhengzhou University used N fertilizer (ABC was used initially, followed by urea) as the nucleus to be coated with FCMP. A slow-release compound fertilizer with two nutrients was obtained. Owing to the surface P fertilizer dissolving slowly, a certain slow-release effect was obtained.

In the middle and later parts of the 1990s, a large amount of research was started into the development of new S/CRF as its objective. Firstly, establishment of research projects were proposed in the important national scientific research plan. Here, we have to mention academician Shi Yuanchun. He played a specific role in the promotion of research in S/CRF. Even though Shi did not specifically carry out research into this aspect, during his participation in the formulation of medium and long term plans of the State, he spared no effort in advocating research on S/CRF. As a result of his proposal, the National Science and Technology Commission included research projects on S/CRF in its "863" Plan and the 10th Five-Year Plan. It was because of his great foresight that research in this domain was able to go on the right track domestically.

In China, apart from some earlier work done by Professor Xu Hechang of Beijing University of Chemical Technology, Xu Qiuming of Beijing Academy of Agricultural and

Forestry Sciences and Zhang Ming of Shandong Agricultural University started their research work in polymer coating techniques. There were other organizations which made some bold attempts that gave impetus to the development of S/CRF in China.

In the numerous research works in S/CRF, proper appraisal and assessment of the performance of S/CRF has always been a complex issue which demands an urgent solution. The group led by Professor Cao Yiping carried out a large amount of research work, in detail and in depth, in this area. After nearly 10 years of comparative research, he combined the water infusion method of polymer coated fertilizer and the soil verification method to establish a complete comprehensive system of determination and assessment. This laid the foundation for enterprise, industry and national standards.

6.1.4 Comparison of the industrial technology level with advanced countries

At present, for the major types of S/CRF developed overseas, there is corresponding R&D in China. However, ratios of the various types of fertilizer are different. According to statistics, sulphur-coated urea accounts for 25% of the total number of S/CRF. Polymer coating film accounts for 25% and the others account for 50%. Prior to 2005, S/CRF in China comprised only stabilised N fertilizer and inorganically coated fertilizers. The various types of products of polymer film coated fertilizers from small-scale production and test processing amounted to only 5,000 t. It can be seen that the technical development in research and development of S/CRF, is not balanced. Although the techniques confined to small tests carried out by some research organizations have reached advanced international standards, the overall standard is not high. Furthermore, the development of supporting equipment is relatively weak. Based on the current research situation, the problem of low input on a short-term basis in technical research is common. The industry of film coating started from a low level. Each enterprise did things in its own way. Low standards are now being repeated. Progress is slow. On the enterprises side, production and business operations lack standardisation. Since large differences exist among the techniques and industry standards are absent, production enterprises have different qualities and some enterprises sell poor-quality fertilizers as good ones. They are abusing the name of S/CRF.

What China needs are types of S/CRF which are truly representative of new high technology. Input in the research on S/CRF made by the State has not even reached 10 years. Technically, China has not attained the same level as seen overseas. Consequently, the common goal, shared by departments in charge of national scientific research, research organizations and production enterprises, is to increase input in basic research and increase the technical contents of S/CRF in order to compete with similar research overseas.

6.1.5 Outlook for technological development

6.1.5.1 Trends in the technical research for S/CRF

Currently, the main problem which affects the extensive application of S/CRF for agricultural production is price. The

major reasons include the high price of materials for controlled-release, high cost of technology, small-scale equipment and non-continuous production. Fertilizer application for field crop production forms the bulk of agriculture development. Therefore, field crops should be the major target for future developments in S/CRF. At present it is applied mainly in the non-agricultural market. Apart from the price factor, there is the problem of awareness. It is generally believed that S/CRFs are expensive. It is not possible for the film-coated fertilizer with its "golden outfit" to find its way to the fields. It can only be used on lawns and flowers/ornamentals. Scientists have not developed an S/CRF with excellent performance that is affordable to field crop farmers.

The growth period of field crops is not very long. Requirements for the release of nutrients in the fertilizer are very different from lawns and flowering plants. Therefore, with the change in target crops, there is a necessity to carry out further research on materials for S/CRF, production techniques and equipment. Besides, it is also possible to reduce cost. The problem of "Development and commercial production of environment friendly fertilizer" (2001AA246023) subsidized by the national 863 Plan, is that it utilizes materials of business operations such as discarded industrial and agricultural materials, as raw materials. Through techniques of coating, recombination of base materials and agglutination, S/CRFs are made on ordinary equipment with prices only about 10-20% higher. The price of some products is even lower than conventional fertilizer. These have laid the foundation for S/CRF products to head for the cultivation fields.

6.1.5.2 Development of new types of high-efficiency materials for controlled-release (CR)

Research into materials for CR represents the leading technology in the development of S/CRF. Recombination type CR materials that are mainly high polymers possess degradability and controllability of nutrient release. Besides, the effects of environment factors on them are unitary, with temperature being the only factor. It is possible for these materials to achieve "intelligent" type CR. On the other hand, a solvent has to be lower priced, highly efficient and non-toxic. Therefore, modified CR is carried out on materials such as lignin, cellulose, inorganic and organic discarded industrial and agricultural materials, turf and efflorescent coal to make cheap and high efficient coating film, recombination of basal materials, agglutinated CR materials and screening for new materials that are environment friendly, such as soil urease inhibitors and nitrification inhibitors. There is definite developmental potential for all these materials.

6.1.5.3 Research in new techniques of CR and new supporting equipment

High polymer coating film techniques requires that the solvent be of low toxicity or non-toxic and must be cheap. In order to increase the rate of recovery, the equipment must be tightly sealed. To increase the rate of utilization of equipment, production must be continuous. With regard to the research and development of new techniques for coating, recombination of basal material type and agglutinated slow release fertilizer, strive for production of qualified and cheap

S/CRF under ordinary temperature conditions and using ordinary equipment.

6.1.6 State of development of the S/CRF industry

6.1.6.1 Existing enterprises of S/CRF in China

The commencement of a true development of S/CRF enterprises in China can be traced back in 2004 when the Shanghai Hanfeng Group and the Beijing Shouchuang Group produced and marketed sulphur-coated urea (SCU) and granular fertilizer with high polymer coating film respectively. In a stricter sense, the first year of manufacture of S/CRF in China would be 2005. Starting that year, a number of enterprises including Shanghai Hanfeng, Beijing Shouchuang and Shandong Jinzhengda officially set up their production workshops and put them into trial production. However, development of enterprises of other types of S/CRF and stabilized N fertilizers had started relatively earlier. For example, in the 1990s the Sanmenxiashi Compound Fertilizer Plant adopted the technique from the Faculty of Engineering at Zhengzhou University to produce the "fertilizer coated with fertilizer," a type of SRF. The urease and nitrification inhibitors developed by the Institute of Applied Ecology of the Chinese Academy of Sciences were used by more than ten production enterprises in the 1990s. In a broad sense, production of S/CRF in China has a history of more than 10 years. However, up to the present, the more successfully extended and applied products include only:

- Urease inhibitor stabilized N fertilizer - by the Institute of Applied Ecology of the Chinese Academy of Sciences,
- "Fertilizer coated with fertilizer" - by the Faculty of Engineering of Zhengzhou University,
- SRF for rice crops - by the Soil and Fertilizer Institute, Guangdong Academy of Agricultural Sciences and
- SR bulk blend fertilizer - by Shanghai Hafeng Slow Release Fertilizer Co., Ltd.

Nearly 100 enterprises purchased urease inhibitors to produce stabilized N fertilizer. Most of these are in the northeast of China, whilst a small number are located in the north and northwest. The fertilizer produced is sold mainly to the northeast though sales are not stable. The accumulated amount is estimated to be 500,000 t. The technique of "fertilizer coated with fertilizer" type of SRF has been transferred to more than ten enterprises. One of them is an American company but its scale is not large. At present, enterprises showing a better performance include the Sanmenxia Compound Fertilizer Plant in Henan Province and the Lexishi Fertilizer Co., Ltd. in Jinan, Shandong Province. They can produce and sell 30,000-50,000 t a year. The Sanmenxia Compound Fertilizer Plant began exporting 10,000 t of SRF to Thailand in 2004. Extension of the SRF for rice crops by the Guangdong Academy of Agricultural Sciences depends mainly on the government which is capable of promoting 5,000-10,000 t each year.

The following is an account of S/CRF enterprises in China with relatively large scales of production. Shanghai Hanfeng Slow-Release Fertilizer Co. Ltd. is a large-scale SRF production enterprise built by joint investments from the Hanfeng Group and the Nu-Gro Corporation of Canada. The company is

located in the Sunqiao National Agricultural Science and Technology Development Park at Pudong New District, Shanghai. Total investment in the first phase project amounted to RMB55 M. The project went into production on 29 April 2004. The company brought in the production technology of SCU with an annual production capacity of more than 20,000 t, producing mainly agricultural, forestry and high-class SRFs. The company plans to establish enterprises producing SRF in the provinces of Zhejiang, Jiangsu, Shandong, Hebei and Heilongjiang to expand the scale of production with the hope of promoting the technology through the development of a domestic S/CRF industry. At present, the Shanghai Hanfeng Group has established its SCU production base in Jiangyan City in the province of Jiangsu. The annual production capacity is 200,000 t.

The Lexishi Fertilizer Co., Ltd. in Jinan, Shandong Province and the Sanmenxia Compound Fertilizer Plant in Henan Province produce, mainly, new types of compound fertilizer jointly developed with Zhengzhou Province. Annual production is around 100,000 t. The core is N fertilizer and the coating material of more than ten secondary and micronutrients, such as AP, K fertilizer, FCMP, S, B, Zn, Fe, and Cu. Phosphoric-sulphuric acid is used as the binding agent. Granules are successively coated to form the product.

The plant nutrients which are water soluble and highly volatile, are coated at different layers with FCMP, which is not easily wetted and not water soluble. This gives a product that is effective in controlling nutrient decomposition, speed of dissolution and release of nutrients, thus raising the efficiency rate of nutrients and achieving the effects of slow release, extension of fertilizer effect and not harmful to the environment. The Lexishi SRF, produced by the Lexishi Phosphate Compound Fertilizer Technical Research and Extension Centre at Zhengzhou, Henan Province, is a new type of CRF. The core is made up of water-soluble N fertilizer such as urea and the coating layer is of inorganic plant nutrient substances with different solubility. Components of the entire coated fertilizer are plant nutrient substances and after their application in the soil, there is no pollution caused by any residues. The fertilizer is environment friendly. Lexishi has flexible formulations. Products with different nutrient ratios can be produced according to the needs of different crop plants. It is widely suitable for golf courses, sports fields and lawns of municipal administration, landscaping plants, fruit trees and cultivation fields. Products have granules of uniform size. The granules are strong with good mobility. Fertilizer application can be accomplished by a machine.

Enterprises that produce S/CRF in China also include:

| Slow-Controlled Release Fertilizer Type | Company |
|---|--|
| Film-coated fertilizer | Nongboshi Green Fertilizer Co., Ltd. in Jinan, Shandong Province |
| Polymer film-coated fertilizer | Shandong Laaizhou Aidier Biotechnology Co., Ltd |
| Super hybrid rice special slow/controlled-release compound fertilizer | Baling Branch of China Petrochemical Corporation |
| Inhibiting type stabilized fertilizer | Jinxi Natural Gas Chemical Industry Co., Ltd. of Huajin Group of Liaoning Province |
| Metaformaldehyde type slow-release fertilizer, | Shanghai Dayang Ecological Organic Fertilizer Co., Ltd. |
| Fertilizer coated in fertilizer type slow-release fertilizer | 1. Batian Compound Fertilizer Co., Ltd. in Shenzhen City 2. Fengyuan Special Fertilizer Plant in Ninigjin County, Shandong Province 3. Dongping County Coated Compound Fertilizer Co., Ltd. in Shandong Province 4. Xinghua City Nongle Fertilizer Co., Ltd. 5. Lianyungang City Hengfeng Phosphate Fertilizer Plant |
| Coated urea | 1. Yucheng Lingnan Compound Fertilizer Co., Ltd in Guangzhou City 2. Hebei Cangzhou Dahua Group Co 3. Beijing Gufeng Chemical Products Co., Ltd. |
| Film-coating type controlled-release fertilizer | Taian Runfeng Agro-technology Development Co., Ltd. in Shandong Province |
| Coated slow-release fertilizer | Langfang Yinong Group |
| Lignin low-release fertilizer | 1. Beijing Lianchuang Changqing Bio-chemical Technology Co., Ltd. 2. Beijing Sangsong Agricultural and Ecological Technology Co., Ltd |
| Controlled-release fertilizer | Guangzhou City Liangtian Fertilizer Industry Co., Ltd. |
| Long-lasting slow-release fertilizer | Liuyang Hualing Chemical Fertilizer Plant in Hunan Province |
| Inhibitor type slow-release fertilizer | Liangfeng Biochemical Industries Co., Ltd. in Jiangxi Province |
| Slow and controlled-release fertilizer | Jiangsu Zongheng Scientific and Technological Industries Co., Ltd. |
| High-efficiency controlled-release fertilizer | 1. Compound Fertilizer Plant of Jinling Petrochemical Co. 2. Yangling Guangtai Fruit Tree High and New Technology Development Co., Ltd. in Shaanxi Province |
| Multi-element film-coating slow-release fertilizer | Zhonghua Sierte Chemical Fertilizer Co., Ltd. of Ningguo City |
| Film-coating slow-release fertilizer | Chongqing Shichuan Taian Chemical Industry Co., Ltd. |
| Luqi Brand lawn fertilizer | Lanyuan Co. |

These enterprises are all engaged in the production of S/CRF. There are also some research organizations providing technical support. However, due to inadequate knowledge on the concept and in the realm of development and application of S/CRF, everyone is applying something that appears similar in concept. Unfortunately, in the strict sense, some of the enterprises mentioned above cannot be counted as having the professional technological qualification for producing this type of fertilizer.

6.1.6.2 Course of development of new fertilizer types and their prospects

Besides the real enterprises of S/CRF, a number of those mentioned above are also involved in the production or sale of S/CRF. In the process, everyone is aware that S/CRF is the new direction for future fertilizer development. However, it is generally thought that conditions are not yet ripe. Very few local techniques can be commercialised and the cost of S/CRF techniques with good performance is high. The technical bottleneck is the crucial factor that limits its progress. Under such circumstances, some enterprises are coming in with enthusiasm. Some look on unconcerned while there are those that fish in troubled waters. In this way, the S/CRF trade with an uncertain future has become even more confused. In foreign countries, the growth and development of the S/CRF trade is relatively slow. The main reason is technical bottlenecks. However, in other countries, participation by large enterprises is much stronger. In China, there is no large enterprise that focuses its attention on the future development of the S/CRF.

In developed countries, the production of coated CRF was first driven by large chemical (fertilizer) companies producing conventional chemical fertilizers. The amelamine American company ADM (Archer-Daniels-Midland Company) was the earliest international large company to develop film formation through reaction in the production of CRF. Its patent was used by the Sierra Chemical Company in 1967 to produce alkyd resin fertilizer (Osmocote) in California. In 1993, the company and its patented product entered the system of Scotts. In 1996, Purcell Technologies began marketing Polyon™ and TriKote™ which are similar to polymer film-coated fertilizer with uniform granules. During the same period, Haifa Chemical Industries put its product, Multicote™ onto the market. The Japanese company, Chisso, developed CRF with polyethylene film coating. They have been producing polyolefin film-coated resin fertilizer since the early 1980s. Nitricote™ and Meister™ are products successfully developed by them. In the past 20 years, the number of international enterprises producing S/CRF is fast increasing. The main ones include Purcell Technologies Inc, The Scotts Company and Agrium Company in the US, Aglukon Spezialdünger GmbH and BASF Attiengesellschaft in Germany, Haifa Chemicals Ltd. in Israel and Chisso-Asahi in Japan. The controlled-release performance of polymer sulphur-coated urea produced by Nu-Gro of Canada has been increased tremendously. Its output is gradually expanding. At present, the company and its cooperative companies have the capacity to produce 400,000 t of SCU per year. In 2006 Agrium also established a production line capable of producing 150,000 t of polymer film-coated fertilizer annually.

6.1.7 External environment of the S/CRF industry

6.1.7.1 Demand and market for new types of fertilizer

The cost of production of polymer film-coated CRF is higher than other chemical fertilizers and the average S/CRF price is also high. This limits the production and scope of utilization of this type of fertilizer. According to statistics in 1995/6, the estimated total consumption of S/CRF in the whole world was about 730,000 t and was growing at the speed of 4.5-5.0% a year (Trenkel, 1997). Even so, in 2005, S/CRF accounted only for 0.5% of world's chemical fertilizer (Table 6-1). The reason is that at present, film-coated fertilizer and other S/CRF are mainly applied in high-value crops such as professional horticulture, nurseries, golf courses, landscape gardens and parks. By looking at the present structure of consumption of S/CRF in the US and Western Europe, the proportion of agricultural use is merely 8.7% and 13.8% respectively. Because of Japan's policy of subsidy, in 2001, the total amount of S/CRF on rice cultivation reached 66,000 t. Of this, film-coated fertilizer made up 44,000 t. The amount of S/CRF used accounted for 30.4% of the total amount of fertilizer applied (Kubo, 2004) and 91.4% of the S/CRF was used in agriculture (Table 6-2). However, this was the result of the special protection policy adopted by Japan and is not a common phenomenon.

Table 6-1 Speed of development of S/CRFs and its proportion to traditional chemical fertilizer ('000 t nutrients)

| Region | 1983 | 2005 | Average Annual Percentage Growth (%) |
|--|--------|--------|--------------------------------------|
| Total amount of S/CRF | 253.6 | 728.6 | 4.9% |
| USA | 202.0 | 49.1 | 4.2% |
| Western Europe | 7.6 | 140.9 | 2.8% |
| Japan | 44.0 | 92.6 | 3.4% |
| Total amount of chemical fertilizer | 134500 | 155600 | 0.8% |
| Proportion of S/CRF to chemical fertilizer | 0.2% | 0.5% | - |

Source : Landels, 2003; IFA, 2005

Table 6-2 Domains of consumption and proportion of S/CRF in some countries and regions in 2005 ('000 tonnes product quantity)

| Domains of Application | USA | Western Europe | Japan |
|------------------------------------|-------|----------------|-------|
| Agricultural crop market | 43.3 | 19.5 | 84.6 |
| Non-agricultural crop market | 451.9 | 121.4 | 8 |
| Total | 495.2 | 140.9 | 92.6 |
| Proportion of agricultural use | 8.7% | 13.8% | 91.4% |
| Proportion of non-agricultural use | 91.3% | 86.2% | 8.6% |

Source: Landels, 2003

It is estimated that currently, the annual production of film-coated CRF in China is about 20,000 t. The annual output of various other types of S/CRF is about 200,000 t. The S/CRF is at the stage of development. So far there is no particular type of crop that requires a large volume of S/CRF as its major source of nutrients. Even in the potential business operations of lawns, golf courses, flowers, horticulture and vegetable cultivation, there are no obvious signs that S/CRF will dominate. There are two reasons why development of China's market for S/CRF has been slow. First is the low awareness among farmers. Traditionally, Chinese farmers think that a fertilizer with quick fertilizer effect is a good fertilizer. However, the fertilizer effect of S/CRF is released slowly. After application, farmers think that they are not as good as those with quick fertilizer effect. It is, therefore, difficult to get recognition by the farmers. Extension is obviously difficult. Second, the price of S/CRF is comparatively high. This discourages farmers and restricts its promotion and application. However, if we assess the ratio between production and input for S/CRF, its high unit price might be acceptable to the users. From Table 6-3, it can be seen that average price of the major film-coated CRF and its different types is 9 times that of urea. However, the price of film-coated CRF developed domestically is only 2-3 times that of urea. Trenkel (1997) made detailed comparisons of the cost factors and the production-input ratio of different types of S/CRF. The results reflected the problem of high input. However, in the actual experiments carried out by Y. Levi, (2003) after the application of S/CRF, production of rice crop increased by 15%, the amount of fertilizer used was 2/3 that of urea and the number of fertilizer applications was reduced by two. In other words, by applying S/CRF, total output value per hectare increased by RMB1,468 (Table 6-4).

Table 6-3 Price of some S/CRF products

| Fertilizer Variety | Time of Release in Months | Selling Price/ (RMB10,000/ tonne) | As a Multiple of the Price of Urea |
|--------------------|---------------------------|-----------------------------------|------------------------------------|
| Osmocote 5 | 5-6 | 1.36 | 8 |
| Osmocote 301 | 3-4 | 1.80 | 11 |
| Osmocote 801 | 8-9 | 2.08 | 12 |
| Multicote 1 | 3-4 | 1.16 | 7 |
| Multicote 2 | 5-6 | 1.52 | 9 |
| Multicote 3 | 8-9 | 1.68 | 10 |
| Cau-A10 | 3-4 | 0.5 | 3 |
| Urea | - | 0.17 | 1 |

With the increasing volume used, the market for S/CRF is growing strongly. Since China is the largest consumer of chemical fertilizer in the world, the potential market is enormous. In particular, research into the agricultural utilization of S/CRF will spur its market to grow bigger. The present commercialization of S/CRF has begun finding its way to the agriculture market. The use of coated urea as the N source in bulk blend fertilizers has been used as a one-time fertilizer application in maize. Domestic research workers generally think that they can achieve cheaper coated fertilizer through their research. Results of studies also indicate that the cost of coated fertilizers with good controlled-release performance developed domestically can be much lower than the selling price of coated fertilizers overseas. It is generally believed that the price of film-coated fertilizers can be reduced from 25-50% of film-coated fertilizers in foreign countries. However, such a price is still about twice that of ordinary chemical fertilizers. There is still a great deal to be done.

6.1.7.2 Development strategies and suggestions

1. Give priority to the development of S/CRF

N fertilizers have the lowest accumulated efficiency rate. China annually loses about 1.5 Mt of N through leaching and atmospheric emissions with economic losses valued at more than RMB30 B. It causes environment pollution. The number one factor that threatens the safe production of agricultural products is also caused by the improper application of N. The effects of P and K fertilizers are less. Therefore, priority should be given to the development of S/CR- N fertilizer.

2. Establishment of standards, test methods, rules and regulations in the industry

Due to the absence of standards in the industry, the market is flooded with products of poor quality that affects the reputation of S/CRF. Establishment of a set of industry or national standards will not only help to standardize the market, it will also spur technical progress of an enterprise. Besides, it gives direction to organizations of scientific research and cuts wastage. China already has a reasonably good foundation in research. The market for S/CRF has grown to a certain extent. China is in a position to formulate standards in the industry (or national standards) and supporting test methods. It is suggested that the relevant departments of the State and research organizations carry out the formulation of standards for S/CRF as soon as possible. In response to the real problems with enterprise production and formulation of standards, four proposals are put forward: First, issue strict standards of

Table 6-4 Comparison between input and production when urea and S/CRF are applied on rice crops (Y. Levi, 2003)

| Type of Fertilizer | Fertilizer Input | | | Manpower Input | | Value of Product | | | Total Value in RMB 10,000 |
|------------------------|-------------------------|---------------------|--------------|---------------------|----------------------|------------------|--------------------------|---------------------|---------------------------|
| | Unit Price (RMB/ tonne) | Amount Used (1000g) | Value in RMB | No. of Applications | Manpower Cost in RMB | Output in tonne | Unit Price in RMB 10,000 | Value in RMB 10,000 | |
| Urea | 1,700 | 225 | 383 | 3 | 150 | 6 | 1,700 | 1.02 | 0.97 |
| Film-coated fertilizer | 5,000 | 150 | 750 | 1 | 50 | 7 | 1,700 | 1.19 | 1.11 |

product specifications; second, clearly formulate test methods and assessment values; third, for different types of S/CRF, corresponding methods of assessment and systems of values should be adopted; fourth, methods of assessment must be in line with international practice in order to gradually establish sound industry and national standards for S/CRFs.

3. Increase inputs of scientific research

Since the 9th Five-Year Plan, the National Science and Technology Committee set up a corresponding fund for the industrial development of new fertilizers. This has helped in promotion and giving guidance. However, in terms of development of the industry and application, there must be an extension of S/CRF as soon as possible. The State should provide a certain amount of funding and, led by the relevant department, development work should be launched in an orderly manner. There should be emphasis on the processing equipment for S/CRFs. Expansion of production scale, increase in technical stability, rate of recovery of solvent and continuous production should also be emphasized. In order to expedite the commercialization of S/CRFs, the government should find connections to make S/CRFs a major measure for elevating the technology in China's fertilizer industry. This will enable the popularity of S/CRFs to grow gradually and be accepted by the farmers.

4. Expedite the innovation of slow-release materials

With regard to innovation of materials, China is obviously falling behind the US, Japan and others. At present, emphasis should be on the screening or development of materials with good SR performance and low price. Expedite the development of solvents with low toxicity and low price. Boldly explore and develop techniques without solvent or using water as such.

5. Multiple channels of fund sources to encourage the transformation of achievements and to expedite commercialization

First of all, attract enterprises to participate or to transfer their technology to other enterprises. With the help of funds and operation mechanisms from the enterprises, promote commercialization of products and marketing. Next, it is suggested that the government invests more to support the development of enterprises in the production of S/CRF.

On a long-term view, agriculture in China will continue to grow over a period of time thus, agricultural development should be viewed from the angle of sustainable development and set the target of avoiding environmental pollution and without excessive use of resources. The characteristic of S/CRF is the slow and long-term release of nutrients. Speed up progress in the development of S/CRF as the situation is pressing.

6.2 General development of the foliar fertilizer industry in China

6.2.1 History of the development of foliar fertilizer

For several thousand years, mankind used foliar fertilizer to promote the crop growth. For example, ancient Greeks used waste water to spray their crops. In ancient China, there were records of people pouring their urine on the leaves of plants. Griss was the first researcher to report that spraying nutrients on leaves could correct nutritional disorders of plants. With the advancement of agricultural science and technology, more and more chemical fertilizers are used in foliar application. Examples include urea, phosphate and sulphate. Scientists carried out research into problems such as the composition of elements in a foliar fertilizer, environmental factors, concentration of foliar application, period and volume of application. Foliar application has become an important part of scientific fertilizer use.

6.2.2 Functions and status of foliar fertilizer in agricultural production

Foliar application of fertilizer is an effective measure used to further increase crop output, and to improve quality, on the basis of a higher level of fertilizer application. It is used mainly for supplementing the secondary and micronutrients required by crops.

Compared with soil applied fertilizer, foliar fertilizer application has the following advantages:

1. There is fast absorption of nutrients. In foliar spray, the rate of nutrient absorption is far greater than the rate of absorption by roots. In general, the peak of absorption is reached in several hours. Therefore, nutrients can be quickly replenished and this is favourable for the correction of nutrient deficiency of crops. It has a very important application value with regard to nutritional problems caused by a weakening of the root systems' ability to absorb nutrients during the early or late stage of crop growth. In such cases, nutrients can be supplemented by foliar spray.
2. The efficiency rate of nutrients is high and nutrient loss is reduced. Foliar fertilizer application does not go through conversion in the soil and the functions are fixed. Nutrients can be directly utilized by plants and the efficiency rate is higher than soil applied fertilizers. For many fertilizers, particularly of secondary and micronutrients which are required by the crop in small amounts, the scope of suitability is narrow. The effectiveness of nutrient absorption is much higher with foliar application than with soil application.
3. Dependence on soil conditions is small. When the fertilizer is applied to the soil, nutrient efficiency is affected by many factors such as soil temperature, humidity, salinity, alkalinity and micro-organisms. In foliar spray on the other hand, nutrients are seldom limited by soil conditions. Effects of fertilizer application are relatively stable. For example, in an environment that is saline and dry, nutrient

absorption by the roots is restrained while foliar spray is able to supplement the nutrients very well. In some soils, content of a certain nutrient or some heavy metals is too high and is not favourable for the growth of crops. It is very difficult for fertilizer application to the soil to produce ideal effects. Foliar spray is able to slow down the toxicity caused by the elements and reduce damage to the crop due to soil factors.

4. Fertilizer application is not affected by the growth period of the crop. Foliar fertilizer application can be carried out during most of the crops growth period. In particular, when the plants are fully-grown and cover the soil, soil application of fertilizer becomes inconvenient but foliar spray is basically not affected by the crops height and density. The type and concentration of nutrients can be regulated according to the period and condition of crop growth. It is also favourable for mechanized operation.
5. Foliar application can be used in combination with pesticides, plant growth regulators and many other active substances that mutually promote foliar absorption and utilization.

The extension of the technique of foliar fertilizer application is revolutionary relative to traditional fertilizer application. It has contributed tremendously to agricultural production.

6.2.3 Course of development of the foliar fertilizer industry in China

China started using foliar fertilizer in the 1950s. Examples include the application of KH_2PO_4 to increase the weight per thousand grains of wheat, and the resistance against dry, hot wind; spraying ZnSO_4 on fruit trees deficient in Zn; spraying ferrous sulphate to control Fe deficiency and spraying urea and plant ash on field crops. However, due to small scale application a foliar fertilizer industry was not established. There was no mention of the term "foliar fertilizer" and neither was there great attention and input from the scientific and research sectors. At the end of the 1970s, agricultural research workers in China brought back with them from overseas some foliar fertilizer products. Some small enterprises put them into production but there was no promotion on a large scale.

In the early 1980s, a group of foliar fertilizer producing enterprises represented by Guangxi Penshibao Company came up in China. Even though the number was small, market competition was mild as they started early. These enterprises grew vigorously. Objectively speaking, they created much interest in the development of foliar fertilizer in China.

Overall, foliar fertilizer enterprises were of a small scale with relatively small investments. Production technique was relatively simple but profit was good. Therefore, during the past 20 years, a large number of foliar fertilizer producing enterprises sprang up. Up to May 2006, there were 534 foliar fertilizer products officially registered in China. There were another 1,331 products registered temporarily. According to incomplete statistics, companies involved in the production of foliar fertilizer in the domestic market numbered 3,000-4,000. Market competition for foliar fertilizer became more intense than the earlier period. Compared with the 1980s, in the past

15 years, the number of enterprises and products increased rapidly. From the market order and effects of application, due to unrealistic claims in product propaganda, the reputation of foliar fertilizer among farmers was still not stable. In addition, there were many enterprises but no established brands or track records. Market competition was intense. Right now, there are few relatively large scale enterprises.

6.2.4 Course of development of foliar fertilizer products

Since the Americans succeeded in using urea to carry out foliar application in 1940, production of foliar fertilizer overseas has gone through three stages.

The composition of first generation foliar fertilizer was mainly inorganic nutrients. The majority of products were in solid state. They were of low price, easy to store and transport and were mostly common type products in terms of usage. Countries that applied more foliar fertilizer include the USA, the former Soviet Union and Britain.

After the 1970s, the second generation high-concentration compound foliar fertilizers with micronutrients were mainly in the chelate form. Their characteristics were:

1. organic high efficiency nutrients in the chelate state, concentrated fluid,
2. special-purpose formulations designed for specific crops with the balance of various nutrients basically achieved,
3. addition of many types of active substances, nutrient carriers and surface active agents to accelerate absorption by crops and increase the efficiency rate of fertilizer.

Representative products include Crop-up of the USA, Madexs of Germany, Frultage of Britain and "Eiyoeiki" of Japan.

The third generation products paid more attention to increasing nutrient concentration and the effectiveness of nutrient absorption. A great deal of work was done in the development of the state of nutrients, types of chelating agent and surface-active agents.

At present, apart from containing nutrient, most of the foliar fertilizer products in the domestic market emphasize the application of active substances, in particular, the application of plant growth regulators such as yellow humic and amino acids. Production is heading towards special-purpose products, series of products and multi-function products.

6.2.4.1 Special-purpose products

At the early stage of foliar fertilizer development, the majority of the products were the broad-spectrum type. The scope of their application was limited to field crops such as cotton and rape. The emphasis was on supplementary nutrition. Because of the different plant characteristics, and the diversity of agricultural crops required by people, special foliar fertilizer formulations were researched on which helped in the development of special-purpose foliar fertilizer products.

6.2.4.2 Series of products

Due to the differences in soil conditions and crop types, agricultural production with fixed formula fertilizer is becoming less popular with users. Many manufacturers

realize that they must choose proper nutrient types and ratios according to the different regions and crops. Production of single element foliar fertilizers also caught the attention of manufacturers, resulting in a series of products with different nutrients as the main components.

6.2.4.3 Multi-function products

With respect to comprehensive research in fertilizer development and fertilizer application techniques, work is no longer restricted to simple research and development of “replenishing whatever element is deficient,” “how to dissolve many types of fertilizers in a solvent” or “how to retain the fertilizer solution on the leaves for a longer time.” More often, regulation and control of foliar nutrients is combined with increasing disease resistance, drought resistance, resistance against salinity and alkalinity, improvement in fruit coloration and flavour. With regard to product composition, emphasis is on the application of active substances and regulators such as yellow humic acid, salicylic acid, amino acid and oligosaccharides to comprehensively raise the effect of foliar fertilizer application.

With regard to the development of new foliar fertilizer products, based on statistics of registration of foliar fertilizer at the Fertilizer Inspection Centre of the Ministry of Agriculture in 2005 (see Table 6-5), the following can be observed.

1. The large quantity of products

Up to the end of October 2005, the quantity of foliar fertilizer products approved by the Ministry of Agriculture for registration totalled 2,032. Of these, there were 219 macronutrient water-soluble fertilizers, 828 micronutrient water-soluble fertilizers, 612 water-soluble fertilizers containing amino acids, 23 water-soluble fertilizers containing humic acid, 60 secondary nutrient water-soluble fertilizers, 40 water-soluble fertilizers containing algenic acid and 38 water-soluble organic fertilizers.

There were 1,583 temporarily registered fertilizer products. These include 150 macronutrient water-soluble fertilizers, 630 micronutrient water-soluble fertilizers, 501 water-soluble fertilizers containing amino acids and 164 water-soluble fertilizers containing humic acid.

There were 449 officially registered products, including 69 macronutrient water-soluble fertilizers, 198 micronutrient water-soluble fertilizers, 111 water-soluble fertilizers containing amino acids and 71 water-soluble fertilizers containing humic acid.

2. Rapid increase in products

According to the condition of registration of foliar fertilizer products recorded in the National Chemical Fertilizer Quality Supervision and Inspection Centre of the Ministry of Agriculture, from 1990-2000, the annual quantity of fertilizer products registered remained relatively stable. The growth trend was stable. Taking the number of certificates of temporary registration as an example, in 1990, less than ten products were approved for registration. By 1999, only 52 products obtained temporary registration. However, in 2000, after the promulgation of the Minister's Order No. 32 by the Ministry of Agriculture, the number of new products registered began increasing. In 2001, with the issuance of Announcement No. 161 of the Ministry of Agriculture, information required for the registration of fertilizer was clearly stated. The administrative work of registration entered a new stage. As the procedure of acceptance for registration was simplified and standardized, the number of products registered increased sharply. In that year alone, 114 certificates of temporary registration were issued. In 2002, the number increased sharply again to 359. Subsequently, the trend of rapid increase was maintained. In 2005, the number of certificates of temporary registration for fertilizers awarded by the Ministry of Agriculture soared to a historical high of 516. It is estimated that, in the future, the number of products for registration will be maintained at 500-700 a year (Cao Weidong and others, 2006).

3. The many types of products

At the same time as when the quantity of products was incessantly increasing new types of products were also being constantly added. In 1999, there were only three types of registered foliar fertilizer products, those containing amino acids, those containing humic acid and those containing micronutrients (Cao Weidong *et al.*, 2006). By 2005, the

Table 6-5 Registration of different types of foliar fertilizers

| Type of Products | Quantity of Temporary Registrations | Quantity of Official Registrations | Total | Ratios of the Various Products in the Total Quantity of Registrations (%) |
|--|-------------------------------------|------------------------------------|-------|---|
| Micronutrient foliar fertilizer | 630 | 198 | 828 | 40.7 |
| Foliar fertilizer containing amino acid | 501 | 111 | 612 | 30.1 |
| Foliar fertilizer containing humic acid | 164 | 71 | 235 | 11.6 |
| Macronutrient water-soluble fertilizer | 150 | 69 | 219 | 10.8 |
| Secondary nutrient water-soluble fertilizer | 60 | | 60 | 3.0 |
| Water-soluble fertilizer containing algenic acid | 40 | | 40 | 2.0 |
| Water-soluble organic fertilizer | 38 | | 38 | 1.9 |
| Total quantity of registrations | 1,583 | 449 | 2,032 | |
| Valid quantity of registrations | 1,252 | 383 | 1,635 | |

Note: The valid number registered was up to 10 October 2005 (source of data is the National Chemical Fertilizer Quality Supervision and Inspection Centre, 2005)

types of products registered expanded to include the seven big categories of macronutrients, secondary nutrients, micronutrients, algenic acid, humic acid, amino acid and water-soluble organic acid. The number of types has doubled. During this period, the products found in the largest numbers were micronutrient foliar fertilizer and amino acid-containing foliar fertilizer. These two types of products accounted for 40.7% and 30.1% respectively, of the total registered number. Next in line were humic acid-containing foliar fertilizer and macronutrient foliar fertilizer.

4. Continuous emergence of new types of products

In 2001, there were eight new products. From 2002 to 2005, there were about 50 each year. The increase was mainly in water-soluble fertilizer containing secondary nutrients, water-soluble organic fertilizer and algenic acid-containing water-soluble fertilizer.

5. Rapid renewal of enterprises and products

During the period of rapid development of foliar fertilizer in China, the renewal of enterprises and products was also rapid. From the records of foliar fertilizer product registration of the Ministry of Agriculture, the total number of registered products as of October 2005 was 1,583 while the total number of valid registered products was 1,252. There is a difference of 20% of the enterprises and products. This illustrates that while new enterprises and newly developed products are entering the market, some enterprises that fail to adapt to market development are on their decline and their corresponding products disappear from the market.

6. Product quality to be raised

Summary and assessments of samples registered in recent years by the National Chemical Fertilizer Quality Supervision and Inspection Centre are shown in Table 6-6 and Table 6-7.

Table 6-6 Test results of samples in 2002- February 2006

| Year | 2002 | 2003 | 2004 | 2005 | 2006 (Jan-Feb) |
|-------------------------------|-------|-------|-------|-------|-------------------|
| Number of samples tested | 735 | 648 | 862 | 1,090 | 162 |
| Number of samples that passed | 484 | 440 | 647 | 823 | 122 |
| Percentage of passing | 65.9% | 67.9% | 75.1% | 75.5% | 75.3% |

Table 6-7 Test results of samples of different types of fertilizer (up to February 2006)

| Type of Registration | Number of Samples | Number that Passed | Percentage of passing |
|----------------------------------|-------------------|--------------------|-----------------------|
| Officially extended registration | 131 | 82 | 62.6% |
| Official registration | 750 | 493 | 65.7% |
| Temporary registration | 2,860 | 2,065 | 72.2% |

From the data in tables 6-6 and 6-7, it can be seen that even though there has been an obvious increase in the passing rate of samples inspected, it is still around 75%. The actual situation may be more complicated. In accordance with "Measures for the Administration of Registration of Fertilizers" temporarily registered products have to go through a period of three years before they are upgraded to the official registration. Officially registered products are allowed to extend their registration only after five years. However, from the results of inspection, the passing rate of sample inspection is in the order of temporary registration > Official registration > Official extension of registration. The percentages of passing are 72.2%, 65.7% and 62.6% respectively. This shows that after three or even eight years of production and sale, there was no improvement in product quality. Instead, quality actually dropped in some cases. It is obvious that long-term attention is required in the problem of quality of foliar fertilizer in China.

6.2.5 External environment for the development of the foliar fertilizer industry

In the course of development of the industry, owing to the lower cost of foliar fertilizer, commercial profit is relatively high. In addition, from the 1980s to the 1990s, through propaganda, promotion and application by enterprises, farmers became aware of foliar fertilizer. The market began to expand. More enterprises participated in the production and foliar fertilizer producers gradually grew in number. The entire industry and market was in chaos. In order to promote sales, businessmen seriously exaggerated the effectiveness of foliar fertilizers. For example, there was erroneous publicity claiming that foliar fertilizer could replace soil applied fertilizer, chemical fertilizer and organic fertilizer. At the same time, large volumes of fake foliar fertilizers were put on the market with various false names. Incidents of farmers being cheated occurred frequently. As a result, in 1987, the National Economy Commission, the former Ministry of Chemical Industry, the Ministry of Commerce, the National Prices Bureau and the Farming, Animal Husbandry and Fisheries Departments jointly published the document of (Jing Zhong [1987] No. 695) "Interim Provisions Concerning the Enhancement of Market Administration, Resolutely Checking and Banning the Production and Sale of Fake and Poor Quality Chemical Fertilizer." In 1989, the "Interim Provisions of the Ministry of Agriculture, PRC Concerning the Inspection and Registration of Fertilizers, Soil Conditioners and Plant Growth Regulators" was issued. Implementation of fertilizer registration by the Ministry of Agriculture was started. The National Chemical Fertilizer Quality Supervision and Inspection Centre (Beijing) was the registration organization authorised by the Ministry of Agriculture to be in charge of registration and inspection matters such as biological tests, toxicology and chemistry of fertilizer products. An initial administrative system for registration of fertilizers was established. After more than ten years, following the development of a socialist market economy and the introduction of new laws and regulations in China, it was gradually realized that part of the contents of the interim provisions was no longer applicable to the conditions and

they must be amended. In 2000, the Ministry of Agriculture issued Minister's Order No. 32 and promulgated "Measures for the Administration of Registration of Fertilizers." In 2001, the Ministry of Agriculture promulgated Announcement No. 161 "Information Required for the Registration of Fertilizer." "Measures for the Administration of Fertilizer Registration" clearly stated the scope of the Ministry of Agriculture and the duties of relevant handling units. It also stipulated that products that have been used in the field for a long period of time and products with national or industry standards can be exempted from registration. The provincial agricultural administrative department in charge was responsible for product examination and the issue of certification for organic fertilizers, acidity regulator for cultivation beds and compound fertilizers. For other fertilizers, the Ministry of Agriculture was responsible for product examination and issue of certification.

With the development of the foliar fertilizer industry, the Ministry of Agriculture conducted discussions with regard to the definition and content of foliar fertilizer and whether or not its composition should be based mainly on its nutrient content. People who formed the technical backbone unanimously agreed that since foliar fertilizer came under the scope of new type of fertilizer, it should be based mainly on its nutrient content. As for the question of inclusion of other substances, after discussions, the technical assessment committee was of the opinion that:

1. Foliar fertilizers must be mainly a nutrient fertilizer;
2. It should not exclude other components. It can contain synthesized but organic products of degradation (nutrient-type bridge-building substances) such as organic humic acid, amino acid and algenic acid. However, it should not contain artificially synthesized hormone-type regulator.

The committee then categorized foliar fertilizers as follows:

1. Foliar fertilizer with mainly macronutrients but may contain a certain amount of micronutrients
2. Foliar fertilizer with mainly micronutrients but may contain a certain amount of macronutrients
3. Amino acid series of foliar fertilizers that must contain micronutrients
4. Humic acid series of fertilizers that must contain macronutrient

The humic acid is divided into black, brown and yellow humic acid. The macronutrient content can be lower if yellow humic acid is the main component.

5. Algenic series of foliar fertilizers

The various categories of foliar fertilizers are divided into the solid and the liquid types. The components and their contents in the various categories of foliar fertilizers are clearly specified.

With the constantly increasing number of foliar fertilizer enterprises and products and inputs in research and development of new types of products, the relevant administrative departments carried out re-demarcation of names and classification of foliar fertilizer. The original five categories were expanded to seven. They are:

1. Macronutrient water-soluble fertilizers
2. Secondary nutrient water-soluble fertilizers
3. Micronutrient water-soluble fertilizers
4. Foliar fertilizers containing amino acids

5. Foliar fertilizers containing humic acid
6. Water-soluble fertilizers containing algenic acid
7. Water-soluble organic fertilizers

Even though the State has formulated compulsory standards for some types of foliar fertilizers, due to reasons of regional conditions, production technology and production cost, the various manufacturing plants produced many types of foliar fertilizers with complex components. Any stipulations will not be able to cover every aspect. This explains the complexity of product classification. These problems have also brought unfavourable effects to the orderly development of the foliar fertilizer and its market administration in China.

6.2.6 Summary of the historical experience in the development of the foliar fertilizer in China

Looking at the course of development of China's foliar fertilizer industry, in the 1980s a group of enterprises were the first to see the business opportunity and they got started early. Besides their good economic benefits, these enterprises gave certain impetus to the market development of foliar fertilizers in China. However, due to the exaggerated publicity on the effectiveness of foliar fertilizer, and businessmen emphasizing the handsome profits, many enterprises jumped on the bandwagon. They were small operations turning out all kinds of products. Some even simply boiled some raw materials in iron pots and washing machines and claimed they had produced some foliar fertilizer. The foliar fertilizer market was in chaos throughout the country. Consequently, the State began to regulate foliar fertilizers and continuously set up and improved on a system of administration. In particular, scientific research organizations got involved in the area of foliar fertilizer and they played a definite role in giving guidance and overseeing the technology. The foliar fertilizer industry is now gradually moving onto the right track. However, as a supplementary measure in fertilizer application, the reputation and influence of foliar fertilizer among farmers must be raised.

Foliar fertilizer development in foreign countries was relatively early. During the 1920s and 1930s, ferrous sulphate was sprayed for the prevention and cure of chlorotic disorders of grape vines. At the beginning, foliar fertilizers were mainly in the solid state, then the liquid form was gradually developed. During the 1940s and 50s, they were mainly based on nutrient content. Later, additional ingredients such as chelating and sticking agents were added through the various techniques to enhance the effects of their application. In the 1960s and 70s, foliar fertilizer overseas were heading for comprehensive development. Some chemical control substances such as those that controlled seed dormancy and fruit formation without seeds were added. At this stage, foliar fertilizers were no longer limited to single material fertilizers, instead comprehensive nutrient solutions were developed. Furthermore, foliar fertilizers were used in combination with spray and drip irrigation.

The development of the foliar fertilizer industry in China fully reflects the demand for new types of fertilizer when China's agriculture is in the process of modernization and categorization by ranking, in particular, the need for improving secondary and micronutrient deficiencies in certain regions and for specific crops. Micronutrient deficiency is a problem

that requires an urgent solution for the future agricultural development. Supplementation of micronutrients through foliar application has its great advantages.

There are three lessons to be learned in the development of foliar fertilizer for more than 20 years in China:

1. Exaggeration and boasting on the effectiveness of products was something that needed to be viewed with seriousness, particularly for products at the early stage of development that lacked technological content. In order to make profits, manufacturers claimed that foliar fertilizer could replace soil fertilizer application, chemical fertilizer and organic fertilizer. Due to boasting about the efficacy, lack of follow-up in technological input and poor management, even the sizable enterprises began to decline. At present, foliar fertilizer enterprises are large in number, small in scale and domestic enterprises with some influence in the industry are rare. Well-known brands are absent and farmers do not think favourably of foliar fertilizer.
2. Most of the production enterprises are of small scale with a low level of mechanization. Application of foliar fertilizer basically depends on manual spraying that requires much labour with low economic benefits.
3. Scientific research organizations were late getting involved in the trade. However, for a long period of time there was no mechanism for collaboration between the scientific research organizations and the enterprises. The development of foliar fertilizers was entirely in the hands of manufacturers and businessmen who lack full knowledge about foliar fertilizer. To pursue commercial profits, they faked data and technology. If the scientific research organizations joined hands with the enterprises to check exaggerations and to guarantee standards, it should be in favour of the proper development of the foliar fertilizer industry. In foreign countries, foliar fertilizer was started by research organizations with the enterprises get support from them thus allowing the entire industry to develop properly.

6.2.7 Progress in the study of the foliar fertilizer technology

6.2.7.1 Characteristics of production technology in foliar fertilizer

The foliar fertilizers sold in the agricultural resource markets of China are mainly in liquid and solid forms. Compared with fertilizer types such as urea, potassium di-hydrogen phosphate and SOP, production technology of foliar fertilizer is simple. Production usually adopts the technique of compound formulation processing (with additional ingredients added) where production is convenient and the technique flexible.

Foliar fertilizer in aqueous solution is the mainstream product in the foliar fertilizer market. Its production uses mainly simple techniques of dissolving and mixing. The main equipment includes a grinder, agitated reactor, and storage tank. Generally, the flow of processing technique is as shown in Figure 6-1. During foliar fertilizer production, it is possible to select many types of components for compound formulation. Examples are nutrients, organic active substances, regulators and pesticides with which products possessing multiple functions are produced. Qualified products must have the following features:

1. must be water soluble and must dissolve rapidly without generating sediments or suspended substances
2. must be compatible with pesticides and growth regulators to reduce work frequency
3. must not require many instruments in working and must be suitable for many types of spraying tools
4. must have obvious fertilizer effects; the quantity used is small and the cost is low but effects are outstanding
5. must be non-toxic, without side effects and do not pollute the environment/ecosystem.

In other countries, production of solid foliar fertilizer mainly adopts the mode of dissolution followed by drying. Purity of fertilizer is high with better water solubility. In China, production of solid foliar fertilizer is mainly by grinding followed by mixing. The technique is simple but with shortcomings such as low effective components, high impurities and poor solubility.

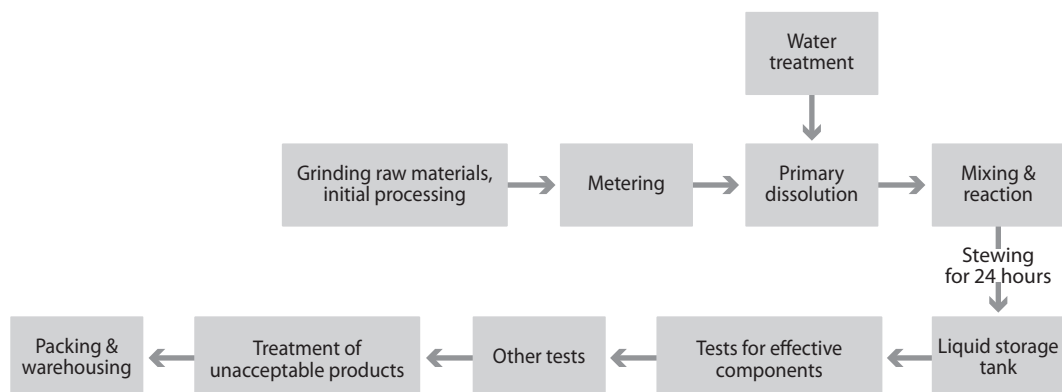


Figure 6-1 Production process of foliar fertilizer in aqueous solution.

6.2.7.2 Existing technical problems in the R & D and application of foliar fertilizer in China

Compared with other countries, application and production of foliar fertilizer in China has been rather speedy. However, there was not enough attention given on the basic research into the nutrient mechanism of foliar fertilizer. Currently, there are fertilizers of all kinds sold under many names in the market with varying product quality. The contradiction between a rapidly developing market of agricultural production materials and weak basic research is not favourable to the continuous growth of the foliar fertilizer industry in China.

1. *The weak basic research results in low technical content of the products*

Foliar fertilizer occupies an important position in the scientific fertilizer application. The effectiveness of nutrient absorption of foliar fertilizer is affected by a number of factors that includes; the type of crop, soil conditions, the nutrient state and the period of fertilizer application. In the development of most foliar fertilizer products, these problems have not been given the emphasis they deserve. The effects of products are not stable and the objective of supplementing micronutrients cannot be achieved. In general, their performance is as follows:

Products are not specific in their actions

Attention is not paid to the differences in soil nutrients in various places and the pattern of nutrient requirement of crops. There is no research into the relationship between the type, nutrient status, the ratios of nutrients and absorption by crops. The selection of nutrient matching is made at will and the fertilizers are not specific. Manufacturers try to produce a formulation with full nutrients and a product that contains everything but is incapable of solving the actual problems. Some even try to keep their formulation a secret in order to mislead farmers.

Lack of research in special-purpose accessory ingredients that accelerate nutrient absorption of foliar fertilizers

The effectiveness of foliar absorption of nutrients is closely related to the nature of the plant leaf surface, characteristics of nutrient absorption, growth environment and the chemical and physical nature of the liquid used in spraying. Some products adopt simple nutrient mixing and formulation. The manufacturer is not capable of, or neglects the need for, special-purpose accessory ingredients. This results in the low absorption efficiency of foliar fertilizer and the objective of supplementing micronutrients is not achieved.

Over-dependence on plant growth regulators

In order to achieve the so-called high efficiency and outstanding effects, over-dependence on plant growth regulators will not achieve the objective of nutrient regulation. On the contrary, it may disrupt the growth and development of the crop itself. It may lead to reduction in crop production and reduced quality.

With regard to product technology, research in synergistic effect between components in a product is weak. Product development fails to take full consideration of the solubility balance of the different components and the differences

in absorption of nutrients in different states. Nutrients, regulators, surface-active agents are added at will. Nutrient contents are low and impurities are high. There may even be sedimentation, flocculation and fixation of effective components.

2. *There is insufficient production capacity*

Equipment requirement is low for the production of foliar fertilizer. Processing is relatively simple and investment at the initial stage for establishing a production plant is not high. In recent years, with the progress of the foliar fertilizer market, the number of production plants has been growing very rapidly with a large number of products. However, compared with production plants overseas, domestic production plants are mostly of small scale. There is inadequate investment in technology and product quality is a matter of great concern. Output in the various plants is nowhere near the designed capacity, causing tremendous waste of resources.

3. *Research in the technique of foliar fertilizer application is still inadequate and the effects are unstable*

The concentration of the foliar fertilizer to be applied, the mode of application, the period of application and the crop demands are to be considered. When concentration of the spray is too high leaves are scorched easily. When the concentration is too low, the desired effects are not achieved. Environmental and weather conditions at the time of application also exert great limitations. Different fertilizers apply to different crops and regions. Many farmers lack the fundamental knowledge on fertilizer application. In order to achieve good effects of application, the government and research organizations should establish and enhance a system of promotion and popularization that supports the techniques of fertilizer application so that the knowledge of scientific fertilizer application is delivered to agricultural villages and the farmers.

6.2.7.3 Typical examples of domestic scientific research organizations

China is relatively weak with respect to research in the mechanisms of foliar nutrition and the techniques of application. This is very unfavourable to increasing the effectiveness of foliar fertilizer application in China. In the 1990s, in China Agricultural University, a group conducting research in new types of fertilizers began looking into the latest principles and characteristics of crop plant/root zone nutrition in modern times. Under the prerequisite of resolving the problem of macroelement nutrition of crops and making nutritional regulation and control of micronutrients in the entire growth period of a crop as the focus, the group began their research in mechanisms of foliar nutrition and series of foliar fertilizer products. The major technical contents include the following:

1. Research in raising the efficiency of foliar absorption of nutrients: Through analysis of the character of leaf surface of the crop plant, study the relationship between the specific characteristics of the leaf and nutrient absorption. Based on the synergistic effect of surface-active agents and features of leaf surface, develop special accessory ingredients for foliar nutrients.

2. Optimize nutrient components: Based on the nutritional characteristics and specific nutrient deficiency, determine the rational nutrient type, nutrient state and nutrient ratios. In combination with organic substances possessing plant reactivity such as yellow humic acid, algenic acid and plant growth regulators, develop special-purpose nutrient substances with different functions for crops in order to increase the efficiency of nutrient absorption, enhance the crop's own resistance and realize maximum utilization of nutrients over a longer period of time (growth period of crop).
3. Optimize the technique of solution compound formulation: Based on sedimentation and dissolution of the solution of a substance, its oxidation and reduction, chelation and dechelation, and the principle of acid-base balance, research was conducted on the effects of pH value of solution, chelating agents and anti-oxidant on the solubility of micronutrients and compatibility of plant active substances and accessory ingredients with micronutrients. There is research in the development of clear-liquid type micronutrients that meet the standards.
4. Research into the technique of using nutrition agents: Conduct research on the effects of nutrition agents on the period of use, method of application and concentration of utilization with respect to different crops. Determine proper technique of using nutrition agents to increase the effectiveness of regulation and control of micronutrients. The research in the techniques of regulation and control of nutrition by foliar fertilizer spray resolved the problems of regulation and control of micronutrients throughout the crop cycle.

After years of research, the China Agricultural University obtained remarkable achievements with respect to mechanisms of foliar nutrition and techniques of foliar fertilizer application:

1. They improved the technique of extraction of yellow humic acid. On the basis of traditional yellow humic acid extraction, they optimized the extraction technique for nitro-yellow humic acid. This technique uses turf of good quality and nitric acid as the main raw materials. The yellow humic acid extracted has a high degree of purity and strong reactivity. As a foliar fertilizer, an added component of seed finishing agent, it can effectively increase nutrient absorption and crop growth.
2. Their work gave rise to the system of technical determination and appraisal of the quantified specific characteristics of the leaf surface of major crops. There is a notable relationship between the efficiency of foliar nutrient absorption and the shape of leaves of the crop, the level of growth and the nature of the waxy layer on the surface of the leaves. However, a complete range of corresponding values for appraisal is absent in China. Through their thorough analysis of the process of infiltration of sprayed liquid on the surface of the crop leaves, the group conducting research in fertilizers in the China Agricultural University arrived at a system of technical determination and appraisal by quantifying the specific properties of the leaf surface of major field crops, fruit trees and vegetables.
3. They successfully developed special accessory ingredients for compound type foliar fertilizers. Based on the specific

characteristics of crop leaves and the nature of active agents on the surface and by utilizing the synergetic effect of surface active agents, many types of special accessory ingredients for foliar fertilizers have been successfully formulated and combined and they are suitable for formulating and forming foliar fertilizer agents on the leaf surface of different crops. The nutrient agent increase effectiveness of foliar absorption of micronutrients that include Fe, Mn, Cu, Zn and B by the crops notably.

4. They accomplished the screening of effective components of many types of special-purpose fertilizers and their optimization design in response to the crop type, soil characteristics, and environmental conditions for the selection of proper components of the solution for spray application. Based on principles of equilibrium such as oxidation and reduction, acid-base neutralization, dissolution and sedimentation, chelation reaction in the solution and by optimising the process technique, many clear-liquid type micronutrients that meet the standards have been developed.
5. They successfully developed many compound type special-purpose fertilizers such as the series of special-purpose foliar fertilizers for soybean, rice, cotton, fruit trees, fruit vegetables, leafy vegetables and maize. These are highly concentrated, clear-liquid type fertilizers that provide nutrients, growth regulators and resistance to diseases at the same time. Their application and testing over large areas throughout the country indicate that the fertilizers have remarkable effects in increasing the resistance of crops and the immediate supplementation of nutrients. In 2000, the "cotton cold insulator" developed by them was conferred the Class III Scientific and Technological Progress Award by the Xijiang Uygur Autonomous Region. In 2005, this achievement turned into successful factory production in collaboration with the Sino-Arab Chemical Fertilizers Co. Ltd. with the annual production capacity designed for 500 t. The actual production in that year was 150 t. The product was promoted for application over large areas throughout the country.
6. They conducted research and developed the technique of application of special-purpose nutrient agents with special foliar nutrients. They carried out research on the concentration, period, and modes of applications of special-purpose fertilizers according to the different period of crop growth, pattern of nutrient requirement and conditions of application.

The former Soil and Fertilizer Institute, Chinese Academy of Agricultural Sciences carried out long-term and a large volume of research on the development of foliar fertilizers and the techniques of applying crop micronutrients. They developed a series of products of high efficiency micronutrient fertilizer. They developed 18 special-purpose products for wheat, rice, maize, cotton, soybean, groundnut, rape, vegetables, capsicum, tobacco, apple (pear), citrus, grape, tea, watermelon, beet, potato and flowers. This was regarded as an important item of national achievement in science and technology to be promoted. In recent years, in response to the common calcium deficiency found in fruit trees and vegetables in China, the Institute has developed

a foliar fertilizer specifically for fruit trees and vegetables. The production technique of "High-efficiency calcium" was conferred the Beijing City Class I Science and Technology Award in 2004 and the Class II National Scientific and Technological Progress Award in 2005.

6.2.8 Market situation for foliar fertilizer

During the period of planned economy, promotion of foliar fertilizer was dependent on the department in charge of agriculture. Foliar fertilizer was forced upon the farmers. The area of foliar fertilizer application was not big. With the establishment of the market economy system, this type of operational mechanism gradually weakened. At present, by far the majority of enterprises producing foliar fertilizer practise the system of sales on a commission basis by setting up agents for their products. There is standardized supply at a standardized price. Regional agents integrate the actual local conditions. They build their contacts at the relevant business stations of the agricultural department or at the agricultural materials department. Through the purchasing and marketing agents in the villages and towns or chain stores, final sale is accomplished. With increasing competition, some enterprises are cooperating with the Agricultural Bank of China and the Post Office to increase sales networks for their products. The effects need more observation.

In recent years, there has been tremendous growth in the production technology of foliar fertilizer, effects of its application, scale of enterprises and market operations. However, there are still contradictions and problems in the foliar fertilizer industry that cannot be ignored. These are described as follows:

1. As foliar fertilizers in China are not products of high technology, fertilizer effect is not obvious and there is over-dependence on regulation by hormones. There is only one formulation for all purposes and the same product is used for a number of years. This is the common failing of most enterprises producing foliar fertilizers. With changes in the market environment, the fast development of new products and flexibility of reaction to the market have become signs of success of an enterprise. As conditions vary from place to place, application of foliar fertilizer tends to be seasonal, professional and independent. Foliar fertilizer producing enterprises must expedite product renewal and raise their ability in agricultural services in order to remain unbeaten.
2. There is fierce market competition. Since production technology is simple, investment requirements are low. In recent years, the number of enterprises that produce foliar fertilizers is increasing very rapidly. Many enterprises that produce compound fertilizers and agricultural pesticides also join in the production of foliar fertilizers. Market competition is becoming more intense. Attracted by the good profits, some foliar fertilizer producers resort to inappropriate measures of competition, leading to market chaos.
3. There is improper capital operation. Affected by changes in agricultural production and intense market competition, the majority of the foliar fertilizers in China are marketed by credit sale. Usually, recovery of debt is done after the sale of product and almost all risks are borne by the

production enterprise. There is no way to guarantee the absolute security of capital.

The promotion of foliar fertilizer application technology has made important contributions to the proper application of fertilizer in China. In order to ensure the sound development of the foliar fertilizer industry, there should be standardization of behaviour in the trade. There should be encouragement of openness, justice and legal competition and enhanced market monitoring. Due to intense competition, in conjunction with rise in the cost of raw materials and production, selling price of foliar fertilizer is dropping dramatically. Some manufacturers compete unfairly by lowering product and service quality. With respect to this, the supervisory department should enhance its inspection. Testing the product quality, particularly the content of effective nutrients is an important measure to guarantee the quality of foliar fertilizer. On the other hand, excessive interference by the government in the market of agricultural materials should be avoided. Government's compulsory sales promotion of a certain brand should be cut down to encourage the orderly development of foliar fertilizer.

6.2.9 Prospects of the foliar fertilizer industry in China

Foliar fertilizers have the characteristics of fast nutrient absorption, immediate rectification of nutrient imbalance and flexible design of formulation. With the development of modern agriculture, foliar fertilizer application has become an indispensable technology in agricultural production. Development of foliar fertilizer is heading in the direction of special purpose, multifunction and environment protection. The technique of application is gradually becoming rational. Efforts should be made to be more precise and accurate in terms of method and time of fertilizer application.

Development of foliar fertilizer is an applied research that is very technical and covers a wide range of subjects. It requires basic knowledge in the theories of soil and plant nutrition, plant physiology, crop production, chemical control of crops, pesticides, chemical fertilizer, precision chemical engineering and product processing. Besides, it is only through the comprehensive application of the latest achievements in the scientific research in these areas that satisfactory products can be developed. In recent years, development and application of foliar fertilizer in China has obtained obvious achievements. The development of new types of fertilizer and the area of agricultural fields applying foliar fertilizer is expanding every year. However, there is insufficient basic research in the technology of foliar fertilizer application. Selection of fertilizer formulation is sometimes carried out at will. Types of nutrients, their ratios and contents cannot be formulated according to conditions of the crop, the soil or the environment. Such foliar fertilizers lack specific targets and seriously affect the effects of fertilizer application. In order to encourage the positive development of foliar fertilizer in China, scientific research must be enhanced and the industry must be standardized and made scientific. Foliar fertilizer must have a more important function in agricultural production.

It should be made clear that as a fertilizer, foliar fertilizer is a supplement and growth regulator in plant nutrition. It cannot possibly replace chemical fertilizer and organic fertilizer, neither can it replace root zone fertilizer application totally. Development of the foliar fertilizer industry is gradually becoming standardized and rational. Summarizing the experience and lessons learned many aspects still need improvement in the subsequent development of the industry.

Firstly, the following must be pursued in the research and development of products:

1. Concentration of effective components of the product must be increased. Increase in the concentration of effective components can lower the cost in packing and transportation. Most of the foliar fertilizer products have low content of effective nutrients. Concentrations of non-effective accessory ingredients and harmful impurities are too high. This has seriously affected the expression of fertilizer effects. Suitable nutrient states and ratios should be selected in response to crop needs. Lower the content of non-effective components to increase the effects of foliar fertilizer application.
2. Enhance the research in special adjuvants. In domestic foliar fertilizer products, the adjuvant used is generally an agricultural pesticide. It has low efficiency in foliar absorption and the problem of poor compatibility between components. Study of the characteristics of crop leaves should be enhanced. By making use of the synergetic effect of the active agents on the surface, develop an adjuvant for compound type nutrient absorption. This is an important technology in the development of foliar fertilizer products.
3. The development of chelating substances should be given serious attention. Conventional chelating substances have

the problems of high cost, high molecular weight and possible damage to the surface of leaves. The development of highly efficient, environment protection types and low molecular weight chelating agents such as oligosaccharide are important contributions in the development of foliar fertilizer products.

4. There should be the application of organic active substances. A foliar fertilizer with outstanding effects is able to supplement nutrients immediately. Besides, it can increase the resistance of crop. Organic components such as yellow humic acid and amino acids increase the application effect of foliar fertilizer. They have become indispensable components in the production of foliar fertilizer. With increased demand for fertilizer application, attention is being drawn to the development of organic active substances with multiple functions.

Secondly, legislation on fertilizers must be introduced. The Ministry of Agriculture and the National Chemical Fertilizer Quality Supervision and Inspection Centre under it have made important contributions to the regulations of fertilizers in China. At present, registration of fertilizers is carried out orderly in accordance with "Measures of Administration of Fertilizer Registration" and based on this, the work of fertilizer legislation is being actively pursued.

Furthermore, enterprises have to take the initiative to communicate with relevant administrative departments of the State and organizations of scientific research. They should strictly follow state standards and abide by the relevant stipulations. Enterprises have to increase their input in science and technology and make it their solid backing and an impetus for self-development, to go international and in increasing their scale.

Chapter 7

The Chemical Fertilizer Marketing and Distribution System in China

The system of circulation or distribution of chemical fertilizers is the channel that links the fertilizer producers to the large number of farmer users. The efficiency and quality of management will directly affect the chemical fertilizer market at the terminal. The system is concerned with the development of agriculture and agricultural villages and has a part to play in the immediate interests of hundreds of millions of farmers. The fertilizer distribution system bears the historical mission of guaranteeing the sustainable development of the fertilizer industry, increasing farmers' income and safeguarding the interests of the farmers. The establishment and development of a fertilizer distribution system that is highly efficient is an important task faced by the chemical fertilizer industry in China. The fertilizer distribution system has gone through a planned economy, a semi-planned and semi-market economy and is now entering a complete market economy. These three phases co-existed with the state-owned and non-state-owned operations. China joined the WTO with these special features, making this the most complicated link in the chemical

fertilizer industry. Revealing the history formed by such complexity and the course of changes is of great significance in understanding the development of the Chinese chemical fertilizer distribution system.

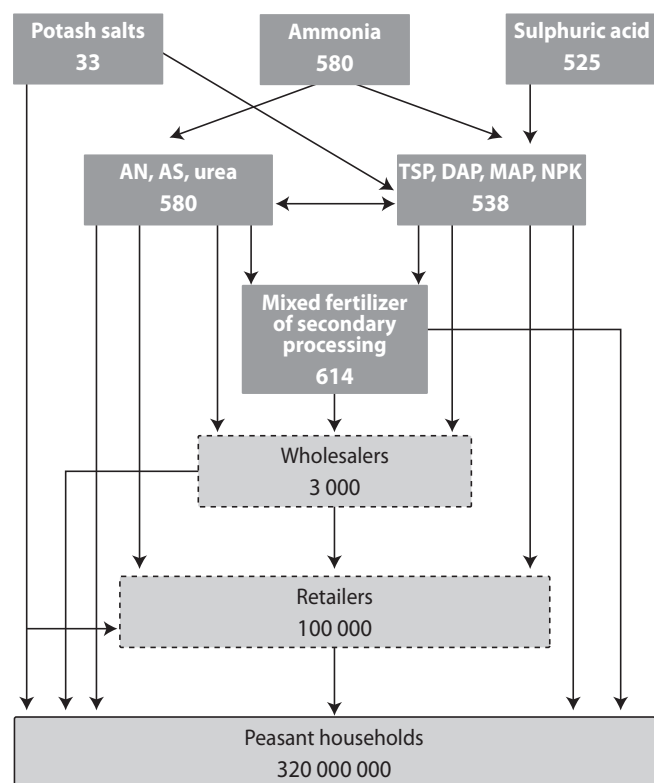
7.1 Present state of the domestic fertilizer distribution system

7.1.1 Framework of the domestic fertilizer distribution system

The present industrial framework of the fertilizer industry in China is shown in Figure 7-1. The entire chemical fertilizer industry forms a typical barrel-shape framework. Its main feature is the existence of a huge number of manufacturers of raw materials, fertilizer manufacturers, secondary manufacturers of fertilizer and distributors and manufacturers of raw materials and fertilizers. The number is more than 2,000. There are more than 600 secondary processing and production plants according to estimate (some estimate it to be more than 1,000) while there are more than 100,000 wholesalers and retailers (qualified to operate independently).

Currently, the main distribution channel of chemical fertilizers in China is made up of two links:

1. Agricultural resource companies that provides the supply, and marketing cooperatives in the villages and towns, the marketing chain of some fertilizer distribution companies (for example, Sinochem has established 15 branch offices, more than 4,000 fertilizer distribution centres and direct selling stores in 16 provinces and cities) and other distribution companies. In villages and towns of many provinces, Level I supply and marketing cooperatives are gradually contracting or disappearing. They are changing into other operational units. Supply and marketing cooperatives above the county level (agricultural resources companies) still carry out important functions. The sale of chemical fertilizers by the supply system and marketing cooperatives (agricultural resource companies) throughout the country, account for more than 60% of the market share.
2. The "husband and wife" stores (mainly composed of farmers of the village) which are widely distributed in the agricultural villages and mobile traders. There are many other channels of fertilizer distribution, particularly channels represented by direct selling points of enterprises and the agricultural three-station marketing points.



Figures represent the number of operators in 2005

Figure 7-1 Framework of the fertilizer distribution system in China.

7.1.2 Characteristics of the domestic fertilizer distribution system

7.1.2.1 Formation of a new distribution pattern with multiple subjects and forms

Since 1998, the system of fertilizer distribution has been in the transition of gradually moving from the seller's to the buyer's market. Breaking up and adjustment of the original distribution system is expedited with new operational main bodies constantly emerging. The three distribution channels stipulated in Document 39 have been broken in reality and a situation of diversified competition has been formed.

1. Diversification of operational main bodies and models

Major entities that are involved in the chemical fertilizer market and distribution competition include the Zhongken Agricultural Resource Development Co. Ltd. (this company is vigorously integrating and developing chains of agricultural business resource operation networks) and the Sinochem Corporation (this company is implementing the developmental strategy of integrated downstream and upstream operation. It is also setting up its own fertilizer marketing companies with agricultural resource companies of supply and marketing cooperatives at different levels at various places, the "three stations" of agricultural system and production enterprises). The "three stations" of agriculture, enterprises of chemical fertilizer production, fertilizer distributors at the various levels and individual operators enter the realm of chemical fertilizer business through hitching, leasing, contracting and sales on a commission basis and face the farmers directly. At present, fertilizer business operators in villages and towns are basically individual operations ("husband and wife store"). They are right at the end of the entire distribution chain and they are also the weakest link scientifically and technologically. Currently, production enterprises, agricultural resource systems, the agricultural "three stations," social capital and private individuals are engaged in the marketing and distribution of chemical fertilizer. Besides, they are making an effort in exploring a business operation suitable for themselves. Currently, major modes of business operation in fertilizer distribution include direct selling, procurement, chain operations, sale agencies, supermarkets, chain membership, sole distributorship and mixed business operations.

2. Intensive competition for resources and networks in the chemical fertilizer market

Fertilizer business enterprises build marketing networks in various forms. They extend all the way to the end-users and strive for the expansion of market space to the maximum limit to obtain profits in the marketing of fertilizers. The fight for market resources and networks that arises from this is becoming more intense by the day. At present, through share participation and stock control in enterprises of fertilizer production, Sinochem Corporation has established a huge business operation network in 15 major agricultural provinces throughout the country. Through stock control and "chain delivery," Zhongken Agricultural Resource Development Co. Ltd. is extending its network downward. Agricultural resource companies of the supply and marketing cooperatives

in the various provinces show different performance with some growing stronger and some weaker. Business in some agricultural resource companies has shrunk but others have taken advantage of their traditional reputation to go into chain operations by integrating downstream and upstream network resources that show their vitality. Some fertilizer production enterprises set up marketing companies or business network points at various places to sell their products directly. For example, the Denong Co. set up agricultural resource chain supermarkets in Shandong and other places.

3. Foreign manufacturers have entered the domain of domestic chemical fertilizer distribution

At present, foreign-owned enterprises have infiltrated and even entered the fertilizer market of China through the following two manners: One is the extension of services. For example, Cargill of USA (merged with the Phosphorus Society of America) has set up a client service station in Shandong Province. Through the establishment of agricultural client service centres they advertise their products to the farmers and establish their brands. The other is joint venture stock control. An example is the Russian Acron Co. By stock control in the Shandong Hongri Chemical Fertilizer Plant it established a marketing network in the name of the production enterprise.

7.1.2.2 The vitality shown by modern modes of distribution

With continuous development and improvement of the fertilizer market system, modern business models and modes of marketing such as chains, delivery, supermarket and e-business are continuously brought into the domain of chemical fertilizer distribution. They gain the recognition of enterprises of production and distribution and the farmer. The business of circulation rapidly goes into high gear. Through the enhancement of the establishment and reform of the distribution network, some powerful domestic fertilizer distribution enterprises gradually achieve the integration of upstream and downstream resources and strengthen their control of the market place. By 1998, when the market of agricultural resources became fully open, the situation changed from "full monopoly" of the supply and marketing system to "one master two generals" and finally to "many warlords fighting for supremacy."

The market of agricultural resources in China is experiencing the competition and elimination of the market economy. In 2002, the Document "Several Opinions Concerning the Promotion of Chain Operation" (*Guo Ban Fa* [2002] No. 49) was transmitted from the General Office of the State Council to the Structural Reform Office of the State Council and the National Economic and Trade Committee. This document clearly indicated the government's support for the development of the chain operation. Numerous large agricultural resource circulation or distribution and chain enterprises appeared in China. More and more regional chain brands and regional leading marketing enterprises are developing. These include the chemical fertilizer distribution centres and central retail supermarkets of the Sinochem Corporation, the "China Agricultural Resource Chain Delivery for Agricultural Services Project" of the Zhongken Agricultural Resource Development Co. Ltd., the

Anhui Huilong Agricultural Resources Group, the Jiangsu Sunong Agricultural Resource Chain, Shandong Agricultural Resources, the “Banglida” Brand of Sichuan Province Agricultural Resources Co. “The Sun” Brand of Yantai City Agricultural Resources Co. the “Zhongdeli” Brand of Linzi District Agricultural Resources Co. the Nanjing Red Sun Chain (production enterprise), the Haolun Agricultural Technology Group Co. Ltd. (private) and the Hebei Shanhe Agricultural technology Co. Ltd.

The development of business chain operations is an important measure in promoting mass distribution and large-scale production. It is also an effective way to reform traditional business practices, increase the competitiveness of the marketing and distribution industry and promote the modernisation of the distribution system. Business chain operation of agricultural resources is one of the important ways in opening channels of fertilizer distribution. There are, however, a large number of different agricultural product types that are seasonal, highly geographical, taking up a large amount of funds but with low profit and difficult for trans-regional management. Chain business operations of agricultural resources face many other difficulties that include standardization of management that must be explored further. In order to further implement the spirit of the Document “Circular on the Opinions Concerning Further Improvement of Circulation of Commodities of Agricultural Villages” transmitted from the General Office of the State Council to the Commercial Affairs Department (*Guo Ban Fa* [2004] No. 57), on 6 February 2005, the Commercial Affairs Department officially issued the Document “Circular Concerning Pilot Projects on Opening a Market of Ten Thousand Villages and One Thousand Townships.” The purpose is to lead enterprises and the various types of capital in the society to actively participate in the network establishment for the distribution of commodities to agricultural villages. Mainly through measures such as discount interest and preferential treatment in taxation, this project used modern modes of distribution such as chain operation and uniform delivery to reform the network of consumption and business operation in the agricultural villages. According to the main objective, beginning in 2005, about 250,000 “farmer’s shops” should be developed within the region of pilot tests. In this way, shops in the city become the leaders with shops in the township forming the backbone and shops at village level being the operators of basic consumption in agricultural villages. This will gradually narrow the consumption gap between cities and townships.

7.1.2.3 Mechanism for regulating the distribution system is being perfected

The principle adhered to in the off-season storage of chemical fertilizer is as follows: Supplies should be built up by the enterprises. The banks extend loans. The government gives discounts. The shops are responsible for the market operation and their own profits and losses. The NDRC and the Ministry of Finance analyse and calculate the demand and supply of chemical fertilizers in regions and provinces throughout the country and determine the off-season storage quantity in the various regions and provinces based on the upper limit of 8 Mt in total. In addition, through invitation to tender, appraise

the capability of the enterprises’ business operation to determine those that are able to undertake off-season storage. Finance in the central authorities will give interest subsidy to enterprises undertaking off-season storage in accordance with relevant provisions of the “Method of Management of Commercial Reserve of Off-season Chemical Fertilizer.” This is to encourage enterprises to store and sell more chemical fertilizers, considering the fact that there are still problems with fertilizer demand and supply in some regions. On 20 January 2005, the NDRC and the Ministry of Finance added a second batch of 1 Mt of fertilizer for off-season storage. This batch was mainly distributed to the major grain production provinces and provinces that were short of fertilizers. At present, there are 28 enterprises with off-season storage of chemical fertilizer throughout the country with a total of 6.2 Mt in storage.

7.1.3 General situation and characteristics of import and export of chemical fertilizers

7.1.3.1 Import of chemical fertilizers by China

After 1949, the chemical fertilizer industry in China developed rapidly. However, relative to the requirement for

Table 7-1 Volume of China’s imported chemical fertilizers and N: P₂O₅: K₂O ratios: 1980 - 2004

| Year | Volume of Import (‘000 tonnes nutrients) | | | | N: P ₂ O ₅ : K ₂ O |
|---------|---|-------|-------------------------------|------------------|---|
| | Total Vol. | N | P ₂ O ₅ | K ₂ O | |
| 1980 | 2625 | 1867 | 570 | 188 | 1: 0.31: 0.10 |
| 1981 | 2618 | 1562 | 430 | 628 | 1: 0.28: 0.40 |
| 1982 | 2940 | 1820 | 600 | 520 | 1: 0.33: 0.29 |
| 1983 | 3964 | 2314 | 1000 | 650 | 1: 0.43: 0.28 |
| 1984 | 4705 | 2579 | 1370 | 756 | 1: 0.53: 0.29 |
| 1985 | 3872 | 2299 | 1160 | 430 | 1: 0.50: 0.19 |
| 1986 | 2559 | 1626 | 520 | 413 | 1: 0.32: 0.25 |
| 1987 | 5551 | 3109 | 1200 | 1251 | 1: 0.39: 0.40 |
| 1988 | 7483 | 4574 | 1440 | 1469 | 1: 0.31: 0.32 |
| 1989 | 7056 | 4409 | 1650 | 997 | 1: 0.37: 0.23 |
| 1990 | 8321 | 4696 | 1850 | 1775 | 1: 0.39: 0.28 |
| 1991 | 9516 | 4686 | 2850 | 1980 | 1: 0.61: 0.42 |
| 1992 | 9259 | 4900 | 2320 | 2039 | 1: 0.47: 0.42 |
| 1993 | 5164 | 2352 | 1290 | 1522 | 1: 0.55: 0.65 |
| 1994 | 6716 | 2481 | 2040 | 2195 | 1: 0.82: 0.88 |
| 1995 | 10503 | 4805 | 2890 | 2808 | 1: 0.60: 0.58 |
| 1996 | 10925 | 4727 | 3500 | 2698 | 1: 0.74: 0.57 |
| 1997 | 9017 | 2927 | 2600 | 3491 | 1: 0.89: 1.19 |
| 1998 | 8090 | 1443 | 2960 | 3687 | 1: 2.05: 2.56 |
| 1999 | 7842 | 1390 | 2870 | 2582 | 1: 2.06: 2.58 |
| 2000 | 6963 | 975 | 1990 | 3998 | 1: 2.04: 4.10 |
| 2001 | 6404 | 960 | 1890 | 3554 | 1: 1.97: 3.70 |
| 2002 | 9443 | 2096 | 2770 | 4577 | 1: 1.32: 2.18 |
| 2003 | 6877 | 992 | 1620 | 4265 | 1: 1.63: 4.30 |
| 2004 | 7064 | 895 | 1450 | 4719 | 1: 1.62: 5.27 |
| 1980-03 | 158430 | 65590 | 43380 | 49470 | 1: 0.66: 0.75 |
| 1980-04 | 165480 | 66480 | 44830 | 54190 | 1: 0.67: 0.79 |

Source : China Petrochemical Industry Planning Institute

vigorous agricultural development, a shortfall in the total volume of chemical fertilizer still existed and there was a low supply of P and K fertilizers. As a result, a certain volume of chemical fertilizer had to be imported each year. Statistics (Table 7-1) show that from 1980-2004, the total volume of chemical fertilizer imported was 165.5 Mt, averaging 6.5 Mt/y. The average volume of import from 1900-2000 was 8.2 Mt. Based on the types of imported fertilizers before 1990, N fertilizer was the main item. After 1990, the proportion of P and K fertilizers increased year after year.

The large volume of imported chemical fertilizers not only make up the shortfall in the total amount of domestic production but also improved the serious imbalance of the NPK ratios in the application of chemical fertilizers in China. In addition, it has played an important role in promoting the sustainable high-speed development of China's agriculture.

7.1.3.2 Export of chemical fertilizer and industrial use in China

Export of chemical fertilizer by China started late (Table 7-2). From 1980 to 2004, accumulated volume of exported chemical fertilizer was 12.7 Mt; 6.1 Mt of N, 3.7 Mt of P₂O₅ and 2.9 Mt of K₂O. China began exporting chemical fertilizer in 1987. P fertilizer was the main item. Starting in 1995,

exports of chemical fertilizer picked up steam. In 1995 the total volume of exports reached 401,000 t. It was 3.2 Mt in 2004, an increase of nearly 800% in 10 years. The average annual rate of increase was 26.1%.

Industrial fertilizer also occupies a certain volume in China (Table 7-2). Between 2000 and 2004, the annual growth was very rapid. In 2004, N for industrial use was 1.2 Mt, K was 460,000 and P was negligible, thus not included. From 1980-2004, accumulated N for industrial use was 10.6 Mt and K was 3.6 Mt.

7.1.3.3 Import and export of chemical fertilizers in the past five years

During the past 5 years, development of the fertilizer industry in China was relatively fast. Production of N fertilizer increased to more than 30 Mt and P fertilizer production has exceeded 10 Mt (Table 7-3). Chemical fertilizer consumption in the whole country is close to 50 Mt. China imports about 7 Mt of chemical fertilizers each year while the volume of export is around 600,000 t to 1 Mt. Looking at the total volume of chemical fertilizers, China is the world's largest producer of N and the second biggest producer of P fertilizers. However, China is also the biggest importer in the world. China is a net importer of chemical fertilizers, making up the required

Table 7-2 Volume of fertilizer export and industrial use: 1980-2004

| Year | Volume of Export ('000 t nutrient) | | | Volume of Fertilizer for Industrial Use ('000 t nutrient) | | | |
|-----------|---------------------------------------|------|-------------------------------|--|--------------|-------|------------------|
| | Total Volume | N | P ₂ O ₅ | K ₂ O | Total Volume | N | K ₂ O |
| 1980 | | | | | 130 | 100 | 30 |
| 1981 | | | | | 160 | 110 | 50 |
| 1982 | | | | | 160 | 120 | 40 |
| 1983 | | | | | 170 | 130 | 40 |
| 1984 | | | | | 190 | 140 | 50 |
| 1985 | | | | | 190 | 150 | 40 |
| 1986 | | | | | 230 | 180 | 50 |
| 1987 | 20 | | 20 | | 270 | 200 | 70 |
| 1988 | 40 | | 40 | | 300 | 220 | 80 |
| 1989 | 30 | | 30 | | 320 | 250 | 70 |
| 1990 | 40 | | 40 | | 360 | 280 | 80 |
| 1991 | 40 | | 40 | | 400 | 300 | 100 |
| 1992 | 88 | 4 | 80 | 4 | 420 | 320 | 100 |
| 1993 | 64 | 12 | 30 | 22 | 470 | 350 | 120 |
| 1994 | 232 | 112 | 100 | 20 | 500 | 380 | 120 |
| 1995 | 401 | 140 | 110 | 151 | 560 | 430 | 130 |
| 1996 | 605 | 135 | 140 | 330 | 630 | 480 | 150 |
| 1997 | 670 | 197 | 60 | 413 | 640 | 500 | 140 |
| 1998 | 439 | 86 | 70 | 283 | 700 | 550 | 150 |
| 1999 | 682 | 62 | 90 | 530 | 800 | 580 | 220 |
| 2000 | 1201 | 512 | 310 | 377 | 980 | 710 | 270 |
| 2001 | 1358 | 735 | 410 | 214 | 1150 | 850 | 300 |
| 2002 | 1022 | 348 | 430 | 245 | 1280 | 920 | 360 |
| 2003 | 2521 | 1540 | 750 | 228 | 1510 | 1110 | 400 |
| 2004 | 3230 | 2167 | 940 | 119 | 1680 | 1220 | 460 |
| 1980-2003 | 9450 | 3880 | 2750 | 2820 | 12520 | 12520 | 3160 |
| 1980-2004 | 12680 | 6050 | 3690 | 2940 | 14200 | 14200 | 3620 |

Source: China Petrochemical Industry Planning Institute

deficit of about 5 Mt through imports. Regardless of whether it is production, import or consumption volumes, China leads the world.

Table 7-3 China's chemical fertilizer production, export and consumption: 2001-2005 ('000 tonnes)

| Type of Fertilizer | | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|--------|---------|---------|--------|---------|---------|
| Nitrogen fertilizer (N) | Prod. | 25320 | 27426 | 28800 | 33041 | 35759.1 |
| | Import | 931.8 | 2057.2 | 885 | 768.9 | 690.1 |
| | Export | 716.4 | 331.8 | 1416.9 | 2195.9 | 927.6 |
| | Cons. | 25540 | 29140 | 28270 | 31704 | 35430 |
| Phosphate fertilizer (P ₂ O ₅) | Prod. | 7394.4 | 8053.8 | 9080 | 10174.5 | 11249.3 |
| | Import | 1853.4 | 2688.6 | 1536.7 | 1358.4 | 1146.9 |
| | Export | 264.8 | 322.7 | 385.1 | 570.3 | 500.8 |
| | Cons. | 8800 | 10020 | 10260 | 10796 | 11890 |
| Potash fertilizer (K ₂ O) | Prod. | 1303.5 | 1471 | 1645 | 2060 | 2326.5 |
| | Import | 3542.6 | 4563 | 4242.9 | 4699.2 | 5737.6 |
| | Export | 214.3 | 245.1 | 155.2 | 104.2 | 96.5 |
| | Cons. | 4630 | 5790 | 5730 | 6163 | 7970 |
| Total | Prod. | 34017.9 | 36950.8 | 39525 | 45175.5 | 49335 |
| | Import | 6327.8 | 9308.8 | 6664.6 | 6826.5 | 7574.6 |
| | Export | 1195.5 | 899.6 | 1957.2 | 2870.4 | 1524.9 |
| | Cons. | 38970 | 44950 | 44260 | 48663 | 55290 |

Source: China statistical information

7.1.3.4 Two-way trade of import and export of chemical fertilizer

1. Export trade of different chemical fertilizer products

In recent years, China has gradually changed from being a net importer to a country that both imports and exports fertilizer. Exports of chemical fertilizer have been increasing in recent years. This has been described in the preceding chapters and no further details will be given here. The main regions for China's export are the Southeast Asian countries and regions. China has taken a certain market share in countries such as Vietnam and Bangladesh. Different chemical fertilizer types produced in China (Table 7-4) were exported.

2. Characteristics of import trade of different chemical fertilizer products

China still maintains its status as a big importer of chemical fertilizer. In particular, the import volumes of DAP; compound fertilizer and MOP always top the list in the world. Table 7-5 lists the latest channels of fertilizer import into China. It can be seen that American DAP still accounts for 91% of the market share. The Russian share of MOP has reached 59% while Canada's market share dropped to 27%. In addition, China also imports small quantities of urea and AN from Uzbekistan and Russia.

Table 7-4 China's export trade of different chemical fertilizer products

| Product | Export Destination | Market Share | Features of Two-way Trade |
|------------------------|---------------------------|--------------|---|
| Urea | Vietnam | 33% | Export volume was 619,000 t in 2004; the number one partner of China's urea export for several years |
| | South Korea | 12% | Import volume was only 32,000 t in 2000. In 2004, the export volume was 212,000 t, occupying the second position. |
| | The Philippines | 10% | Export volume in 2004 was 173,000 t, occupying the 3rd position |
| | Taiwan, China | 8% | Export volume in 2004 was 137,000 t, occupying the 4th position |
| | USA | 6% | Export volume was 104,000 t in 2004 |
| | Other countries & regions | 31% | In 2000, Sri Lanka was still the number two export partner for urea. In 2004, it was out of the list. |
| Ammonium Sulphate | Vietnam | 34% | Import began in 2001. In 2004, it rapidly became the largest destination. |
| | Sri Lanka | 21% | Share in the ammonium sulphate exported from China is decreasing |
| | Malaysia | 21% | Share in the ammonium sulphate exported from China is decreasing |
| | The Philippines | 14% | |
| | Thailand | 6% | |
| | Other countries & regions | 4% | |
| Single Super Phosphate | Bangladesh | 40% | Occupying the top position for several years and the export share is augmenting |
| | Indonesia | 22% | Export share increased from 14% to 22% during the period of 2000-2004 |
| | Australia | 10% | No import before 2000; jumped to the second position in 2004 |
| | Pakistan | 7% | No import before 2000; import volume has been increasing rapidly in recent years |
| | Myanmar | 5% | Relatively stable volume of import |
| | Other countries & regions | 16% | |

| | | | |
|------------------------|---------------------------|-----|---|
| Diammonium Phosphate | Vietnam | 57% | During the period of 2000-2004, import volume increased from 159,000 t to 483,000 t but export share fell from 78% to 57% |
| | The Philippines | 15% | In the period of 2000-2004, export share rose from 2% to 15% |
| | Thailand | 14% | During the period of 2000-2004, import volume increased from 2,000 t to 120,000 t; export share increased from 1% to 14% |
| | South Korea | 6% | Increase in export share since 2000 |
| | Malaysia | 3% | Increase in export share since 2000 |
| | Other countries & regions | 5% | |
| Monoammonium Phosphate | India | 20% | Accounted for 43% of China's export in 2000; decreasing in recent years |
| | The Philippines | 19% | Export share has greatly increased since 2000 |
| | Taiwan, China | 13% | Export share has been relatively stable since 2000 |
| | Australia | 11% | Export share has greatly increased since 2000 |
| | Vietnam | 7% | There has not been much change in export share since 2000 |
| | Other countries & regions | 30% | |
| Potassium chloride | Vietnam | 48% | Export share of 28% in 2000; growth is vigorous |
| | Indonesia | 39% | Export share since 2000 has been stable |
| | Malaysia | 7% | During the period of 2000-2004, the export share fell from 10% to 7%. |
| | Japan | 6% | |

Table 7-5 Import trade of different chemical fertilizer products

| Product exported | Country Source | Market Share | Features of Two-way Trade |
|------------------------|---------------------------|--------------|--|
| Urea | Uzbekistan | 55% | Import of 21,000 t of urea in 2004; occupies the top position |
| | Russia | 44% | Import of 17,000 t of urea in 2004 |
| | Other countries & regions | 1% | |
| Ammonium nitrate | Russia | 50% | Import of 47,000 t in 2004 |
| | Ukraine | 48% | Import of 45,000 t in 2004 |
| | Romania | 2% | |
| Diammonium phosphate | USA | 91% | Import of 2.1 Mt DAP in 2004; great reduction beginning from 2000 and this trend still continues |
| | Morocco | 5% | Bilateral trade has been stable since 2000 |
| | Tunisia | 4% | Bilateral trade has been stable since 2000 |
| Monoammonium phosphate | Kazakhstan | 100% | Import of 104,000 t in 2004 |
| Potassium chloride | Russia | 59% | Import reached 4.2 Mt in 2004, an increase of 10% compared with 2000 |
| | Canada | 27% | Import of 1.9 Mt in 2004, a decrease of 11% compared with 2000 |
| | Jordan | 4% | |
| | Belarus | 2% | |
| | Other countries & regions | 8% | |

7.2 Development of the fertilizer distribution system

The development of the chemical fertilizer distribution system in China has a history of more than 50 years. As chemical fertilizer is an important agricultural commodity that is related to the national economy and people's livelihood, the State never relaxed on its supply and supervision. From the initial planned purchase and marketing by the State to the present chain operation, the State is continuously working out policies to establish a sound system of chemical fertilizer distribution. The course of reforming the distribution system has always been in line with social development and the reform of the economic system. The development of the fertilizer distribution system in China has roughly gone through the three historical periods, of completely planned management, combination of planned and market management and deployment of resources according to the market.

7.2.1 Stage of completely planned management and evolution of its policies

7.2.1.1 Stage of planned and centralized management

1. Basic characteristics

From the early 1950s to the mid-1960s, with vigorous promotion, farmers learned of the effect of chemical fertilizers and demand grew rapidly. There was a certain growth in domestic chemical fertilizer production. A number of medium scale N fertilizer plants and a large group of small county fertilizer plants were set up and went into production. However, fertilizer resources were still far from meeting the demands for agricultural production. In order to balance resources and stabilize the market, the State brought the production, purchase, import, allocation and pricing of chemical fertilizers into planned management, implemented uniform planning and centralized management. Business

operations and the distribution of chemical fertilizers were handled by the Department of Agricultural Production Data of the Supply and Marketing Cooperatives.

2. Evolution of the allocation policy

Vigorous promotion of chemical fertilizer

From the early 1950s to the early 1960s, many regions adopted the advance allocation and subsequent settlement method of distribution. With regard to supply, the method of technical guidance followed by fertilizer supply was adopted. With the basic accomplishment of socialist reforms in agriculture and the continuous growth in strength of a collective economy, beginning in 1956, there was a common promotion for chemical fertilizers. The situation of demand exceeding supply arose. For chemical fertilizer distribution during this period, grain crops were given priority over cash crops. Based on the assurance of key emphasis and giving consideration to issues in general, fertilizer was distributed according to targets by provinces, regions and the counties. In 1958, in order to support increased production of cotton and other cash crops, arrangements were made to produce special-purpose fertilizers. During this period, the State authorized supply and marketing cooperatives and the Ministry of Agriculture jointly determined the scheme of allocation of chemical fertilizers and worked out the plan of allocation.

Exchange of chemical fertilizer for grain purchase and premium sale

From the early to mid-1960s, there was a greater development of the production of chemical fertilizer in China. The State invested in a number of large-scale chemical fertilizer plants. A three-level fertilizer resource in the form of central authorities-province-county was established. The distribution of chemical fertilizer was based on the requirements of national economic development and market arrangement needs. It directly hinged on important agricultural and sideline products that the State had to control. For farmers who delivered and sold their cash crops, including cotton, flue-cured tobacco, hemp, sugar crops and oil crops, fertilizer was sold as premium sale or chemical fertilizers was used to exchange for grains with farmers. Relevant policies that looked after remote regions where agricultural production was low and cash crops were relatively less were also introduced. The State carried out the standardized policy of premium purchase of agricultural and sideline products throughout the country. Chemical fertilizer was included as important material for premium sale. On 3 April 1961, the "Targets Concerning the Implementation of Grain Incentives in the Purchase of Important Cash Crops" stipulated that the implementation of grain incentives on important cash crops included cotton, major oil crops, flue-cured tobacco, hems, tea, silkworm cocoon, sugar crops, some fruits for export and some traditional Chinese medicines and native products. Regardless of whether it was a major producing area or secondary producing area, this method of incentive had to be implemented. In 1962, the State Council promulgated the "Notice Concerning the Method of Premium Purchase of Cash Crops and Livestock Products" in which it mentioned that there should be appropriate reductions in the use of cash crops and livestock products for premium purchase of

grains. Premium sale of cotton, oil crops and hemp should be stopped. Instead, it should be changed to premium sale of chemical fertilizers where 1 kg of fertilizer replaced 1 kg of grain. At the same time, standards for the premium sale of fertilizer were specified for tobacco, silkworm cocoon, tea, traditional Chinese medicines and several native products.

During this period, chemical fertilizers were moving from a single grade to multiple grades. Phosphate fertilizers were promoted. The use of NPK compound fertilizers on flue-cured tobacco had started. The principle of allocation of chemical fertilizer was to emphasize the cash crop areas and give appropriate consideration to the Third Line Regions and remote provinces and regions. Appropriate consideration was given to grain crop bases and areas of centralized production of commercial grain crops. There should be a slight increase in the overall level of allocation compared with the previous year.

7.2.1.2 The stage of uniform planning, local management and balance allocation

1. Basic features

From the mid-1960s to the end of the 1970s, according to requirements for cutting down the operational links for commercial products put forward by the State, in 1962, 1964 and 1965, chemical fertilizer marketing business of 17 medium and large scale organizations under the management of the central authorities that included the Sichuan Chemical Plant, Guangzhou Nitrogen Fertilizer Plant, the Nitrogen Fertilizer Plant No. 3 and the Phosphate Fertilizer Plant of Nanjing Chemical Industry Co. the Main Plant of Wujing Chemical Industry, the Wuhan Iron and Steel Co. the Benxi Iron and Steel Co. the Anshan Iron and Steel Co. and the Jilin Calcium Carbide Plant and the business of receiving imported fertilizers at the ports of Shanghai, Qingdao, Yantai, Tianjin and Dalian were transferred to the Department of Agricultural Production Data of the Supply and Marketing Cooperatives of the province or city where the plant or port was located. Purchase and receipt of fertilizers were carried out according to the plans from the central authorities. After deducting the local allocation outside the plan of the central authorities, balanced allocation would be carried out, thus, slashing the link of the Level I station of supply and marketing cooperatives and the central authorities.

2. Evolution of the distribution policy

Domestic enterprises of centralized distribution were turned over to the local authorities

At this stage, there were great changes in the distribution system of chemical fertilizers. According to statistics of 1969, there were 34 domestic enterprises of centralized distribution. Of these, 22 were enterprises of chemical industry. There were 10 metallurgy enterprises and 20 petroleum enterprises. Output of chemical fertilizer under uniform central planning was 2.2 Mt which accounted for 24% of the total output of the whole country. After implementing the reforms in the distribution system in 1970, 31 domestic enterprises of centralized distribution transferred their operation to the local authorities. The State only reserved the Jilin Chemical Fertilizer Plant, the Nanjing Phosphate Fertilizer Plant and

the Taiyuan Phosphate Fertilizer Plant. These plants adopted the policy of “fixing the quantity that goes out and retaining what has exceeded the production” with regard to the fertilizer they produced. According to 1975 statistics, the amount of chemical fertilizer sent out by the 3 plants of Jilin, Nanjing and Taiyuan was 802,000 t, accounting for about 3% of the country’s total output.

Transfer of right of use to the local authority before unification throughout the country

At the end of the 1960s, the State took into consideration the factor of fertilizer application for special-purposes in the premium purchase of grains, cotton and oil crops in the provinces. However, in order to change the tedious distribution method used in the past, the right of use was transferred to the local authority according to items. It would no longer be itemized and listed in the plans. Instead, uniform arrangements were made by the various regions, cities and provinces. In 1969, at a meeting of the State Council on the Plan of Chemical Fertilizer Distribution, it was pointed out that regions of the Great Third Line and regions in the north where there was a shortage of grains, should receive an increase in fertilizer allocation. The policy of premium purchase of chemical fertilizer for large quantities of crops such as grains and cotton remained unchanged. This was specifically controlled by the revolutionary committee of the various regions, cities or provinces, with the limits gradually contracting and the standards lowering. In March 1970, the State Council changed the method of distribution of chemical fertilizer when most of the products were transferred to the local authorities for distribution. Under the prerequisite of guaranteeing the accomplishment of the mission of upward transfer in the full amount and according to schedule, the method of “uniform planning, balance allocation, product retention for over-fulfilment of production target and a decision each year” was implemented.

In 1970 Document No. 14 from the central authorities stipulated that: purchase of cotton should continue. Firstly, 40 *jin* (1 *jin* = ½ kilogram) of chemical fertilizer is allocated in advance. Subsequently, based on the purchase price of 100 *jin* of ginned cotton, there will be 70 *jin* of premium purchase of fertilizer as settlement. In 1971, Document No. 8 from the central authorities pointed out that: “Implementation of rational policy of reward for selling grain to the State must be continued without being changed at will.” During this period of distribution, the principle was: emphasis should be on taking care of regions of the Great Third Line and regions in the north where there is grain shortage. There should be the guarantee of the fulfilment of premium purchase and special-purpose fertilizer for crops such as grains, cotton and oil crops. There should be appropriate allowances made for fertilizer utilization in general regions.

From 1969-1972, with regard to the standard of premium purchase of agricultural and sideline products, types/varieties were far from uniform and this was not favourable for production and purchase. Consequently, in 1973, the “Circular Concerning the Implementation of Uniform Premium Purchase of Agricultural and Sideline Products” from the State Council stipulated: “With regard to chemical fertilizer for premium purchase required for the purchase of

cotton which is a special apportionment from the Ministry of Commerce and Settlement, the rest will be uniformly arranged by the local authorities. The grain and chemical fertilizer types required for which external trade is in charge, payment will be made and settled by transfer.” “Cotton will be according to sowing plans with 40 *jin* of chemical fertilizer apportioned in advance for every *mu* (1 *mu* = 0.0667 hectares). Settlement will be made with the production team after the autumn harvest. Based on the actual volumes of delivery and sale, for every 100 *jin* of ginned cotton, there will be premium sale of 70 *jin* of chemical fertilizer.” “For the over-produced and over-purchased hemp, sugar and tobacco, the State will continue to apportion the special-purpose fertilizer.”

3. Evolution of pricing policy

The pricing of chemical fertilizer strictly followed the policy of low price and thin profit. There was overall uniform adjustment of the price of chemical fertilizer “package” for the purchase of made-in-China, price of imported fertilizer, price of allocated fertilizer and retail price. In addition, many policies were introduced at this stage.

Buying price of chemical fertilizer

In the “Provisions Concerning Pricing of Commodities of State-owned Industrial and Commercial Enterprises” approved by the State Council and transmitted to the National Commission for Commodity Prices in September 1964, the principle of formulation of ex-factory price of chemical fertilizer was clearly stated. The buying price of chemical fertilizer includes the made-in-China and the agreed price of imported fertilizer. The buying price of made-in-China chemical fertilizer is the ex-factory price. As for the price of imported fertilizer, before 1964, fertilizer imported through the Ministry of Foreign Trade was transferred to commission agents in accordance with the provisions of “Method of Uniform Pricing of Imported Commodities.” Foreign trade companies’ priced imported commodities by adding 3% commission to the landed cost. Import duty, industrial and commercial consolidated tax and import expenses after arrival at the domestic ports would be borne by the head office of the national supply and marketing cooperatives. In February 1965, it was stipulated in the “Circular Concerning Opinions on Pricing of Several Imported Commodities” by the National Commission for Commodity Prices that: For chemical fertilizers and pesticides imported by the head office of the national supply and marketing cooperatives, pricing was changed and based on domestic ex-factory price. For chemical fertilizers without domestic ex-factory price, following consultation with the foreign trade company, pricing was in accordance with the price set by the head office of the National Supply and Marketing Cooperatives to the provinces, autonomous regions and municipalities directly under the Central Government with deduction of specified expenses. In addition, on 24 January 1973, the “Circular Concerning the Problem of Computation and Collection of Port Charges for Chemical Fertilizers Imported in Bulk” ([73] *Jiao Shui Yun Zi* No. 133) was introduced to standardize the price of imported chemical fertilizers.

Setting the price of chemical fertilizer for allocation

In the “Circular Concerning Price Regulation of Chemical Fertilizers, Pesticides, Petroleum and Traditional Chinese Medicine” issued by the Ministry of Commerce in 1971, it was stipulated that: The original method of pricing chemical fertilizers by deducting from the retail price the various expense ratios and freight charge quotas at the various levels of operations below the provincial level, was changed to the method of pricing by carrying out deductions from comprehensive expense ratios (including expenses of operation and short-distance transportation) of regions formulated according to conditions of transportation and distribution plans within the province.

Retail price of chemical fertilizers

According to the “Provisions of the State Council on Prices of the List of Products (Commodities) Managed as Division of Labour by Relevant Departments” promulgated by the State Planning Commission in December 1973, there were six types of products that came under the market selling price of fertilizers managed by the head office of the National Supply and Marketing Cooperatives. They were urea, AS, AN, AC, SSP and NPK compound fertilizers. In May 1974, based on the policy that “prices must be consolidated,” there must be an appropriate centralized authority in price management. Enhancement of strength in management must be carried out. The “List of Commodities with Balanced Prices” was issued. The supply and marketing cooperatives throughout the country were responsible for balancing the prices of 12 chemical fertilizer types, including ABC. Over a long period of time, as a result of the implementation of the policy of low price with small profit, even though demand outstripped supply in the market by a huge amount, the retail price was gradually falling. The price of AS dropped six times and the price of urea fell three times.

7.2.1.3 The stage of unified planning and distribution and graded management

1. Basic characteristics

At the end of the 1970s the 13 large urea plants were completed by the State and went into production. This brought a big change to the domestic chemical fertilizer industry in terms of quantity and distribution. In order to strike a balance with the newly added resources, guarantee central planning and implementation of chemical fertilizer policy and at the same time encourage the enthusiasm in local management of fertilizer distribution, the State carried out adjustments with regard to the target chemical fertilizers distributed. That is, under unified planning, the central government manage the product distribution and prices of large scale fertilizer plants. The local government manage the fertilizer distribution and price of medium scale chemical fertilizer plants.

2. Evolution of the distribution policy

Implementation of “pro-rate share” in large fertilizer plants with unified distribution

When the 13 large chemical fertilizer plants imported by the State were completed and went into production and when

the Shanghai Wujing Chemical Fertilizer Plant designed by China also began its trial production, to facilitate the production, distribution and transportation for the 14 newly-built large chemical fertilizer plants, in 1997, in the “Circular Concerning the Issue of Interim Provisions on the Distribution, Acquisition and Transportation of Products of the 14 Newly Built Large Chemical Fertilizer Plants,” it was stipulated that “for agricultural chemical fertilizers (including all solid and liquid chemical fertilizers) produced by large fertilizer plants, 40% should go to the State and 60% should be reserved for local use.” “Sharing is carried out according to the actual output in a particular year. That is, advance division is carried out quarterly and annually and at the end of the year, settlement is carried out according to the actual output.” From 1977, the Jilin Chemical Fertilizer Plant, the Nanjing Phosphate Fertilizer Plant and the Taiyuan Phosphate Fertilizer Plant, which originally came under unified distribution by the State, began to follow these 14 large plants by submitting 40% of their output to the State and keeping 60% for local use. In 1978, it was changed to 50% for both – half of the output was submitted to the State and the province where the production plant was located kept the other half. The product submitted to the State was entirely in the form of solid fertilizer. As the ammonia water produced by the large fertilizer plants was not suitable for long distance transportation, it was all kept for local use and for areas nearby. When used to take the place of pro-rate share, it would be computed at 30%. Starting in 1999, the pro-rate share was stopped and the entire production was retained for the use of the districts, city and the province. In 1979, the actual amount of domestically produced chemical fertilizer for unified distribution was 4.5 Mt and this accounted for 8.7% of the total national output.

Expansion of local self-sufficiency and unified regulation by the central authority

In 1976, the State Planning Commission proposed that when the 14 newly built large scale chemical fertilizer plants went into production, there should be gradual expansion of areas that are sufficient in chemical fertilizer. Fertilizer utilization should be planned and arranged by the local authority. The chemical fertilizer that comes from government regulation should be used mainly for taking care of people in remote and poor areas, the old and the young. Imported chemical fertilizer should be reduced gradually each year. The principle of distribution during this period was to guarantee premium purchase, exchange of purchases, subsidy and fertilizer for special policy. Attention should be paid to fertilizer consumption of commodity food grains and the base for export commodities. The outlying provinces and regions, where the standard of agriculture is low and where there are few cash crops, should be given proper attention.

7.2.2 Stage of combination of planned and market management and evolution of its policies

7.2.2.1 “Two-tiered pricing system” of chemical fertilizers

1. Basic characteristics

In the early 1980s to 1988, after the 11th *San Zhong Quan* Meeting, the idea that fertilizer was not a commodity began to change. With the rising purchase price of agricultural products, the principle of production, business operation, break-even and small profit gradually gave way to rationality. In 1983-84, the State raised the ex-factory price and selling price of major grades of domestically produced and imported chemical fertilizers three times. The Ministry of Commerce issued the “Measures (Trial) for the Procurement and Allocation Contract” on 15 August 1984. In early 1985, the “Circular of the State Council’s Approval to the State Price Bureau Concerning the Report on Conditions of Introduction of Price Reform and Price Stabilization Measures” was issued. For the first time, in the chemical fertilizer market, there were two different prices for the same product. This marked the first attempt for the market economy model to be tried out in the domain of chemical fertilizer circulation.

The “two-tiered pricing system” means that prices within state planning will be uniformly formulated by the State while prices outside state planning will be regulated by the market. On 9 July 1986, the “Circular Concerning the Issuance of Chemical Fertilizer Administration and Price List of Pesticides” was issued by the Ministry of Commerce. Owing to price increases for raw materials and demand for chemical fertilizer outstripping supply, an increase in market-regulated price outside state planning was faster. On the other hand, the price of chemical fertilizer within state planning was restricted by various conditions and it was difficult for it to be regulated in time. This led to the gap between the two growing bigger. Prices outside state planning were generally more than twice the price uniformly fixed by the State within state planning. In order to lessen the difficulty encountered by chemical fertilizer enterprises producing and doing business within state planning, the method of formulating temporary local prices according to the principle of small profit after break-even adopted by the price department at the provincial level for some of the fertilizers such as ammonium nitrate and urea (produced with coal coke as raw material) was adopted. The temporary local prices became much higher than the State’s unified fixed prices. These measures produced positive effects in easing difficulties faced by enterprises and in maintaining the normal production and operation of chemical fertilizer enterprises. However, due to the continued condition of demand exceeding supply and the co-existence of many forms of prices, profiteering was serious and the order of distribution was chaotic. This caused the selling price to shoot up further.

2. Evolution of distribution policy

The policy of “pro-rate share” and unified distribution by the central authority was still implemented in large fertilizer plants. According to the development of agricultural production and market conditions in China, for chemical

fertilizers by the unified distribution of central authority, the policy emphasize on regions and crops with good economic performance, great potential for yield increase and a high rate of commoditisation. Thus, appropriate consideration should also be given to regions where the level of agricultural production is low and places where there is little chemical fertilizer for agricultural production. However, there are generally no change in the special premium purchases for agricultural products in these areas.” In 1985, based on the average values of actual amounts of distribution in the preceding three years, local authorities implementing unified distribution of chemical fertilizers adopted the policy of contracting. Under the prerequisite of being responsible for a task until it was completed, local authorities would determine autonomously whether to continue implementing the scope and standards of premium purchase of chemical fertilizer. During this period, the products of small chemical fertilizer plants would be distributed by the local government according to the land area of agriculture production where the fertilizer would be used.

In 1987, to encourage the enthusiasm of farmers in the production of grains and cotton, the State decided to take out some of the fertilizers from the two polarized fertilizer sources of central and local authorities for implementing the method of contractual purchase and linking up the acquisition of grains and cotton with chemical fertilizers. In 1989, the standard of linking up chemical fertilizers with the contractual purchase of grains and cotton was further elevated.

7.2.2.2 Specialized and integrated marketing of chemical fertilizers

1. Basic characteristics

During the period 1988-1992, with adjustment in agricultural policies, the prices of agricultural products rose. Farmers were very enthusiastic in grain production. Demand for chemical fertilizers increased sharply and the fertilizer market was in disorder. In September 1988, in order to check interference from many parties and profiteering, the State Council issued the “Decision of the State Council Concerning the Implementation of Monopoly for Chemical Fertilizers, Pesticides and Agricultural Plastic Films” (*Guo Fa* [1988] No. 68) stipulating that the State authorized China Agricultural Production Materials Group Company and the units of Agricultural Production Materials of the Supply and Marketing Cooperatives at the provincial level to carry out monopoly of agricultural resource commodities that include chemical fertilizers. Good quality chemical fertilizers produced by medium and large scale chemical fertilizer plants were acquired uniformly by the Monopoly Department, regardless of whether they were inside or outside state planning. For chemical fertilizers produced by local small scale fertilizer plants, the Monopoly Department would purchase them by contract or would jointly sell them with the fertilizer plants; sell them on a commission basis or the plants would sell them directly to the farmers. The local government decided which form of selling to adopt.

In December 1989, the “Circular of the State Council Concerning the Perfection of the Method of Monopoly of

Chemical Fertilizers, Pesticides and Agricultural Films” marked the formation of a system of fertilizer marketing with one main channel supported by two supplementary ones. This established a system of chemical fertilizer monopoly by the China Agricultural Production Materials Company and the units of the Agricultural Production Materials of the Supply and Marketing Cooperatives at the various levels as the main channel, and the three stations of agriculture below the county level and the production enterprises as the supplementary channels.

2. Evolution of price policy

In order to rectify the chaotic condition of chemical fertilizer prices and distribution and to control the unreasonable rise in prices, the State Price Bureau issued the “Report by the State Price Bureau and the Ministry of Commerce Concerning the Implementation of Compound Average Selling Price” (February 1988) and the “Circular of the State Price Bureau Concerning the Thorough Execution of the Implementation of Compound Average Selling Price.” Based on these, the compound average selling price was launched throughout the country. The price departments at various places were required to find the weighted average of the different ex-factory prices of major fertilizer types inside and outside state planning, add the commercial distribution and marketing expenses and formulate the compound average selling price. For good quality fertilizer produced by domestic medium and large scale chemical fertilizer plants and imported fertilizers, the price department at various places worked out the compound-selling price, taking the province as the unit. For chemical fertilizers produced by local small scale fertilizer plants and fertilizer adjusted between districts, the maximum ex-factory price and the controlled selling were implemented.

Other departments also issued relevant documents to stabilize fertilizer prices and to improve the distribution system. On 5 February 1989, the “Circular of the State Taxation Administration Concerning the Problem of Income Tax Computation and Imposition with the Implementation of Compound Average Selling Price of Chemical Fertilizer” ([89] *Guo Shui Suo Zi* No. 006) was issued. On 22 October 1990, “Circular of the State Taxation Administration Concerning the Problem of Tax Reduction and Exemption for Chemical Fertilizer Products” (*Guo Shui Han Fa* [1990] No. 1297) was issued. In 1991, the State Taxation Administration specifically issued the “Circular Concerning the Problem of Handling the Taxation and Financial Matters after the Implementation of Compound Average Selling Price for Chemical Fertilizer” (*Guo Shui Han Fa* [1991] No. 090) to guarantee the smooth implementation of the compound selling price.

In 1989, in order to resolve the price problem of imported chemical fertilizer outside state planning, Document No. 68 of the State Council clearly pointed out that imported chemical fertilizer would be administered by the state planning. On 4 March 1989, the State Price Bureau issued the “Official Reply Concerning the Problem of Pricing of Fertilizer Imported outside State Planning” ([1989] *Jia Zhong Zi* No. 140). In order to resolve the problem of imported chemical fertilizer being affected by shipping documents not being delivered on time, the Customs Head Office issued the “Circular Concerning the Problem of Customs Clearance for Fertilizer Imported in

Bulk by Sinochem” (*Shu Shui* [1990] No. 1148, 15 November 1990) and “Circular of the Ministry of Communications and Customs Head Office Concerning the Matter of Transshipment of Chemical Fertilizer in Bags” ([91] *Jiao Yun Zi* No. 206, 7 March 1991) jointly with the Ministry of Communications.

7.2.2.3 Planned supply supplemented by market regulation

1. Basic characteristics

During the period 1992-98, chemical fertilizer supply was still, mainly, planned. In the process of reforming the distribution system for fertilizers, there were continuous attempts to regulate the market and composite selling price continued. In 1992, with the establishment of the system of socialist market economy, the marketing and distribution of agricultural materials also gradually picked up speed. At the same time, to guarantee the low price of chemical fertilizers, from 1992, relevant documents were issued for five years in a row, expediting the gradual transition from monopoly to more relaxed operations.

2. Evolution of the chemical fertilizer monopoly policy

In 1992, the State Council issued the “Circular of the State Council Concerning Enhanced Administration in the Business Operation of Chemical Fertilizers, Pesticides and Agricultural Films” (*Guo Fa* [1992] No. 60) which clearly stated the continued enhancement of the right of administration of the State with respect to fertilizer prices. Detailed provisions were stated with regard to the system of chemical fertilizer monopoly.

The Circular stipulated that: China Agricultural Production Materials Co. and the units of Agricultural Production Materials of the Supply and Marketing Cooperatives at various levels constituted the main channel of business operation of agricultural materials. Reclamation areas directly under the Ministry of Agriculture and supplied by it (including Construction Corps, Land Reclamation Head Office, Administration Bureau, State-owned farms) continued to execute the central and local direct supply system. The reclamation areas organized the supplies. The crop protection, the soil fertility and the agriculture extension stations (the “three stations of agriculture” for short) were launched, supporting chemical fertilizers. These were required for technical extension and payable technical services. All fertilizers listed in the State’s unified distribution plan would be supplied by companies of agricultural materials according to the wholesale price. Those not listed in the State’s unified distribution plan would be supplied according to the mechanism of market operation. They could also be supplied by companies of agricultural materials based on wholesale price. The specific types and quantities were determined by supply and demand. They could also be ordered directly from the production enterprises and transferred to farmers, based on the local retail price. For chemical fertilizers under the unified distribution by the central and local authorities, the China Agricultural Production Materials Co. and the provincial (district, city) Agricultural Materials Companies were authorized to operate specifically according to the policy of acquisition and distribution stipulated by the State.

For fertilizers other than those for unified distribution, production enterprises could purchase by contractual order, joint sales, commission basis sales, or selling to farmers independently. They could also accept advance booking by farmers and practise different prices for the hot season and off-season periods. Apart from the stipulated units mentioned above, no organization or individual persons were allowed to trade in fertilizers.

On 16 December 1993, the document "Circular of the State Industrial and Commercial Administration and the Ministry of Agriculture Concerning the Enhancement of Market Management of Fertilizers, Pesticides and Seeds" (*Gong Shang Shi Zi* [1993] No. 373) reiterated the policy of fertilizer monopoly and planned two supplementary channels of fertilizer business operation and limits of authority. With regard to fertilizers required for extension and payable technical services by the Department of Agriculture Extension and which was confined to soil fertility, crop protection and agriculture extension stations (centres), the fertilizer producing enterprises, confined to selling through its own channels, must carry out registration after approval. All fertilizers locally produced or imported must apply for registration with the Ministry of Agriculture (conventional fertilizer types need not be registered).

In 1994 the State Council issued the "Circular Concerning the Reform of the Distribution System of Agricultural Production Materials" (*Guo Fa* [1994] No. 45) which further made clear the policy of "one main channel with two supplementary channels" in the distribution of chemical fertilizers. Attempts were made to revamp business operation in the distribution of chemical fertilizer. The Circular pointed out that for agricultural materials, companies may continue to be the main channel while the three stations of agriculture and enterprises of chemical fertilizer production would be the supplementary channels. All other organizations and individuals were not allowed to operate a fertilizer business. At the same time, in order to reduce circulation links and lower distribution costs and to truly give benefits to the farmers in the allocation and transfer of chemical fertilizers by the central authority, the practice of four levels of wholesale and one level of retail (that is, wholesale by the central, provincial, prefecture and county authorities and retail by grassroots supply and marketing cooperatives) was changed to two levels of wholesale and one level of retail, that is, wholesale by the central and provincial authorities while retail was taken care of by the combination of agricultural materials companies in the county and the grassroots supply and marketing cooperatives. The grassroots supply and marketing cooperatives pursued the agency system and abolished wholesale, marketing and settlement of central authority's chemical fertilizers by a one-level station in a big prefecture. At the provincial level, allocation and transfer of chemical fertilizer was changed from three levels of wholesale and one level of retail (wholesale by the provincial, prefecture and county authorities and retail by grassroots supply and marketing cooperatives) to one level of wholesale and one level of retail, that is, wholesale at the provincial level and retail by the combination of agricultural materials companies in the county and the grassroots supply and marketing cooperatives. The agency system was pursued.

In 1995, the document "Circular of the State Council Concerning Deepening the Reform of the System of Purchase and Sale of Chemical Fertilizer for Grain and Cotton Production" (*Guo Fa* [1995] No. 8) required that purchase and sale of grains and cotton, and the supply of chemical fertilizer be further improved. In order to implement the State Council's requirement thoroughly, on 18 May 1995, the State Industrial and Commercial Administration issued the "Supplementary Circular Concerning Further Enhancement of Market Management of Fertilizer for Grains and Cotton" (*Gong Shang Shi Zi* [1995] No. 120) requiring the industrial and commercial administration to bring its duties and functions to full force to further enhance the supervision and control over the grain, cotton and fertilizer markets and to ensure the smooth reform of the purchase and sale systems. It also required that in the business operation of chemical fertilizers, the "one main channel with two supplementary channels" mode of marketing must be persevered with. The agricultural material companies, supply and marketing cooperatives, the three agricultural stations and enterprises of chemical fertilizer production must be strictly controlled within the limits of selling through their own channels. The total amount of fertilizer that these enterprises sold through their own channels should not exceed 10% of their fertilizer output. In addition, they could only sell to organization with management rights.

In 1996 the document "Circular of the State Council Concerning Further Improvement of the System of Chemical Fertilizer Circulation" (*Guo Fa* [1996] No. 19) again attempted to smooth the fertilizer distribution channel and to standardize the operational links. The Circular pointed out that the system with the Governor of the province in charge must be seriously implemented. For the 17 large scale fertilizer production enterprises, the proportion of the fertilizer sold through their own channels must not exceed 10% of the total sales volume. For chemical fertilizers produced by over fulfilling the production targets, it could be sold through one's own channels by following the 10% proportion. For chemical fertilizer allocated and transferred by the central authority, the two wholesale levels and one level of retail continued. For fertilizer allocated by the provincial authority, the practice of one wholesale level and one retail level continued. For chemical fertilizer handled by agricultural materials companies and grassroots supply and marketing cooperatives, wholesale and retail were combined and the system of agency was pursued.

3. Evolution of price policy

In order to strengthen the administration of fertilizer prices, a retail price of chemical fertilizer was formulated by the price department at the provincial level according to the principle of pricing stipulated by the State and based on actual local conditions. The various charges in the distribution of fertilizer were reorganized. On 20 February 1993, the State Council issued the "Circular of the State Council Concerning the Enhancement of Administration of Prices of Agricultural Production Materials and the Implementation of An Upper Limit to the Price of Major Products" (*Guo Fa* [1993] No. 13). At the same time, in order to check the price increase of agricultural materials such as fertilizer, the appendix of the above document "Table of limits to the highest ex-factory

price throughout the country for chemical fertilizers outside the planned prices of the State” stipulated that prices fixed by the State must be strictly executed for agricultural production materials inside state planning. For agricultural production materials outside state planning, the highest price limit must be implemented. The limit for ex-factory prices for major N fertilizers outside state planning was formulated by the State while the limit for selling or retail price was formulated by the local government. For the other chemical fertilizer products not included in state planning, the limit for ex-factory prices and limit for retail prices were formulated by the local government. For imported fertilizers outside state planning, in principle, the highest limit of the ex-factory price was executed for domestic allocation. When a true difficulty was encountered, it must be reported to the price administration department at the same level for separate approval.

In April 1994, continuous increases in the purchase price of crude oil, natural gas, finished oil products, grains and cotton occurred. Through “Circular of the State Council’s Reply to the State Planning Commission Concerning the Commission’s Request for Instructions with regard to the Measures of Control over Price Reform for Chemical Fertilizers” ([1994] No. 27), the State Council implemented a reform scheme, a measure to control the price, and increase the ex-factory price of chemical fertilizers with a unified fixed price throughout the country. In order to further standardize chemical fertilizer prices, and avoid the past practice of tightening the control over some but relaxing it over others that led to confusion in prices; the government brought all fertilizer prices under its control and implemented the system of central and local control at different levels. The ex-factory price of chemical fertilizers was changed from one with different price forms inside and outside the state planning to an averaged ex-factory price, whose range of upward and downward fluctuations was specified by the State. Enterprises may determine prices autonomously within the limits permitted by the State according to difference in season, region and conditions of market demand and supply. Allocation of fertilizers and the retail price are controlled by different composite profit rates.

The pricing of chemical fertilizers allocated to the local authority by the central planning was uniformly formulated by the State. At the provincial level and below, pricing of chemical fertilizer was formulated by the People’s Government in the various provinces, autonomous regions and municipalities directly under the central government. As for the domestic pricing of imported chemical fertilizers, it is formulated according to the principle of “same price for the same quality” by following the price of Chinese made chemical fertilizer of the same quality. “The better the quality, the higher is the price.” In addition, it was also stipulated that supervision and control of the price of chemical fertilizer must be strengthened. With respect to chemical fertilizer production, enterprises had to practise a system of putting price adjustments on record and report on costs and prices.

In August 1994, in its reform of the distribution system for agricultural production materials that include chemical fertilizers, the State Council made further stipulations on the administration of chemical fertilizer prices. Firstly, the fertilizer produced by the Ningxia Chemical Plant originally priced by the local authority was brought within the scope

of the State uniform fixed price. This brought the number of chemical fertilizer enterprises that executed the State uniform fixed price to 17. At the same time, it was stipulated that when enterprises sold chemical fertilizer through their own channels, the ex-factory price would be formulated by the price department at the various levels of the province according to the principle of lower than the local retail price of chemical fertilizer of the same quality. Secondly, the domestic pricing of imported chemical fertilizer was determined within the range of 10% above the ex-factory price of chemical fertilizer of the same type produced in China. A price risk fund system was set up for imported chemical fertilizers. When the difference between the price set for imported chemical fertilizer and the cost of import was a surplus, it would be deposited in the price risk fund. When the difference was a deficit, there would be subsidy from the fund. Thirdly, there was control on the rate of operating difference with respect to retail price of chemical fertilizer besides standardizing the method of pricing. A uniform rate of operating the difference was implemented for good quality fertilizer operated by an agricultural material system within and below the provincial level. That is, price departments at the provincial level formulated the weighted average price for domestically produced and imported fertilizer respectively according to the different channels of purchase. On this basis, a 10% composite rate of operating difference and reasonable transportation and miscellaneous charges were added. In the same region (province or prefecture, or city), a unified retail price was implemented.

After August 1994, prices of chemical fertilizers in the international market skyrocketed, particularly the price of urea. Enterprises dealing in imported chemical fertilizer suffered huge losses. In March 1995, the State Council convened a meeting on deepening the reform of the system of circulation of grains, cotton and chemical fertilizer. After the meeting, Document No. 8 “Circular Concerning Deepening the Reform of the System of Purchase and Sale of Grains, Cotton and Chemical Fertilizer” was issued by the State Council. The Circular stipulated that in order to maintain the relative stability of the overall retail price of chemical fertilizers, a system of putting the Head of the local government in charge was implemented. To put the spirit of the above meeting and circular into practice, the State Planning Commission issued documents to further improve the measures of control on the price of chemical fertilizer. The documents stipulated that the ex-factory price of chemical fertilizer uniformly formulated by the State would remain unchanged. For fertilizer produced by exceeding the production plan, its ex-factory price would be formulated by the local price department at the provincial level according to the actual situation of the enterprise and local conditions and based on the principle of breakeven and small profit. For urea and ammonium nitrate produced by the other enterprises, the ex-factory price would be formulated by the local price department at the provincial level, based on the principle of breakeven and small profit. For chemical fertilizers imported by the central authority, the domestic price would be determined by the State Price Control Department based on the actual import cost and the domestic reasonable allocation of expenses for breakeven. The pricing for chemical fertilizer

imported by the local authority would be determined by the various price departments at the provincial level.

In order to thoroughly carry out the spirit of documents *Guo Fa* [1994] No. 45 and *Guo Fa* [1995] No. 8, the "Circular of the State Planning Commission Concerning the Problem of Policy Related to the Price of Chemical Fertilizer" (*Ji Jia Ge* [1995] No. 221), "Circular Concerning Further Enhancement of Control of the Price of Chemical Fertilizer" (*Ji Jia Guan* [1996] No. 156), "Provisions Concerning the Implementation of a Trial Comprehensive Allocation Price for Imported Chemical Fertilizer" (*Ji Jia Guan* [1996] No. 320) and "Circular of State Planning Commission and the National Supply and Marketing Cooperative Head Office Concerning the Enhancement of Control of the Price of Chemical Fertilizer and the Rectification of the Order of Circulation of Chemical Fertilizer" (*Ji Jia Guan* [1996] No. 648) were issued. In these documents, improvement and enhanced control on the ex-factory price, allocation price and retail price of chemical fertilizer were stipulated.

Ex-factory price

The system where the price was fixed by the government and price control at different levels continued. For urea and AN produced by the 17 large enterprises, the ex-factory price of the portion for unified distribution within state planning, the State Planning Commission would formulate the price which would be reasonably adjusted at appropriate times. The same price was still used for industrial and agricultural urea. The above-mentioned enterprises sold fertilizers within state planning through their own channels according to permission stipulated. The price department at the provincial level in various places were authorized to formulate the ex-factory price of urea and AN produced in excess of the planned production based on the principle of breakeven and small profit. They were put on record and reported to the State Planning Commission. For urea and AN produced by other enterprises, the ex-factory price would be formulated by the local price department at the provincial level, based on the principle of break-even and small profit. For other fertilizer products besides urea and AN, the ex-factory price would be administered by the local price department at the provincial level. Enterprises were not allowed to fix their own price. The specific form of pricing and the method of control at different levels would be determined by the local price department at the provincial level by linking them to the actual local conditions.

Allocation price

Firstly, the relevant enterprises must strictly execute the relevant provisions of the State on the allocation and pricing of domestically produced chemical fertilizer. For domestically produced chemical fertilizer allocated to local authorities by the central authority, the allocation price would be formulated by the State Planning Commission. China Agricultural Production Materials Group Company deals in chemical fertilizers produced in China. For fertilizer that went through the warehouse in transit, on the basis of the ex-factory price, composite rate of difference not exceeding 4% (including transportation and miscellaneous charges) was added. For fertilizer that did not go through the warehouse, it should

not exceed 1.5% (including interest). Secondly, the method of allocation and pricing of imported chemical fertilizers must be improved. The Ministry of Foreign Trade continued to practise pricing by agents for the import of chemical fertilizer. The standard of agent commission was RMB11/t. For chemical fertilizer imported by the central authority, the domestic price set would be determined by the State Planning Commission according to the actual purchase cost plus reasonable domestic allocation expenses for break-even.

Retail price

Since big differences existed in agricultural production in various places, geographical environment, state of finance, chemical fertilizer resources and channels of purchase, retail price of chemical fertilizer was still formulated by the local price department at the provincial level according to the principles stipulated by the State and based on actual local conditions. Be it the main channel of business operation or the supplementary channels stipulated by the State, the retail price policies stipulated locally must be executed. One of them was the policy to actively link up placement of orders for grains and cotton with premium purchase of chemical fertilizer. Fertilizer resources and standards of link up, price level, form of fulfilment and method of supply would be drawn up by the local governments according to actual local conditions.

4. Evolution of taxation policy

In order to guarantee the implementation of chemical fertilizer monopoly and price control policies with documents of the State Council as the basis, relevant departments in the country introduced the relevant taxation policy. On 29 March 1994, the Ministry of Finance's document of "Circular of the State Taxation Administration Concerning the Regulation of Increase in the Rate of Value Added Tax (VAT) of Agricultural Products and the Exemption from VAT for Several Items" (*Cai Shui Zi* [94] No. 004) adjusted the VAT of agricultural products from 17% to 13%. Ammonium dihydrogen phosphate, ordinary SSP and FCMP produced and sold by production enterprises and by enterprises that switched to the production of urea, AP and ammonium sulphate phosphate, would be exempted from VAT before the end of 1995.

In order to resolve the existing problems in the business operation of small scale fertilizer-producing enterprises, on 23 June 1994, the State Taxation Administration issued the "Circular Concerning the Problem of Refund of Tax Payment after the Small Chemical Fertilizer Plants Have Been Exempted from VAT." The above-mentioned commodity produced in the period between 1 January and 30 April 1994 by small scale chemical fertilizers enterprises would also be exempted from VAT and there would be refunds of tax already collected. On 14 November 1996, the State Taxation Administration issued the "Circular Concerning the Problems of Taxation and Financial Matters After the Implementation of Compound Average Selling Price for Chemical Fertilizers" (*Guo Shui Han* [1996] No. 663) which reiterated the taxation and financial problems involved in the process of executing the compound average selling price for chemical fertilizers by enterprises of agricultural materials. On 4 December 1996, the "Circular from the Office of Customs Tariff Commission of the State

Council, the State Planning Commission and the Ministry of Finance Concerning the Problem of Import of Phosphoric Acid by Sino-Arab Chemical Fertilizers Co., Ltd.” (*Shui Wei Hui* [1996] No. 28) which stipulated that from 1996, raw materials including phosphoric acid and SOP needed for the production of compound fertilizers for domestic marketing by the Sino-Arab Chemical Fertilizers Co. Ltd. would be brought into the import plan of the State which allowed the company to enjoy corresponding taxation policies.

5. Evolution of transport policies

For many years, when the State was collecting various types of transport funds, chemical fertilizers and phosphate rock (PR) were exempted. Railway and transport enterprises operated at a loss with regard to chemical fertilizers and PR which showed the support given to agricultural production by the State and transport enterprises. Individual transport enterprises and some local authorities increased their charges without permission, thus aggravating the price increase of chemical fertilizers and phosphate rock. On 20 June 1995, the State Planning Commission, the Ministry of Railways and the Ministry of Communications issued the “Circular Concerning Continuation with the Priority Given to the Transport of Chemical Fertilizers and Phosphate Rock and Checking the Problem of Improper Collection of Charges” (*Ji Jia Ge* [1995] No. 794), requiring the price departments in various places to sort out and rectify the relevant items of charges and to carry out strict supervision and inspection. In 1996, the document “Explanations Concerning the Problem of “Chemical Fertilizer” Freight Charges Applicable to Imported Commodities” (*Yun Shu Ju* [1996] No. 01) further clarified the problem of freight charges of chemical fertilizers. In 1996 and 97, the Ministry of Railways issued successively the following documents to regulate railway freight charges: “Circular Concerning the Regulation of Railway Freight Charges and Revision of the Rules of Freight Charges of Railway Cargo” (*Tie Yun* [1996] No. 18 *Dian*), “Circular Concerning Amendment (First Time) to the Rules of Railway Cargo Freight Charges” (*Tie Yun Han* [1996] No. 212) and “Circular Concerning the Rules of Regulation of Railway Freight Charges and Amendment to Railway Freight Charges” (*Tie Yun Han* [1997] No. 58). The policy favouring the transport of chemical fertilizers and PR remained unchanged all along.

7.2.3 Stage of market deployment of resources and evolution of its policies

From 1998 the chemical fertilizer distribution system guided by the deployment of market resources was gradually formed. In the course of market orientation of the distribution system, chemical fertilizer supply was still full of problems. In particular, prices were rising too rapidly which caught widespread attention. In order to check the rising prices of fertilizers, the government introduced a series of relevant policies and reform measures. The process of becoming market-oriented for enterprises dealing in agricultural materials is still continuing. The government continuously adjusts the relevant policies and measures to support and guarantee the sound operation of the chemical fertilizers distribution system.

7.2.3.1 Breakthrough in the reform of the distribution system

1. Background on the distribution system reforms

With the rapid development of China’s agricultural economy, and the continuous advancement and improvement of the socialist market economy, reforms in the fertilizer distribution system were also scheduled. There was much emphasis on the reform of fertilizer distribution system from the State Council. In 1998, the Office of Structural Reform of the State Council was specially entrusted to take the lead together with the State Planning Commission, the Ministry of Finance, Head Office of the State Taxation Administration, the Ministry of Foreign Trade and Economic Cooperation, the Ministry Agriculture, the People’s Bank of China, the Agricultural Bank of China and the Supply and Marketing Cooperative Head Office. They carried out a long period of inspection and study. The Prime Minister and Deputy Prime Ministers of the State Council were briefed on the matter many times and they gave important instructions after each briefing.

On 16 November 1998, the State Council issued the document “Circular Concerning Deepening the Reform of the System of Circulation of Chemical Fertilizers” (*Guo Fa* [1998] No. 39, shortened to “Document 39” below). The issuing of Document 39 marked the fundamental change in the distribution system of chemical fertilizers, from a planned economy to a socialist market economy. It also marked an important turning point.

2. Contents of reform of the distribution system

The main breakthroughs of Document 39 were as follows:

1. Market deployment of resources
Planned production of domestic chemical fertilizer under instructions and the plans of unified distribution and purchase were abolished. The fertilizer-producing and business-operating enterprises carried out activities of purchase and sale autonomously.
2. The “one main channel with two supplementary channels” business format was broken. Chemical fertilizer producing enterprises could sell their chemical fertilizer to the agricultural material companies at different levels, agriculture extension stations, soil and fertilizer stations, plant protection stations and enterprises that utilized chemical fertilizers as raw materials. They could also set up sales points to sell directly to the farmers. The current practice of allowing reclamation units, forestry, tobacco growers and the army to sell chemical fertilizers within the present system was retained. As for their sources of chemical fertilizers, they could entrust agricultural material companies to purchase on their behalf. They could also purchase their fertilizers from fertilizer-producing enterprises.
3. Based on requirements of balance in the total quantity, resource deployment, and optimization of composition of product types, the National Economic and Trade Committee awarded the right of domestic trading of chemical fertilizers to Sinochem. At the same time, the China Agricultural Production Materials Group Company was awarded the agency business right for imported chemical fertilizers.

4. Establish a mechanism for the formation of market price with the government guidance. The ex-factory price of chemical fertilizers was changed from price fixing by the government to pricing with government guidance. As for the de-controlled retail price, when necessary, a limit for the highest price can be specified for some fertilizer types.
5. There should be preferential policies for chemical fertilizer production and business operation. Raw materials and energy sources such as petroleum, natural gas, coal, mineral ore and electrical power required by production enterprises of chemical fertilizer should be guaranteed and supplied with preference. Railway, transport and port authorities should give preference to ensure the transport of chemical fertilizers and their raw materials. Besides, for organizations qualified to deal in fertilizer, they should be offered preferential freight charges for transporting their chemical fertilizer and phosphate rock.
6. Establish a system of central annual reserve of disaster relief fertilizer for emergency needs. Before the rainy season starts each year, 500,000 t in product quantity of various fertilizer types for disaster relief would be prepared through collection, storage and import. The reserve fund was arranged by the Agricultural Bank of China with interest payment only for half a year every year. The central and local finance authorities would bear half each. Purchase of disaster relief fertilizers and the ex-warehouse price would be determined by the State Planning Commission together with the relevant departments. Business operation was the job of the China Agricultural Production Materials Group Co.

7.2.3.2 Development of a distribution system and the evolution of policies under a market economy

1. Evolution of the price policy

Price policy in the chemical fertilizer market

In order to fully implement the spirit of Document No. 39, on 16 December 1998, the "Circular of the State Planning Commission Concerning Measures for Administration of Further Reform in the Price of Chemical Fertilizers" (*Ji Jia Ge* [1998] No. 2552), shortened to "Document No. 2552" below) by which measures for the administration of the price of chemical fertilizers was further reformed and a mechanism of fertilizer pricing formed mainly by the market under government guidance was established. The main measures include: (a) Ex-factory price of chemical fertilizers was changed from fixing by the government to pricing with government guidance. Government guided pricing was based on the cost of production of chemical fertilizer and adjustment at the right time as a result of changes in market supply and demand; (b) Allocation price of chemical fertilizer imported by the central authority was formulated by the State Planning Commission according to the actual cost of importing the commodity plus reasonable operating expenses based on the principle of breakeven and small profit; (c) For the de-controlled retail price of chemical fertilizers, whenever necessary, the price department in the various places at the provincial level may set a limit for the highest price for some fertilizers type; (d) Prices of central disaster relief fertilizer reserve were formulated by the State in a unified manner; (e)

A system of reporting the cost and prices of large N fertilizer enterprise was established for understanding and mastering the developments in production cost and price of chemical fertilizers.

With China's accession to the WTO, the supply and demand situation in the fertilizer market has undergone great changes. The continuous rise in the price of chemical fertilizer has affected farmers' enthusiasm and fundamental interest in grain production. For this reason, the State has adopted "the policy of limiting the price" to control the market price of chemical fertilizer. In 2004, the State issued the "Circular of NDRC Concerning Further Enhancement of Supervision and Control of the Price of Chemical Fertilizer" (*Fa Gai Jia Ge* [2004] No. 523), "Urgent Circular Concerning the Proper Production and Supply of Chemical Fertilizer for its Price Stabilization" (*Fa Gai Dian* [2004] No. 1), "Urgent Circular Concerning the Implementation of Interference with Excessively Rapid Rise in the Price of Agricultural Production Materials that Include Chemical Fertilizers" (*Fa Gai Dian* [2004] No. 24 and "Circular Concerning Relevant Problems in the Administration of the Price of Imported Chemical Fertilizer" (*Fa Gai Ban Jia Ge* [2004] No. 325). These circulars were meant to strengthen the administration of chemical fertilizer wholesale and retail prices and stabilize delivery (port delivery). With regard to the ex-factory price of domestically produced chemical fertilizers included in the local list of fixed-price items and the port delivery price of imported chemical fertilizers, the local price control department must determine them seriously. With regard to chemical fertilizers produced in China, a limit was put on the highest ex-factory price or a system of declaration of raised prices and a system of recorded price regulations would be implemented. For the wholesale price, the rate of difference between purchase and sale must be specified. In the case of the retail price, the highest price limit or the rate of difference between whole and retail must be specified.

After the introduction of the policy of price limits, the trend of rising prices for chemical fertilizer was somewhat controlled. However, the policy of price limits also brought some negative effects. In order to promote the production and accelerate the circulation of chemical fertilizers, promote agriculture, in particular grain production and protect the interests of the farmers, on 20 January 2006, the NDRC and the Ministry of Finance jointly issued the "Circular Concerning the Accomplishment of Production, Supply and Price Regulation of Chemical Fertilizers in 2006" (*Fa Gai Jia Ge* [2006] No. 124) stating that urea produced by large scale N fertilizer enterprises (annual production capacity of more than 300,000 t) included in the list of fixed prices by the central authority, the implementation of government guided price would continue. The extent of increases in ex-factory prices was from 10-15% while there was no limit for downward fluctuation. With regard to wholesale and retail prices, the rate of difference between purchase and sale would still be practised. For retail prices, the rate of difference between wholesale and retail or the highest price limit was used. From the factory to the retail outlets, the rate of difference of multipurpose economic operation should not exceed 7% in principle. For products with lower unit value, such as ABC, the rate of difference could be appropriately extended.

Price policy for imported chemical fertilizers

Document 2552 of the State Planning Committee stipulated that prices of chemical fertilizers imported by the central authority (price with delivery at the port) would be formulated by the State Planning Committee according to the principle of break-even and small profit through computation of the actual cost of purchase plus reasonable operating expenses. On 25 May 1999, the “Circular of State Planning Committee that Further Made Clear the Policy on the Price of Imported Chemical Fertilizers” (*Ji Jia Ge* [1999] No. 584) which once more reiterated the right of the State Planning Committee to formulate the price of chemical fertilizers imported by the central authority.

On 7 May 2000, in response to the price situation of the international chemical fertilizer market, the “Circular of State Planning Committee Concerning Further Reform of the Measures of Administration for the Price of Imported Chemical Fertilizer” (*Ji Jia Ge* [2000] No. 514) was issued. The Circular stipulated that the government’s fixed price would continue to be implemented as the price of delivery at the port for potash fertilizer imported by the central authority. For DAP and compound fertilizers imported by the central authority, the implementation of the government’s fixed price was changed to the government’s guided price. In order to support the policy of price limits for chemical fertilizers introduced by the National Development and Reform Commission, in 2004, documents *Fa Gai Ban Jia Ge* [2004] No. 35 and *Fa Gai Ban Jia Ge* [2004] No. 523 were issued in succession for stabilizing the price of delivery at the port for imported fertilizers. In addition, departments in charge of prices in the various places were instructed to carry out strict verification. In 2006, through the document of *Fa Gai Ban Jia Ge* [2006] No. 124, the State further expedited the process towards a market economy for chemical fertilizer prices by changing the delivery price at the port for imported fertilizer from government’s fixed price to government’s guided price with maximum increase set at 3% but without any limit for downward fluctuation. Relevant policies since 1999 are shown in Table 7-6.

2. Evolution of the taxation policy

In 1999, in order to implement the spirit of Document 39, with the approval of the State Council, the Ministry of Finance issued the “Circular Concerning the Problem of Imposition of or Exemption from VAT in the Import of Grains, Chemical Fertilizers and Raw Materials for Agricultural Films in 1999” (*Cai Shui Zi* [1999] No. 13) stipulating that potash fertilizers, DAP and compound fertilizers imported within state planning be exempted from VAT but not for imports of N fertilizers. Subsequently, the “Circular of the Customs Head Office Concerning the Problem of Exemption from VAT in the Import of Grains, Chemical Fertilizers and Raw Materials for Agricultural Films in 1999” (*Shu Shui* [1999] No. 114) was issued. The issued “Supplementary Circular of the Ministry of Finance and the National Taxation Administration Concerning the Problem of Exemption from VAT during the Course of Chemical Fertilizer Importation” (*Cai Shui Zi* [1999] No. 42) stated the supplementary provisions with regard to handling the formalities of tax exemption.

On 20 July 2001, in order to support the development of agricultural production more effectively, with approval from the State Council, the Ministry of Finance and the Head Office of the National Taxation Administration jointly issued the circular *Cai Shui* [2001] No. 113 “Circular Concerning Exemption from VAT for Several Agricultural Production Materials.” The range of chemical fertilizer products exempted from VAT was expanded to include the production and sale of N fertilizers except urea, and P fertilizers except DAP, K and compound fertilizers whose major raw materials were tax-exempt chemical fertilizers (the cost of tax-exempt chemical fertilizers used to produce compound fertilizer products should account for more than 70% of the total cost of chemical fertilizers used as raw materials). In addition, there was a unified imposition of VAT on the production and sale of urea. In 2001 and 2002, the policy of collection of VAT followed by its refund was implemented. The full amount of the tax collected in 2001 was refunded. In 2002, the refund was 50%. From 2003, the refund was stopped.

In 2004, in view of the demand situation for urea, the “Circular of the Ministry of Finance and the Head Office of the National Taxation Administration Concerning the Problem of Collection of VAT Imposed on Urea Products Followed by Its Refund” (*Cai Shui* [2004] No. 33) was issued. The Circular stipulated that from 1 January to 31 December 2004, for urea products produced and marketed by urea-producing enterprises, VAT would be collected in accordance with its provisions. Subsequently, there would be 50% refund based on the actual amount of VAT paid.

In order to increase the domestic chemical fertilizer supply volume more effectively, exports were reduced. On 29 December 2005, the issued “Circular of the Ministry of Finance, Head Office of the National Taxation Administration and the NDRC Concerning the Continued Suspension of Tax Refund for the Export of Some of the Chemical Fertilizer Products” (*Cai Shui* [2005] No. 192) suspended the export tax refund for urea, DAP and MAP.

In 2006, the document *Fa Gai Jia Ge* [2006] No. 124 stipulated that the suspension of tax refunds for the export of urea, DAP and MAP should be continued. The imposition of seasonal and tentative customs duties on the export of urea would continue. The imposition of seasonal and tentative customs duty on the export of urea would be at the rate of 30% for the period of January to September and 15% for the period of October to December. This was executed in accordance with relevant provisions of the “Circular of the Customs Tariff Committee of the State Council Concerning the Scheme of Implementation of Customs Duty for the Year 2006” (*Shui Wei Hui* [2005] No. 33).

3. Evolution of the transport policy

On 26 June 2000, the documents “Circular of State Planning Committee and the Ministry of Railways Concerning the Adjustment of Railway Freight Rate” (*Ji Jia Ge* [2000] No. 797) and “Circular of the Ministry of Railways Concerning the Adjustment of Railway Freight Rate and Revision of Rules on Railway Freight Rate” (*Tie Yun* [2000] No. 71) were issued simultaneously. In the documents, the freight rate of PR was adjusted from Freight Rate No. 2 to Freight Rate No. 1. The base price upon arrival was RMB4.2/t for the entire car

Table 7-6 Circulars on price allocation of imported chemical fertilizers issued by the State Planning Committee or by the NDRC from 1999

| Date of Promulgation | Title of Document | Document Number | Target Organization |
|----------------------|---|-----------------------------------|--|
| 7 Jan 1999 | Circular of Price Section of the State Planning Committee concerning Instructions to Lower Levels about Allocation Price of Some Imported Chemical Fertilizers | Ji Si Jia Ge Han [1999] No. 1 | China Agricultural Production Materials Group Co. and local Price Bureau |
| 10 Feb 1999 | Circular of Price Section of the State Planning Committee concerning Instructions to Sinochem Corporation about Allocation Price of Some Imported Chemical Fertilizers according to 1998 Contracts and the Policy of Dealing with Different Countries on Their Own Merits | | Sinochem Corporation and local Price Bureau |
| 25 April 2000 | Circular of Price Section of the State Planning Committee concerning Instructions to Zhongken Agricultural Resource Development Co., Ltd. about Allocation Price of Some Imported Chemical Fertilizers | Ji Si Jia Ge Han [2000] No. 41 | Local Price Bureau and China Agricultural Production Materials Group Co. |
| 26 Jul 2000 | Circular of Price Section of the State Planning Committee concerning Instructions to the Central Authority Importing Chemical Fertilizers about Delivery Price at the Ports | Ji Si Jia Ge Han [2000] No.72 | Local Price Bureau and China Agricultural Production Materials Group Co. |
| 2 Aug 2000 | Reply of Price Section of the State Planning Committee to the Central Authority Importing Chemical Fertilizers about Delivery Price at the Ports | Ji Si Jia Ge Han [2000] No.76 | China Tobacco Production, Purchase & Sale Co. |
| 8 Aug 2000 | Reply of Price Section of the State Planning Committee to the Central Authority Importing Chemical Fertilizers about Delivery Price at the Ports (Reply 2) | Ji Si Jia Ge Han [2000] No.77 | China Tobacco Production, Purchase & Sale Co. |
| 3 Dec 2001 | Circular of General Office of the State Planning Committee concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Ji Si Jia Ge Han [2001] No.1418 | China Agricultural Production Materials Group Co. |
| 14 Dec 2001 | Circular of General Office of the State Planning Committee concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Ji Si Jia Ge Han [2001] No.1490 | Sinochem Corporation |
| 12 Jul 2002 | Circular of General Office of the State Planning Committee concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Ji Si Jia Ge Han [2002] No.9030 | China Agricultural Production Materials Group Co. |
| 23 Jul 2002 | Circular of General Office of the State Planning Committee concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Ji Si Jia Ge Han [2002] No.9420 | Sinochem Corporation |
| 4 Oct 2002 | Circular of General Office of the State Planning Committee concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Ji Si Jia Ge Han [2002] No.1424 | China Agricultural Production Materials Group Co. |
| 20 Dec 2002 | Circular of General Office of the State Planning Committee concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Ji Si Jia Ge Han [2002] No.1683 | China Agricultural Production Materials Group Co. |
| Apr 2003 | Circular of General Office of the NDRC concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Fa Gai Ban Jia Ge [2003] No. 31 | China Agricultural Production Materials Group Co. |
| 19 June 2003 | Circular of General Office of the NDRC concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Fa Gai Ban Jia Ge [2003] No. 371 | China Agricultural Production Materials Group Co. |
| 30 Sept 2003 | Circular of General Office of the NDRC concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Fa Gai Ban Jia Ge [2003] No. 060 | Sinochem Corporation |
| 14 Oct 2003 | Circular of General Office of the NDRC concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Fa Gai Ban Jia Ge [2003] No. 1010 | China Agricultural Production Materials Group Co. |
| 1 Dec 2003 | Circular of General Office of the NDRC concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Fa Gai Ban Jia Ge [2003] No. 1291 | China Agricultural Production Materials Group Co. |
| 17 Jun 2004 | Circular of General Office of the NDRC concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Fa Gai Ban Jia Ge [2004] No. 1006 | China Agricultural Production Materials Group Co. |
| 1 Mar 2005 | Circular of General Office of the NDRC concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Fa Gai Ban Jia Ge [2005] No. 384 | China Agricultural Production Materials Group Co. |
| 2 Dec 2005 | Circular of General Office of the NDRC concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Fa Gai Ban Jia Ge [2005] No. 2634 | Sinochem Corporation |
| 30 Dec 2005 | Circular of General Office of the NDRC concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Fa Gai Ban Jia Ge [2005] No. 2917 | Sinochem Corporation |
| 3 Feb 2006 | Circular of General Office of the NDRC concerning the Delivery Price at the Ports of Some of the Chemical Fertilizers Imported by the Central Authority | Fa Gai Ban Jia Ge [2006] No. 277 | Sinochem Corporation |

of chemical fertilizer for agricultural use. The base price for transporting was RMB0.02 /t-km.

Document *Fa Gai Jia Ge [2006] No. 124* stipulated that the exemption of rail transport for chemical fertilizers from payment of railway construction fund would continue in 2006. As the rate of railway construction fund was RMB0.033 /t-km, far higher than the increase of RMB0.004 /t-km when the freight rate was changed from Freight Rate No. 2 to Freight Rate No. 1, exemption from the railway construction fund was very favourable in the transport of chemical fertilizers.

4. Evolution of chemical fertilizer reserves policy

During the period of planned economy, disaster relief fertilizer was about 15% of the total plan. The other projects that number more than ten include forestry, animal husbandry, traditional Chinese medicine, farms run by the army, petroleum, industrial and agricultural sideline production, breeding for good varieties, spices and scientific research whose fertilizer consumptions were not listed in the state plan. The price of reserve fertilizer was always formulated by the State. On 25 April 1998, the State (Development) Planning Committee issued the "Circular Concerning the Price of Reserve Chemical Fertilizer at the Time of Leaving the Warehouse" (*Ji Jia Guan [1998] No. 719*), stipulating the method of computation of the price of 1Mt of chemical fertilizer in product quantity in the reserves of China Agricultural Production Materials Group Co.

Following the implementation of Document 39, the system of disaster relief reserve of fertilizer was officially put into effect. On 18 June 1999, the "Circular of State Planning Committee Concerning the Price Policy on the Central Chemical Fertilizer Reserve for Disaster Relief" (*Ji Jia Ge [1999] No. 706*) clearly stipulated that the purchase price of domestically produced chemical fertilizer reserve should be determined after consultations between the China Agricultural Production Materials Group Co. (shortened to "Zhongnong" below) and production enterprises within the scope of guidance stipulated by the State.

In order to regulate and control the market price of chemical fertilizers and to guarantee the interests of farmers, on 12 January 2005, the NDRC and the Ministry of Finance issued the "Measures of Administration of Commercial Chemical Fertilizer Reserves During Off Season" (Order No. 26 of NDRC and the Ministry of Finance). In order to improve the work on chemical fertilizer reserve, on 1 November 2005, the NDRC and the Ministry of Finance jointly issued the "Supplementary Provisions on Measures of Administration of Commercial Chemical Fertilizer Reserve During Off Season."

5. Evolution of market supervision and control policy

With the issuing of Document 39, the government enhanced the supervision and control of the chemical fertilizer market. Aside from strengthening the supervision on prices the government also carried out strict monitoring of the quality, production and business operations of chemical fertilizers.

On 12 June 2001, the "Circular of the National Bureau of Quality Monitoring, Inspection and Quarantine Concerning the Issue of Change of Licence for the Production of Four Types of Products that Include Chemical Fertilizer" (*Guo Zhi Jian Han [2001] No. 153*) was issued. On 30 September

2004, in response to problems such as production without a licence, manufacture and sale of fake or poor quality chemical fertilizers that victimized farmers, the document "Circular of National Bureau of Quality Monitoring, Inspection and Quarantine, the Ministry of Agriculture, Head Office of the State Industrial and Commercial Administration and Head Office of the Chinese National Supply and Marketing Cooperatives Concerning Further Development of Special-Purpose Chemical Fertilizers and Centralized Punishment Activities" (*Guo Zhi Jian Zhi Lian [2004] No. 427*) was issued emphasizing actions taken against the production and sale of fake and poor quality fertilizer in regions, towns and villages and in markets of agricultural materials where such activities were rampant. In addition, a full-scale general survey was conducted on the quality of chemical fertilizer products throughout the country. Regional activities violating the law in the production and business operation of chemical fertilizers were dealt with vigorously. Severe actions were taken against markets of agricultural materials with serious problems of fake fertilizers and fertilizers of inferior quality. The manufacture and sale of fake and inferior fertilizers that victimized farmers were cracked down with much force.

6. Evolution of the tariff quota policy

After more than ten years of difficult negotiations, on 11 December 2001, China officially joined the WTO. In order to fulfil the WTO undertakings, a tariff quota was implemented for the import of urea, DAP and compound fertilizers and the system of automatic registration was implemented for the import of K fertilizer. There were two modes in the import of chemical fertilizers – state trading channel and the non-state trading channel. The principle of distribution of tariff quota for the import of chemical fertilizers by the state and non-state trading enterprises was as follows: For urea, each year, not less than 10% of the tariff quota would be arranged for non-state trading enterprises to import fertilizer for business operation. For DAP and compound fertilizers, in the first year after joining the WTO, not less than 10% of the tariff quota would be arranged for non-state trading enterprises to import fertilizer for business operation. Subsequently, there would be an increase of 5% each year. Finally, the proportion of import by non-state trading enterprises reached 49%. According to the agreement, the volume of imports per year of the above-mentioned products by tariff quota, for import volume within the tariff quota, tax rate applicable is stipulated at 5% but actual execution was 4%. For imports that exceeded the amount of tariff quota, the tax rate (outside the tariff quota) was 50%.

On 15 January 2002, the National Economic and Trade Commission and Customs Head Office jointly issued the "Interim Procedures for the Management of Tariff Quota in the Import of Chemical Fertilizers" which stipulated that within the Gregorian year, the State should determine the chemical fertilizer products for the implementation of tariff quotas and the annual volume that could be allowed on the market. For imports within the determined quantity, a tax rate within the tariff quota was adopted. For imports exceeding this quantity, a tax rate outside the tariff quota was used. The National Economic and Trade Commission is responsible for the administration of the total volume of

chemical fertilizer imported under tariff quotas, release and distribution, and organization of implementation and execution of coordination.

On 9 September 2002, the National Economic and Trade Commission issued the "Announcement of the National Economic and Trade Commission, 2002, No. 63" according to which an adjustment of the tariff quota for the import of chemical fertilizers was carried out. On 27 August 2003, the document "Announcement of the Ministry of Commerce, 2003, No. 46" explained the issue of redistribution of tariff quotas for the import of chemical fertilizers in 2003 and allowing the tariff quota that had not been used up to be returned to the original organization authorized by the National Economic and Trade Commission that administered the import quota. On 14 October, the document "Announcement of the Ministry of Commerce, 2003, No. 55" promulgated the total volume of imports of chemical fertilizer under the tariff quota in 2004, the principle of distribution and procedure of application. On that day, through the document "Announcement of the Ministry of Commerce, 2003, No. 57," the Ministry promulgated the results of redistribution of the tariff quota for chemical fertilizer. On 5 January 2005, the document "Announcement of the Ministry of Commerce, 2004, No. 102" promulgated the situation of distribution of tariff quotas for the import of chemical fertilizer in 2005. On 30 December, the document "Announcement of the Ministry of Commerce, 2005, No. 111" promulgated the situation of the distribution of tariff quotas for the import of chemical fertilizers in 2006: There was 6.9 Mt of DAP of which 4.5 Mt went to state trading enterprises and 2.4 Mt to non-state trading enterprises. There was 3.5 Mt of compound fertilizer of which 2.2 Mt went to state trading enterprises and 1.2 Mt to non-state trading enterprises. The volume of urea was 3.3 Mt of which about 3.0 Mt went to state trading enterprises and 330,000 t to non-state trading enterprises.

7.3 Effects of joining the WTO on the system of fertilizer distribution in China

7.3.1 Unfavourable effects on the system of fertilizer distribution

7.3.1.1 Increase in the import of agricultural products will affect the volume of consumption of chemical fertilizer

According to the agricultural agreement, it is required to abolish measures that include non-tariff measures and reduce tariffs and import tax of agricultural products from 21% to 14.5-15%. Furthermore, the import quota for wheat, maize and cotton are to be increased. A large part of it will be for private trading. China will gradually withdraw from the soybean oil trade. China is constrained by land resources and the low level of production technology. Agricultural production and operation is on a small scale with low labour productivity. Prices of many agricultural products are already higher than prices in the international market. For example, the price of wheat is 26.8% higher than on the international market. Maize is 71.2% higher and rice is 17.8% higher. With

China's domestic market now opened to the outside world, foreign agricultural products that are good and cheap will have a great impact on the domestic market and agricultural production.

China has been depending on a high tariff wall to limit foreign agricultural products from entering. For some major agricultural products such as grains, cotton and oil, imports are limited by practising registration of limited quantities and tariff quotas. After joining the WTO, this wall will cease to exist. Large quantities of good and cheap foreign agricultural products will enter China. Competitiveness of China's agricultural products in the international market is very weak. Few Chinese agricultural products have found their way onto the international market. At the same time, foreign enterprises of agricultural products are trying in every possible way to get established in the Chinese market. They are fighting for a market share through agents and services. With the continuous rise in the standard of living of both urban and rural inhabitants, growth in the demand for good quality products, foreign agricultural products that are good and cheap have a ready market and competitiveness in China. For example, the annual output of special-purpose wheat of good quality accounts for only 8.5% of the amount of consumption. China has to depend on imports when supply cannot meet the demand. The annual import volume of wheat with a low content of gluten specially used in making biscuits and pastries is as high as 5 B kg. According to estimates for wheat alone, the reduction in total production will be RMB17.2 B or a fall of 9%. Imports will increase by RMB26.8 B or a growth of 205.5%. This will lead to a decrease in the area of cultivation of large-scale grain crops. According to analysis, during the ten years prior to joining the WTO, the area of agricultural cultivation in China will decrease by 18.38% and the import of agricultural products is equivalent to importing chemical fertilizer. On the other hand, the government's policy of structural adjustment to the agricultural industry such as the recovery of forests, grassland and lakes from former farmland is gradually being implemented. The area of cultivated land is fast decreasing. Reduction in the output of agricultural products will aggravate competition in the market and will lead to a decrease in the prices of agricultural products. This will affect the income of rural population. Purchasing power of farmers may, therefore, drop which will affect the enthusiasm of investing in more inputs for agricultural production. This will then affect the volume of consumption of chemical fertilizer by grain crops, thus, decreasing the demand for chemical fertilizer.

7.3.1.2 Increase in resources causes more intense market competition

After joining the WTO, the administration of chemical fertilizer imports will be switched from the present absolute quota to tariff quota and it will be easier for foreign chemical fertilizer of better quality to enter China's domestic market. Factors that constitute the system of tariff quotas include incoming volume permitted during the base period (import volume in the first year), annual rate of increase in the quota, tax rate within and outside the quota and ratio of non-state trading. A low tariff is imposed on chemical fertilizers imported within the quota whilst a high tariff will be imposed

outside the quota. According to the agreement, incoming volumes permitted during the base period for urea, phosphate fertilizer and NPK compound fertilizer are 1.3 Mt, 5.4 Mt and 2.7 Mt, respectively. These are growing at an annual rate of 5%.

Joining the WTO means, that local enterprises will compete with foreign enterprises in the domestic agricultural materials market under the same rules. This will constitute a pressure on the domestic market in terms of quantity and price. In addition, this has aggravated the difficulty in the operation of the agricultural materials market. It has affected the marketing of chemical fertilizers and there may be a drop in the profit of imported chemical fertilizers. Furthermore, with the increase in the channels of imports, macro-management of the State becomes more challenging. There is the possibility that the State may lose control of the volume of chemical fertilizers imported. Fertilizer may be imported blindly causing prices to go haywire. The domestic market will be under even greater pressure. Besides, with imported fertilizers pouring in, there will be a richer variety of products and the market will be more saturated. Farmers have more choices and they will tend to purchase whenever they need the fertilizer. This will certainly lead to more serious inventory problems for fertilizer traders and increase their business risk.

7.3.1.3 More competitors will make business operations more difficult

According to international rules, there must be an opening of the market for agricultural materials. There should be less restriction by the State on the qualification for business operation in agricultural materials. There will be more diversification. Apart from the domestic "three stations," factories and small businesses run by individuals, many other companies of every description will emerge in large numbers. Five years after joining the WTO, foreign distributors will be allowed to conduct wholesale and retail chemical fertilizer business in the domestic market. With more operators in the business, pressure from competition will increase.

With the introduction of advance marketing methods, foreign distributors brought with them totally new business ideas, marketing systems, modes of services and systems of investment which will directly challenge the existing marketing system and services in China. There will be a tremendous impact on the business operation of agricultural materials. In addition, the heavy historical burden of the system of agricultural resources and the huge amount of debts that shows no sign of easing have become serious obstacles to the growth of enterprises. It was in 1998 that the chemical fertilizer market began functioning. Owing to the fact that marketing of chemical fertilizer distribution under the market economy in China started late and the system of agricultural materials distribution came under the protection of the State policy over a long period of time, improvements have to be made in the system of management, method of operation, technical guidance, services and composition of employees.

7.3.1.4 The market price of chemical fertilizers will be affected

When large quantities of low-priced chemical fertilizers pour in from foreign countries, a price war cannot be avoided. Because of their advantages in technology, equipment and management, it is easier for foreign fertilizer enterprises to control costs. Besides, they enjoy advantages in quality, brand name and funds.

On the contrary, there is nothing optimistic about the state of production of domestic fertilizer enterprises. In regions where the planned economy model is in place, the uniform treatment of fertilizer enterprises resulted in irrational deployment of production resources and high costs of production. There are nearly 1,000 small scale chemical fertilizer plants with scores of large ones. There is little benefit from scale. N fertilizer produced with natural gas as raw material only make up 20% and the price of natural gas is more than twice that of countries superior to China. 70% of the P fertilizer is produced with low to medium grade PR of low concentration, high price and with large volumes to transport. There is no standardization of taxation and price of resources between large and small scale fertilizer plants. Taxation for domestic and imported products is not standardized. The problem of local protectionism is serious. The market is flooded with fake and inferior compound fertilizers. Market order needs to be reorganized. Most of the state enterprises are in heavy debts. They are over-staffed with heavy social responsibility. The cost of labour is high. Very often, production is not geared to market needs. In most enterprises, the corporate administrative structure is not standardized. The organizational structure and the requirements of information economy are not adaptive to the buyer's market. Many unwanted assets are generated in the course of development. Enterprises lack experience in production management and international business operation. They are unable to go forward with their burdens discarded. They are rather passive in the regulation and control of prices and may even lose their market initiative and be at the mercy of others.

7.3.1.5 Effects on the production of chemical fertilizers

After joining the WTO, the system of fertilizer quota and licences is abolished. Both domestically produced and imported chemical fertilizers enjoy the same treatment. Imported low-priced fertilizers enter the domestic market which is actually good for the huge number of farm households in China. However, the chemical fertilizer industry in China will face a tremendous challenge. Owing to the lower cost of raw materials for imported chemical fertilizers, the more advanced production techniques and technological equipment and high standards of management, compared with domestic chemical fertilizer enterprises, the competitive advantages of imported fertilizers are obvious. At present, the majority of the chemical fertilizer products internationally are by far priced lower than the domestic price in China. If foreign chemical fertilizers are allowed to pour into China without any restriction, the impact on the domestic fertilizer market will be tremendous. Compared with the chemical

fertilizer industry in advanced countries, the industry in China has the problems of irrational product composition, low degree of centralization, irrational deployment and weak overall competitiveness. The chemical fertilizer industry in China will have to face a severe test in structural adjustment and upgrading.

7.3.2 Favourable effects on the system of fertilizer distribution

7.3.2.1 Favourable to the structural adjustment of chemical fertilizer products

The structure of the chemical fertilizer market in China is irrational. It can be described as “less P, deficient in K and N saturated.” In recent years, through government interference, China has been controlling the ratio of imported chemical fertilizers. The main imports are P compound fertilizer and K fertilizer while N fertilizer is domestically produced as far as possible without any imports. Basically, a balanced relationship between supply and demand of chemical fertilizers has been achieved. However, after joining the WTO, depending on market regulations and through market deployment of resources, the ability of the regulation of excess products within and outside the country is raised and ways to obtain deficient products internationally has been increased. This has very positive effects on the balanced development of chemical fertilizer products in China. The impact on agriculture is the greatest on joining the WTO which hastened its speed of adjustment as an industry and encouraged the path of high-efficiency to be taken. Farmers will now grow good quality grains, fruits and products of livestock farming and aquaculture. This will initiate the transformation of the product structure and the distribution of cash crops. As Chinese fruits and vegetables have a higher competitiveness and are favourable for export, chemical fertilizer enterprises can also expand their market in this area. After joining the WTO, although the requirement for fertilizers by grain crops decreased, fertilizer requirement for cash crops with high added value such as vegetables and fruits increased. Production and marketing of chemical fertilizer will have to look for new markets in the adjustment of agriculture. The trend of development of fertilizers will be high-analysis good quality compounds, formulated, special-purpose, foliar, green and environmentally friendly. Products of agricultural resources in business operations will be more extensive, with better composition and a wider scope.

7.3.2.2 Favourable to the opening of export businesses

Unlike developed countries in Europe and America and fertilizer resource-type countries such as Russia and those in the Middle East, chemical fertilizer enterprises in China lack comprehensive competitive advantage. However, relative to third world countries, Chinese chemical fertilizer enterprises still enjoy certain advantage. After joining the WTO, export expands further. Conditions are more favourable for agricultural resource enterprises to organize the export of superior products and fight for a share in the world market, as well as make use of the advantageous resources

in other countries. By making use of their technology and management experience, enterprises in China should invest in production plants in countries with rich fertilizer resources but with an undeveloped fertilizer industry and join in the international market competition directly. In 1999, exports of chemical fertilizer by China were very strong and the situation appeared good. Export business will become the new economic growth point for chemical fertilizer manufacturers and marketing enterprises.

7.3.2.3 Provision of new business opportunities

On joining the WTO, working according to international rules and further opening the markets are undertakings that must be fulfilled. Gradual opening of the market is favourable for co-operation between agricultural resource enterprises and trans-national corporations. It will attract more trans-national corporations to inject funds, technology and invest in personnel training in China. Foreign manufacturers are not familiar with the Chinese market. They hope to establish a firm channel for entering the Chinese market through agents or distributors. This provides more business opportunities, opportunities for cooperation and ways of funding for those agricultural resource enterprises that have changed their management system, enterprises with good performance, good business operation and excellent network. In addition, cooperation also helps Chinese enterprises to make use of the existing marketing channels and networks of trans-national group corporations.

7.3.2.4 Fair competition will be favourable in maintaining an orderly market

In accordance with the “Principle of non-discriminatory trading” of the agreement, the policy of tax exemption for imported chemical fertilizer will be abolished. The government has to re-formulate a tax rate for imported chemical fertilizer in order to create an environment of fair competition. A unified policy of preferences will be adopted for domestic and imported chemical fertilizer. All business operation bodies will compete on the same starting line and the environment of market competition will be cleansed. This is favourable for the growth of some good enterprises. After years of renewal, the technical content of Chinese chemical fertilizer products will gradually improve. Prices are gradually moving towards international levels. Many Chinese made chemical fertilizer brands have occupied a certain position in the domestic market and in the minds of farmers.

7.3.2.5 Promotion of reform in the marketing of chemical fertilizer

Facing a new market situation after accession to the WTO, China's fertilizer marketing and distribution enterprises will be urged to change their thinking and reform their ways of marketing and services, expedite the transformation of their mechanism of operation to truly practise freedom in operation, mobility of staff and income flexibility in order to arouse maximum staff enthusiasm and creativity. The adoption of new ways of marketing that include chain stores, delivery, supermarkets, direct sale and integration of production and marketing and the development of many types of operation will inject a new lease of life and vitality to the enterprises.

7.3.2.6 Favourable to the structural adjustment of the chemical fertilizer industry

After joining the WTO, small enterprises with weak competitiveness, whose products fail to adapt to market needs will experience closure, stop production, merger or transformation. They can transfer part of their market shares to large, highly competitive enterprises that produce high-analysis chemical fertilizers in order to expand their market, expedite their development, express their superiority in scale and products, and accelerate the reorganization of the chemical fertilizer industry to increase the degree of centralization and its comprehensive competitiveness. Technological progress and technical innovation, adjustment of product structure, raising product status, realization of product upgrading and renewal can be accelerated through association, acquisition, merger and reorganization.

7.3.2.7 Favourable to the improvement of enterprise management and uplifting of overall quality

Confronted by competition and pressure posed by the new market, a production or a marketing and distribution enterprise will turn the pressure into force. They will actively explore, scientific and effective ways of management, development strategies based on changes in domestic and foreign markets, formulate correctly and prevent errors in major decisions. In response to the enterprise's weak links, they should emphasize the proper management of cost, financial and quality management. Besides, they should continuously learn and draw lessons from the management experience of advanced enterprises domestically and overseas to enable their enterprise to raise the standard of management appreciably.

Chapter 8

The Medium and Long-term Development Outlook of the Chemical Fertilizer Industry in China

8.1 Development of the international fertilizer industry

8.1.1 State of development of N fertilizer

8.1.1.1 State of development of energy sources in the world

The world is rich in natural gas. However, its distribution is uneven. 80% of the reserves are concentrated in Russia, the Middle East and regions of Central Asia, that is, regions in the Middle East, Central Russia, North Africa, south western China, southern part of the US and regions surrounding the Pacific including the south west of Canada. In 2004, verified world reserve for exploitation was 179.5 trillion cubic metres. The volume of exploitation for the whole year was 2.7 trillion cubic metres and the volume of consumption was almost 2.7 trillion cubic metres. Based on the rate of exploitation in 2004, the verified reserves can last for only 66 years. With the progress of mankind, demand for natural gas will keep increasing. Some experts predict that in 2020, the proportion of natural gas will be raised to about 29% of world energy resources. In this century, natural gas will overtake other energy resources to become the major energy resource. When that time comes, mankind will enter a century of natural gas. By then N fertilizer producing countries that use natural gas as raw material will face an enormous challenge. For example, even though Russia's natural gas reserves top the list in the world, owing to her large production, the reserve and production ratio drops to 81 (Table 8-1). Reserves in the US and Canada are not great, and over exploitation has resulted in the reserve: production ratio to be 10 and 9 in these two countries. Output in China is not relatively high but owing to her low reserves, the reserve: production ratio is only 55. It is worth noting that some of the new N fertilizer producing countries has shown obvious advantages. For example, the reserve to production ratios of natural gas in Qatar, Iran and Saudi Arabia are all above 100. In Qatar, it is 658.

According to the BP statistics World Energy Source Organization, in 2004, verified coal reserves in the world amounted to 909.1 Bt. Of this, anthracite and raw coal accounted for 478.8 Bt. Sub-anthracite and lignite accounted for 430.3 t. Calculated according to the present exploitation capability, production can only last 164 years. Distribution of coal resources in the world is not even. They are mainly concentrated in the northern hemisphere, with 70% distributed between latitudes 30°N and 70°N. 67.2% of the workable reserves of coal in the world are concentrated in the US (27.1%), Russia (17.3%), China (12.6%) and India

(10.2%). The four countries of Australia, Africa, Ukraine and Kazakhstan account for 21.2%. However, anthracite of good quality that can be used for coking is mainly distributed in Australia, the US and Canada. Worldwide coal is used mainly for power generation and coking, but China and a few other countries are still using it for fertilizer production. Table 8-2 shows the reserve and production ratio of coal in some main N fertilizer producing countries. Larger reserves are in Russia, the US and India where the times scale for coal production exceeds 200 years. In the case of Russia, it even exceeds 500 years. In China where reserves are the third largest, coal can only be mined for 59 years.

Table 8-1 Reserve and production ratio of natural gas in some N fertilizer producing countries in 2004

| | | | | | | |
|----------------------------|----------|-----------|--------------|--------|--------|--------|
| Country | Qatar | Iran | Saudi Arabia | Russia | Egypt | China |
| Reserve & Production Ratio | 658 | 322 | 106 | 81 | 69 | 55 |
| Country | Malaysia | Indonesia | Bangladesh | India | Norway | Poland |
| Reserve & Production Ratio | 46 | 35 | 33 | 31 | 30 | 26 |
| Country | Romania | Holland | Germany | USA | Canada | |
| Reserve & Production Ratio | 22 | 12 | 10 | 9 | | |

Table 8-2 Reserve and production ratio of coal in some N fertilizer producing countries in 2004

| | | | | | | |
|----------------------------|--------|----------|-----------|---------|---------|--------|
| Country | Russia | Pakistan | Ukraine | USA | India | Canada |
| Reserve & Production Ratio | * | * | 424 | 245 | 229 | 100 |
| Country | Poland | China | Indonesia | Germany | Rumania | France |
| Reserve & Production Ratio | 87 | 59 | 38 | 32 | 16 | 17 |

Note: "*" indicates that the number of years of mining exceeds 500.

8.1.1.2 Five types of N fertilizer enterprises in the world

After nearly 100 years, the international N fertilizer industry is becoming mature with growth and developmental characteristics showing. They can be divided into the following 5 types:

Type I: Large trans-national group companies that deal with many types of fertilizers. These companies operate businesses that deal with many types of chemical fertilizers in a number of countries and regions. Representatives of this type of enterprises include Yara of Norway, Mosaic of the US, PCS and Agrium of Canada, Kemira of Finland and K+S of Germany. These companies have their own characteristics. For example, the ability of Yara, Agrium and Kemira to supply N fertilizer is very strong. Mosaic is very strong in supplying P compound fertilizers while PCS and K+S are the most important suppliers of K fertilizers in the world. These enterprises show the historical tracks in the development of the world's N fertilizer industry. The predecessor of Yara was Norway Hydrogenation Co (Norsk Hydro). In the 1970s- 80s, the company made huge profits in petroleum and natural gas as coincidentally the fertilizer industry in West Europe at that time was undergoing comprehensive re-organization. It was with the huge amount of money they earned that they continued to acquire chemical fertilizer companies in Europe and in other parts of the world. In addition, they carried out rational adjustments to their own industrial structure to gradually become the largest chemical fertilizer company in the world. At present, the marketing network of Yara covers 120 countries with powerful sales and market organizations in 50 countries. Yara produces and markets mainly N fertilizers. In order to optimize the structure of fertilizer supply, the company also produces P and K fertilizers and markets them together with N fertilizer through its global downstream networks. Kemira Group of Finland was in the same situation as Yara but its acquisition activities started slightly later. PCS Co. of Canada was formerly a Canadian Royal company that was started in 1975. In the first 3 years after its formation it acquired about 40% of the production capacity for K fertilizer. This company was privatized in 1989. Subsequently it acquired a few more companies. It is now the world's largest K fertilizer producer and the second largest N fertilizer producer in North America. Recently, the company acquired 20% of the shares of Sinochem (Hong Kong) Co. Ltd. with two directors on the Board.

Type II: These are subsidiary holding companies of state-owned petrochemical groups. As the production of N fertilizer is closely associated with petroleum and natural gas, large petrochemical groups usually make use of this advantage to develop the production of N fertilizer. This has become the trend in countries that are rich in petroleum and natural gas resources. An example is the Saudi Arabia Basic Industries Corporation (SABIC) that uses the rich natural gas reserves to produce various types of petrochemical products, including chemical fertilizer. It is the largest single urea manufacturer and exporter. Its production is concentrated in three world-class subsidiary companies – SAFCO with 41% shares in the company, SAMAD with its stocks partially held by Taiwan

Chemical Fertilizers and IBN Al-Baytar National Chemical Fertilizer Company and IBN Al-Baytar itself. Another example is Qatar Fertilizer Company (QAFCO) which is a subsidiary of Qatar Petroleum. Others include Kuwait Petrochemical Industries Company (PIC), Gulf Petrochemical Industries Company (GPIC) and Pequiven, an affiliate of the biggest state-owned petroleum company of Venezuela, Petróleos de Venezuela S.A. (PDVSA) (with annual exports of 4-5 Mt of urea). All these companies are controlling N fertilizer production in their respective countries. Among the 27 large N fertilizer production plants, 13 (about 50% of the total production capacity of large N fertilizer plants) belong to the 3 state-owned petrochemical companies of PetroChina Co. Ltd., Sinopec and China National Offshore Oil Corporation (CNOOC) respectively.

Type III: Chemical fertilizer branch of integrated chemical industry groups

Many chemical industry enterprises, in particular chemical enterprises for agricultural purposes and N fertilizer enterprises have the same groups of clients and industrial chains. N fertilizer is a branch of the chemical industry and many chemical enterprises also deal in fertilizer business that includes N fertilizer as their main supplementary operation. A typical example is the German chemical company of BASF. It is one of the largest integrated chemical companies in the world. It was once a heavyweight in the chemical fertilizer industry in Germany. Today, its main N fertilizer business has been transferred to the K+S Company. The Dutch company of DSM, one of the top 500 enterprises in the world is also an integrated chemical enterprise. This company was at one time the largest manufacturer of calcium ammonium nitrate (CAN) in West Europe. Now, it is dealing in many types of fertilizer products. On 18 January 2005, Cangzhou Dahua, whose main business is N fertilizer, was brought under the umbrella of Sinochem and was included in the overall development plan of Sinochem to promote its industrial development. This was a new example in China.

Type IV: Enterprises of single N fertilizer

N fertilizer is the main business for these enterprises. They are mostly small and medium sized even though there are large fertilizer giants as well. An example is the American company of Terra Industries. This company is the largest manufacturer of N fertilizer in the US. Its annual production capacity for synthetic ammonia is 3.8 Mt. In 2004, due to the skyrocketing price of natural gas, production was reduced to almost 3 Mt. This company even acquired the chemical fertilizer assets of the British company of ICI in 1998. Another example is the Koch N Company of the US. Its annual production capacity for synthetic ammonia is about 3.7 Mt. This was reduced to 2.7 Mt in 2004. The company is a private family business but exerts great influence in the American N fertilizer industry. Many of the N fertilizer enterprises in China, especially the small and medium scale enterprises can be grouped under this category. They number about 500.

Type V: Farm cooperatives

In North America, the system of cooperatives organized by farmers is very well established. The scale of operation is large.

They also participate in the production and sale of chemical fertilizers. In the US, the two most well known cooperatives are CF Industries Holdings Inc. and Farmland Industries, Inc. CF Industries is owned by farm supplies cooperatives in 12 regions. This company operates a production and marketing network in the US and Canada. It provides services to members of cooperatives. Its scope of business covers 46 American states and the states of Ontario and Quebec, possessing large-scale production capacity for K and N fertilizers. Farmland Industries Inc. is a regional cooperative that conducts food promotion and supplies materials to farms. The main products of this company are ammonia and N solutions.

8.1.1.3 Five development trends in N fertilizer enterprises

Trend I: Going big and going global

This refers to the organization of large trans-national groups. Usually, this is done through acquisition of small and medium scale enterprises or by the alliance between two strong parties. The process by which Yara became a fertilizer giant was one of acquisitions and reorganization. The alliance of IMC and Cargill created the subsequent Mosaic. Through acquisition and expansion, large trans-national groups gradually control and integrate upstream and downstream markets and resources, forming a marketing and service network that runs through the entire fertilizer industry chain. The production and marketing networks of large trans-national groups are spread all over the world, something favourable for the deployment of resources for overcoming imbalances in supply and demand. This puts them in a very favourable position in fierce competition. Large trans-national enterprises are able to earn more profits. They also need very high management standards and appropriate developmental strategies.

Trend II: Seizing superior raw materials and resources

With the continuing rise in the price of energy, the production of N fertilizer is becoming more and more costly. Consequently, N fertilizer enterprises compete to occupy the low-end raw material market to secure the advantage. Large trans-national groups achieve their objective of controlling the resources through acquiring shares in small and medium scale N fertilizer enterprises in energy-rich regions where they provide technology to these enterprises and help them market their products. Yara acquired shares in the Trinidad N Company and the Qatar Fertilizer Company. Koch possesses shares in Pequiven of Venezuela. Agrium became the cooperative partner of Argentina's Profertil Company and has the sole power to export and market its products. PCS purchased equity from the Trinidad Fertilizer Company and the Trinidad Urea Co. Ltd. and thus, it possesses large-scale production capacity for ammonia and urea. Many companies are becoming more aware of the importance of raw material supply and are co-operating with enterprises located in places with cheap energy sources. Between 2005 and 2009, CF Industries, Terra Industries and ANSAMCAL Ltd. are jointly setting up four sets of production plants of synthetic ammonia/urea/solution of urea and AN in Trinidad. Indian fertilizer enterprises are also launching a number of

cooperation projects with Oman, Saudi Arabia and Egypt. In the coming years, the new bases of the world's N fertilizer – Iran, Oman, Qatar and Egypt will have to depend on joint-venture projects in order to quickly grow in strength.

Trend III: Occupation of fertilizer consumption market

Demand for fertilizer in East Asia, South Asia and South America is growing rapidly. These are the three regions that many fertilizer enterprises cannot afford to ignore. Many fertilizer giants are trying their best to carve out a share from this huge cake through acquiring shares in local enterprises or establishing new joint-venture N fertilizer projects in order to enter the market. Yara depends on its technological superiority to help some countries, in the above regions, in the establishment of N fertilizer plants, subsequently obtaining the right to market the products. PCS acquired shares of Sinochem Fertilizer in Hong Kong which fully indicates the importance it attaches to the Chinese market.

Trend IV: Build an enterprise with scientific technology

Enterprises of N fertilizer have to blend with the integrated chemical enterprises and adopt the scientific technological path of development. This is also an important trend of development for the N fertilizer enterprises. Integrated chemical enterprises utilize their strong research and development to continue raising the high-technology content of their N fertilizer products. Therefore, there is a complementary link between the industrial chains of N fertilizer enterprises and integrated chemical enterprises which spurs their joint development.

Trend V: Increase in the number of exporting joint-venture enterprises

Production capacities for N fertilizer increase rapidly in areas near resources. This is not a result of gradual increase in the demand for N fertilizer at the place of production of resources. Consequently, this gives rise to international trading. Usually, N fertilizer enterprises of countries rich in oil and gas enter into joint ventures or co-operation with large fertilizer groups. Gradually, a group of export-oriented joint venture enterprises are formed to expand export. Yara owns 25% of the shares of Qatar Fertilizer Company. It also possesses the sole marketing right for the products of the company. The Fertinitro Company, the largest export-oriented plant in the Americas has become the joint venture company of Venezuela's Pequiven and Koch of the US. The plant is capable of producing 1.4 Mt of synthetic ammonia and 1.5 Mt of urea.

Looking at the trends of the above-mentioned categories of enterprises, it can be seen that there is no fixed model for the development of an enterprise. The stages of development strategies adopted by the enterprises in different regions vary. N fertilizer enterprises in China should be founded on conditions in China. A development strategy that is suitable for China's characteristics should be formulated based on circumstances at home or overseas. For the manufacturers, expansion of scale, lowering cost, cooperation in technology and resources, proximity to raw materials are the inexorable trends. For the traders, split with the manufacturers and adopt the model of globally integrated procurement and marketing

will present a better picture. For the small enterprises of chemical fertilizer, increasing the functions of marketing and service, reducing investment in primary processing of raw materials will be a smart move.

8.1.2 State of development of P fertilizer

8.1.2.1 State of international PR and phosphoric acid resources

1. Phosphate rock (PR)

Phosphate rock is the basic raw material of P fertilizer. It is also a resource that cannot be regenerated. In 2001-2005, world production of PR increased from 126 to 147 Mt. China contributed 46%, the US 21% and Morocco, 15%. IFA has estimated that by 2010, world PR production will reach 195 Mt, with 30% coming from China. The volume of consumption is increasing but the volume of resources is limited. In the past 5 years, verified reserves of world's PR have only increased from 170 to 180 Mt. The US's reserves increased by 200 Mt. In India and Egypt, 100 Mt of recoverable reserves were found respectively. There was nothing found in other countries.

As the volume being mined increases, the quality and price of PR are undergoing unfavourable changes. American PR is of decreasing quantity and falling quality. Compared with the 1990s, production has dropped by 20%. Average grading has dropped from 66% to 63%. Cost of mining, on the other hand, has gone up by 24%. The volume of global phosphate rock trading dropped from 34 Mt in 1997 to 30 Mt in 2004, the major reason being the increase in demand for the phosphate fertilizer industry in Morocco and China, causing exports to decrease. According to IFA and Mosaic estimates, the volume of global PR trading will decrease further.

The quality of PR in China is also deteriorating whilst its price is increasing at a fast rate. Consequently, the local governments are beginning to adopt a number of measures to plan and restrict the mining of PR. Hubei Province has begun enforcing planned mining of PR. The latest promulgated document of "Interim Measures for the Control of PR Resources in the Province of Hubei" stipulates the implementation of controlling the total volume of PR according to scale of mining. The system of licensing is implemented for PR enterprises. Mining enterprises with a scale of less than 100,000 t are given a time limit to reform their operation.

2. Sulphur (S)

World S resources are almost inexhaustible. However, as a natural resource, the utilization of S is very limited. In 2002, the world's S reserves were around 1.3 Bt and the basic reserves stood at 3.5 Bt, mainly distributed in North America, the Middle East, Europe and East Asia. Computed according to reserves, Canada, Poland, Saudi Arabia, China and the US occupy the first five positions. The sum of reserves in these five countries accounts for 41.5% of the world reserves. Canada has about 160 Mt or 12.3% of the world's total. Reserves in Poland, Saudi Arabia and China are also above 100 Mt. The S used in social development comes chiefly

from recovered S in the utilization of petroleum and fuel gas. In 2004, S production was estimated at 46 Mt. Of this, S recovered from petroleum, heavy oil and fuel gas reached 45.2 Mt or about 98%. Other outputs were less than 2%. S outputs by North America, the former Soviet Union and the Middle East account for 38.2%, 17.9% and 25.4% respectively, of the world's total S production.

Demands for and production of S in the world are growing simultaneously. However, the points of growth in world S production are concentrated in the former Soviet Union, the Middle East and regions of Latin America. It is estimated that total production of S in the world will reach 51 Mt in 2007. According to IFA estimates, during the period of 2006 to 2010, the annual global excess of S will be 2.6 to 2.8 Mt. This represents an opportunity for the Asian region where the annual import is as much as 7 Mt. However, for S, there is great heterogeneity between supply and demand. Output and the S content of petroleum and natural gas determine the supply of S while the demand for P fertilizer determines the demand for sulphur. Besides, the supply of S is also dependent on the conditions of physical distribution between the place of production and the region of consumption. The cost of transport by sea, rail and road all play a part in determining the supply of S. For example, at the beginning of December 2003, the Baltic Dry Index (BDI) reached the highest record in its 20-year history. It has been rising since 2004. The trend of successive falls in S prices was halted and prices started climbing steadily (Figure 8-1). This brought tremendous effects on the S market and the P fertilizer industry in China, India and the North African region. At present, the S supply volume is directly regulated and controlled by some technologies to a very large extent. Of these, re-injection of acidic gases causes complex effects on the supply of S. There are more than 60 re-injection projects going on in North America. In western Canada, re-injection of hydrogen sulphide into exhausted wells has reached a sizable scale and has begun affecting the supply of S in this region. In the Caspian Sea region, many projects are also being planned. Application of the technology of re-injection will reduce S output of 70,000 t/y at the peak of oil production to 20,000 t. All these are major variables in the international S market. As a result, they also determine the instability of S supply in China.

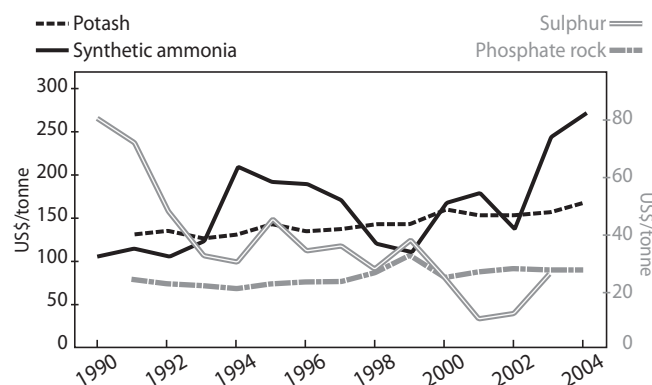


Figure 8-1 Trend of international raw material prices.

8.1.2.2 International P fertilizer development – towards preponderant mergers and augmentation of scale

Even with resource and market restraints, world P fertilizer enterprises are fast moving onto the new track. Going big is the major feature. In January 2004, the two largest P fertilizer manufacturers – American Cargill and IMC - announced their merger to establish a new listed company. The production capacity for P fertilizers of the new company after merger was 14.4% (based on P_2O_5) of the world's total production capacity. The annual production capacity for high-analysis P fertilizers (DAP/MAP/TSP) exceeds 13 Mt. The annual production capacity for K fertilizers exceeds 10 Mt (IMC) or 15.5% of the world total. The Al-Jalamid project being planned for construction by the Saudi Arabian mining company of Maden is the largest P fertilizer joint production enterprise in the world. This project includes the phosphonitrile mine with an annual production of 4.5 Mt (located in the north-western part of Saudi Arabia) and a DAP plant with an annual production of 2.9 Mt (located at Ras Al Zawr, that is, the Arabian Gulf). The project was started in July 2005 and by December 2008 the first DAP production line will be in operation. The products will enter Asian markets with the main destinations being Iran, India, China and Pakistan.

8.1.2.3 P-deficient countries – where P fertilizer growth is fast but where there is a lack of funds, technology and, support in resources

For countries with a huge demand but deficient in resources, seeking cooperation is the major course to take. The Indian Farmers Fertilizer Cooperative Limited (IFFCO) plans to build a phosphoric acid plant capable of producing 500,000 t of P_2O_5 a year at Kandla but the project is still being studied. The Brazilian company of Copebras P Industry invested US\$250 M to expand its Catalao and Cubatao P fertilizer plants with the plan to raise its P ore flotation capacity to 2.2 Mt a year and to double its production capacity for MAP, SSP and TSP (from an annual production of 1.3 Mt to 2.8 Mt). The expansion plan will be accomplished according to estimate. The Thai company of Granular Growth will build a high-analysis compound fertilizer plant capable of producing 300,000 t/y at Rayon in Eastern Thailand. South Africa and India will carry out co-operation in the area of P fertilizer. The Indian company, Coromandel Fertilizer, will acquire 2.5% shares in the South African Foskor Phosphate Fertilizer Company, its shareholding reaching 16.5% three years later. Office Chérifien des Phosphates (OCP) in Morocco and Fauji Fertilizer Bin Qasim Ltd. (FFBL), a P fertilizer company in Pakistan are investing 800 M Dirhams to build a phosphoric acid plant with an annual production of 375,000 t of P_2O_5 in Morocco. Its production will be used mainly in resolving the demand for phosphoric acid by the DAP production in Pakistan. Paradeep Phosphates Limited (PPL) in India plans to increase its annual DAP production from 720,000 t to 1.2 Mt. In Vietnam, annual production capacity of domestic NPK compound fertilizer will reach 2 Mt and the country will no longer import NPK compound fertilizer (Vietnam still indicates its intention to import 2.2 Mt of other chemical fertilizers, including 850,000 t of urea, 550,000 t of DAP and 450,000 t of AS. (quoted from *Huafei Daobao*, 2004).

8.1.3 State of development of K fertilizer

8.1.3.1 State of international K resources

There is no global shortage of K resources. At present, the verified reserves amount to 8.1 Bt with the bases of reserves at 16.7 Bt. This can be exploited by the world for more than 300 hundred years. However, K mines in the world are concentrated in four countries, Canada, Russia, Belarus and Germany. The verified reserves of these countries account for 92% of world reserves. Canada accounts for two thirds of the world's total resources. Imbalanced distribution of resources puts pressure on most countries deficient in K and import is the only channel for them. Data about K fertilizer companies in Canada indicate that only 12 countries produce K fertilizer but there are 150 countries applying this fertilizer. The world import-export volume accounts for more than 80% of the total output volume. This determines the highly international nature of the K fertilizer industry. Currently the major K fertilizer exporting countries in the world are Canada and Russia. Belarus, Germany and Israel are the other exporters. The major K fertilizer importing countries are the US, China and Brazil. The volume of consumption of these three countries accounts for 40% of world consumption.

8.1.3.2 Development trend of the international K fertilizer industry

Since the production of K fertilizer began in 1861 by a German extracting KCl from brine, the industry has gone through stages of “growth – reduction – growth again.” After the 1960s, with growing demand in the international K fertilizer market, output grew by 800,000 t each year. It reached its peak in 1988. Subsequently, with the demand for K fertilizer in the developed countries shrinking, international K fertilizer giants adopted the strategy of determining production according to sale. Output gradually dropped and it hit rock bottom in 1993. During this period, on average, the annual reduction in output was 2.2 Mt. Later, the K fertilizer industry began to recover because of increased demand from developing countries. However, it was obvious that supply outstripped demand. The major suppliers generally maintained their rate of operation at 65% to 70%. Since 2000, demand in the international K fertilizer market boomed further. International K fertilizer suppliers increased the utilization rate of their installations. In 2004, the utilization rate was raised to more than 80%. By the first half of 2005, idle production capacity was very low. Data of the United States Geological Survey indicated that, in 2004, global K fertilizer output totalled 29 Mt. Of this, Canada accounts for 9 Mt, Russia 5 Mt, Belarus 4.3 Mt, Germany 3.2 Mt, Israel 2.1 Mt and Jordan, 1.3 Mt.

The highly concentrated distribution of K resources has led to the highly concentrated and large-scale production of K fertilizer industry in the world. Data from the Canadian company, Potashcorp, indicates that the annual production capacity of the company has reached 12.5 Mt of MOP. In 2004, output was only 8 Mt. Its idle production capacity was 86% of the total idle capacity throughout the world. For Belaruskali in Belarus and Mosaic in the US, their outputs in 2004 were more than 7 Mt. Next come ICL of Israel, Uralkali in Russia, K+S (Kali & Salz) in Germany and Silvinit in Russia. The annual production of these companies was between 4 to 5 Mt.

Besides, Arab Potash in Jordan and Agrium, an agrochemical company in Canada produce about 2 Mt annually. These large companies monopolize the major K production internationally. With improvement in the international market, some international companies are increasing their production capacities and others are still planning to expand their capacity. The Canadian Potash Company is planning to expand its production capacity while the Arab Potash Company (APC) has decided to raise the production capacity for K at Safi by 25% in 2007 which will then reach 2.5 Mt.

8.2 Development outlook of the chemical fertilizer industry in China

8.2.1 Nitrogenous fertilizer

Analyses of information from IFA and Chinese authorities indicate the next few years are peak years for the development of the chemical fertilizer industry. In its summary of plans for petroleum and chemical industries in the "11th Five-Year Plan," the CNFIA has described the prospects for the development of N fertilizer in China. It is estimated that by the end of 2005, the production capacity of newly added urea plants should be 3.4 Mt (not including gap filling, revamps, expansion, the same below). By 2006, newly added urea production capacity will be about 4.0 Mt. This includes eight sets of "1830" (1 set includes 180,000 t ammonia and 300,000 t urea capacity per year) and 1 set each of 620,000 t, 700,000 t and 250,000 t urea capacity per year. From 2007 to 2010, it is estimated that there will be another 4.3 Mt of new installations going into production. By then, the production capacity of newly built urea installations by domestic enterprises will bring an increase of 11.7 Mt compared with 2004. For other N fertilizer types such as ABC, production capacity will be maintained at a more stable level. On the other hand, AC will increase to 2.5 Mt (output at 2 Mt). By 2010, total production capacity for N fertilizers will be increased from 37 Mt in 2005 to 43 Mt. It is estimated to reach 55.5 Mt of which total production capacity for urea will increase from 22 Mt to 28.2 Mt.

8.2.2 Phosphate fertilizer

IFA recently estimated that the world consumption of P fertilizer before 2008 would grow at a rate of 2.7% and the volume of demand would reach 30 Mt. Globally, production capacity will grow at an annual rate of 11%. Up to 2008, the net increase in production capacity will be 4.6 Mt, bringing the total capacity to 46.4 Mt. The volume of increase in China will be 2.3 Mt of which 80% will be high-concentration products of DAP and others. Based on a 3% increase in demand, the CPFIA estimates that consumption of P fertilizer will reach 12.8 Mt by 2008, about the same as the production capacity. This includes 3.9 Mt SSP, 700,000 t of FCMP, 3.9 Mt of MAP, 380,000 t of TSP, 100,000 t of NP and 1.5 Mt of NPK. By then, the production capacity, in terms of product quantity, for DAP and MAP will be 8.5 Mt and 6.5 Mt respectively and NPK will be above 10 Mt. By 2010, production capacity according to estimate will be increased from 13 Mt in 2005

to 15 Mt which is even faster than the estimate made by the CPFIA in 2005 (Table 8-3). Production capacity for AP will reach 8 Mt of nutrients.

Table 8-3 Production capacity and target output by 2010 for P fertilizer in China ('000 tonnes of P₂O₅)

| Year | Newly Added Capacity | Lost Capacity | Production Capacity | Output | Demand |
|------|----------------------|---------------|---------------------|--------|--------|
| 2005 | | | 13000 | 11000 | 11000 |
| 2010 | 1500 | 300 | 14200 | 12000 | 12000 |
| 2020 | | | 15000 | 13000 | 13000 |

Note: Newly added capacity in 2010 will be 1.5 Mt. Loss of production capacity of 300,000 t due to reasons that include change in the line of production, switch to other products, market competition, environment protection, elimination resulting from poor management, closure, shrinkage in the production capacity of low-analysis P fertilizer. Actual growth in capacity will be 1.2 M t. Data obtained from the CPFIA, 2005.

In its "Programmes for the 11th Five-Year Plan," the CPFIA put forward its idea of the development of three 70 per cents. According to the Association, by the year 2010, the proportion of high-analysis P fertilizer production will reach 70%; production capacity of bases will account for 70% of the country's total output and output by large enterprises will be 70% of the total. At present, AP production bases are being formed in the provinces of Yunnan, Guizhou and Hubei. Yunnan Sanhuan Zhonghua has started building its installation for producing 1.2 Mt of DAP annually. Work on the Phase II installation of 600,000 t at Furui will soon commence. On completion of these two projects, production capacity for DAP in the province of Yunnan will exceed 4 Mt. The Kailin Group in Guizhou Province is planning to set up a DAP plant capable of producing 1.2 Mt annually. Preliminary work is being stepped up. The construction of a P compound fertilizer base has been under consideration in Hubei Province. The Hubei Ezhong Chemical Industry Group Company plans to set up a compound fertilizer installation with an annual capacity of 400,000 t at Yidu with total investment of RMB160 M. In the provinces of Shandong and Sichuan and the northwest region, development in compound fertilizer is more popular. The Shandong Shikefeng Chemical Industry Co. Ltd. presently has an annual production capacity of 800,000 t for compound fertilizers and MAP. At this juncture, work has commenced on its 1 Mt compound fertilizer project in the Linyi Economic Development District. Total investment is RMB920 M. The annual production capacity for P compound fertilizer of Zhonghua Fulin Chemical Industry will be raised to 2 Mt. Construction of compound fertilizer installations (two of capacity of 200,000 t) is going on in the provinces of Ningxia and Shaanxi.

8.2.3 Potash fertilizer

Unlike the development of the international K fertilizer industry, the K fertilizer industry in China started late. However, it began growing very fast from the 1990s. In 2004,

output had already reached 2.1 Mt (K_2O). If we take into consideration the repeated production resulting from part of the KCl production being switched to the production of SOP, the actual KCl output will be about 1.5 Mt (K_2O). This amount of output placed China in the fifth position in the world. Of course, compared to Canada and Russia, there is a big gap. With the 2 Mt Qinghai K project going into production (in 2004, 1.1 Mt from the Chaerhan Salt Lake and 1.4 Mt from the Chaidamu Basin), completion of the Citic Guoan Group's $K-MgSO_4$ project in 2007, official commencement of operation of the 1.2 Mt SOP project at Luobupo in Xinjiang Province (long-term construction is for 3 Mt with a total investment of RMB8 B), the development of K resources in the northeast of Thailand by the China Mingda Chemical Industry Group with an investment of RMB1.7 B (initial production of 1 Mt of KCl, long-term production of 3 Mt) and the 1 Mt KCl project to be developed in Thailand by China Zhongliao Mining Industry Co. Ltd., it is estimated that by 2010, the production capacity of K fertilizer in China will be raised from 2.5 Mt in 2005 to 3.5 Mt. Considering the fact that the ratio of soluble K resources is low and reserves of insoluble K resources are high in China (average content of K_2O being 10%), it is very difficult to make up the present deficit of more than 4 Mt. Besides, there is still room for the growth in demand for K fertilizer. The first main reason is that increases in the area of cultivation of cash crops and people's demand for products of higher quality may lead to increased demand. Secondly, the extension of the technique of fertilizer application based on formulation after soil test encourages the development of compound fertilizer and this will also increase the recommended quantity of K fertilizer. Such conditions have determined the scenario of long-term dependence on imported K fertilizer.

8.3 State of agricultural production and demand outlook

8.3.1 Analysis of the state of fertilizer demand in China

8.3.1.1 Factors affecting the demand for chemical fertilizers in China

Chemical fertilizer is a special commodity. Both its production and application involve human activities but the real consumers are plants. Plants must absorb nutrients for growth. It is because nutrient supply from the soil and the environment cannot satisfy plant needs that fertilizer application is required. The theoretical rational nutrient requirement of crops for chemical fertilizer is defined as "the quantity of chemical fertilizers that must be supplemented for the achievement of a set growth objective under certain environmental conditions." These requirements are affected by the crop itself and conditions of the environment in which the crop grows, such as the climate, the crop variety, geographical conditions, soil fertility and input of organic fertilizer. Since the people applying chemical fertilizer are influenced by various social factors, their final decision on the volume of consumption often deviates from the theoretical requirement,

thus, forming the market or demand for chemical fertilizer. The definition of market demand should be "the required quantity of chemical fertilizer derived when the actions of farmers are unable to attain the ideal, scientific level under the influence of the society, the economy and technology." Market demand is relatively complicated. Factors that affect market demand sometimes work independently or are inter-related. Therefore, it is difficult to forecast market demand. These two concepts of chemical fertilizer requirement are different and yet relatively unified, as theoretical requirement will also be influenced by changes in farmers' objectives of production (output, area, variety). These objectives change with changes in socio-economic development. The theoretical requirement is the foundation, a possibility of long-term existence, whereas market requirement is a form that is expressed within a short period. In the forecast of demand for chemical fertilizer, different methods of calculation should be used depending on the objectives and the influencing factors.

The chemical fertilizer industry in China has its own uniqueness. According to theories of industrial economics, the supply and price of chemical fertilizer will affect its consumption. On the other hand, theories of agricultural production and investment, states that the amount of income of peasant households, sources of income and the efficiency of input-output will have an effect on the consumption of chemical fertilizer. According to plant nutrition theories, changes in the cropped area, land use structure and crop production will have an effect on the consumption of chemical fertilizer. Based on the social nature of chemical fertilizer, growth in population, changes in the measures of macro regulation, control and adjustment of agricultural policies will affect chemical fertilizer consumption. These many factors and their interlocked changes have made it very difficult to forecast the demand for chemical fertilizer. Looking at the course of development of Chinese society comprehensively, population growth, urbanization, and changes in the food composition brought by improved standard of living should be the unavoidable trend. The environmental problems that accompany this have caught the attention of the entire society. Even though agriculture has a long period of technological transformation, great changes are very likely to occur within 10 to 30 years. Technological factors must be taken into consideration in long-term development. Consequently, forecasts of long-term demand for chemical fertilizer must take into consideration the trend of change in the above factors. In the short term, factors that are likely to change within 5 years include agricultural policies, structure of cultivation and economic development. Population, food composition and levels of technology are less likely to change in the short term and they, therefore, have smaller effects.

8.3.1.2 Development trends of major influencing factors

1. Trend of development in agriculture

Taking a long-term view, with continuous growth in the population, total demand for food in China will increase further. According to programmes for the national agriculture and rural economic development in the 11th Five-Year Plan (2006-2010), the following developmental targets are to be

realized with much effort. Firstly, a steady growth must be maintained for the supply of major agricultural products, that is, not less than 103.3 M hectares should be sown with grain crops and the overall production capacity for grains should be about 500 Mt. Output of cotton, oil crops and sugar crops should reach 6.8 Mt, 32 Mt and 120 Mt, respectively. There should be stable, if not, increased supply of vegetables and fruits. Total production of meat, eggs and milk should be 84 Mt, 30 Mt and 42 Mt, respectively. Total output of aquaculture products should reach 60 Mt. The direction of future agricultural development indicated in the "11th Five-Year Plan" is the stabilization of the area of grain cultivation; raising the output of the various crops and optimization of operational structure.

In the short-term, the good trend in the preceding two years has been extended to 2006 as shown below.

Growth in output

In October 2006, information from monitoring announced by the National Grain & Oil Information Centre indicated that in 2006, total grain output throughout the country had exceeded the set target by 490 Mt. Maize output increased by 1.2% with the total output at 141 Mt. Wheat output increased by 5.7%, with the total output reaching 103 Mt. Rice output grew by 1% with the total production amounting to 182 Mt. Production of soybean was reduced by 5.2%, bringing down the total output to 15.5 Mt. It is worth noting that the growth in grain production in China at this stage is not completely dependent on increases in cultivation area. For example, area cultivated for wheat increased only by 2.1% but the total output increased by 5.7%. The area cultivated for maize also increased by 2.1% but the contribution from the increase in unit production is getting bigger.

Enhanced support

The Ministry of Agriculture has fully initiated the enhancement of the comprehensive production capacity for grains throughout the country, striving to raise the overall production capacity for grains by an average of 5 B kg/y and per unit area production by 1% during the period of the 11th Five-Year Plan so that by the end of the 11th Five-Year Plan, the average grain production per *mu* (1 *mu* = 0.0667 hectares) will reach 325 kg and the overall production capacity will reach the goal of 500 B kg. On the other hand, in order to enhance grain production capacity, the subsidy for grain production in 2006 was further increased. Direct grain subsidy was RMB14.2 B and the direct comprehensive subsidy for agricultural materials was RMB12.5 B. This works out to be an average of about RMB18 per *mu*. This will further increase the enthusiasm of peasant households in grain production.

2. Trend of technological development

Relevant information from the Ministry of Agriculture indicates that the central finance authority has arranged for a total of RMB700 M for the implementation of the subsidized project on fertilizer application, according to formulation after soil tests, in 600 counties. The local finance authorities arranged for RMB360 M to carry out fertilizer applications, according to formulation after soil tests, on different scales and extents in more than 500 counties. Through the joint

effort of the agriculture departments, fertilizer application, according to formulation after soil tests, has accelerated the increase in grain production. The range of increase in crop production is on average 8-15%. In some cases, 20% is obtained. The utilization rate of chemical fertilizers can be raised by more than 5% and on the average about 10 kg of fertilizer can be saved per *mu*. According to expert estimates, if the system is extended throughout the country, more than 2.3 Mt (conversion to pure nutrients) of fertilizer can be saved each year. The energy saved is more than 10 Mt of standard coal. A survey on cultivation carried out by the Ministry of Agriculture showed that in 2006 in the province of Henan, yield per *mu* on average increased by 32 kg or 9%. The total increase in wheat production was 800 M kg. A comparison between fertilizer application according to formulation after soil tests and conventional fertilizer application for double cropping of rice in the province of Hubei, showed unit area production was increased by more than 10% and the total increase in rice yield was 1.6 B kg. In 93 counties carrying out the project on winter wheat, improper application of fertilizer was reduced by 37,000 t (conversion to pure nutrients) saving production cost by RMB160 M. Total increase in wheat production amounted to more than 400,000 t and income increased by RMB680 M. The amount from cost-saving and improved effects totalled RMB840 M or RMB37 per *mu* on average. In the first half of 2006, reduction in the use of N fertilizer and increase in the consumption of K fertilizer was observed in 600 counties carrying out the project. All these go to explain that output can be increased with slight improvements in the technique of fertilizer application, saving chemical fertilizer at the same time. In the "11th Five-Year Plan," it is emphasized that while enhancing the overall production capacity for grains, the utilization efficiency rate of chemical fertilizer has to be increased by 5%. If the utilization rate of fertilizer could be raised by 5%, based on the year 2005, the amount of fertilizer saved would be 5 Mt and grain production would be increased by 500 Mt.

3. Trend of market development

For more than half a century, the use of chemical fertilizers has been increasing at the rate of 1 Mt of pure nutrients each year. Based on the average consumption in the past 5 years, there is a 3.26Mt annual increase per year. In the apparent volume of consumption, N fertilizer accounted for two thirds and it seems the increase in the consumption of N fertilizer has been the main driving force. The average increase in the consumption of chemical fertilizers in agriculture throughout the country in the past 5 years was only 1.0 Mt. The yearly increase of single N, P and K fertilizers was only 130,000 t, 76,000 t and 179,000 t, respectively whilst the average annual increase in compound fertilizers was 640,000 t. Statistical data from enterprises showed that even though nutrient distribution ratios of compound fertilizers have changed tremendously, for 50% of the compound fertilizers, the nutrient distribution ratios are still 15:15:15. Apart from compound fertilizers, the average volume of increase for N, P and K fertilizers in the past 5 years was 343,000 t, 289,000 t and 392,000 t, respectively. The main effect of the increase in the consumption of compound fertilizers is the promotion of consumption of P and K fertilizers.

From the above-mentioned analysis, the following can be determined:

- a. Firstly, driven by a population increase in China, fertilizer production will continue to increase but at a slower rate.
- b. Secondly, growth in the consumption of single fertilizers will not be rapid. Instead, growth in the consumption of compound fertilizer will be the main contributor. The application of compound fertilizer will accelerate the consumption of P and K fertilizers.
- c. Thirdly, fertilizer application, according to formulation after soil tests, will help save chemical fertilizer without affecting output or with increases in yield. Its potential is tremendous. If this project can be implemented steadily in the coming few years, chemical fertilizer consumption throughout the country will not increase. Instead, it may drop by 5 Mt.
- d. Fourthly, the small quantity of organic fertilizer applied in China is the chief reason why the demand for P and K fertilizers continues to grow and this has also promoted the consumption of compound fertilizers. In the few years that follow, with the expansion of the system of intensive animal husbandry in China and the establishment of dominant regions of cultivation, the shortage of organic fertilizer encountered by small peasant households may still be around. Therefore, shortages of P and K fertilizers will still have to be resolved. Thus, consumption of P and K fertilizers may increase further.

8.3.2 Demand for N fertilizer

N is the major raw material in the synthesis of protein and chemical fertilizers are the main source for its replenishment. Therefore, with an increase in population, demand for chemical fertilizer will continue to grow. However, as excessive input of N may result in environmental problems such as the enhancement of the greenhouse effect and nutrient enrichment of water bodies, N has become a nutrient that is indispensable but one that cannot be applied in excess. Population and the environment will be the major factors affecting the demand for N fertilizer. Based on the three schemes of high, medium and low population growth rates presented by the proper authorities and in accordance with the parameters that include per capita grain requirement in the diet of a fairly well-off standard of living [400 kg/(person year)], food sufficiency rate (90%), the minimum value of nutrient requirement for grain production and the present value of nutrient supply of chemical fertilizers (N: 70%), N fertilizer efficiency rate of 35% and the demand for N fertilizer by grains being 67.1% of the total demand, we can calculate the quantity of demand for N fertilizer to guarantee food security. According to the scheme of low population growth rate, the quantity of demand for N fertilizer in China will reach the highest value in 2020, that is, 34.5 Mt (pure nutrients). According to the scheme of medium population growth rate, the highest value of 36.5 Mt will be reached in 2030 while according to the scheme of high population growth; demand for N fertilizer will continue to increase until 2050.

When viewed from the angle of environment protection, if we calculate using the maximum and the minimum values of N input volume according to different soil types and crops in

accordance with European agricultural environment policies, the minimum permitted quantity of N fertilizer input that should be set for the protection of the environment (attaining the European environmental standards) is 27.3 Mt and the maximum limit is 39.2 Mt. However, in 2002, N fertilizer consumption (29.1 Mt) in China had already exceeded the minimum limit for environmental security mentioned above. Even under the low population growth rate scheme, increase in the demand for N fertilizer in China will put further pressure on the environment. By 2050, it will exceed the lower limit for environmental safety of 2.3 Mt. If we relax the environmental standards and calculate according to the highest value of the upper limit for environmental safety, the estimated demand for N fertilizer according to the scheme of low population growth rate and the scheme of medium population growth rate, the quantities of demand for N fertilizer are still within the limits of environmental safety. However, using the scheme of high population growth rate, by 2030, the demand for N fertilizer will exceed the upper limit of environmental safety.

From the results mentioned above, future demand for N fertilizer will still increase in order for China to guarantee food security. This type of developmental trend will surpass the load-bearing capacity of the environment. Even though the environmental problems and conditions of agricultural production in Europe are rather different from China, there are lessons to be drawn from their measures of environmental restrictions. In order to learn something from Europe's experience of tackling the pollution issue only after it has taken place, China should adopt measures to raise the efficiency of chemical fertilizer. Seen from the angle of agriculture, if N accumulated in the soil and other sources of N in the environment can be fully made use of, then besides greatly reducing the volume of N fertilizer used, the rate of N fertilizer efficiency can be raised up to 40-70%. In addition, the promotion of crop varieties with high and stable yield and adjustments in the cultivation practices are also key measures in reducing the volume of N fertilizer used and in protecting the environment. To the chemical fertilizer industry, improving product quality, raising the standard of agrochemical services and giving material support for the efficient utilization of N fertilizer are of utmost importance. Enterprises of N fertilizer should get a clear understanding of the situation to avoid simple increases in output. From the point of laws and regulations, even though China does not set values for environmental safety with regard to fertilizer input, the experience in Europe should be taken as reference in the formulation of similar policies based on the conditions in China. Such policies should cover the twofold requirement of balancing food and environmental safety through the setting of proper standards for chemical fertilizer application, dissemination of knowledge and consciousness.

8.3.3 Demand for P fertilizer

There are different principles in the demand between P and N fertilizer. N is the component that constitutes crop protein. With an increase in crop production, the amount of N removed will also increase. P is the material component of the metabolic process of crop nucleic acid. Its content in the crop plants is not high (about 20% the content of N). Under

certain demand for the N element, it is sufficient to maintain the element of P at a relatively suitable content. On harvesting the crop, the straw and root system will retain most of the P. After returning to the soil, this part of the P will supplement the next plant P nutrient requirement. The oversupply of P does not increase yield; it may bring many negative effects. Consequently, when applying P fertilizer, it should be on the basis of maintaining the level supplied by the soil. It is replenished by the right quantity based on soil fertility as the standard of assessment. At the same time, the bearing capacity of the environment is taken into consideration.

The difference in the level of effective P in Chinese soils is large, from 6-30 mg/kg or even higher. Through a literature review, Cao Ning and others from the China Agriculture University estimated the average effective P in Chinese soils to be 19 mg/kg. In the 1970s, China switched from a deficient to a surplus status. By 2003 P accumulated in the soil was about 3.3 Mt. In terms of the unit area of cultivation, it was 392 kg/ha. Comprehensive calculation of the P surplus will increase the level of effective P by 0.03 mg/kg. Based on international and domestic experience, effective P in the soil should not exceed 60 mg/kg; otherwise it will lead to leaching loss, causing damage by nutrient enrichment of water bodies. Maintaining it between 30-40 mg/kg is advantageous to crop growth and favourable for environment protection. Based on this, the peak of demand for P fertilizer in China will appear around 2020, the quantity of demand being 12.5 Mt (based on grain output of 640 Mt in 2030). Once this quantity is reached, P fertilizer input should be reduced and surplus P in the soil should be made use of fully. Demand for P fertilizer will still grow before 2020. If grain production reached 500 to 550 Mt in 2010, the amount of P removed by harvesting grain crops would be 1.9 to 2.1 Mt. In order to effectively improve soil fertility, the quantity of P fertilizer applied should be 1.5 times the amount removed by the crop. Grain crops require about 6.5 to 7.2 Mt of P_2O_5 . The area of cultivation of other cash crops may continue to expand but present consumption of fertilizer is already very high and there is the possibility that it may decrease. Consequently, assuming that the volume

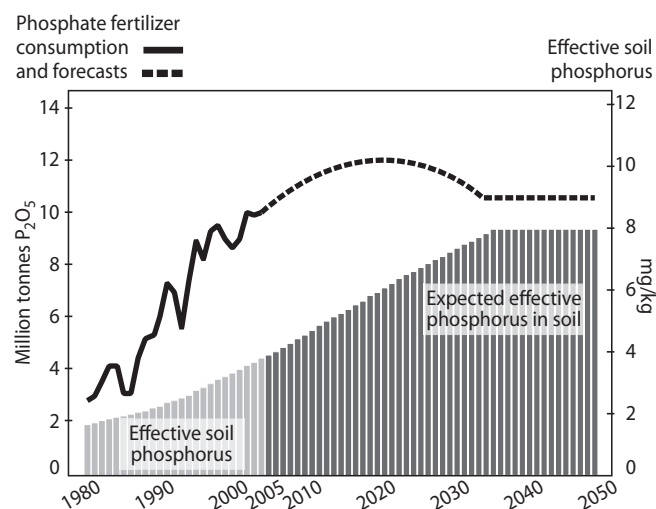


Figure 8-2 Forecasting China's phosphate fertilizer demand by the maintenance of soil fertility (Cao Ning *et al.*, 2007).

of P fertilizer (P_2O_5) used by other crops is maintained at the present level, that is, 2.7 Mt for cash crops such as fruit trees and vegetables, 1.3 Mt for forestry, 200,000 t for grass and 360,000 t for fisheries, then in 2010, it is estimated that the overall quantity of demand each year will be about 11.1 to 11.8 Mt (Figure 8-2).

From 1980 to 2005, values of effective soil P were actually calculated and are indicated in black. Values after 2005 are forecasts and are indicated in grey stripes.

8.3.4 Demand for K fertilizer

The trend of K fertilizer demand is similar to N fertilizer. The K content of crops is second to N, thus with an increase in crop output, demand for K will also increase. K is easily fixed in the soil. The efficiency rate is low in the current season of cultivation, and the K left in the soil cannot be used efficiently by the next crops. K remains mainly in the straw of crop plants. With increases in other uses for straw, the rate of re-utilization will decrease. As a key factor that forms the good quality of the edible part, the increase in the quantity of demand for K will assume the shape of a flight of stairs, that is, when the output of crop is raised to a certain level, there is an abrupt increase (also referred to as extravagant absorption). Based on the above features, the future demand for K fertilizer in China will increase further. With the present level of technique in fertilizer application and the small fluctuations in the output, forecasts are still being carried out according to the present level of utilization, at the same time, taking into consideration the per capita grain requirement in the diet of a fairly well-off standard of living [400 kg/(person year)], the food sufficiency rate (90%), the minimum value of nutrient requirement for grain production, the present value of nutrient supply of chemical fertilizers (K: 40%), the efficiency rate of K fertilizer is 47.5% and the ratio K fertilizer required by grains crops to the total demand is 64%. In this way, we can calculate the quantity of demand for K fertilizer to guarantee food security. According to forecasts about China's population in 2010 by the Population Department of the United Nations (divided into the three schemes of high, medium and low birth rates), based on the scheme of low population growth rate, the quantity of demand for K fertilizer in China in the year 2010 will be 12.5 Mt K_2O . Based on the scheme of medium population growth rate, the quantity of demand will reach 12.6 Mt in 2010 and based on the scheme of high population growth rate, it will reach 12.7 Mt.

8.3.5 Overall demand for chemical fertilizer

According to IFA forecasts, demand for chemical fertilizer will grow in the coming years but there will be differences in the demand for different fertilizer types. It is estimated that N fertilizer will grow at a slower rate while P and K fertilizers will grow at a slightly faster rate (Table 8-4). About 60% of the growth will come from developing countries, in particular, China. According to the population growth and food demand in China for the next 25 years, on the assumption that 90% of food demand will be supplied domestically, it is predicted there will not be a big increase in the basic demand for

nutrients for agricultural production. From 2005 to 2030, the theoretical demand for N fertilizer will increase from 16.8 Mt to about 20 Mt, an increase of 3.2 Mt. The theoretical demand for P fertilizer will increase from 6.2 Mt to 7.4 Mt, an increase of 1.2 Mt. The theoretical demand for K fertilizer will increase from 17.2 Mt to 20.4 Mt, an increase of 3.2 Mt (Table 8-5). If all these nutrients are to be supplied by chemical fertilizer, and the efficiency rate of chemical fertilizer is about the same as in developed countries, then the existing consumption of chemical fertilizer has exceeded the desired volume. Because of the low efficiency rate of chemical fertilizers in China (average efficiency rates of N, P₂O₅ and K₂O are 30%, 26.7% and 40%, respectively), the extremely low level of input of organic nutrients (organic N, P and K make up 30%, 50% and 70% of the total volume of input of nutrients), an increase in the demand for chemical fertilizer will continue. If domestic chemical fertilizer efficiency rate is able to reach the level in the experimental fields presently (60%, 66.4% and 60% of N, P₂O₅ and K₂O respectively), then the quantity of demand for chemical fertilizer throughout the country will be far lower than the present actual volume of consumption (Table 8-5) and growth will be very small, reaching the maximum volume by around 2020. If no measure is taken to improve the efficiency rate and the present situation continues, there will still be a big increase in demand for chemical fertilizer and the maximum quantity of demand may reach 49.9 Mt of N, 14.8 Mt of P₂O₅, 16.4 Mt of K₂O and the total volume may probably exceed 80 Mt. From the analysis of these two situations, the level of demand for chemical fertilizer in China depends, to a very large extent, on fertilizer application techniques and increases in the utilization efficiency rate of chemical fertilizer. The present situation of low utilization efficiency rates is the main cause for the continuous increase in the demand for chemical fertilizer. Consequently, in order to increase the utilization efficiency rate of fertilizer from the present 30% to 40%, relying on actions in fertilizer application according to formulation after soil tests and the extension of other techniques, we have to follow the example in more advanced countries so that the utilization efficiency rate of fertilizer exceeds 50%. It can thus be seen that there are many variable factors that affect fertilizer demand forecasts.

Advanced techniques of fertilizer application will enable the level of demand to be its minimum while backward fertilizer application techniques will push the quantity of demand for fertilizer towards the maximum, causing more serious problems of resources and environment.

Table 8-4 Demand forecast for chemical fertilizer in the world ('000 Mt)

| Variety | 2005/2006 | 2010/2011 | Average Increase |
|-------------------------------|-----------|-----------|------------------|
| N | 90858 | 99389 | +1.8% |
| P ₂ O ₅ | 36771 | 41790 | +2.6% |
| K ₂ O | 26443 | 30706 | +3.0% |
| Total | 154072 | 171885 | +2.2% |

Note: Data from Patrick Heffer, 2006. Medium-Term Outlook for World Agriculture and Fertilizer Demand 2005/06-2010/11, www.fertilizer.org

8.4 Outlook for industrial policies and suggestions

8.4.1 Analysis of influence exerted by policies

8.4.1.1 Degree of policy support

An overview of the history of development of the chemical fertilizer industry, shows the relevant policies of the State went through the three stages of "support, planned management and adjustment." Even though the industry is gradually moving in the direction of market adjustment at present, most of the support policies are still in place. Of these, preferential prices for natural gas and electric power take the lead among preferential prices for raw materials. However, preferential price for electric power only applies to small and medium scale chemical fertilizer enterprises. A preferential price for coal does not exist. At present, the preferential price for transport is only for finished products, without any preferential prices for raw materials. With respect to preferential tax, for the

Table 8-5 Demand forecast for chemical fertilizer in China ('000 tonnes)

| Year | Basic Nutrient Requirement for Crop Growth ¹ | | | Minimum Requirement for Chemical Fertilizer ² | | | Maximum Requirement for Chemical Fertilizer ³ | | |
|------|---|-------------------------------|------------------|--|-------------------------------|------------------|--|-------------------------------|------------------|
| | N | P ₂ O ₅ | K ₂ O | N | P ₂ O ₅ | K ₂ O | N | P ₂ O ₅ | K ₂ O |
| 2005 | 16808 | 6204 | 17177 | 19609 | 4672 | 8589 | 39218 | 11619 | 12883 |
| 2010 | 18237 | 6732 | 18638 | 21085 | 5024 | 9235 | 42937 | 12720 | 14104 |
| 2020 | 19663 | 7258 | 20095 | 22041 | 5251 | 9654 | 47679 | 14125 | 15662 |
| 2030 | 19974 | 7373 | 20413 | 21696 | 5169 | 9503 | 49864 | 14773 | 16380 |

¹ Basic nutrient requirement for crop growth refers to the quantity of basic nutrient requirement that satisfies food production under general growth conditions in population.

² Minimum requirement for chemical fertilizer refers to the chemical fertilizer demand under conditions of low population growth and maximum utilization efficiency rate of chemical fertilizer.

³ Maximum requirement for chemical fertilizer refers to the demand for chemical fertilizer under conditions of high population growth and inability to increase the utilization efficiency rate of chemical fertilizer.

production of N fertilizers, the partial refund of VAT has been changed to full exemption. For P fertilizer production, with the exception of DAP, products are exempted from VAT. In the production of compound fertilizers, it is stipulated that when tax-exempted raw materials used account for 70% or more, the products will be tax-free (in fact, manufacturers of compound fertilizer rarely enjoy this policy). For chemical fertilizer imported within the quota, there is imposition of VAT followed by its refund. According to the policy of reserve discount interest for off-season, reserve fertilizer can enjoy interest subsidy of RMB50 /t. Due to the effect of off-season reserve quotas and market fluctuations, this support policy exists only in name. Domestically, it is generally thought that funds spent on supporting chemical fertilizer amount to RMB13 to 15 B. Recent statistical data indicate that such funds may have exceeded RMB40 B.

1. Preferential price for natural gas

The use of natural gas to produce N fertilizer was once the mainstream of development. However, with the shortage of natural gas, its price went up and some of the N enterprises began changing their raw material composition. The most important consideration was changing from natural gas to coal. In 2005, output of synthetic ammonia using gas was almost 10 Mt, accounting for 22% of total output. Gas used by N fertilizer production plants is still divided into two types of pricing – gas price within the plan and gas price outside the plan. Due to different gas sources or different technological levels, the effects of the price of natural gas on the cost of chemical fertilizers are also different. For instance, as announced by the NDRC, the price of Grade I natural gas used for the production of chemical fertilizer was RMB590 /1,000 m³. The price of gas for industrial use was RMB725 /1,000 m³. When the plans were merged, the price reached RMB980 /1,000 m³ (*Fa Gai Jia Ge* [2005] No. 510). Through their survey, the CNFIA found that the actual price of gas within the government plan used by 34 N fertilizer enterprises was RMB746 /1,000 m³ while gas outside the plan cost RMB1100 /1,000 m³ (CNFIA, 2006). According to the actual situation, taking into consideration differences in the consumption of gas by small, medium and large scale enterprises, the preferential treatment given to natural gas used in N fertilizer enterprises actually amount to RMB3.96 B.

2. Preferential price for electric power

Electric power used for the production of N, P and compound fertilizers by small and medium scale enterprises in China have enjoyed preferential price for a long period of time. Currently the preferential price for power consumption of chemical fertilizer enterprises is about RMB0.2-0.4 /degree, averaging RMB0.3 /degree. On the other hand, industrial power consumption is RMB0.5 /degree. The preference given is RMB0.2 /degree. In 2005, power consumption for N fertilizer production throughout the country was about 55.2 B degrees (inclusive of power consumption by synthetic ammonia, power for processing of synthetic ammonia to ABC and urea). Consumption by small and medium scale enterprises was RMB54 B. Therefore, in 2005, the preferential treatment enjoyed by small and medium scale enterprises were about

RMB10.8 B. Power consumption by P compound fertilizer is lower. In 2005, total output of P compound fertilizer for the entire country was 11.3 Mt. Power consumption was 3.7 B degrees and the preferential treatment amounted to RMB750 M. Thus the total preferential price for power consumed by the fertilizer industry amounted to RMB11.6 B.

3. Preferential price for transport

Transport of chemical fertilizer throughout the country has been enjoying preferential freight rates all the time (RMB4.2 + RMB0.03 × tonne km) and it is exempted from contributing to the railway construction fund (RMB0.03 /t-km). Assuming that chemical fertilizers are treated as general chemical products, that is, transport charges are according to the present Freight Rate No. 4 (9.3 + RMB0.043 × tonne km) with railway construction fund added, calculations based on the average distance of transport of chemical fertilizer of 1,000 km throughout the country show that the preferential price given to chemical fertilizer transported by railway is RMB55.4 /t. In 2005, the total volume of chemical fertilizer resources was about 159 Mt in product quantity (volume of production + volume of import). This quantity has not included the volume of the secondary transportation of about 10 to 20 Mt of products in the course of secondary processing and all fertilizer products that change hands repeatedly. Preferential prices given to rail transport of these computable resources alone amounts to RMB8.8 B. If it were thought that low-analysis chemical fertilizers (ABC and SSP) would not be transported by rail, then the quantity of chemical fertilizer transported by rail could be reduced to 87 Mt and the price preference given to rail transport would be RMB4.8 B.

4. Preferential value added tax (VAT)

Preferential VAT should include tax exemption for production and tax reimbursement for imports. VAT is a universal tax regulation. In general, the rate is 13% but can be as high as 17%. Usually, its computation involves subtracting taxes on incoming transactions from taxes on outgoing transactions. For chemical fertilizers, after subtracting taxes on incoming transactions from taxes on outgoing transactions, the actual payable tax rate is about 8%. Every link in the production of chemical fertilizer is tax-exempted. In 2005, sales income for the N fertilizer industry amounted to RMB125.6 B, with payable VAT at RMB10 B (The total exemption of VAT commenced in July 2005. Prior to this, for large scale enterprises, the policy of imposition followed by refund was implemented). In 2005, sales income for P fertilizer was RMB96.7 B and payable VAT was RMB7.7 B. In reality, DAP and most of the compound fertilizers have paid RMB1.1 B of VAT. The total amount of unpaid tax in the P fertilizer industry was RMB6.6 B. In 2005, sales income of the K fertilizer industry was RMB5.9 B and payable VAT was about RMB500 M. The volume of imported chemical fertilizer in 2005 was worth almost US\$3 B and the VAT payable was RMB1.9 B. Based on the above, in 2005, the total amount of VAT exemption was RMB16 B, with the total preferential treatment amounting to RMB40.3 B.

8.4.1.2 Existing problems in the policies concerning the industry

Policies on the chemical fertilizer industry in China give positive encouragement to the rapid and sound development of the Chinese society and economy as described below:

1. The rapid development of agricultural production has guaranteed national economic development and food requirement.
2. The rapid development of the chemical fertilizer industry has lightened the burden of exchange payments in China and reduces the inputs by peasant households (in 1990 the price of imported DAP was almost RMB2,800 /t while domestically produced DAP was only about RMB2,000 /t). From 1994 to 2004, DAP grew rapidly which helped Chinese peasant households reduce their inputs by some RMB20 B.

The present policies on the chemical fertilizer industry have also generated many negative effects as described below:

1. The policy of determining sale and requirement by production has induced excessive fertilizer applications. Data from a large-scale survey conducted in 2000 and 2002 by the Ministry of Agriculture showed that a third of peasant households applied fertilizer excessively. Calculations based on the volume of fertilizer application for a relatively high output recommended by experts showed that in 2004, over application of N fertilizer exceeded 4 Mt. The volume of N fertilizer consumption in that year according to statistics of the Ministry of Agriculture was 25.8 Mt. So excessively applied N fertilizer was nearly 20% of the volume of consumption of N fertilizer in that year. On the other hand, policies on the chemical fertilizer industry in China encourage the development of high-analysis urea and P compound fertilizers. At present, urea has already accounted for more than 60% of the total N fertilizer output while the proportion of P compound fertilizer in P fertilizers has exceeded 50%. However, urea is not the most ideal N fertilizer. In comparison, there is reduced consumption of urea in developed countries, including Europe. Instead, the volume of consumption of AN and CAN is being increased.
2. The market is chaotic
Business operators are lowly qualified and there are many levels of operations. Pricing is not clear and counterfeits abound.
3. Production enterprises are growing rapidly albeit unhealthily. The number of chemical fertilizer producing enterprises in China has exceeded 2,000. If we add small enterprises that produce mixed fertilizers to this number, the total may exceed 3,000. Every year, more than 20% of these producers run at a loss. The average profit rate is lower than 5%. The barrier of joining and withdrawing from the trade has already created the situation of vicious competition. At present, the development of this trend is accelerating. From 2003 to 2005, both chemical fertilizer output and growth exceeded 10% in China. Output increased by 5 Mt each year, equivalent to a third of the chemical fertilizer consumption of India. In fact, the cultivated area in China is slightly smaller than that of India. Whether or not enterprises are competitive will be determined by policies. The enterprises lack initiatives.

The long-term influence of industry policies has led to the emergence of many problems. The crux lies in the fact that traditional thinking which formulates the policies failed to keep up with changes of the present trend as described below:

1. For a long time, chemical fertilizer has been regarded as a material that supports agriculture, not a commodity. From the 1960s to the 1990s, chemical fertilizers were used for the production of grains and cotton. However, China has become the number one chemical fertilizer producer and consumer in the world. Chemical fertilizer has long entered the stage of complete commercialization.
2. Chemical fertilizer enterprises have been given the responsibility to support agriculture. Until today, the government is still maintaining the thought of "small profit and big sales" with regard to management of chemical fertilizer enterprises. But with market orientation of raw materials, competition intensifies. The concept of "small profit and big sales" can no longer meet the aspiration of the expanding enterprises.
3. For a long period, the government has been harbouring the idea that the slow growth of agriculture in China is due to insufficient input of chemical fertilizer, however, facts indicate that excessive chemical fertilizer application is already found in many regions and the benefits from chemical fertilizer use is beginning to decrease.
4. Chemical fertilizer is treated as a strategic material. The thought of self-sufficiency is deep-rooted. The self-sufficiency rate for chemical fertilizer is 94% and 103% for N fertilizer. The over protection of the domestic fertilizer industry has aggravated the undesirable competition, and decreased China's international competitiveness.

8.4.2 Analysis of the direction of policy adjustment and the extent of its influence on the fertilizer industry

8.4.2.1 Direction of policy adjustments in the fertilizer industry

From the year 2004, the State began contemplating the issue of changing the policy with regard to chemical fertilizer. In 2005, the NDRC carried out a full investigation and study in collaboration with a number of departments. It became clear that there is a need to enhance and change macro regulation and control. The concrete method involves gradual deduction of existing preferences and establishment of a mechanism of deployment of resources according to the market, enhancement of reserves, regulation of imports and exports and market management. With the announcement on 12 January 2005 of a regulation concerning reserves during the off-season and the gradual establishment of an early warning system for fertilizer by the Ministry of Commerce, measures for policy changes on preferential treatment are gradually being carried out in 3 steps!

1. Adjustments of the price of natural gas and rail freight charges are combined in order to raise slightly the price of natural gas used for the production of chemical fertilizer and rail freight charges, finally achieving the objective of having prices of natural gas both inside and outside the state plan to run parallel to each other.

2. The preferential price for electric power and preferential freight charges are to be abolished.
3. The preferential VAT is abolished.

Implementation of the first and the second steps have commenced (according to the stipulation in the NDRC, from 26 December 2005, the price of natural gas used for the production of chemical fertilizer would be raised by RMB50-100 /1,000 m³. From 30 June 2006, on average, price of electric power sold throughout the country would be increased by RMB0.03 /kWh, including the price of power used for the production of chemical fertilizer). The third step will also be implemented gradually.

Adjustment of policies on industries is the general trend. The possible changes include the following aspects:

1. After adjustment of policies on the industry, a large number of weak enterprises will perish due to increase in cost. This will lead to a reduction in the capacity to supply the domestic market;
2. Affected by factors such as the international market and raw material market, uncontrollable fluctuations will occur with domestic market supply and price;
3. Production expenditure of farm households will increase, thus causing unfavourable effects on grain production and farm household income. Whether or not these problems will arise depends on the knowledge that people have about the present policies on the industry and changes in agricultural requirements. Below is a discussion about these problems from the analysis of policies on the industry and forecast of the scenario.

8.4.2.2 Computation of policy influence

As the first step, if the parallel running of prices for natural gas is implemented, subsequent prices of natural gas will be according to the lowest price announced by the NDRC (RMB980 /1,000 m³) and the deduction from preferential price will amount to RMB2.6 B. Consequently, the cost for enterprises using natural gas as raw material goes up by RMB224-276 /t ammonia (small scale enterprises using gas consume more electric power but relatively less gas), equivalent to the cost of urea being raised by RMB132-163 /t. According to CNFIA statistics, the present cost of enterprises using natural gas as raw material is RMB1,028-1149 /t urea (large-scale – small-scale). With parallel natural gas prices, costs may be RMB1,191-1,281 /t. However, this cost is still slightly lower than the cost of producing urea using coal as raw material by small and medium scale plants (RMB1,265 /t for a small plant, RMB1,315 /t for a medium plant). Enterprises using gas accounted for 22% of the country's total N fertilizer production which is perceived unlikely to cause big fluctuations in the price of the entire market. After the abolition of preferential prices for natural gas, the difference between the cost of large enterprises using gas and other enterprises will be narrowed, lowering the competitiveness of this type of enterprise and urging them to change their scale.

The products of most of the urea enterprises require long-distance transport. If parallel rail freight charges were to be implemented at the same time, the cost of 1,000 -km of transport would be increased to RMB85.3 /t and the cost price of urea produced by enterprises using gas would be further increased to RMB1,276.3-1,366.3 /t. This is already

higher than the average cost in the market and it is, therefore, reckoned that the market price will rise. The rise in the cost of transport expenses will affect the production of P compound and K fertilizers in the same way. If transport expenses rise generally, it will directly cause a rise in the market price. This is particularly so for products with a large transport radius, such as compound fertilizer, DAP and KCl whose market prices will be increased by at least RMB55.4 /t.

In the second step, if the preferential prices of electric power, natural gas and transport are abolished, subsequent prices of natural gas will climb to RMB1,100 /m³. The cost of urea produced by small to large scale enterprises using gas will rise by RMB200-238 /t and reach RMB1,266-1,349 /t, higher than the market average cost. After the abolition of the preferential electric power price, the cost of urea produced by small to large scale enterprises using gas will increase by RMB32.7-353 /t and will reach RMB1,299-1,702 /t. The cost of urea produced by small to large scale enterprises using coal will increase by RMB43-479 /t to reach RMB961-1,744 /t. After the further abolishing of the preferential price for transport, market cost of enterprises using gas will be RMB1,384-1,787 /t while the market cost of urea produced by enterprises using coal will be RMB1,046-1,829 /t. It can be seen that after policy adjustments in the second step, market costs will be tremendously elevated. In particular, the rise in the price of electric power will have a great effect on the small and medium scale enterprises whose output accounts for 68% of the total production in the country. It is very likely that the price of chemical fertilizer will rise with the increase in the cost of small-scale enterprises. The price of urea may rise to RMB2,000 /t (based on 10% gross profit), an increase of RMB100-200 /t over the actual market price in 2005. Based on power consumption of P fertilizer products at present, after abolishing the preferential power price, the cost of the products may increase by RMB5-45 /t. The effect on DAP is the greatest. On the abolition of transport subsidies, the transport of DAP from the provinces of Yunnan and Guizhou to North China, Northeast and Northwest China covers a radius of more than 2,000 km. Market costs will go up by at least RMB100 /t (the preferential treatment for transport over 1,000 km amounts to RMB55.4). Transport of KCl in China is mainly from the provinces of Xinjiang and Qinghai to the coastal regions such as the province of Shandong. The transport radius will exceed 2,000-3,000 km and the cost will increase by RMB100-150 /t. In the third step, the preferential VAT is abolished. In the N fertilizer industry, a concession of VAT of RMB10 B is equivalent to a concession of RMB280 /t N and a concession of RMB129 /t urea. In the P fertilizer industry, it is equivalent to a concession of RMB67 2/t P₂O₅. DAP is less affected because VAT has been paid normally. The cost of MAP is increased by RMB296 /t. The cost of compound fertilizer goes up by RMB101 /t. The cost of low-density P fertilizer will also increase by RMB95 and for K fertilizer, the cost per tonne increases by about RMB129.

It can be seen from the overall analysis (Table 8-6) that if the first step is implemented (realization of parallel running of the two types of prices of natural gas and transport charges), the production cost of N fertilizer enterprises that use gas will rise by 12-16% and market competitiveness will go down. For enterprises that use coal, some small ones may

even have their advantage enhanced, thus forcing large scale enterprises that use gas to scale down. If the reduction of concession for transport is added to the list, the market of large scale enterprises using gas will shrink. Consequently, in the first step, consideration should be given to large scale enterprises that use gas. If many of these scale down, it will doubtlessly cause a great wastage of resources. However, if only the preferential concessions of natural gas and transport are deducted, there will be no big fluctuations in market prices. Besides the large scale enterprises using gas analysed above, other products will also be affected. In particular, for those high-analysis P and K fertilizers with a larger distance of transport, the situation is worse. This may lead to changes in the deployment of market resources but these changes are within the limits of the market's ability to regulate.

If the second step is carried out (abolition of concessions for the price of electric power and transport), the cost of N fertilizer may rise by 48% at its highest (small and medium scale enterprises) and the market price may go up by 53%. Affected by the rise in the cost of N fertilizer, the cost of AP and compound fertilizer will also increase by an estimated 2-14% (the cost of synthetic ammonia in AP is calculated according to 30%). The market price of P fertilizer is estimated to rise by 11%. Owing to the lower electric power consumption in its production, the change in the cost of production of K fertilizer is smaller (within 2%) and the market price will increase slightly (6%, taking into consideration an increase in transport costs). Comparatively low-analysis products such as ABC and SSP will not be much affected since the consumption of electric power is lower and long-distance transport is not required. Even though the implementation of policy adjustments in the second step may result in fluctuation in the market price, this kind of change may be favourable to the structural adjustment of the industry. It reduces the competitiveness of small and medium scale enterprises with low energy consumption (large scale enterprises using coal are the least affected) but elevates the competitiveness of large scale enterprises. This puts pressure on the small and

medium scale enterprises to reorganize and in turn impels the entire industry to work harder on energy saving and reduction of energy consumption. Looking at the course of technological reform in the chemical fertilizer industry, at least a buffer period of 3-5 years should be given to achieve an overall elevation. The effects of power prices on P fertilizer enterprises seem to be much smaller than on N fertilizer enterprises. However, the abolition of preferential transport charges will reduce the competitiveness of enterprises of high-analysis P fertilizer in the regions of raw material supply and relatively raising the competitiveness of enterprises in regions without raw materials. This results in the structural adjustment of the P fertilizer industry which is not favourable to its centralization in regions of raw materials production. Enterprises of compound fertilizer are the hardest hit by the abolition of preferential transport charges as there is a big requirement for the transport of raw materials and products. The flexibility of the market price for compound fertilizers is smaller than for other fertilizers causing large scale compound fertilizer enterprises' costs in the non-raw material regions to increase. Business benefits will drop and it is not favourable for the development of group companies.

If the third step is implemented, (abolition of preferential VAT) it will directly bring about changes in the market price. The price of N fertilizer may rise by 64%. The price of urea is bound to break the RMB2,000 /t mark. It may even hit RMB2,700 /t or higher (average price in 2005 is taken to be RMB1,800 /t). The price of P fertilizer will also go up by almost 18%. After the price of MAP (tax payment has started for DAP and compound fertilizer) and low-analysis P fertilizer has gone up, it becomes even more difficult to compete against DAP and compound fertilizer and their market share will shrink further. After abolishing the preferential treatment in VAT, the biggest effect is lowering the competitiveness of the entire national chemical fertilizer industry, in particular, the domestic P compound fertilizer and K fertilizer industries which have just entered the period of high growth. It is necessary to adopt more measures to raise competitiveness.

Table 8-6 Analysis on the extent of effects of policy changes on the chemical fertilizer industry

| Scenario | Financial Expenditure (million RMB) | Increase in Cost % | | | Increase in Price% | | | Extent of Effects on Product (Enterprise) Arranged in Descending Order |
|-----------------------|-------------------------------------|--------------------|--------------|--------------|--------------------|--------------|--------------|--|
| | | N fertilizer | P fertilizer | K fertilizer | N fertilizer | P fertilizer | K fertilizer | |
| Status quo maintained | 403.1 | - | - | - | - | - | - | Urea (large > small) > DAP > KCI > ABC > SSP/FCMP > NPK |
| First step | 275.5 | 12-16 | 4-5 | - | 0-4 | 3-4 | 4 | Urea (large gas > small gas) > DAP > MAP > NPK > KCI |
| Second step | 160 | 5-48 | 2-14 | 2 | 11-53 | 4-11 | 6 | Urea (small gas > small coal > large gas > large coal) > ABC > DAP > MAP > NPK > KCI > SSP/FMP |
| Third step | 0 | 5-48 | 2-14 | - | 25-64 | 4-18 | 12 | Made-in-China (urea > ABC > MAP > SSP/FCMP > KCI > DAP > NPK) > import |

Note: "-" refers to the basic situation in 2005, obtained by estimation according to the above analyses.

The effect of policy adjustments on an industry is complex. With enhancement, market price is bound to rise. Very big changes in the structure of the industry and product composition are bound to occur. However, this type of adjustment is beneficial in the long-term development of the industry. It spurs the dominant enterprises to emerge victorious and enhances the overall power of the industry, thus enabling the relevant resources of the State to be utilized efficiently.

8.4.3 Policy suggestions and countermeasures

In summary, policies on the chemical fertilizer industry in China are undergoing changes. The overall trends should be:

1. Encourage farmers to apply fertilizers in a proper manner and discourage excessive fertilizer application;
2. Create an environment of fair competition, to further strengthen laws and regulations, improve product quality and standard of service and to guarantee the interests of the consumers;
3. Further integration of foreign and domestic markets to form the mainstream of development with rational competition;
4. Encourage protection and saving of resources and contain wastage.

With these opportunities and challenges, it is believed that the chemical fertilizer industry in China will gradually be on the right track of development and become stronger. As long as enterprises are able to adjust their train of thoughts with regard to development, be reliant on resources, be guided by the market and be driven by innovation, they will be able to survive and prosper. However, they must realize that rising prices brought by open policies and higher degree of market competition will finally be borne by the farmers. How to avoid increases in agricultural production cost and decreases in the income of farmers have become problems that demand urgent solutions. The government and the enterprises should begin by educating the farmers, carrying out research and development of technologies and giving agricultural subsidies. They should enhance basic work and work hard to achieve a joint industrial and agricultural development for building a harmonious society.

