

Fertilizer industry profile

• Achievements

- The industry has made significant efforts to develop and adopt new technologies that have significantly reduced emissions from fertilizer production.
- The industry has been instrumental in getting distributor and adviser certification schemes off the ground in some countries.
- Leading fertilizer associations and research organisations are involved in research and training to improve the efficient use of plant nutrients.

• Unfinished business

- Internal knowledge and technology transfer will help all fertilizer production facilities come up to the levels set by industry leaders.
- The fertilizer industry's safety record is among the best of the chemical-related sectors, but continual improvement is an absolute imperative.
- The industry's community and stakeholder relations have developed significantly in recent years, but more can be done globally.

• Future challenges

- As commodity products, most fertilizers currently have little in-built technology to enhance the efficiency of nutrient uptake.
- More research is needed on removing naturally occurring impurities from fertilizer raw materials.
- The fertilizer industry faces the challenge of more fully engaging its traders and retailers in efforts to address sustainability issues.

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Industry as a partner for sustainable development

Fertilizer Industry

International Fertilizer Industry Association (IFA)



Developed through a multi-stakeholder process
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First published in the United Kingdom in 2002.

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ISBN: 92-807-2183-6

Production

Design by Beacon Creative
+44 (0) 1825 768811

Printed by The Beacon Press using their **pureprint** environmental print technology that is both water and alcohol free. No film processing chemicals were used and 90% of the cleaning solvent was recycled.

The electricity was generated from renewable resources and vegetable based inks were used. Registered to the environment management system ISO14001 (Certificate No. E.9586) and EMAS the Eco Management and Audit Scheme (registration no. UK-S-00011), and the printer holds FSC Chain of Custody certificate number SGS COC 0620. Over 85% of any waste associated with this product will be recycled.

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In a multi-stakeholder consultation facilitated by the United Nations Environment Programme, a number of groups (including representatives from non-governmental organisations, labour unions, research institutes and national governments) provided comments on a preliminary draft of this report prepared by the International Fertilizer Industry Association (IFA). The report was then revised, benefiting from stakeholder perspectives and input. The views expressed in the report remain those of the authors, and do not necessarily reflect the views of the United Nations Environment Programme or the individuals and organisations that participated in the consultation.

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Part I: Introduction

Preface

This document is not really complete and probably could never be so. Understanding of sustainable development evolves constantly. So much effort goes into addressing these issues that we could not possibly cover it all in so few pages, and new projects are being launched at least weekly. However, behind this flurry of activity, there is a relentless march forward.

The industry should be particularly proud of its record on the production side. Efficiency is in some cases reaching theoretical limits. Social issues have received increasing attention.

The fertilizer industry remains concerned about the effects of its products even after they leave the factory gate, and it began promoting efficient and balanced use long before most industries were adopting life cycle product responsibility. In theory, as many as two billion farmers could use fertilizers on any given day. Ensuring that they have the best agronomic information, quality fertilizers and appropriate and efficient technology is a daunting task. However, under-use, over-use or unbalanced use all unleash negative impacts that must be eliminated to achieve truly sustainable production of quality food.

Technology has a role to play, but capacity-building is probably the most important factor. Managing these key agricultural inputs on a global scale requires mobilisation of industry, international organisations, governments, scientists, educators and trainers, farmers, agricultural workers, non-governmental organisations (NGOs) and local communities, all working together.

Although the research to prepare this report revealed much progress, a number of challenges remain.

This report is the first attempt of its kind to look at the contribution of the fertilizer industry to sustainable development, and to consider the challenges that face the industry as regards sustainability. Material from across the globe was reviewed, and we are grateful to the numerous organisations that provided information.

Invaluable stakeholder input was contributed by Mahmood Ahmad (Federation of Pakistan Chambers of Commerce & Industry), Jingen Cheng (Ministry of Agriculture, China), Arend Hoogervorst (Eagle Environmental Consulting), Bob Pagan (Cleaner Production Group), Richard Perkins (WWF), Rudy Rabbinge (Wageningen University & Research Centre), Heino von Meyer (OECD) and Bill Vorley (IIED). Keith Isherwood and Dianna Rienstra assisted in drafting and editing the report. UNEP, of course, played the invaluable role of facilitator and its support has been substantial.

Sincerely,
L M Maene
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Associations (IFA)

Executive summary

Imagine the world 50 years from now. World population has stabilised. What will be the major role of mineral fertilizers? What does the world fertilizer industry need to do to become sustainable in the long term after that date? In this context, sustainability can be viewed as having two parts.

How can the mineral fertilizer industry and its products support the sustainable development goals of the wider community?

1. By contributing to food security on a local level, thus contributing to poverty alleviation and human development.
2. By helping prevent and correct soil degradation to meet global environmental objectives such as combating desertification.
3. By ensuring that negative environmental impacts of fertilizer production and use are eliminated where possible and otherwise minimised.

What measures need to be taken by the industry to ensure that mineral fertilizers are produced and used in ways which contribute to those objectives?

1. Development of improved products with greater nutrient efficiency.
2. Processes which remove unwanted impurities and, where possible, identification of new uses which turn these waste products into valuable resources.
3. Working to ensure that the entire fertilizer value-chain, down to retailers, is involved in capacity-building to enable correct use of fertilizers.
4. Ongoing training and capacity-building of farmers and their organisations;
5. Further development of stakeholder relationships.

It is clear that the industry must develop better, value-added products and services to help meet the major challenges posed by sustainability. The industry must establish a pattern of minimal losses, maximum efficiency and maximum recycling. Today is not too early to start imagining this future and the shifts that need to occur to realise this vision.

More research and product development are key. Farmers must receive better training in the use of fertilizers, but how? By whom?

This report seeks to put fertilizers in context today, discuss ways that the fertilizer industry has moved towards sustainability and, most importantly, highlight ways to move forward toward a vision of sustainability.

Part 2: Putting the mineral fertilizer industry into the sustainable development context

A brief overview

An FAO definition of sustainable agricultural development is: 'The management and conservation of the natural resource base, and the orientation of technological and institutional change, in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations. Such development... conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.' [Loftas, 1995]

Are mineral fertilizers necessary for this purpose? Professor Vaclav Smil of the University of Manitoba has made the calculations and writes: 'If we were to provide today's average per capita food supply with the 1900 level of agricultural productivity, we could feed only about 2.4 billion people,' and 'Nitrogen fertilizers provide the protein requirements of 40% of the world's population.' [Smil, 1999, pp. 10-11] The same author has written: 'We know that even the most assiduous recycling of inorganic wastes combined with crop rotations, including leguminous crops and green manures, cannot supply more than 120-150 kg N/ha in highly intensive traditional cropping. Such agroecosystems can produce around 200 kg of protein per hectare and feed at least ten to 11 people on largely vegetarian diets. In contrast, today's most productive agroecosystems yield around 800 kg of protein per hectare in multicropped fields receiving high applications of inorganic nitrogen.' [Smil, 2001]

Evidently maximum use should be made of materials such as organic manures before mineral fertilizers are applied. Mineral

fertilizers are then needed to supply the remainder of the crop's nutrient requirements, the main nutrients being nitrogen, phosphate and potash.

There is ample evidence that mineral fertilizers are in no way inferior to organic manures as suppliers of nutrients, and in some ways they are superior. Some people believe that mineral fertilizers reduce soil organic matter; whereas they can actually increase it, due to the larger quantity of crop residues. Organic manures and mineral fertilizers complement each other, particularly under certain tropical conditions.

Organic farming is another, separate issue. Work in the UK [Leake A, 1999] has demonstrated that organic farming gives wheat yields about 60% to 70% of conventional systems. This can be compensated by subsidies and the price premium for such products. There is a good market for such products where people can afford to pay the price, but on a global basis a reduction in food production of much less than 30% to 40% would lead to starvation in the poorer countries of the world.

The fertilizer industry is far from being a monopoly of monolithic companies from developed countries. Until the 1960s, its development was indeed in the developed countries of Europe, North America and Japan. However, in the 1970s and early-1980s, the construction of new nitrogen fertilizer plants shifted to the gas-rich countries of the Soviet Union, Caribbean and Near East and to some large consuming countries such as China, India, Indonesia and Pakistan.

During the same period there was a trend towards the processing of phosphate rock in

countries with substantial natural resources of this material, especially in North Africa and the United States, but also in the Near East and South and West Africa. Potash is produced mainly in the few countries where the major ore deposits are located.

As a result of these trends phosphate and potash production is concentrated in a few countries, nitrogen less so since the materials required for its production, atmospheric nitrogen and energy, are universally available.

Over the past 40 years technological progress has resulted in the practical size of ammonia and nitrogen plants increasing by a factor of five or more. Integrated phosphate mining and processing offer significant technical and economic advantages. Economies of scale have led to gradual elimination of small fertilizer plants, mergers and consolidation.

In western Europe a massive restructuring of the fertilizer industry and a large number of mergers and acquisitions took place from 1980 onwards. Since 1983, the number of people employed in the western European fertilizer industry has declined by more than 80%. The United States fertilizer industry also has experienced a large number of mergers and acquisitions since the beginning of the 1980s. In India, five companies account for 48% of the ammonia capacity and 54% of the urea capacity. Several of the major fertilizer producers are state-owned or farmers' co-operatives – the fertilizer industry is not one of large multinational corporations.

Basically the manufacturing processes are simple. To produce nitrogen fertilizers the industry fixes atmospheric nitrogen. Phosphate rock is treated with acids to make it more soluble and hence more readily available to plants. Potash needs little chemical processing. However, the large scale of the plants has required considerable technical innovation, and the scale enables the most advanced technology to be incorporated. In

modern plants the use of energy is highly efficient. Most atmospheric emissions have been reduced to acceptable levels. Other losses to the environment are minimal. The emission of carbon dioxide in ammonia production is unavoidable, but can be minimised by optimising energy-use efficiency. As in other spheres of human activity, this is the price to be paid for the benefits of large-scale food production which are currently considered to outweigh the cost.

The elimination of certain naturally occurring harmful elements in phosphate rock is a problem that remains to be resolved due to the economics. Fertilizers are very bulky, low value materials which cannot support expensive processing.

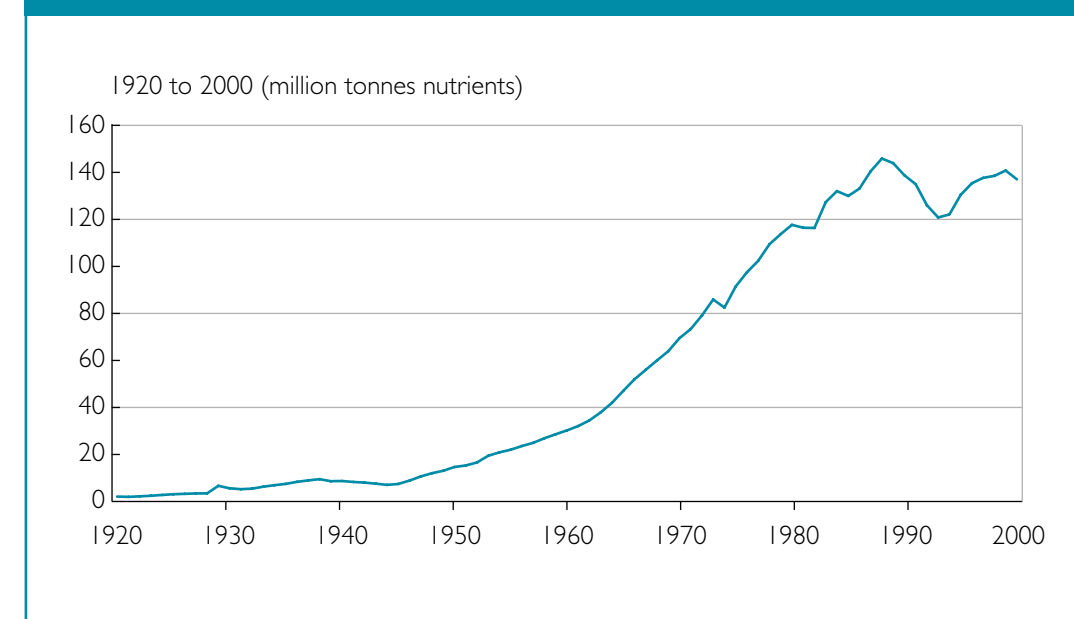
The natural resources required for the production of fertilizers are sufficient for centuries to come. They are unlikely to be a constraint to fertilizer production even in the very long term, but, of course, waste should be avoided and recycling optimised.

The report argues, therefore, that the main constraint to sustainability is at the use level, on the farm. The problem is that nutrients, especially nitrogen and phosphate, which escape into the environment can lead to the proliferation of plant organisms whose presence in excess is harmful, quite apart from the wasteful economic loss.

At present, nutrient use efficiency is low in most developing countries. In developed countries considerable progress has been made but more can be done. Influencing the use of mineral fertilizers is difficult in view of the very large number of farmers are involved. Furthermore, the manufacturer is often separated from the end user by a distribution system that has to handle millions of tonnes of material. In India, for example, there are 260,000 fertilizer retailers in direct contact with the farmer.

2.1 Introduction

Figure 1: World fertilizer consumption



Source IFA

Mineral fertilizer use has increased dramatically in recent decades to meet the food needs of a fast-growing population. About 2.2 billion people now depend directly or indirectly on fertilizer for their daily food. As a result, in many developing countries, fertilizer supply is as politically sensitive as food supply itself [Park, 2001]. Fertilizer use is uneven: in some places it is overused, in others too little is applied, and in still others they are optimally used. These differences occur within and across countries and even seemingly 'optimal' total applications may hide imbalances between individual nutrients.

Discussions about mineral fertilizers and sustainable development must be based on a clear awareness of the differences between developed and developing countries. Developed countries are mature markets, where food security is assured and overproduction not unheard of. Major soil fertility problems have been solved and

environmental concerns have become as important politically as food supply, if not more so. Developing countries continue to face food insecurity and serious problems of soil degradation exacerbated by nutrient mining.

Agricultural conditions are also very different. Most developed countries lie in temperate zones where soils retain organic matter for long periods, and many developing countries are in the tropics where soil organic matter breaks down as much as four times faster.

2.1.1 A review of the challenges

This report attempts to review the relationship between the mineral fertilizer industry and sustainable development, outlining the contributions that mineral fertilizers can make and the challenges that must be met if the industry's future is to be sustainable. It presents industry initiatives and responses, and outlines major areas for future improvement. Although every attempt has been made to

give an accurate overview, space constraints limit the depth of discussions and the exhaustiveness of case studies. Nor does the report purport to have solutions for all the challenges listed.

The issues are crosscutting and overlap into many areas. Readers may be surprised by the amount of space dedicated to agriculture. This is because the fertilizer industry recognises that the major environmental impacts of its products occur in the field, and accepts its role in minimising unwanted effects beyond the factory gate.

We also included positive impacts that the industry has had with regard to the various sustainable development issues brought into focus by the United Nations conference on environment and development. This is because we believe that a discussion of the sustainability of the industry should take the good with the bad, especially as decisions about what is most sustainable may involve trade-offs between different objectives. Obviously these contributions do not in any way cancel out the efforts that need to be made in other areas.

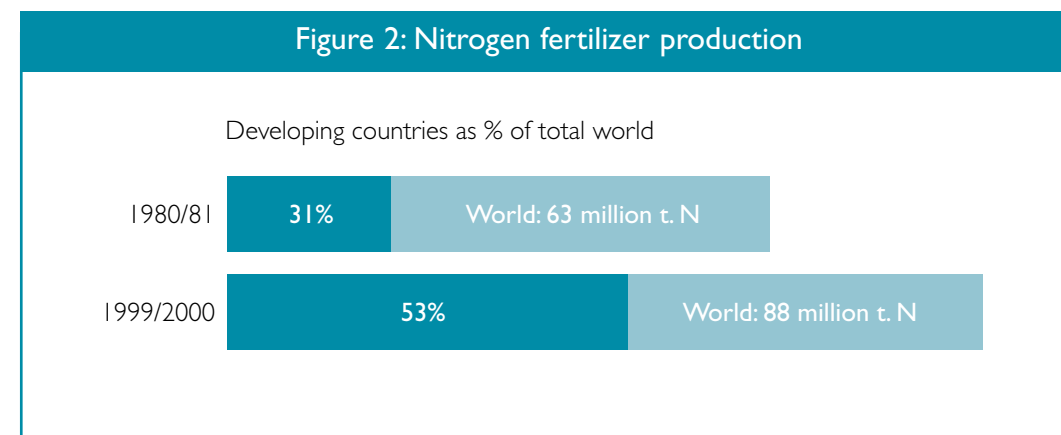
The task for this report was to look at progress since 1992, but many efforts from the fertilizer industry began well before this date, in an early recognition of the importance of overcoming major sustainability challenges. The reader is encouraged to see this

document as a starting point for discussion and co-operation among a wide range of relevant players.

2.1.2 The fertilizer industry

The world mineral fertilizer industry is extremely heterogeneous. Among the largest producers, one finds giants of the chemical industry in all parts of the world – companies with sales measured in billions of dollars. Producers of the main raw materials for fertilizer production form an important part of the petrochemical and mining industries. At the other extreme, there are many small enterprises which have no primary chemical production at all, they buy all their materials to make mixtures or blends, which are often termed 'compound' fertilizers.

Because of this complexity, not all initiatives undertaken by the fertilizer industry are covered in this report. Notably, readers are referred to chemical industry and mining reports to learn more about initiatives such as Responsible Care and the Global Mining Initiative (and its 'Mining, Minerals and Sustainable Development' project) in which many members of the fertilizer industry participate. Fertilizer companies also participate in sustainable development initiatives of organisations like the International Chamber of Commerce (ICC) and the World Business Council for Sustainable Development (WBCSD).



Source IFA

In the 1970s and 1980s, the geographical balance of the industry shifted strongly toward the former communist economies and the developing countries. The communist countries pinned their faith on fertilizers to spearhead the modernisation of their agriculture and improve poor crop yields. The developing countries viewed fertilizers as a strategic necessity to combat the threat of famine in a situation of rapid population growth. Those with abundant natural gas, phosphate rock or potash saw fertilizer production as a primary means of economic development. Finance from lending agencies such as the World Bank was often available on favourable terms.

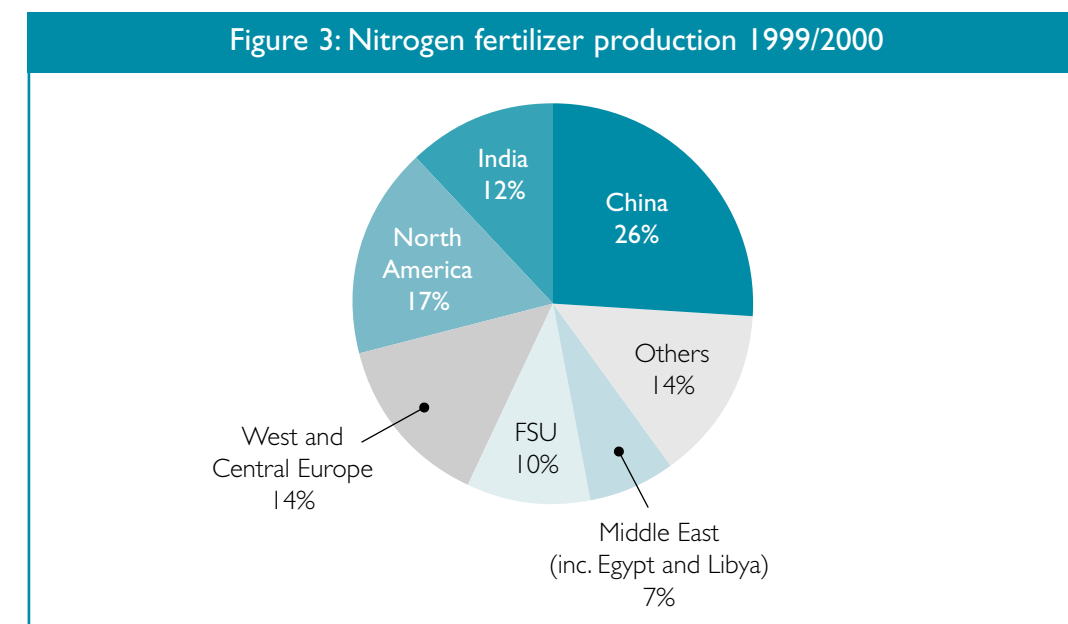
All this led to a rapid growth of production capacity and a sharp increase in state ownership. In the 20 years from 1965 to 1984, the share of state enterprise in the world ammonia industry rose from 30% to 64%. In the potash industry, it rose from 40% to 65%, and in the phosphoric acid industry, from 10% to 46%. Similarly, by the mid-1980s, nearly 60% of world phosphate rock production was state-owned.

The collapse of the Soviet Union and the strong privatisation movement of the 1990s reversed this trend. In Russia and throughout eastern Europe, the withdrawal of state ownership and the reduction or elimination of heavy subsidisation of both industry and agriculture, led to a large fall in the production and consumption of fertilizers, and the industry was largely transferred into private or semi-private hands.

A worldwide excess of production capacity, the trend towards industrial globalisation, and continuing competition from state-owned, or state-regulated enterprises in numerous developing countries, notably India and China, obliged the private sector to concentrate its resources. This led to widespread plant closures, numerous company mergers and acquisitions, and massive restructuring.

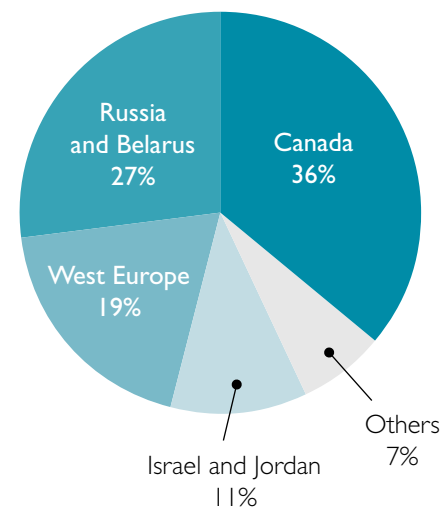
2.1.3 Fertilizer production

Mineral fertilizers are mainly produced from a small number of distinctly different raw materials and intermediate products. Some of these are also used directly as fertilizers. The main raw materials are hydrocarbons/energy, phosphate rock, potassium salts and sulphur.



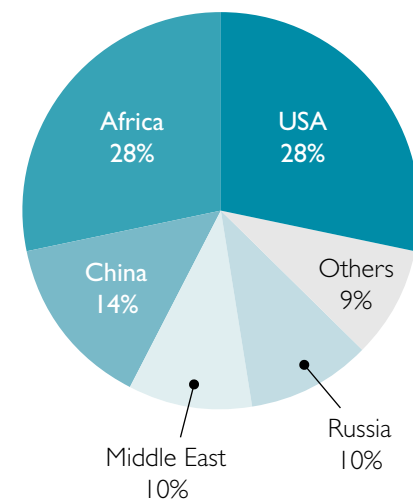
Source IFA

Figure 4: Potash production 2000



Source IFA

Figure 5: Phosphate rock production



Source IFA

The main sources of energy are natural gas and other hydrocarbon materials. Natural gas also provides a large proportion of the world supply of sulphur, as many commercial gas deposits are 'sour' and the gas cannot be used until the sulphur has been removed. Phosphate rock and potassium salts are mined in various

parts of the world. The mining of elemental sulphur is also important. In addition, sulphur is recovered from oil refineries, iron and copper pyrites and by-product sulphuric acid.

Using these raw materials, the number of chemical process routes to the finished

products is relatively small. But at the end of the production chain a great diversity of final products appears.

Each product has its own advantages for a particular crop, soil and climate. It may be solid or fluid. Solids may be either chemically homogeneous particles or mixtures (blends) of different products. Fluids may be salt solutions or suspensions of solid particles. They may even take a gaseous form, as in the case of the injection of anhydrous ammonia directly into the soil – a widespread practice in the United States and a few other countries.

The content of nitrogen, phosphorus pentoxide (P₂O₅) and potassium oxide (K₂O) in a fertilizer forms the main basis of its commercial value. It may also contain other macro-nutrients such as calcium, sulphur, and magnesium, as well as micro-nutrients like boron, iron, manganese and zinc, which all affect its value.

In 1999/2000, the world fertilizer industry produced about 88 million metric tonnes (Mt) of nitrogen, 41 Mt of P₂O₅ and 26 Mt of K₂O – a total of 155 Mt of primary plant nutrients which were contained in about 380 Mt of the various finished products.

Nitrogen fertilizer production is based mainly on the synthesis of ammonia from atmospheric nitrogen and the hydrogen in hydrocarbons. This transformation is necessary, because elemental nitrogen is inert and therefore unavailable for plant nutrition.

In the case of phosphate fertilizers, nearly three quarters of the world production of P₂O₅ is based on phosphoric acid, which requires large amounts of sulphur in the form of sulphuric acid, in order to convert the P₂O₅ in phosphate rock to a more soluble form. Ammonia, phosphate rock, potash and sulphur have many other industrial uses apart from fertilizers, but the fertilizer industry consumes most of their production. Consequently, the geographical structure of the fertilizer industry

is not only governed by the location of its markets but also by the location of commercial sources of these raw materials and intermediates.

The wider fertilizer industry family also includes engineers, traders and numerous regional and national associations as well as research institutes which are closely affiliated with the fertilizer industry. These latter have been set up on one hand to speak out on the general issues concerning the industry, but also to carry out those activities which are outside the scope of a single company, such as research and training. Most companies belong to multiple associations and support more than one research institute.

2.1.4 Fertilizers and the imperative for sustainable agriculture

In developed countries, most people no longer have a close link with rural areas and agricultural production. This subsection therefore briefly explains the role of fertilizers in sustainable agriculture.

In agriculture, solar energy is converted into chemical energy with the help of chlorophyll in plants. However, essential nutrients are required to sustain plant life: nitrogen, phosphorus and potassium, sulphur, calcium, magnesium and a number of micro-nutrients or trace elements.

Rainfall supplies water and some oxygen, while the atmosphere supplies carbon (as CO₂) and the rest of the oxygen. Legumes and certain other plants can obtain part of their nitrogen requirement from the atmosphere, but most plants obtain almost all their nitrogen from the soil. All other plant nutrients must be obtained entirely from the soil.

Like the food that humans eat, mineral fertilizers are made up of the nutrients that plants need. Adding nutrients is necessary for the following reasons:

- soils may not naturally contain all the nutrients that a crop needs;
- today, very few farming systems are closed systems where nutrients pass from soil to plants to animals and people and then back to the soil in the same location. Every time a truck leaves the farm loaded with produce, the farm and its soil lose some productive capacity unless those nutrients are replenished;
- even in 'closed' systems, there are unavoidable losses of plant nutrients.

The challenges of sustainable agriculture include soil degradation, inefficient use and pollution of water and loss of biodiversity. In addition, lack of proper infrastructure and insufficient education, advisory services and research in developing countries prevent wider adoption of practices which address these problems.

Restoring, maintaining and preferably increasing soil productivity are essential for sustainable food production. A proper and a balanced nutrient supply is important for maintaining soil productivity and reducing soil degradation. Fertilizers can have a positive effect on the environment in several ways [Lægneid et al, 1999]:

- the efficient use of plant nutrients ensures that yields are higher than those obtained on the basis of inherent soil productivity by correcting deficiencies or imbalances of nutrients;
- fertilizers replenish nutrients removed from soil by harvested produce, thus maintaining and enhancing production potential;
- because they increase yield per unit area on good, arable land, fertilizers allow land of poor quality, such as land susceptible to erosion, to be withdrawn from cultivation. This relieves overall pressure on the land, for example by reducing deforestation and overgrazing of currently non-cropped areas. Sustained high yields on a limited amount of land also prevent the

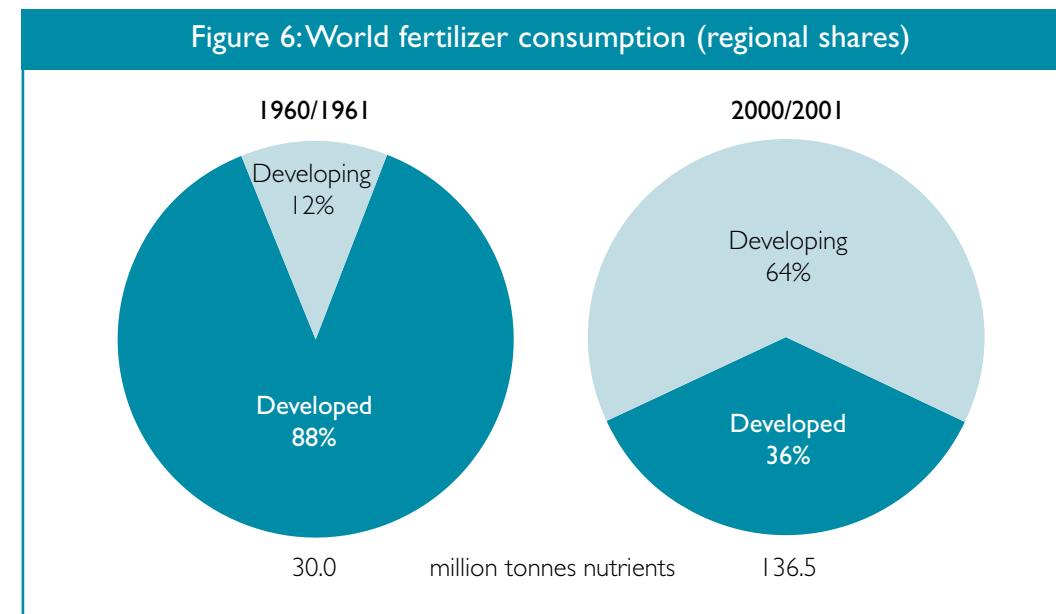
- encroachment of agriculture into uncultivated areas that are likely wildlife habitats. (Fertilizers can also enable cultivation on marginal lands. Although this might be necessary on a local level to ensure adequate food supplies, it is not desirable at a global level);
- plant nutrients ease the problem of erosion-control on cropped land because of the protection provided by a dense and vigorous crop cover;
- properly nourished crops use water more efficiently.

Mineral fertilizers are estimated to contribute about 40% of the nitrogen taken up by the world's crops. Crops provide about 75% of all nitrogen in human protein consumption (either directly or indirectly through animals), thus nearly one-third of this protein depends on fertilizers. In western Europe, at least half the present agricultural output can be attributed to fertilizers [Smil, 2001].

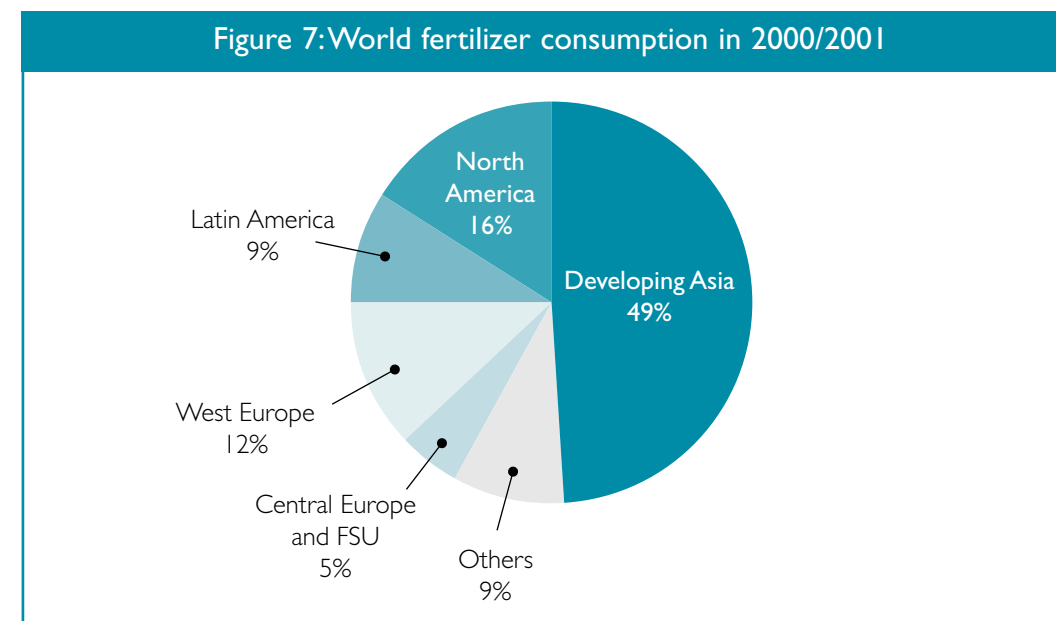
2.1.5 Expanding fertilizer consumption

The use of fertilizers as a regular farming practice began in most European countries in the mid- to late-19th century, but consumption increased dramatically in the three decades following World War II.

Their increasing use in developing countries started in the 1960s and by 2000, accounted for about 60% of the world total, compared with 12% in 1960. This trend is continuing. As populations increase in developing countries, agriculture production and the development of fertilizer use is a high priority – and rising on both national and international political agendas.



Between 1989 and 1994, fertilizer consumption in developed countries as a whole fell from 84Mt nutrient in 1988 to 52Mt nutrient in 1994. This was largely due to the poor economic situation in eastern Europe after the fall of the Berlin Wall. In addition, fertilizers were used most inefficiently under the centrally planned systems. Source IFA.



Between 1993/94 and 1999/2000, world total fertilizer nutrient consumption increased from 120 to 141Mt, an average rate of increase of about 3% per year. Consumption in China, South Asia and Latin America increased by 12, 7 and 2.5Mt respectively. In 2001, world fertilizer consumption fell, for various reasons, to return to its 1997/98 level. Source IFA.

2.1.6 An opportunity and a challenge in developing countries

In sub-Saharan Africa, the current net nutrient loss from the soil is estimated at some 10Mt per year. Even today's low-yielding crops are extracting nutrients from the soil three or four times faster than they are being replaced. While the recycling of organic matter is recommended, it is not adequate under these circumstances.

The rates of fertilizer used are generally very low in many developing countries, but they are higher in the commercial plantation sector. Rates of fertilizer-use for food crops are particularly low. There is a large variation in application rates between countries. FAO expects this trend to continue, with concerns about declining soil fertility as a result [FAO 2000]. Appropriate mineral fertilizer use can help produce higher yields, simultaneously increasing food production and the availability of soil organic matter, but it requires overcoming obstacles to access.

2.1.7 The industry's duty in the vertical and horizontal life cycle

The life cycle of fertilizers must be considered vertically (the passage of nutrients through the food chain from fertilizer, to soil, to crop and on to the final food product and the eventual destination of waste products) but also horizontally (the transportation of nutrients, often great distances, from their source to the land where they are applied and on to the final consumer). In turn, the life cycle of plant nutrients is linked to the natural nitrogen and carbon cycles and the increasing food and fibre demands of a growing world population [IFA, 1999].

The industry has a responsibility to promote an efficient, economic, environmentally-conscious use of mineral fertilizers, and to ensure that relevant scientific information is made available. Despite many outreach projects, it is not possible for the industry to have a direct influence on each of the world's two billion farmers. Therein lies one of the challenges of sustainable mineral fertilizer use.

Part 3: Meeting the challenges of sustainable development

This section aims to give an overview of major sustainable development issues as they relate specifically to mineral fertilizers. Where indicated, section headings reflect relevant issues in Agenda 21. Many of the headings that do not mention a specific chapter of Agenda 21 fall under Chapter 14, 'Promoting sustainable agriculture and rural development'. Some topics may not fit neatly under one of the chapters of Agenda 21, but were nonetheless considered useful in this discussion of sustainable development. Examples of industry responses are also included to give an indication of ongoing efforts to contribute to sustainable development.

3.1 Social and economic dimensions (Agenda 21, Section I)

Over the last 50 years, fertilizer production, consumption and trade has become a significant factor in the world economy. Fertilizers and fertilizer raw materials are produced and consumed in very large quantities – the total traded in the bulk shipping market is fourth in volume after only iron ore, coal and grains.

In the mid-1990s, the total trade in fertilizer materials was typically 120Mt, accounting for 8% of all sea-borne bulk trade. This compares with the grain trade, which averaged 190-200Mt. [Park, 2001] Because of fluctuating commodity prices, comparisons of the monetary value of fertilizer products in two different years are not very useful for measuring the magnitude of the industry. In fact, by general Wall Street standards, the return on investment in the mineral fertilizer industry is very low.

3.1.1 Global food security

The world population is expected to grow from approximately six billion today to more than eight billion by the year 2020. More than 97% of this projected growth will take place in developing countries. At present more than 800 million people suffer from hunger or malnutrition.

These figures make it clear that adequate agricultural production at global level does not necessarily imply food security at local level. As distribution issues are unlikely to be solved soon, the best option is to increase yields in developing countries, requiring significant intervention in cases where soil fertility is poor. Davis, Thomas and Amponsah write: '...Imports may be appropriate to bridge short-term gaps or during emergencies, but for most developing countries imports cannot substitute for local production...the argument that global food production is sufficient and that food security problems can be solved by redistribution is inadequate...' [Davis, 2001].

At the same time, most developing countries are experiencing economic growth, and their populations are demanding higher-grade foodstuffs, such as meat and dairy products. This will require increased agricultural productivity.

The International Food Policy Research Institute (IFPRI) recently estimated that the world's farmers will have to produce some 36% more grain in 2020, compared with 1997, [IFPRI, 2001]. However, the expansion of the cereal area is unlikely to be more than 5%, almost two-thirds of which will be in the difficult region of sub-Saharan Africa.

Inevitably, most of the higher production must come from higher yields-per-unit area, which will require a correspondingly larger quantity

of plant nutrients. Generally the 'nutrient budget' is negative. Nutrients in soils are mined, leading to soil degradation and erosion. In southern Mali, for example, about 60% of farmers' income is, in effect, derived from stripping the soil of its nutrients.

3.1.2 Combating poverty (Agenda 21, Chapter 3)

There is consensus that eliminating poverty, hunger and malnutrition is the cornerstone of sustainable development. Poverty remains the principal challenge for feeding the world's population in a sustainable manner. Global food supply has improved considerably over the past 20 years, but poverty is still widespread. Many people cannot buy enough food. Africa, in particular, has seen dramatic declining food availability per capita, and many African countries face a bleak future unless this trend can be reversed.

Hunger and malnutrition also create conditions which perpetuate poverty. The 167 million children who will go to bed hungry tonight are likely to suffer from stunted physical and mental development which will decrease their chances of becoming fully-productive adults. The after-effects of the diseases and impairments of the hungry and physically weak add an additional financial and healthcare burden to already poor states and families.

Most of the world's poor are rural. Even when they are not engaged in their own agricultural activities, they rely on non-farm employment and income which depend directly or indirectly on agriculture. Rural people account for more than 75% of the poor in many sub-Saharan and Asian countries.

3.1.2.1 Agriculture is an engine for economic development

There is wide agreement that with a few exceptions, prosperous agriculture is a necessary condition for economic growth in most developing countries. However, some developing countries do not attach sufficient

importance to agricultural development in policy planning. A recent United Nation report noted, 'While a shift from agriculture to manufacturing and services is part of the normal process of economic development, it is often occurring prematurely in developing countries...' [United Nation, 2001]

The multiplier effect of agricultural growth in developing countries is well documented and is probably a necessary precursor to industrialisation. A study [Mellor, 1995] examined in depth eight countries and states, of which six were judged to have successfully used agriculture to lead growth over a century. The authors concluded that in all the cases, sustaining agricultural growth depended on cost-reducing, yield-increasing technologies.

Agriculture also has an amplifying effect on the economy in developed countries. For example, in the United States and France, the total value of the food sector is several times higher than that of agricultural production itself.

If agriculture is to be productive, it follows that crops should receive, from one source or another, the nutrients they require. It is suggested that the lack of manure, and excessive exploitation of soil and water resources beyond their population-carrying capacity, have been major factors in the collapse of several ancient civilisations. Cases in point are the Sumerians in Mesopotamia and the Mayans in Central America, where soil disintegration was caused respectively by salinisation and deforestation – two of the major threats of today. [Johnston, 1995]

It is now recognised that soil fertility is a major pillar for building any strategy for sustainable land and natural resources management. Case studies have demonstrated the increased profitability of improved soil fertility practices, and it is obvious that increased incomes lead to improved socio-economic conditions and the well-being of the farmer.

Case studies: Richer soil reduces poverty

1. Soil fertility kick-starts growth in Brazil

The Brazilian extension organisation EMATER, in the region of Pato Branco, Paraná (Bragagnolo, 1997) [Pieri, 1998] did a survey of 477 farms at the onset of a soil fertility project in 1989/90 and five years later. The following results were measured:

- the area of rural buildings increased by 58%, mostly from chicken houses and piggeries;
- all farmers now own their farms, and 14% of them have increased the size of their property from 26.84 to 29.32ha;
- the farm area under soil conservation practices increased by 60%, from an average of 11.2ha to 18ha;
- farmers possess more equipment: on average, 8.14% more tractors, 10.21% more broadcast spreaders for lime and 14.29% for cattle manure;
- animal populations have increased in total head by 3.8% (cattle and pigs) per farm;
- gross income per family labour unit increased from 3,400 to 5,475 reales;
- the average farmhouse increased in size by 5.04 sq. metres;
- families bought 5.5% more refrigerators and 9.7% more gas cookers.

There were also spin-off benefits such as market/purchasing activities, infrastructure development and education programmes which have not been officially accounted for but are clearly perceived by individuals and the society at large in Paraná and neighbouring states.

2. Fertilizers and sustainable agricultural development in West Africa

The 'Fertilizers & Sustainable Agricultural Development (F&SAD) project', financed by IFA and USAID, started its first activities in the agricultural season of 1996 in three West African countries: Togo,

Benin and Niger. The project is being implemented by the IFDC through its Africa Division, IFDC-Africa, in collaboration with the national agricultural research institutes in the respective countries. Emphasis is put on demonstration of integrated soil fertility management (ISFM) technologies.

ISFM strategies are based on the combined use of soil amendments and chemical fertilizers. Lime and gypsum are the products most frequently used to improve pH; soluble sources of phosphorus (P) and rock phosphate can be used to increase the availability of P.

The more difficult challenge is to improve the status of organic matter in the soil, more and better organic manure is needed. However, it is difficult to get organic matter when inappropriate agricultural practices cause soil degradation and the cost of transportation of organic matter is high. Crop residue recycling, green manure, fodder crops or agro-forestry can eventually improve the availability and quality of organic matter.

The F&SAD project has produced considerable evidence that ISFM provides a feasible pathway for sustainable agricultural intensification – and a way out of the vicious circle between poverty and land degradation. Partnerships have been extended to extension services, rural development projects and non-governmental organisations (NGOs). Farmers, bankers, traders and policy makers at the local level have become the key stakeholders.

There are now ISFM projects in seven West African countries, with 2,500 farmers directly involved. IFDC-Africa collaborates with international and national agricultural research institutes to develop new ideas on ISFM technologies for different agro-ecological zones.

3.1.2.2 Employment

For those countries with large fertilizer industries, there are significant employment and revenue implications with attractive potential spin-off benefits into other industry sectors. These include shipping, trucking, warehousing, packaging, sack-making, urea-formaldehyde resins, melamine, explosives, fibres and detergents.

Exact employment figures are difficult to compile as the fertilizer industry cuts across many sectors, including mining, raw material suppliers, manufacturing, warehousing, packaging distributing, transportation, retailing and farming – to name a few. About 50% of the industry is located in developing countries.

Highest employment rates occur in developing countries which, as a general rule, have less advanced technology for production. Improved production techniques used elsewhere have minimised environmental impacts of fertilizer production, but often include mechanisation that has eliminated much individual employment in the sector. Increased productivity in western Europe has reduced jobs there from some 120,000 in the early 1980s to less than 20,000 today, and ongoing cuts are likely.

Despite high production levels, there are likely to be numerous jobs eliminated in coming years in the industry in developing countries, with China being a notable case. Some

Case study: Easing the social and economic transition

Fertilizer producers in China will have many examples of companies around the world that have gradually reduced their workforces as production techniques have become less labour-intensive. However, the changes in China could come abruptly as the country's membership in WTO will allow foreign producers enter the market and set up production facilities on a scale not previously experienced.

The experience of a potash mining community in north eastern France provides an excellent example of how a company can continue to positively impact economic and social development even as it prepares to reduce or end its direct influence on the daily life of a community.

Mining of the potash orebodies in the region began in 1910. The workforce peaked in 1965 at around 14,000 and dropped to 1,300 by mid-2000. The ore deposit is approaching exhaustion, with completion of mining anticipated by 2004. Company planning and preparation for this eventuality began a number of years back and, looking beyond

environmental aspects of the closure, has included creation of alternative employment for the workforce and community.

Incentives have been provided for the creation of new businesses with an emphasis on small- and medium-size enterprises (SMEs). A number of the old mine buildings are being refurbished to provide space to house some of these new enterprises. Training is provided to interested employees to allow them to develop their own businesses or prepare for work in a new industry.

Additionally, a hazardous waste management company has commenced operation, using underground openings created during the extraction of salt for long-term storage of hazardous waste. This has created around 100 new jobs for former potash miners.

Communication with employees and the community on the closure plans and activities has been important in alleviating concerns. An interesting method that has been used by Mines de Potasse d'Alsace to assist this process is the publishing of a comic book story that conveys information about the forthcoming closure in a manner and style that is easily understood by all.

experts estimate that modernising Chinese production facilities could do away with as much as 90% of the approximately 1.2 million jobs in the sector today. Policy-makers will have to take this likely development into account to avoid significant social and economic impacts at local level.

3.1.2.3 National income for exporting countries

For many exporting countries, fertilizers have become an important source of national income, with substantial encouragement in the past by the World Bank. In the Soviet Union, for example, fertilizers were one of the few industrial products which met world quality standards and could be exported for hard currency. With the collapse of domestic demand in recent years, exports have only gained more importance for the Russian economy.

In the 1970s and early-1980s, the Soviet Union supplied ammonia to the United States in exchange for superphosphoric acid. It also purchased modern plant equipment from western contractors. Today, pipelines and export facilities make the countries of the former Soviet Union as a bloc the world's biggest exporter of ammonia and urea.

In the early 1990s, the World Phosphate Institute (IMPHOS) estimated that phosphates and derived products accounted for 40-50% of exports from the IMPHOS member countries. Phosphate production acts as catalyst for transformation industries, equipment manufacturing and the development of the service sector.

3.1.2.4 Fertilizer policy in developing countries

In some developing countries, changes in fertilizer prices and/or subsidies are as politically sensitive as changes in food prices. China, in an effort to be more self-sufficient, has focused on building up its fertilizer industry. In India, fertilizer subsidies are a

significant portion of the national budget; the total direct subsidy bill in 1998-1999 was budgeted at USD2.2 billion.

India and China have made major efforts through national plans to develop a domestic supply and avoid an over-dependence on the world market. In China, new urea plants that came into operation between 1996 and 1998 added 2.6Mt of nitrogen to the existing capacity. At the same time, the output of small- and medium-scale urea plants increased. As a result, nitrogen fertilizer production increased from 16.7Mt nitrogen in 1994 to 20.4Mt in 1997, and then to 21.9Mt in 1998. It increased by a further 1.4Mt nitrogen in 1999. This amply supplied national requirements, and China essentially ceased to import nitrogen fertilizers in 1997.

However, both China and India rely on imports for all their potash requirements and for a substantial proportion of their phosphate requirements.

Some analysts believe that in early days, domestic subsidies can help the fragile national industry get off the ground and stimulate demand. The challenge for developing countries is then to move away from subsidies in such a way that does not cause structural damage. This unfortunate scenario happened in many African countries. Central government planning was abandoned, leaving a void, as there were no market structures or distribution systems in place to take up the slack. This has contributed greatly to Africa's declining soil fertility and problems feeding its population.

3.1.3 Promotion and protection of human health (Agenda 21, Chapter 6)

3.1.3.1 Safety in the workplace

Most fertilizer materials are mineral-based and non-hazardous in nature. Ammonium nitrate-based fertilizers with a nitrogen content greater than 28% must comply with additional safety precautions as they have oxidising

Case study: The European Fertilizer Manufacturers Association (EFMA) 'Guidance for the compilation of safety data sheets for fertilizer materials'

In 1996 EFMA published a series of model safety data sheets for ten different fertilizers and fertilizer materials, compiled in the *Guidance for the Compilation of Safety Data Sheets for Fertilizer Materials*. Each sheet has sections on: composition, hazards identification, first-aid measures, fire-fighting

measures, accidental release measures, handling and storage, exposure control/personal protection, physical and chemical properties, stability and reactivity, toxicology, ecological considerations, disposal, transport and regulations. There are models for anhydrous ammonia, ammonia solution, ammonium nitrate, ammonium nitrate solution, ammonium sulphate, calcium ammonium nitrate, diammonium phosphate (DAP), monoammonium phosphate (MAP), nitric acid, NPK fertilizer (ammonium nitrate based), phosphoric acid, sulphuric acid and urea.

properties. Nonetheless, the fertilizer industry has traditionally paid great attention to safety standards.

This care has resulted in a safety record superior to much of the chemical industry. There have been extremely few major accidents in the history of the fertilizer industry. To maintain this safety record most fertilizer associations have produced safety handbooks, product safety sheets, inspection recommendations and other guides. The European Fertilizer Manufacturers' Association (EFMA) recently ran its fourth safety seminar. Most companies already have disaster-preparedness plans.

Both EFMA and IFA have incident-reporting schemes which allow member companies to exchange information on minor mishaps, 'near misses', and the rare full-scale accident. By learning from shared experiences, this system helps avoid the repetition of preventable incidents and their potential undesired impacts. Electronic communications have facilitated incident reporting.

In recent months, associations and companies alike have been re-evaluating existing safety standards and looking for any weakness that may have previously been overlooked. In some countries, companies are also being warned to redouble vigilance around products which

could be misused for violent purposes.

3.1.3.2 Fertilizers and crop quality

Correct fertilization has a positive impact on the quality of agricultural produce. The baking quality of wheat, the brewing quality of barley and the colour, crispness and texture of various vegetable crops all benefit from appropriate fertilization. Similarly, potassium improves the quality of potatoes and the sugar content of sugarcane, and sulphur increases the protein content in grain and the oil content of oil-seed crops. [Isherwood, 2000b] Proper, balanced plant nutrition avoids crop quality disorders and improves their resistance to stress due to drought, frost, diseases and pests.

3.1.4 Changing consumption patterns (Agenda 21, Chapter 4)

Inefficiencies in use represent both an environmental hazard and a substantial economic loss. A 20% loss of nitrogen means that one-fifth of what the farmer spent is wasted.

More efficient fertilizer uptake by plants has two major benefits. Farmers can apply less fertilizer while maintaining increased yields, thus saving money. More efficient absorption also reduces the quantity of plant nutrients which might otherwise leach into water systems. The aim is to optimise production per

unit of fertilizer while applying the required quantities to satisfy the world's agricultural requirements.

Farmers control the quantity and mixture of nutrients applied, which is the ultimate determinant of whether fertilizer use is balanced and efficient. Nonetheless, the industry has a responsibility to facilitate good use and must provide the farmer – industry's primary consumer – with safe, quality products and guidance on their use. Best practice in this regard is specific to each farm and represents a delicate balance between environmental aspects, the quality of produce and profitability.

Where they have access to improved cultivation practices, application techniques and crop varieties, farmers have shown their eagerness and skill for adapting integrated management practices. Promising results are also emerging in the field of 'site-specific' or 'precision agriculture'.

In the long-term, these successes may influence the structure of the industry – perhaps changing it from a commodity, raw material supplier into a value-added service provider, offering farmers a fully integrated system in which the fertilizer is merely an ingredient and the delivery mechanism is the profit centre. [IFA, 1999] This vision offers hope for improving the long-term sustainability of the fertilizer industry, but under present circumstances, there are few signs of it being realised.

Larger farmer co-operatives in the United States and India which both produce fertilizer and provide nutrition services are, unfortunately, the exception rather than the rule. Under current market conditions, it is unclear how the industry can take this leap, as current profit margins do not allow for the added cost of providing these services. Farmers are unlikely to voluntarily pay more for fertilizers as long as their own margins remain quite low.

3.1.4.1 Nutrient accounting

Nutrient accounting is a tool for reducing unwanted environmental impacts. In brief, this management technique requires a farmer to budget the quantity of nutrients introduced to the farming system and the quantity escaping either through crop harvest or losses to the environment.

Nutrient accounting was first developed in Europe to respond to concerns about nitrogen pollution of water. Balanced fertilization, as well as timely and appropriate application, can help achieve the correct nutrient budgets. In some cases, nutrient budgeting has entailed a reduction of the amount of fertilizer applied, but has probably resulted in increased efficiency of use in many of these cases through better targeting of the amounts applied.

The nutrient accounting technique is a useful tool because it generates information on:

- the health of soils in various areas under various cropping systems,
- the current efficiency of fertilizer use,
- the scope for increasing organic fertilization,
- minimising losses of plant nutrients from the system,
- appropriate fertilizer strategies for intensifying crop systems.

Required nutrient accounting might spur the industry into developing more value-added products in future because farmers would then have a strong incentive to pay more for more efficient nutrients.

3.1.4.2 Precision agriculture

In developed countries, computers and satellite technology have paved the way for precision agriculture, which uses high-tech systems to map the specific nutrient needs of small plots within crop fields. This allows a farmer with the proper equipment to tailor the application of nutrients to suit the needs

of each metre of his or her field. This has greatly increased the efficiency of fertilizer use and reduced the loss of nutrients into the environment.

While such technology is beyond the means of most farmers in developing countries, the principles of testing and mapping can still be harnessed to help farmers apply the appropriate mix of fertilizers for each part of a field. They can improve the precision of their plant nutrient programmes given soil testing facilities and sound advice.

3.1.4.3 Fertigation, controlled-release fertilizers and other speciality products

Fertigation enables farmers to maximise the use of water resources and to increase the efficiency of fertilizer use. It is particularly useful for high value crops under arid and semi-arid conditions. It involves adding soluble fertilizers into irrigation systems using a drip system which allows uniform water distribution and feeding of the crop. Fertigation creates a double efficiency: properly fed plants absorb water better; and the careful targeting of fertilizers optimises nutrient uptake. However, as with any technique, it must be properly managed; use and maintenance require skilled labour. Initial investment costs are high.

Controlled-release and other speciality fertilizers hold a lot of potential for use in developing countries. Because the technology is built into the product through a special formulation which only releases nutrients gradually or under certain conditions, even farmers using animal traction could benefit from the precision of these products. However, their higher costs mean that, at this time, use is even more unlikely in developing countries than that of traditional fertilizers.

3.1.5 Distribution and transport issues

The cost of getting fertilizers from the plant to the farm accounts for a substantial proportion of the farm-delivered cost. In remote corners of developing countries, transportation

difficulties, logistical complications and the ensuing high costs can effectively prevent farmers from having access to fertilizers and other agricultural inputs.

Even if the products make it to the farmer's market, the prices are likely to have become so high that a small farmer cannot hope to buy them. Such chronic problems require creative thinking on the part of all players, including industry.

Fertilizers are bulky. As a result, transport costs are a major element of the total cost of delivery to the farm and can have a major impact on the profitability of a factory or distributor. More efficient fertilizers would take up less space and weigh less, have a lower transport cost per unit of nutrient and reduce the environmental impacts of distribution.

Costs vary widely. According to a 1998 survey [Dante, 2000] of the situation in Asia and the Pacific, the costs of transporting fertilizer from the factory to the survey area ranged from as low as USD2 per tonne in Fiji to a high of USD45.8 in Indonesia, where transportation costs accounted for 84% of total marketing costs. In landlocked countries of Africa, the cost of fertilizers at the farm gate can be several times higher than the cost in the port of entry.

The key element before processing is the cost of delivering the raw materials and intermediates to the factory (sea freight, discharge at port, storage at port, transport by truck to the factory). Following processing, the cost of transport to the farmer (involving transport by truck to an intermediate store, discharge, storage, re-loading and final delivery to the farmer) adds significantly to the final total.

A large proportion of sea-borne trade involves supply of raw materials and intermediates to the major manufacturers and also intra-company movements of intermediates and finished products from one site to another.

An important aspect of distribution is the development and standard of the road and railway system, the availability of water transport, or a pipeline. In many developing countries the density of the roads is low. The poor transport system is probably the single most important factor limiting China's ability to benefit from its great agricultural diversity. This results in a growing division between a prosperous, diversified agriculture around the coastal periphery (with its large cities) and a poor, relatively unprogressive agriculture in the remote interior. Only governments can effectively deal with such infrastructure issues.

A factor contributing to high transport costs in some countries is the insistence of some governments that fertilizers be made available to all farmers, even in the most remote areas. Not only does this increase transport costs, but the increased amount of food produced must in turn be transported to markets at a higher cost. Food producers which, by reason of their location, are best placed to produce food for the market are penalised by having to absorb the costs associated with transport to and from remote areas.

Case study: Providing small farmers with access to fertilizers

One creative solution for helping farmers overcome the high-cost barrier was put in place by a Kenyan NGO, the Sustainable Community-Oriented Development Programme (SCODP). In 1995 SCODP opened seven shops in western Kenya to sell seeds, fertilizers, pesticides and other inputs. Commercially-available fertilizers were purchased in 50kg bags and weighed out and sold in quantities according to farmers' requests.

Because a 50kg bag may cost the equivalent of several chickens or a 90kg bag of maize, the programme was off to a slow start until 'mini-packs' – provided by the fertilizer industry – were introduced for experimentation.

However, purely economic efficiency is not the only consideration: if universal access to fertilizers is managed in such a way as to ensure balanced plant nutrition by those who would be farming anyway, and in this way prevent nutrient mining, a government may deem that a legitimate policy objective and worth the economic cost.

3.1.6 Quality control

To ensure quality control, a number of IFA companies have adopted the ISO 9000 series for quality assurance. In an informal survey in 1999, 56 IFA member companies reported that they had already adopted these standards.

Although quality is carefully controlled by the manufacturer, mineral fertilizers can easily be adulterated during distribution, and the farmer is usually unable to check the quality. In developed countries, regulations ensure the quality of the product remains high until it reaches the farm. In most developing countries, even where regulations exist, means for enforcement are not adequate.

Containing a few vital ingredients, the 100g mini-packs were sold. Farmers then started buying affordable 1kg bags of ammonium phosphate fertilizer; and most progressed to buying 10kg or 25kg bags once they saw the results. The shops became profitable, crops flourished and the local communities now enjoy better nutrition and greater economic development.

Farmers themselves can experiment with this new technology without going into debt. As SCODP says: 'Because mini-packs are not given away free, farmers respect the inputs and use them carefully. Because they cost money, farmers are encouraged to treat agriculture as a business... (Farmers) invariably return to SCODP to seek more advice, and to purchase inputs in larger quantities.'

3.2 Conservation and management of resources (Agenda 21, Section II)

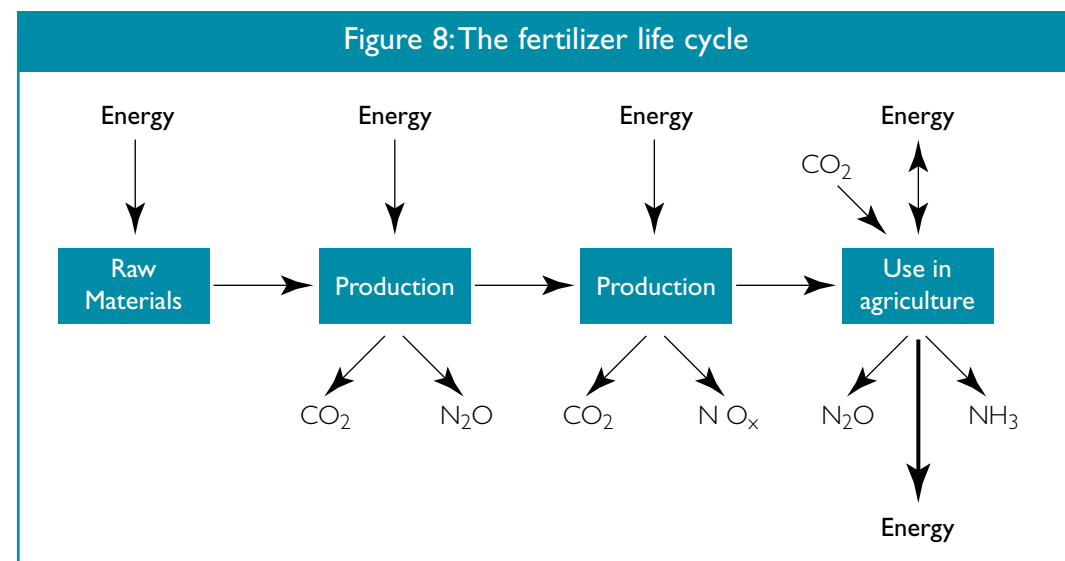
Fertilizers help minimise soil degradation, in particular soil erosion and plant nutrient mining, while maintaining and enhancing soil fertility as a whole. They improve farming efficiency and water conservation. Mineral fertilization, with macro- and micro-nutrients, provides for nutrient balance and optimum soil-productivity to stimulate healthy, vigorous crop growth. Fertilizers allow for quick canopy cover and establishment of efficient root systems and more aboveground plant growth. They also play a positive role in carbon dioxide (CO₂) assimilation by improving the fixation of carbon by crops.

Modern fertilizers are relatively simple inorganic chemicals. Nonetheless, there are

significant environment issues throughout the fertilizer life cycle that this section will consider.

Since the Earth Summit held in Rio de Janeiro in 1992, IFA and UNEP have together prepared a series of publications drawing attention to the environmental issues at each stage of the fertilizer life cycle:
Environmental Aspects of Phosphate and Potash Mining (2001)
Mineral Fertilizer Production and the Environment (1998)
Mineral Fertilizer Distribution and the Environment (2000)
Mineral Fertilizer Use and the Environment (2000, revised edition)

A complete overview of the fertilizer industry and its relation with food supply is presented in:
The Fertilizer Industry, World Food Supplies and the Environment (1998)



Environment Impacts	Solutions
Air	Environmental management systems
Water	Technical
Soil	Regulations and policy
Health and safety	Knowledge
Energy	
Resource depletion	

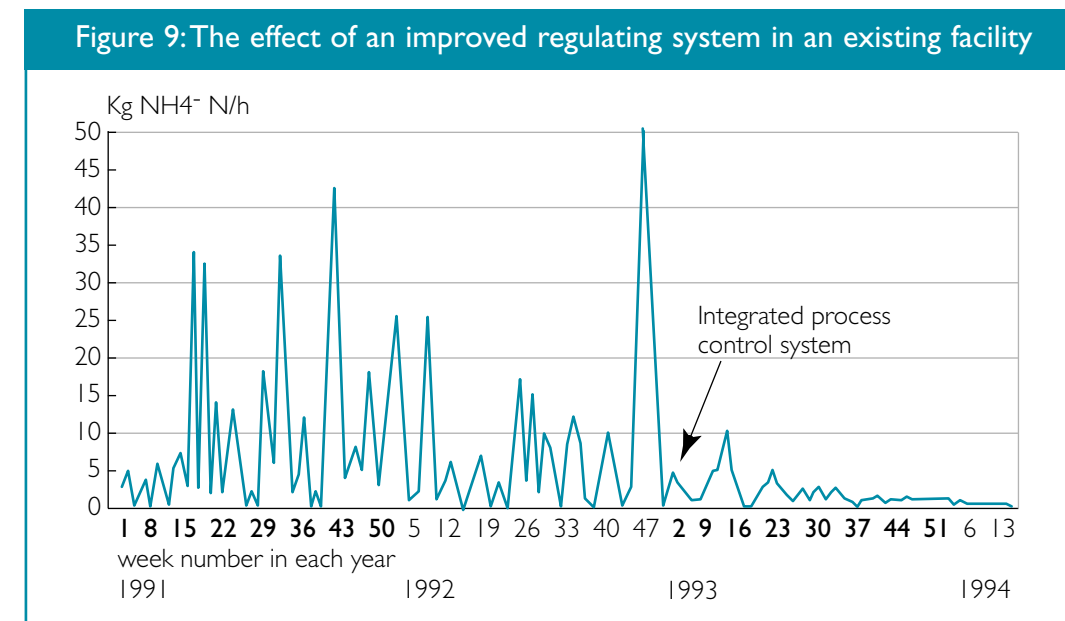
Source IFA

3.2.1 Mineral fertilizer production

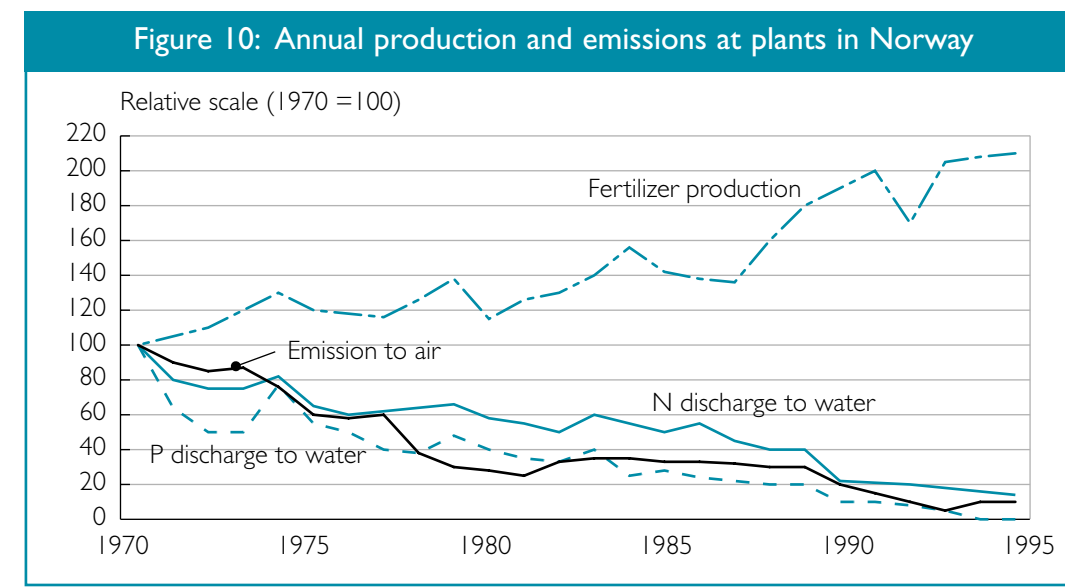
Production is normally associated with large factories, sources for emissions of acidifying components to air and water: Large amounts of energy are consumed (or transformed into plant nutrients) with emissions of greenhouse

gases. Using modern technology, emissions can be reduced to acceptable levels. At least in the industrialised countries, and in several developing countries, fertilizer manufacturers have made great progress in this respect during the past two decades.

As an example, the following diagrams illustrate how Norsk Hydro has reduced emissions from its plants in Norway:



Source Norsk Hydro



Source Norsk Hydro

These results were obtained by putting a substantial amount of money into old plants, partly building new ones based on improved technology, and, last but not least, doing things more cleverly. In the first figure, the consequences of introducing improved regulating systems into an old plant, providing better training for the people who operate the plant and tying a bonus system to the level of emissions are evident. [Lie, 1997]

Most phosphate fertilizers are produced through a route which involves the acidulation of phosphate rock to produce phosphoric acid. A by-product of this process is phosphogypsum, five tonnes per tonne of P₂O₅ produced. It is difficult to find a commercial outlet for phosphogypsum because of contaminants coming from the rock. In most countries disposal into waterways or the sea is strictly regulated, and the material has to be stored in large stacks.

Case study: ISO 14001 and QAFCO, Qatar

During the process of implementation of ISO 14001, one of the Qatar Fertilizer Company's (QAFCO) important tasks was the identification of environmental aspects and the evaluation of these aspects for significance. This process covered the activities, products and services of the organisation, and involved all functions of QAFCO. Considering all the inputs and outputs of the activities, services and products permitted relevant aspects to be identified in the following categories:

- resources,
- air emissions,
- discharges to the sea,
- waste management,
- soil ground water,
- ozone depletion agents,
- physical agents,
- services,
- products.

The aspects were ranked according to their importance. Each aspect was evaluated for normal, abnormal and emergency situation, and also whether it is a current, present or future issue.

So far QAFCO has identified 105 aspects, of which nine were considered 'significant' and one 'emergency'. For the 'significant aspects', policy was re-formulated, objectives and

targets were made and environmental management programmes were prepared.

Another consideration was communication with the local community. For this purpose, QAFCO organised various environmental campaigns (in which several hundred community members and QAFCO employees participated), exhibitions, school competitions, etc., together with posters carrying environmental messages and different promotional materials.

This environmental management system was implemented successfully thanks to the following factors:

- firm management commitment;
- allocation of adequate resources;
- clear definition of roles, responsibilities and authority;
- environmental awareness and training of all employees;
- setting measurable and achievable goals;
- QAFCO's work culture and experienced work force.

The EMS complemented the already-existing waste-management programmes, safety and quality-management systems and emergency procedures and preparedness.

Certification was not an end in itself, but seen as the means to maintaining and continually developing a sound environmental management system. [Al Haimi, 1999]

3.2.1.1 ISO 14000 Series

By 1999, 13 IFA member companies had implemented the ISO 14000 series for environmental management systems. An updated survey would likely show a much higher current application of ISO 14000 as member interest in ISO certification has consistently registered as being very high in recent years. A number of other systems are in place as well, such as the European Environmental Management Assessment System (EMAS).

3.2.1.2 Best available techniques (BATs)

EFMA began a series of booklets on best available techniques in 1995 and updated them in 2000. Public concerns were incorporated. The BAT approach has now gained wide acceptance to the extent that the European Union's Integrated Pollution Prevention and Control (IPPC) directive provides a mandate for BAT References (BREFs) to be drafted for a wide range of technologies. Through EFMA's BAT efforts, the industry has gained heightened credibility, not only with the public but also with national and European regulatory authorities.

The BATs are set out in the series of booklets *Best Available Techniques (BATs) for Pollution Prevention and Control*, which serve as references for facilities around the globe:

- *Production of Ammonia.*
- *Production of Nitric Acid.*
- *Production of Sulphuric Acid.*
- *Production of Phosphoric Acid.*
- *Production of Urea and Urea-Ammonium Nitrate.*
- *Production of Ammonium Nitrate and Calcium Ammonium Nitrate.*
- *Production of NPK Compound Fertilizers by Nitrophosphate Route.*
- *Production of NPK Compound Fertilizers by Mixed Acid Route.*

In the booklets, two sets of emission guidelines are given, one set for new plants and the other

for existing facilities (those built before 1990). For new plants, modern prevention technology can be readily integrated into the process design. For existing plants, emissions can be reduced only by installing end-of-pipe technologies or through costly revamps. In both cases, careful operation and maintenance is still necessary to achieve the emissions target.

These standards represent the best balance between emissions, wastes and energy consumption, based on the fact that a reduction of one emission may give an increase in another, or a higher energy consumption. Local environmental conditions may dictate a specific balance of what can be achieved. EFMA and IFA carry out benchmarking to help member companies see how their performance compares with these goals.

Deviations from the BAT standards may be acceptable:

- if the environment can tolerate higher emissions, without local, regional or inter-regional negative effects;
- if the social cost of achieving the standard is too high;
- if the size of the production process, the availability of energy sources and raw materials, or the product range being manufactured, are different from what is assumed in the EFMA BAT booklets;
- during start-up and shut-down operations and in emergencies.

The booklets include sections giving details of suitable analytical techniques and recommended frequencies of analysis for the control of both air and water pollution by fertilizer manufacturers.

It was found that achievable emissions levels for plants built after 1990 are often 25-30% of those for older, less innovative facilities.

3.2.1.3 Cleaner production

At the annual conference in Oslo, (May 2000), the President of IFA signed the UNEP International Cleaner Production Declaration on behalf of members, whereby they pledged to promote the cleaner production principles across their operations. As section 3.2.2 shows, the industry had already taken significant steps towards cleaner production, and continues to make progress.

3.2.1.4 Environmental legislation

Environmental legislation may set out emission limits or guideline values, together with an enforcement system based on official inspection. Such a system should contain details of recognised test methods. In many countries there is a national (federal) authority such as the United States Environmental Protection Agency (EPA), policing environmental pollution from all sources, but authority is sometimes delegated to lower levels of government.

The enforcement of legislation may be effected through fiscal incentives, taxation, subsidies, environmental liability, civil law and market forces. In most developed countries, state and local advisory organisations are fully involved. Enforcement may be international, national or local, depending on the type of legislation. Sanctions may be under criminal or civil law depending on the offence.

Environmental protection is usually in the hands of national government bodies, with regional enforcement. Sanctions include fines and possible closure of polluting plants. In the United States, the federal government has direct enforcement authority for its environmental programmes, but there are also state and local environmental officials and requirements. Even where the federal government has legislated in a particular area, most of the environmental laws leave the states free to adopt stricter standards.

Case study: Cleaner production in Canada

Based on government estimates, about 3% of Canada's greenhouse gas emissions (measured in tonnes of CO₂ equivalent) comes directly from the use of nitrogen sources, including mineral fertilizer, manure and legumes.

Realising that this issue could significantly impact the domestic industry, the Canadian Fertilizer Institute (CFI) took a proactive stance to gather more information and look at possible responses. Canada is the world's largest potash producer and exporter with approximately 40% of world trade. It is also a major source of nitrogen and the world's largest supplier of traded sulphur. In total, Canada supplies some 12% of the world's fertilizer materials.

In a first step, the institute initiated three research projects: one to gather data on

fertilizer manufacturing emissions, a second to obtain more accurate estimates of the actual greenhouse gas emissions from agricultural nitrogen sources, and a third to consider the potential role of carbon sequestration.

The results of this early work showed that focusing only on fertilizer production facilities would have little overall effect, since the Canadian industry has already made great strides to reduce the environmental impacts of its activities, and Canadian facilities are now among the most energy-efficient in the world.

Ongoing work in this area has therefore considered, among other options, how the Cleaner Development Mechanism (CDM) can be applied in the industry. Doing so could have multiple benefits as it would help Canada meet its Kyoto commitments, would reduce the negative environmental impact in another country and would also help maintain the competitiveness of the Canadian fertilizer industry.

Individual states are also taking the lead in developing controls over packaging, used product disposal, recycling, environmental advertising and related matters. Sanctions range from the serving of 'improvement notices', which require action to be taken within a reasonable time limit, through fiscal penalties and imprisonment to temporary or permanent plant closure.

3.2.2 Distribution issues

The potential negative environmental impacts of mineral fertilizer distribution are obvious – accidents in storage facilities, spillage, misuse of the products and losses of nutrients to the environment during transport and storage. These are addressed by a number of innovative solutions. One company recently developed new equipment to allow for dustless filling of bulk fertilizer containers.

If the farmer is to have the fertilizer in a timely manner and in the form required for optimum use, an efficient distribution system is the key. However, in some developing countries, consumption has overtaken that of developed countries, while distribution systems have not kept pace, resulting in waste and inefficiencies. [Isherwood]

In general, the distribution sector of the industry receives insufficient attention. IFA, in co-operation with FAO and UNEP, has prepared several publications on the subject:

- *Fertilizer Retailing Guide* (with FAO, 2001, updated French version and 2002 updated English version);
- *Mineral Fertilizer Distribution and the Environment* (with UNEP, 2000).

3.2.3 Mineral fertilizer application

'It is in the application of its products in agriculture that the fertilizer industry is most vulnerable from the environmental point-of-view. The challenge is to retain the benefits of fertilizers while minimising adverse consequences.' [Maene, 2000].

Insufficient and excess fertilizer application as well as unbalanced use can have unwanted environmental impacts. Proper use is made more challenging by the diversity of site-specific factors which influence local requirements. In the mine-to-crop continuum, it is the application of fertilizers which represents the biggest potential environmental effect. The complex issues involved are detailed in the following sections.

3.2.4 Protection of the atmosphere (Agenda 21, Chapter 9)

3.2.4.1 Dust – common throughout all mining activities

Dust generated by vehicle traffic can be reduced by a variety of means. Regular watering with mobile water trucks or fixed sprinkler systems is effective but raises issues on wastefulness of water use. The application of surface binding agents, the use of suitable construction materials and the sealing of heavily-used access ways can be more suitable. Dust emitted during the treatment of phosphate rock can be controlled by water sprays, baghouses and wet scrubbers. Captured dust can usually be returned to the process.

3.2.4.2 Efficiency gains in production

Atmospheric pollution is high on the global environmental agenda. The industry has responded well to the challenge of improving the efficiency of fertilizer production, particularly energy consumption and especially in Europe and North America. Since the Environmental Protection Agency began

collecting data in 1987, nitrogen fertilizer plants in the United States have cut emissions by about 75%.

One expert calculated that energy consumption using best available production techniques (BATs) was about half in 1998 what it was in 1968 – 2,743 Gigajoules versus 5040 for 134Mt total nutrients. This improvement can be directly attributed to improved production technology.

The production of fertilizers currently accounts for about 2% of total global energy consumption, used mostly in nitrogen production. Although nitrogen production will always consume large amounts of energy, because the processes require high temperatures and pressures, the industry has become much more energy-efficient. Ammonia factories built in 1990 used about 30% less energy per tonne of nitrogen than those designed around 1970. In the best plants, the theoretical efficiency limit is being approached.

Fertilizer production accounts for about 1% of global carbon dioxide emissions. The emission of carbon dioxide is an unavoidable

by-product of the ammonia production process, but improving the efficiency of energy consumption reduces the emission of carbon dioxide.

The process used for the production of most phosphate fertilizers involves the production of sulphuric acid, with a risk of emissions of sulphur compounds. Emissions of sulphur compounds may give rise to acid rain, which increases soil acidity over wide areas, with adverse effects on the flora and fauna. Most countries impose strict limits on sulphur emissions. Modern technology permits the recovery of almost all the gaseous sulphur compounds emitted from sulphuric acid production. In the decade beginning 1987, phosphate fertilizer plants in the United States reduced their emissions by 83%.

3.2.4.3 Emissions benchmarking

As discussed above, EFMA's BATs reveal that achievable emissions levels for plants built after 1990 are often 25-30% of those for older, less innovative facilities. EFMA carries out a benchmarking exercise to help member companies see how their performance compares with these goals.

IFA has recently extended this benchmarking to the international level. In a first round, 37 companies participated, of which 29 were from developing countries, six from developed countries (IFA uses the FAO classification in which South Africa is a developed country) and two from countries in transition. Some 80% were found to conform to the emissions guidelines specified for existing plants in the BATs. Participating companies receive a report which shows how their performances compare with the industry at large. A second round of benchmarking will be carried out in two years, which will allow companies to plot individual improvements and reveal overall trendlines.

3.2.4.4 Emissions from applied fertilizers

In future, greater attention must be paid to

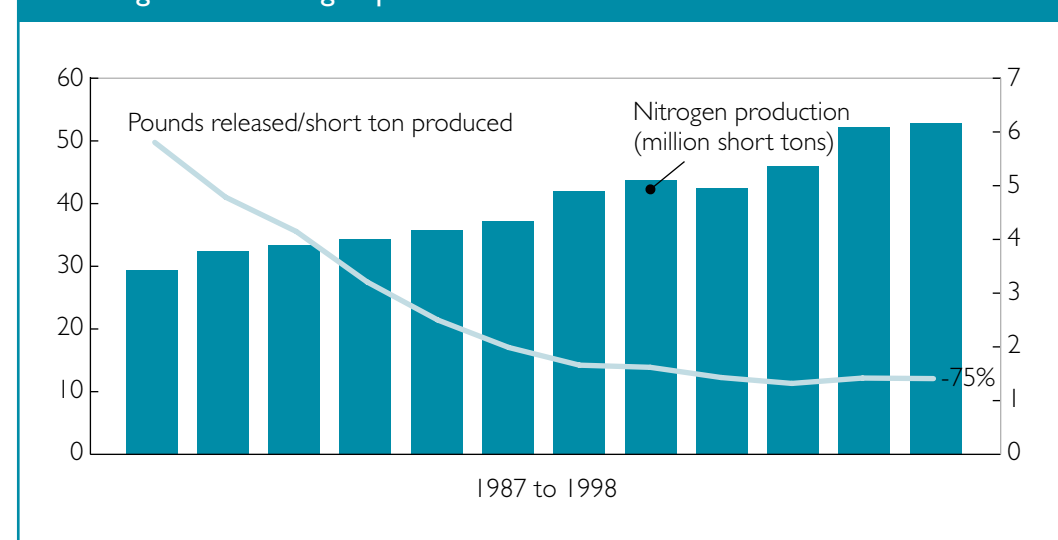
atmospheric emissions from applied fertilizer and the agro-ecological system. Experiments have shown that ammonia lost to the atmosphere following the application of urea can amount to 20% or more under temperate conditions. Losses are even higher – 30% to 40% and more – under tropical conditions on flooded rice and crops which do not involve the tilling of the soil such as bananas, sugar cane, oil palm and rubber.

This environmental challenge may drive the search for a fundamentally different mechanism to supply crop nutrients, perhaps using some combination of biological and chemical processes. However, a new study jointly commissioned by FAO and IFA from A Bouwman, a respected expert in the subject, suggests that the contributing factor of nitrogen fertilizer to N₂O emissions is considerably lower than earlier versions of his models indicated, averaging 0.8% per tonne of nitrogen applied as opposed to 1.25% [Bouwman, 2001].

IFDC's 'Adapting nitrogen management technologies' project focuses on environmentally-friendly and efficient nutrient-management technologies to improve the uptake of nitrogen in rice paddies, which will help reduce emissions. Since the mid-1990s, farmers in Bangladesh and now Nepal and Vietnam have been placing small urea briquettes, by hand, up to four inches deep in the saturated paddies. Briquette farmers report yields up to 20% higher while cutting back on nitrogen by as much as 59%. In addition the project has provided a new market for local machine shops from which private entrepreneurs buy the briquette-making machines. The International Fund for Agricultural Development (IFAD) supports the project, and a total of nine NGOs collaborate.

Fertilizer industry associations and research institutes strive to improve scientific knowledge regarding greenhouse gas emissions from fertilized fields, and in trying to design and

Figure 11: Nitrogen plant emission reductions in the United States



Source: The Fertilizer Institute

promote better plant nutrient management systems to mitigate these emissions. The Bouwman study is an example of this. As well as updating models to take into account the evolution of expertise in this field, the new study looks at the specific contribution of different types of nitrogen fertilizers to greenhouse gas emissions. Important contributing factors are highlighted to help identify the best preventative measures.

FAO/industry working group activities on climate change include some reports prepared on the release of emissions from the use of fertilizers. IFA was also the reference for data on fertilizer consumption and use by crop.

3.2.5 Integrated approach to the planning and management of land resources (Agenda 21, Chapter 10)

In 1996 IFA published *Plant Nutrients for Food Security*, a paper which focused on the importance of the effective management of plant nutrients as a major component of agricultural development. The sources of plant nutrients may include mineral fertilizers, biological nitrogen fixation and/or organic materials.

At an FAO conference on the topic of Integrated Plant Nutrition Systems (IPNS) for sustainable development held in New Delhi (India) in 1997, recommendations to further develop IPNS included an improved service to farmers in the form of technical advice, inputs, credit, marketing facilities and public investment in agriculture. IPNS, they decided, should address both increased productivity and profitability for farmers, with special attention paid to the alleviation of poverty in rural areas. In addition, it should:

- integrate the maintenance and rehabilitation of natural resources and the enhancement of productivity in agriculture;
- be system-oriented, in particular taking into

account the interactions between plant nutrient supply and water supply, and between plant nutrients supply and the control of pests and diseases;

- improve the availability of energy for the rural population, to save fuel wood and organic materials used as an energy source;
- be science-based, embracing agronomy, ecology and social science;
- use a 'farming systems' approach, not limited only to cropping systems.

IFA supports the 'Soil Fertility Initiative for Africa', together with IFPRI, the International Centre for Research in Agroforestry (ICRAF), FAO and the World Bank, which focuses on integrated plant nutrition management programmes designed to reverse the trend of declining soil fertility in many parts of sub-Saharan Africa.

3.2.5.1 Soil conservation

'The single most important factor limiting crop yields in developing nations worldwide – and especially among resource-poor farmers – is soil infertility. This problem is acute in much of sub-Saharan Africa and in the highland areas of Latin America and Asia. Unless soil fertility is restored in these areas, farmers will gain little benefit from the use of improved varieties and more productive cultural practices. Soil fertility can be restored effectively by applying the right amounts of the right kinds of fertilizers,' according to D. Norman Borlaug, who won the Nobel Prize for his role in the Green Revolution and helping large numbers of people avoid starvation. [Borlaug, 1994].

This problem is particularly acute in developing countries, where year after year far more nutrients are being extracted from soils than are being replaced, (this potential exists on any farm where nutrients are transported off the farm through crop sales). In 1990, FAO described plant nutrient depletion in many developing countries as 'a real and immediate threat to food security and to the lives and livelihoods of millions of people'. [FAO, 1990].

More recently an IFPRI report on the world food situation said that past and current failures to replenish soil nutrients in many countries must be rectified: 'While some of the plant nutrient requirements can be met through the application of organic materials available on the farm or in the community, such materials are insufficient to replenish the plant nutrients removed from the soils. It is critical that fertilizer use be expanded in those countries where a large share of the population is food insecure.' [IFPRI, 1997].

Major impacts on soil quality

In mining activities, the land surface and sub-surface is disturbed by such activities as the extraction of ore, the deposition of overburden, the disposal of beneficiation wastes and the subsidence of the surface. Removal and stockpiling of topsoil for rehabilitation is carried out by many mining operations within the fertilizer industry. Close co-ordination and planning is required between mining and rehabilitation operations.

Deforestation, agricultural mismanagement, industrial pollution and warfare cause soil degradation, with hillsides and dryland regions most vulnerable. Crops remove considerable quantities of nutrients from the soil which must be replaced if soil fertility levels and long-term sustainability are to be maintained. In many countries, soils have been put at risk by mining both the nutrient and organic matter contents of the soil.

Most forms of agriculture increase the erosion potential, especially practices which leave the surface of land vulnerable. Globally, moderate to severe erosion affects about 900 million ha. Prevention of soil erosion is a key issue in the sustainability of agriculture.

Fertilizers can reduce the problems associated with erosion by:

- increasing crop growth so that the soil is rapidly covered by vegetation which reduces the eroding action of raindrops;
- increasing yield not only of the crops, but also of roots which bind soil particles and of crop residues which cover the soil after harvest;
- contributing to the maintenance of soil organic matter;
- helping to re-establish plant cover where erosion has removed the topsoil and nutrients;
- increasing yields, thus reducing the need to expand crop-growing onto fragile soils.

There is sound evidence that the proper use of fertilizers increases the organic matter of soils because increased yields generate more crop residues from roots and tops. An indirect impact may, however, be that mineral fertilizer use permits practices such as mono-cropping which burn up the organic matter. This can be countered by using mineral fertilizers within an integrated plant-nutrition management scheme which includes the regular incorporation of organic matter.

Some symptoms of erosion can be masked for a while by increased fertilizer application, but fertilizer should form part of soil management plans, not be used as a substitute for good management practices [Lægneid et al., 1999].

Balanced fertilization

If any plant nutrient is deficient, crop growth is affected. Balanced fertilization is the nutrient mix which gives the optimum economic return in the sense that the proper balance assures that the plant absorbs each nutrient and does not waste any of what is applied.

Farmers tend to prefer using nitrogen fertilizers because of their relatively low cost per unit, their widespread availability and the quick response of the plant. However, increased yields due to nitrogen application in isolation deplete the soils of other plant nutrients. For this reason, a healthy balance between nitrogen, phosphorous, potash and other necessary plant nutrients must be maintained if soils are to be managed in a sustainable manner:

China's most productive double-cropped paddies in Hunan or Jiansu, which received no mineral fertilizer in 1950, yielded less than



2.5 t/ha. They now receive more than 400 kg of nitrogen and a single crop produces more than 6 t/ha [Smil, 1999]. While this has helped increase food production significantly, application has largely been unbalanced towards nitrogen. Efforts are underway to encourage farmers to use only as much nitrogen as needed by plants and in proportion to other nutrients made available to the crop.

Some balanced fertilization projects around the globe:

- *Balanced fertilization project in India* – carried out in co-operation by the Fertilizer Association of India, IFA and the Sulphur Institute, this project is in its second phase. During the first phase, a survey was carried out to identify sulphur deficiencies, which are becoming prevalent in India. Results from the experiments showed significant responses to sulphur. Publications in local languages with information about sulphur use have been provided to farmers.
- *The BALCROP project*, established in 1994 in Vietnam deals with balanced fertilization for better crops.
- In recent years, the World Phosphate Institute (IMPHOS) has carried out

balanced fertilization projects in developing countries in Asia, the Mediterranean region and sub-Saharan Africa. Following the drop in fertilizer demand in central and eastern Europe triggered by the collapse of Communist economies, IMPHOS has undertaken a special plan of work to evaluate the effects of sustained low phosphate consumption in this region.

- The International Potash Institute (IPI) promotes balanced fertilization in a wide range of countries, the most recent being Argentina, Belarus, Brazil, Bulgaria, China, Czech Republic, Egypt, Hungary, India, Iran, Morocco, Poland, Romania, Russia, Slovakia, Turkey and Vietnam. IPI currently publishes in 20 languages, which allows farmers in many countries to draw on information about the importance of balanced fertilization.

3.2.6 Conservation of biological diversity (Agenda 21, Chapter 15)

3.2.6.1 Fertilizers contribute to preserving natural habitat

Without the additional nutrients supplied by fertilizers, farmers would not have been able to sustain the growing world population without a massive expansion of the agricultural area and a consequent loss of natural habitat and biodiversity. Fertilizers alone have not achieved this, but they have been an essential ingredient in the mixture of improved crop varieties and other agricultural technologies which have contributed greatly to keeping many hectares from going under the plough.

In 1960, farmers harvested about 1.4 billion ha. By the 1990s, there were still less than 1.45 billion ha under cultivation, yet food and feed supplies had been doubled. [IFA (with UNEP), 1998]

With intensification, the agricultural area is tending to decrease in much of the developed world, with corresponding increases in forested area. But in the developing world, the agricultural area is increasing, tropical forest is being transformed into agricultural land and agricultural land is being lost to urbanisation. This results in a loss of biodiversity.

Plants and animals may be directly affected by variations in the quality of water, air and soil and sediments and through disturbance by noise, extraneous light, and changes in vegetative cover. These changes in turn affect the biosphere, for example habitat, food and nutrient supplies, breeding areas, migration routes, vulnerability to predators or changes in grazing patterns, which in turn may have a secondary effect on predators.

Soil disturbance and removal of vegetation and secondary effects such as erosion and siltation directly affect ecosystems. They may also lead

to indirect effects by upsetting nutrient balances.

Over-grazing is one of the major causes of soil erosion and the grazing livestock population is tending to increase. The increased production of fodder, with appropriate fertilization practices, is one way to reduce the pressure of livestock on grazing land.

The heavy fertilization of grassland, especially with nitrogen fertilizers, can reduce biological diversity. The fertilization of pasture and animal fodder crops accounts for 30% of world nitrogen fertilizer use. Half of this is concentrated in the regions of western Europe with maritime climates which favour grassland and high rates of fertilization. Elsewhere, rates of fertilizer use on grassland are low and unlikely to have a major impact on biodiversity. Phosphate and potash applications may, in fact, favour biodiversity.

Mineral fertilizers which result in the acidification of soils have also been accused of having an adverse effect on soil invertebrates, in particular earthworms. This can easily be mitigated by adding lime and other soil amendments, as farmers have been doing for thousands of years.

3.2.6.2 Some effects of mining and extraction activities

The land surface and sub-surface is disturbed during mining by activities which could result in a wide range of potential impacts on the land, geological structure, topsoil, aquifers and surface drainage systems. Additionally, the removal of vegetation may affect the hydrological cycle, wildlife habitat and biodiversity of the area.

The fertilizer industry, which is a signatory to the UNEP Cleaner Production Declaration, is committed to minimising the impacts of its activities on the land where it operates. The replanting of small trees from areas to be mined and the placement of dead trees on

rehabilitated areas has been used to accelerate the establishment of vegetation and provide a wildlife habitat.

Today, rehabilitation of mined areas has become the industry norm and is a fundamental principle of good business practice in the mining sector. Rehabilitation activities generally involve the design and reaction of stable and safe landforms, followed by the establishment of self-sustaining ecosystems to replace those disturbed during the mining process. The effectiveness of rehabilitation is enhanced by integration with the mine plan and conducting it progressively throughout the life of the mine. The objectives of rehabilitation can range across a spectrum:

- complete restoration of the area's original natural values;
- reclamation to re-establish the pre-mining land use;
- development of a completely new use for the area, such as lakes, forestry or agriculture;
- leaving land of marginal value in a safe and stable condition.

In some countries, post-mining land-use is determined through discussion and consultation with stakeholders such as state and local government agencies, local communities and private landholders, to develop an appreciation of their needs and desires. Important considerations for decision-making include the climate, topography, soils, pre-mining land-use of the site and surrounding areas, legal requirements and the degrees of post-closure maintenance and management.

Rehabilitation involves a sequence of activities such as:

- topsoil removal and placement,
- landscaping of disturbed areas,
- re-vegetation and re-establishment of the nutrient cycle,

- wildlife introduction,
- maintenance of rehabilitated areas,
- monitoring and determination of rehabilitation successes.

More extensive information is reported in the IFA-UNEP joint publication *Environmental Aspects of Phosphate and Potash Mining* (2001).

3.2.7 Protection of the quality and supply of freshwater resources and of the oceans and seas (Agenda 21, Chapters 17 and 18)

Agriculture uses more than 70% of the world's supplies of developed water, and in the drier farming regions, crop production is heavily dependent on irrigation. Agriculture is facing increased competition for limited water resources. Over the next three decades, there will be an increasing number of water-deficit countries and regions.

The efficiency of irrigation is often low – about 50% of the increase in demand for water could be met by increasing the effectiveness of irrigation. [Sherwood, 2000] The industry recognises the critical importance of efficient water use. It is established that something approaching the economic maximum of plant material ensures high water efficiency. This objective will only be achieved with a well-nourished plant. Experiments have demonstrated that the return from nitrogen is much increased by irrigation. According to FAO, any input factor which increases economic yield will improve water use efficiency.

3.2.7.1 Protecting water quality during mining

During the mining phase of fertilizer production, water quality can be affected by the release of slurry brines and contaminants into process water. Surface waters may be contaminated by:

- the erosion of fines from disturbed ground such as open-cut workings, overburden dumps and spoil piles, and waste disposal facilities;
- the release or leaking of brines;
- the weathering and potential leaching of contaminants in overburden material (barren removed to expose the ore in surface mines).

Surface and ground water contamination may occur through the release or seepage of tailings effluent and brings from dams, ponds and stacks.

In addition, large volumes of water are used which may lead to a fall in the water

table, affecting the surrounding eco-system and potentially resulting in competition with other users.

Principles found in the UNEP International Cleaner Production Declaration are also applied to industry activities which might impact on local water resources.

3.2.7.2 The quality of water and fertilizer application

In its nitrate form, nitrogen is highly soluble and therefore may leach into groundwater if plants do not efficiently absorb it. Nitrate itself is not toxic but nitrate in drinking water is considered to be a public health problem. Two factors are involved:

Industry dilemma: Economic viability can undermine environmental stewardship.

A critical challenge regarding mineral fertilizers lies in the marketing and application of nitrogenous fertilizers. Even the most responsible fertilizer producers are in a dilemma on how to move forward.

Low-cost commodity nitrogen fertilizers produced by countries such as Russia, with its large resources of low-cost natural gas and various financial advantages, are readily available worldwide. At the same time, there are few constraints on farmers as regards fertilizer application, and misuse can have important environmental consequences as evidenced by concerns over nitrates in some areas and research on the contribution of fertilizer use to greenhouse gas emissions. Compulsory plant nutrient plans are restricted to a small number of mostly small western European countries and problem areas such as the polluted Chesapeake Bay in the United States.

This situation discourages companies from making substantial investments in more

efficient but more costly fertilizers. For farmers in developing countries who can at best barely afford typical fertilizers, more expensive speciality products are not an option. Indeed, few farmers, most of whom do not fully understand the potential environmental impacts of nitrogen overuse and who are facing low prices for their products, see the logic in paying extra for more efficient fertilizers.

At the same time, low fertilizer prices have forced producers to cut back on the very extension and training services which could increase the uptake of best agricultural practices and raise awareness of the environmental imperative for buying 'improved' products. In fact, in the age of information overload, such efforts by fertilizer companies are likely to be regarded with suspicion as veiled marketing.

This creates a real dilemma on how to move forward. Clearly, value-added products are desirable from an environmental point-of-view, but in a commodity-based industry with low margins, how can this research and development investment be funded, especially if farmers are not willing to pay more for the extra value these products would provide?

- nitrate in drinking water has been associated with cases of the 'blue baby syndrome', whereby the oxygen-carrying capacity of the blood is reduced. It occurs in babies up to six-months old, normally when very high nitrate levels are associated with polluted water. The occurrence of the syndrome is now rare;
- nitrite reacts with compounds in the stomach to produce nitroso compounds, which have been found to be carcinogenic in certain animal species. A link to cancer in humans has not been demonstrated. The United States National Research Council, for example, concluded that 'exposure to the nitrate concentrations found in drinking water in the United States is unlikely to contribute to human cancer'. In fact, there is recent evidence that some nitrate is beneficial to human health. [Leifert and Golden, 2000 and L'hirondel and L'hirondel, 2002]

These two factors together have resulted in a 'precautionary approach'. In the mid-1980s the World Health Organization (WHO) set a guideline of 50 mg of nitrate, NO₃, per litre of water. It reviewed the guideline value in April 1997 and concluded that, on the basis of the latest scientific evidence, the value of 50mg/litre should be maintained.

Surface waters

The over-enrichment of surface waters leading to an excessive multiplication of algae and other undesirable aquatic plant species, with various undesirable consequences, is a phenomenon known as eutrophication. Whereas phosphate tends to be the limiting nutrient in inland waters, both nitrogen and phosphate appear to be involved in the eutrophication of coastal waters, depending on the circumstances. Potassium has no known adverse impact on human health or the environment at the concentration found in ground water.

Inland waters

Phosphate in the soil is rather immobile, and

the loss of water-soluble phosphate through leaching is low. The primary losses of phosphorus from the soil are by erosion (wind and water), run-off and through crop removal. Excessive surface applications of animal manures can result in significant losses in particulate matter due to run-off.

Phosphate enrichment of lake and river water may lead to the growth of algae and other undesirable aquatic plant species. Urban and industrial wastes usually account for most of the phosphate loading. However, surface runoff (including soil erosion) from cropland, pasture and forest, can contribute to phosphate loading of surface waters.

In tropical lakes, there is evidence that nitrogen also can be the limiting nutrient, whose input may result in eutrophication. Phosphate concentrations in the water are often higher than in temperate regions, while inputs of nitrogen from surrounding land may be low.

Coastal waters

In Europe large areas of the North Sea coastlines and areas of the Mediterranean have experienced eutrophication due to nitrates. In the United States, nitrates and phosphates are suspected of being among the factors causing hypoxia (low oxygen content) in some shoreline waters of the Gulf of Mexico. However, there is a great deal of controversy as to the importance of agricultural nutrients relative to other factors such as fresh water flow volume into coastal regions and other sources of nutrients. Indeed, the final action plan of the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force identified at least three causes of hypoxia, all of which should be addressed in an integrated fashion if efforts to reduce the problem are to be successful.

No direct link has been established between agricultural phosphorus inputs and sporadic *Pfiesteria piscicida* outbreaks in the Chesapeake Bay and the waters of North Carolina, but the issue has heightened public concern about

nutrient enrichment of surface waters. The fertilizer industry shares concerns over these issues. It is involved in numerous programmes which promote nutrient management practices intended to minimise the potential for negative impacts on water quality while maintaining the productivity and profitability of agricultural systems. Good progress in improving nutrient-use and land-use efficiency in these regions has occurred over the last two decades. The industry is committed to the continuation of these trends.

The agricultural techniques for minimising nutrient loss to water bodies and the associated eutrophication, while at the same time allowing for the most efficient use of fertilizers, are known, are being continually evaluated, and are included in the recommendations of best agricultural practices published by fertilizer industry bodies. In the United States, for example, fertilizer companies have been instrumental in forming the National Conservation Buffer Council, designed to encourage farmers to employ this practice. The industry has also worked closely with the USDA to urge farmers to meet the national goal of planting two million miles of conservation buffer strips by 2002.

3.2.8 Waste disposal issues (Agenda 21, Chapter 21)

Three major waste streams are produced during the mining of phosphate rock: brines, fines and salt tailings. These products may cause a variety of adverse environmental effects if not managed and disposed of in a safe, stable and environmentally-sound manner. The industry uses a variety of disposal methods, including:

- stacking salt tailings on the surface;
- retention of the fines and brines in surface ponds for solar evaporation;
- deep well injection of brines into confined permeable geological strata;
- backfilling of mined underground openings

with salt tailings, fines and brines;

- release of wastes to rivers or seas after being treated for contaminants.

The methods used at each location are influenced by the characteristics of the waste and the site as well as legal requirements.

3.2.8.1 Production wastes

Phosphogypsum

All phosphate ores contain traces of radioactive elements and a number of metals. The main waste is phosphogypsum, which contains trace amounts of the mineral impurities which accompany phosphate rock. One of these is radium, the parent of radon. Other trace impurities include arsenic, nickel, cadmium, lead, aluminium, fluoride and phosphoric acid. Mainly because of the radon content, the United States Environmental Protection Agency restricts use of phosphogypsum and stipulates that no phosphogypsum with radium of 10 pCi/g can be removed from stacks adjacent to the chemical plants.

The industry has made recommendations concerning the design and construction of phosphogypsum disposal areas. The use of phosphogypsum for other purposes has been widely encouraged, but economic and/or quality problems and/or the low demand for the resulting products frequently inhibit this. There is ongoing research and development in this area.

Disposal of spent catalysts

The steam reforming process for ammonia requires that catalysts be replaced every two to six years. Spent catalysts containing oxides of hexavalent chromium, zinc, iron and nickel are returned to the manufacturer or other metal recovery companies. The carbon dioxide removal stage can use potassium hydroxide solutions containing activators, aqueous amine solutions or other chemicals. The industry encourages and promotes the responsible management of spent catalysts.

Part 4: Means of implementation (Agenda 21, Section IV)

4.1 Transfer of environmentally sound technology, co-operation and capacity-building (Agenda 21, Chapter 34)

Technology transfer and capacity-building have been part of the fertilizer industry's history since production began shifting to developing countries. Joint ventures on new plants have been a particularly fruitful way of bringing modern production technology to developing countries.

The industry has also begun training programmes to raise awareness of the need for and capacity for carrying out production in the most efficient and environmentally friendly manner. In 2001, for the first time, IFDC conducted a training workshop on advanced fertilizer production technology. This workshop will be repeated every two years and is targeted at engineers early in their careers to encourage thinking about the off-site effects of production over the long term.

There were 54 participants from 22 countries at the first workshop, and participation was evenly divided between delegates from developed and developing countries. In the case of the latter, this was significant, because it was feared that the registration fee and costs

for accommodation and travel might act as a disincentive to attend.

The industry also dedicates significant resources to training and technology transfer for end users of fertilizers. Providing the necessary site-specific information on fertilizer-use to such a broad range of people poses a daunting challenge. One FAO official recently noted that the industry-supported FAO Fertilizer Programme which lasted over 30 years had made some significant achievements in this regard. Unfortunately, the programme was discontinued by FAO in the early- 1990s.

The challenge is particularly thorny in regions such as Africa where basic infrastructures render even distribution of fertilizers difficult, let alone adequate training for retailers and farmers. But there is scope for both top-down and bottom-up approaches in technology transfer and co-operation activities. For example, the village retailer has an invaluable role to play as a conduit for communication of information in both directions. The role of the fertilizer distributor needs to be re-examined and expanded.

The Arab Fertilizer Association's annual Technical Conference seeks to improve the capacity of the regional industry to satisfy international norms for safety and environmental protection.

Case study: The Food and Agriculture Organisation of the United Nations (FAO) fertilizer programme

The FAO fertilizer programme, from its start in 1961, promoted the idea of 'balanced fertilization'. This programme started as the fertilizer industry's contribution to FAOs:

'Freedom from hunger' campaign. Later, it became a joint venture between governments of developed countries, governments of developing countries, the fertilizer industry and FAO. The evaluation of the data from 100,000 trials and demonstrations showed that 1 kg of plant nutrient (N + P₂O₅ + K₂O) from mineral fertilizers produced on average between 8 and 12 kg of extra grain.

Case study: Rebuilding distribution channels in Russia

Several major Russian fertilizer companies have launched a market development initiative both in Russia and neighbouring republics through promotional activities and investments in facilities.

The Russian Fertilizer Demand Working Group was established in the mid-1990s to assist the industry to manage domestic fertilizer distribution following the collapse of the country's agriculture. In June 2001, it conducted a comprehensive assessment of fertilizer market development activities underway by major Russian fertilizer enterprises and Belgorod regional governments.

Today, initiatives include the establishment of farm input distribution centres, bulk blending units and extension services. New fertilizer application approaches are being assessed with a view to optimising crop production while eliminating waste and environmental degradation resulting from misuse. In November 2001, a Russian delegation visited French farms, fertilizer units and co-operatives to evaluate best practices.

The working group comprises major industry associations, including EFMA, IFA and the Fertilizer Institute (United States). It is associated with IFDC and representatives of major fertilizer producers in Russia. These joint activities will benefit from international co-operation with a view to enhancing sustainable development.

4.1.1 Fertilizer use recommendations

The industry has prepared many guidelines to promote correct fertilization practices. In conjunction with other associations, IFA has produced or updated the following best agricultural practices to optimise fertilizer use for a number of regions within the past decade:

- Western Europe - with EFMA (EFMA also produced a Best Code of Agricultural Practice for Nitrogen in 1999),
- Asia and the Pacific – with the Fertilizer Advisory, Development and Information Network for Asia and the Pacific (FADINAP);
- Latin America – with PPI and Associação Nacional para Difusão de Adubos (ANDA), available in English and Spanish;
- The Philippines – with the Philippine Fertilizer & Pesticide Authority (available in English and a local language),
- North America.

Dissatisfied with the dissemination of these guides, IFA is now exploring ways of leveraging various stakeholder partnerships to improve their uptake, including the possibility of translation and adaptation to national-level

conditions. The International Federation of Agricultural Producers has agreed to co-operate in this effort to provide farmers with the guidance on optimal fertilizer use. However, regional guidelines still require significant tailoring to the specific on-farm conditions, so most farmers would benefit from implementing them under the guidance of a crop advisor.

IFA has published a 632-page *World Fertilizer Use Manual* containing detailed information on use recommendations and practices for a wide range of world crops. Following an introduction on fertilizers and their efficient use, there are chapters on individual crops or groups of crops, each written by an author who is a recognized expert on the crop(s) in question; some 80 agricultural experts contributed to this project.

Each chapter contains: information on the biology of the crop, plant and soil analysis data, nutrient uptake and removal figures, recommendations for fertilizer use, current fertilizer practice in different countries, and further reading. A Chinese version of the

Case study: The New Zealand fertilizer code

New Zealand's environmental regulation addresses the impact nutrients have on plant growth and the environment, rather than trying to establish limits to fertilizer use out of context. Fert Research, the fertilizer industry association in New Zealand, developed a code of conduct in 1999 which combines the commercial needs of farming with the environmental requirements of sustainable land management.

The Code demonstrates that these two

activities need not be in conflict by placing responsibility for good environmental practice in the hands of individual farmers. It requires farmers to establish their production goals with regard to economic and environmental outcomes, and gives guidance on how to go about achieving those outcomes without compromising either economic returns or the environment.

The success of the Code in achieving its objectives is demonstrated by its inclusion in a number of regional plans, where compliance with the code is seen as compliance with the plan.

Table 1: Recommended/optimum levels of NPK for lowland rice (selected countries)

Countries	Recommended/optimum levels (kg/ha)		
	N	P ₂ O ₅	K ₂ O
Bangladesh	80	28	17
Bhutan	75	50	0
Egypt	100	37	0
India	90-125	26-45	45-50
Indonesia			
Lampung – Dry season	140	35	30
Wet season	80	18	30
West Java	115	25	40
Japan	170	122	170
Malaysia	80	30	30
Pakistan	120-135	26-40	0-37
The Philippines	80-100	28-50	0-30
Sri Lanka	73	58	58

This table extracted from page 45 of the *World Fertilizer Use Manual* gives a flavour of the guidance offered in the 18-page chapter on rice fertilization and illustrates the impossibility of making blanket recommendations. Source: IFA, 1992

manual has been published. It has been put onto a CD-rom and on the Internet in a way that enables users to access information on a chosen crop.

Fertilizers and Their Use, a pocket guide for use in the field by extensions officers, was produced jointly by IFA and FAO as a handy tool to explain various aspects of application. It has been disseminated widely through both FAO channels and requests to IFA. More than 2000 copies have been sent, mostly to government ministries where they will be used to educate farmers.

4.1.2 Training farmers

At farm level, much technology is market – and product-driven, and distributors play a major role in providing information to the farmer. Only by successful transfer of technology to individual farmers will the worldwide benefits of increased fertilizer efficiency be realised. The following are just a

small number of the hundreds of industry-supported fertilizer projects being run throughout the world.

- *BALCROP project* – managed by the Potash & Phosphate Institute and the Potash & Phosphate Institute of Canada (PPI/PPIC), BALCROP, in its second phase, involves IFA with a number of Vietnamese groups. Established in 1994, it deals with balanced fertilization for local conditions to achieve better crops. The third phase began at the end of 2001, when the Vietnamese partners took ownership of the project. During the past decade, the balance of nutrients applied has greatly improved. In 1991, the nutrient ratio (N:P₂O₅:K₂O) was 100:21:3 and now is closer to 100:37:24.
- *Fertilization and Sustainable Agriculture Development* – this project in West Africa is carried out in co-operation with IFDC. Started in 1996, it promotes agricultural

intensification through a combination of measures including soil and water conservation, soil fertility restoration and improvement, as well as support for rural organisations and institutions working to improve access to inputs for farmers. Farmers are encouraged to intensify their agricultural production through affordable appropriate technology packages.

- *Addressing stagnating rice yields in Asia* – field-specific integrated nutrient management in intensive irrigation rice systems, carried out in co-operation with IRRI, PPI and IPI and the government of Switzerland, is in its second phase. The first phase involved on-farm research and provided good results with a better application of fertilizers. The second phase was more concerned with the transfer of knowledge of these improved technologies to farmers. Known until recently as FSINMIRS, the project is now called Reaching Towards Optimum Productivity (RTOP).
- *Farmer Field Schools* on integrated plant nutrient systems and the development of an input supply micro-credit scheme in

Zambia were co-ordinated by FAO, IFAD and the Ministry of Agriculture in Zambia from March to October 1998. Field schools were held on 41 days in five provinces and attended by 900 farmers and more than 100 technical and extension staff. The Zambian Ministry of Agriculture provided provincial and district agricultural advisors, economists, irrigation engineers and camp officers to ensure comprehensive agronomic skills training.

4.1.3 Fertilizer use recommendations

4.1.3.1 Progress depends on stakeholder involvement

Because of the enormity of training two billion farmers, progress depends on effective co-operation among the large number of stakeholders to determine priorities and co-ordinate efforts. Most important is involvement of farmers in evaluation and adaptation of techniques and technologies. Once the needs and problems of farmers have been identified, universities and similar institutes must undertake the fundamental research work. Governments have a major role in providing and funding training, as well as in creating national and international policy frameworks and necessary infrastructures.

Case study: Soft-drink technology quenches crops' thirst

Despite drought conditions, in 2000 some 5,000 farmers in Niger were better able to avoid crop failures by using beverage bottle caps to dispense accurate amounts of fertilizer. Farmers who micro-dosed millet crops – Niger's staple food – with a capful of fertilizer placed in the planting hole not only prevented harvest losses, but significantly increased production.

Because soils in the region lack phosphorus and are low in nitrogen and organic matter, plants respond dramatically to very small amounts of fertilizer.

Farmers who applied this method harvested 50% to 100% more millet than their neighbours. In some cases, production doubled, while other harvests broke local records using only one-third, and often less, of

the amount of fertilizer commonly used in Europe and North America.

Millet, the world's most drought-tolerant cereal crop, is all that stands between survival and starvation for the 50 million people living in the Sahel. Farmers have traditionally tried to improve soil quality by applying animal manure, but the land cannot generate enough forage to feed the animals needed to produce the large volumes of manure required. As a result, soil fertility has continued to decline. According to the World Bank, Niger's millet yields have decreased by almost 3% annually since the mid-1980s even though the area cultivated has doubled.

The research was carried out by the Sahelian Centre of International Crops Research Institute for Semi-Arid Tropics, IFDC (an international centre for soil fertility and agricultural development), Niger's Institute for National Agricultural Research, FAO and the University of Hohenheim.

Industry dilemma: Success depends on appropriate public policies.

A programme aimed at enhancing public-private co-operation shows great potential for increasing both yields and balanced fertilizer use in China. However, results to date show that, without appropriate government policies, research and demonstration trials, although necessary, are not sufficient if China is to develop sustainable high yield agriculture.

If fertilizer sector policies are not favourable to correct use, imbalances will continue to occur. The Balanced Fertilization Demonstration Programme (BFDP) was launched 15 years ago with support from the

Potash & Phosphate Institute/Potash & Phosphate Institute of Canada (PPI/PPIC) and the Canadian Potash Export Co. Ltd.

The programme used simple comparison demonstration field plots, harvest field days, field inspections for leaders, media outreach, scientific and popular publications, as well as videos to publicise the economic and environmental benefits of balanced fertilization.

In 1989, the programme redefined balanced fertilization to include all essential plant nutrients, to address the fact that a mixture of deficient secondary and micronutrients exists throughout the various soil types in China [Meister Publishers, 2001].

4.2 Science for sustainable development (Agenda 21, Chapter 35)

Increased efficiency will be born out of research worldwide, both on how to improve farm practices and to discover innovative technologies. The challenge lies in incorporating new ideas into practical farming techniques and encouraging their adoption by farmers. Research also needs to take a holistic approach to farm systems.

4.2.1 International Fertilizer Award

Since 1993, the IFA International Fertilizer Award has been offered every year to an individual for research that has led to a significant advance in the efficiency of mineral fertilizer use, and that has been communicated to the farmer in the form of practical recommendations. The positive environmental impacts of the research have now been assigned a greater weight in the evaluation process.

The award alternates each year between research relating to conditions in developed and developing countries. Individuals from the public or private sector, from the industry, research or educational institutes may be nominated.

4.2.2 The declining research base

In an industry with very low margins, fertilizer

companies are limited in their ability to carry out costly research and development activities. For this reason, the industry supports national and international associations and organisations as well as institutes and universities which engage in R&D and education initiatives.

Research on mineral fertilizers has been dramatically reduced over the past two decades in both the private and public sectors. As a result of new vogues in scientific and policy circles, competent researchers have chosen other fields of study. IFA was forced to discontinue an annual prize targeted at young researchers in the field due to a dearth of qualified applicants.

For this reason, IFA – and other industry-supported non-profit associations and research institutes – is a major source of information about the global industry. However, scientists and other experts peer review all publications, as is common practice by such associations.

The sustainability challenge may ultimately drive more research by fertilizer industry companies. Already, a few companies are leading the development of a range of speciality fertilizers, including slow-and controlled-release fertilizers and specially-tailored formulations for specific applications and crops. However, as discussed earlier, there is little incentive to invest in the R&D of a low-

Case study: Co-operation is the way forward

Fertilizer Requirements in 2015 and 2030, published by the Food and Agriculture Organisation of the United Nations (FAO) in 2000, is an excellent example of fruitful co-operation between the private and public sector. The study looked at which crops will account for future fertilizer demand. Geographic distribution was also an

important factor, which helps policy-makers anticipate future food production developments and potential environmental impacts. The results are considered of fundamental importance for world agriculture and the world fertilizer industry.

The joint study represents an unprecedented co-ordinated effort involving five organisations – FAO, IFA, USDA Economic Research Service, The Fertilizer Institute and IFDC. [Daberkow, et al., 1999]

priced, bulky commodity that offers little scope for product differentiation.

4.3 Promoting education, public awareness and training (Agenda 21, Chapter 36)

4.3.1 Certified crop advisers

Certified crop advisers have provided an effective way to promote efficient and responsible use of fertilizers and other agricultural inputs in a number of mature markets.

The fertilizer industry in the United States supported the establishment of the Certified Crop Advisor Programme (CCA), administered by the American Society of Agronomy, in 1992. The credential demonstrates that an adviser has the knowledge and skills necessary to help farmers make decisions to produce economical and environmentally-sound crops. Certification is voluntary, based on an examination which covers nutrient management, soil and water management, integrated pest management and crop management. Applicants also sign a code of ethics. To encourage continued learning, the programme grants 'Continuing Education Unit' which add to the value of certification. The Canadian Fertilizer Institute brought the CCA to Canada in 1996.

FACTS is an independent certification scheme for sellers and advisers on fertilizers in the UK which was established in 1993 to improve dealer expertise on environmental and technical issues. All fertilizer staff who sell and give advice are strongly recommended to obtain the Certificate of Competence within three years of entering the industry, during which time they should be working under the supervision of a qualified member of staff.

The FACTS Committee comprises representatives from the Fertilizer Manufacturers' Association (FMA), the United

Kingdom Agricultural Supply Trade Association (UKASTA), the Agricultural Development Advisory Service (ADAS), the Association of Independent Crop Consultants (AICC), the Department for Environment, Food and Rural Affairs (DEFRA), the National Farmers Union (NFU), National Association of Agricultural Contractors (NAAC), the National Association of Principal Agricultural Education Officers (NAPAEO) and the Potash Development Association (PDA).

4.3.2 Publications

Many associations and research institutes publish basic publications which explain the role of various nutrients in soil fertility and plant nutrition. These are often adapted for national or regional audiences.

Various publications act as a bridge between the fertilizer industry and its stakeholders. They may explain the international policy framework in which the industry operates, for those inside the industry whose focus on business concerns may make it difficult to follow the intricacies of international governance. At the same time, these publications highlight some of the ways in which the fertilizer industry is addressing issues of sustainability, such as climate change and concerns over clean water.

Part 5: Future challenges and goals

Much of the material in this section is drawn from *Fertilizer Strategies*. [FAO (with IFA), 1999]

How can sustainable food availability be achieved? Each country needs to take a decision to produce more or import. Given limited financial resources, macroeconomic and social goals and a comparative advantage in agriculture, many countries opt to produce more.

One possibility to do so is to bring more land under cultivation. However, this extra land is often more marginal and less productive. Moreover, with a growing population, farm land suffers from encroachment by urban and industrial uses. Thus, the potential is generally rather limited.

Another approach is to increase the efficiency and reduce the wastage of current practices through improved management. In many countries there may well be considerable scope for improvement. However, there is a practical ceiling to such improvement.

A third way, which offers the greatest potential, is to bring about sustainable increased food production by intensifying balanced fertilizer use. The basic idea underpinning the proposals outlined below is that crops which provide farmers with stable higher profit margins will encourage them to adopt and increase their use of fertilizers.

At the agricultural sector level, and in the presence of an appropriate macroeconomic policy, a supportive agricultural marketing and pricing policy should facilitate efficient market operation and ensure competition. (If some industries are natural monopolies, they will need regulation.) Emphasis on competition in markets is key as competitive markets have important efficiency advantages.

At the same time, as economic development leads to greater domestic and international economic interdependence and commercial activity, new and improved methods of doing business and of organising activity will be needed to maximize the benefits of this economic development. This will require a proactive and dynamic fertilizer policy. Thus, government still has a significant role to play in the provision of public goods with a view to creating and sustaining a market-friendly environment through:

- legislation,
- information,
- infrastructure,
- education,
- research.

Some services may no longer be provided by business and industry after liberalisation and may have to be provided by government, either in a transition period or permanently. These include credit (especially inputs), sharing of risk and extension/education.

Output market development programmes can contribute to fertilizer profitability by reducing farmer's risks and transaction costs. The expansion of market infrastructure can reduce farmers' marketing costs and increase profitability, so promoting smallholder use of fertilizer.

Some measures can improve fertilizer and output market efficiency simultaneously, such as the reduction of road taxes within national boundaries and the improvement of infrastructure, especially roads and communications, as there is a strong correlation between fertilizer use and kilometres of road per hectare.

5.1 Policies for effective plant nutrition

Long-term planning and monitoring of the use of plant nutrients and fertilizer must reconcile four objectives:

- agronomic and economic efficiency to maximise agricultural output from available nutrients,
- increasing the production capacity of the natural resource base,
- consistency with a country's overall economic and environmental goals,
- safeguarding social security and equity for rural populations.

An agenda for effective policy should address the following topics:

- determining the balance between domestic food production and food imports for countries aiming at food self-reliance;
- assessing plant nutrient requirements;
- choosing the sources and combination of plant nutrient supplies;
- determining domestic production and imports of fertilizer products and raw materials;
- setting price levels for nutrients vis-à-vis the price of produce;
- providing distribution marketing and credit facilities, including adequate foreign exchange allocation;
- legislation;
- supporting extension and research (access to technology).

In the presence of an appropriate macroeconomic setting and agricultural policy, increased fertilizer use can make a significant contribution to achieving the objective of guaranteeing and increasing food availability. In recent decades, input subsidies have boosted fertilizer adoption and use. However, due to the economic distortions and high fiscal burden this approach involves, it cannot be sustained indefinitely.

Other measures to improve farmers' capacity to use fertilizer correctly and to facilitate their access to it are important. However, in the long run, fertilizer use will depend on whether farmers believe they will make more money with the fertilizer than with alternative uses of the available cash. If farmers can obtain stable, higher margins on the crops they currently produce, or indeed change over to other higher value crops, then they will gain the confidence to adopt and/or increase their use of an input whose purchase represents a significant outlay for many of them. The terms of trade facing farmers should be improved to enable sustainable agricultural development.

It should be recognised that although there may well be pressure for change, there will also be resistance to it. Fertilizer policy is complex and politically very sensitive. It needs to be seen in the context of a much broader set of issues. The goal, objectives and intended beneficiaries need to be clearly understood and agreed on. The effects of the components of fertilizer policy and of changing them need to be understood in the context of macroeconomic and other sector policies and possible changes therein. There is a need for a comprehensive, objective, quantitative analysis of the factors in/effects of current policy and various alternatives.

5.2 Key areas of industry progress

In general, the industry is environmentally aware both in extraction, mining and production practices and in its holistic approach to contributing towards sustainable agriculture and world food supply. But the move from awareness to action is not yet complete.

- Mining of raw materials continues to be dogged by many of the environmental community-relations issues which face all mining sectors – the importance of rehabilitation, protection of water and other local environmental assets and social impacts on surrounding communities. Best practices have been widely adopted, but there is always room for continual refinement to achieve even better results.
- On the production side, the industry has developed best available techniques to encourage the conversion of older plants to new technologies and the construction of state-of-the-art facilities. Greater energy-efficiency has been achieved, and significantly reduced emissions have resulted from the adoption of improved processing technologies instead of end-of-the-pipe fixes. But this progress is uneven across geographies, and some processes are approaching theoretical limits of efficiency.
- The industry's safety record is generally superior to that of the overall chemical industry. There have been very few major accidents to date. Incident reporting schemes allow member companies to exchange information on minor mishaps and encourages dissemination of best practice.
- In a limited number of places, the industry has been instrumental in getting distributor and adviser certification schemes off the ground.

- Regarding the effects of fertilizers in the field, efforts have been made to ensure best practices which avoid the unwanted effects of fertilizer use, but considering that one-third of the world's population are farmers, many of them scattered in remote regions, projects to date have only managed to reach a limited number of farmers.

There are important driving factors which jointly need to be overcome within a multi-stakeholder framework. These include infrastructure, differences between small-scale farming and larger agro-industry enterprises, and the need for appropriate government policies, to name just a few.

The industry recognises the need to overcome and reduce environmental problems and has made considerable progress to date with a view to promoting the efficient use of plant nutrients in agriculture. Some highlights discussed in this report include:

- The industry has consistently invested in capacity-building in developing countries as demonstrated, in part, by the partnership case studies in this report.
- The industry has pursued policies which address consumption patterns. It attempts to engage in a 'mine-to-crop' approach, through information and training, and has developed codes of best practice. The industry continues to advocate for – and support – farmer education and training initiatives.
- A number of techniques are used by agricultural scientists for reducing nitrate-leaching losses, including growing high-yielding crop varieties, deep placement and split application of nitrogen fertilizers, and use of ammonium or amide fertilizers in addition to adoption of Integrated Plant Nutrient Systems (IPNS). The industry supports such initiatives and funds research and development (R&D).

- Some new and promising methods include the use of nitrification inhibitors, and slow-release nitrogen fertilizers including indigenous materials such as neem cake or oil-coated materials. However, technology alone cannot prevent over-enrichment with nutrients, so the industry needs to remain actively involved in fostering farming practices which manage all nutrients within the system widely.

5.2.1 Building stakeholder relationships

The fertilizer industry consists of many interlocking organisations, institutes, programmes and associations, as well as individuals. Each organisation or individual is to some extent constrained in what he can do because part of the supply chain is outside his control. There is no common view of how synergies can be created, nor is there an outline of useful roles for each group so that their contribution adds to a collective movement in the direction of sustainable development.

The fertilizer industry cannot be considered in isolation. It is an important but not the only agricultural input, and the purpose of all the inputs is to enhance the production of agricultural products. The market for the latter is subject to the demand of consumers.

At least 11 categories of institutions are involved.

1. Farmers' associations. Given their very large numbers, it is difficult to communicate directly with individual farmers, particularly small-scale farmers.
2. Fertilizer manufacturers and distributors. Different categories of company have different strengths. For example, multinationals are strong in technology, while local companies have lower overhead and management costs and are closer to the customer.
3. Fertilizer associations (national and international) can expand the

representation of their members and influence policy.

4. Other input suppliers and their associations – seeds, plant protection products.
5. The agricultural marketing sector, food processors and retailers.
6. Banks and credit institutions.
7. Educational establishments.
8. National governments. Ministries of agriculture and of environment and other ministries such as planning, health, labour can play a regulatory role. Governmental research and advisory services are particularly relevant to the fertilizer sector.
9. Inter-governmental organisations. The European Commission, FAO, OECD, UNEP, UNIDO, World Bank and others can play important enabling roles.
10. Non-government organisations (NGOs). Certain NGOs have effective programmes for small-scale farmers and good relations with the government services. Environmental organisations should be involved. NGOs are relatively flexible and can operate across national boundaries.
11. Donors (bilateral and multilateral). These can support the high costs of providing access and capacity-building.

In the case of mineral fertilizers, there are major problems of underuse, overuse and misuse, inadequate research and advisory activities. Neither business and industry nor governments alone can resolve the problems. The participation and vision of the entire supply chain is needed for sustainable development.

5.2.1.1 Talking about fertilizers

Communication by the fertilizer industry is increasingly based on the premise that many people today are unaware of both the link between the food in supermarkets and the farmers who produce it and of the role of fertilizers in that process.

Case study: Stakeholders and fertilizers in France

A good example of stakeholder involvement is the Ferti-Mieux operation in France, whereby under the government-established Comité française d'étude et de développement de la fertilization raisonnée (COMIFER), rational fertilization is promoted by making use of all scientific, technical and practical means. It is composed of representatives of public authorities and

educational establishments, farmers' organisations, fertilizer producers and distributors.

Ferti-Mieux defines the steps to be taken in order to obtain, in a given catchment area, a progressive change in agricultural practices that would minimise the risk of polluting water: Participation is voluntary. In 1998 there were 54 approved Ferti-Mieux operations, most of which are located in vulnerable zones as defined by the EU Nitrate Directive.

Convinced that a communications failure about food production could be devastating, one North American fertilizer producer recently decided to be proactive and tell a wide range of stakeholders what fertilizers are all about. The company was inspired to act by a poll of United States Congressional staff members which revealed that 70% did not know the source of either the nitrogen or potash that plants use, and 61% had no idea about phosphate's origin. The resulting 'Fertile Minds' campaign has included a symposium and 'mini-expos' which allow discussion alongside traditional one-way communication tools, like advertisements. There is also a Web site at: <http://www.fertile-minds.org>.

This step reflects a growing awareness within the fertilizer industry of the need to directly engage a wide range of stakeholders.

5.2.1.2 The International Agri-Food Network (IAFN)

The establishment of IAFN in 1996 was a step forward in international co-ordination for all participating sectors. It is an informal network for liaison among the professional organisations in the agri-food chain at global level. IFA was instrumental in the creation of IAFN.

As a major group focal point, IAFN was the co-ordinating mechanism for the participation of business and industry at the eighth session

of the United Nation Commission on Sustainable Development (CSD-8) in April 2000. It continues to serve as the focal point in the ongoing multistakeholder dialogue on agriculture mandated by CSD-8 and facilitated by FAO.

Since the multistakeholder dialogue in April 2000, the five major groups that participated (farmers, NGOs, indigenous people, business and industry and trade unions) have been working with FAO to push forward discussions about solutions for Sustainable Agriculture and Rural Development (SARD). The ongoing relationships have proved extremely beneficial to constructive co-operation at the international policy level.

At international, regional and national levels, the fertilizer industry seeks continuing opportunities to meet with other business groups, government representatives, NGOs, consumers and other stakeholders. In some cases, these encounters are facilitated by international organisations like the United Nations Environment Programme (UNEP) or umbrella organisations like the International Chamber of Commerce (ICC).

5.3 Where does future progress need to be made?

5.3.1 Product research and development

Clearly one of the greatest unresolved sustainability issues facing fertilizer producers is the relative inefficiency of uptake of the nutrients from these products. Limited resources of some nutrients make this an especially pressing issue, but the impacts of runoff and leaching of unused nutrients also raise concerns.

This creates an imperative for improved products which deliver nutrients more efficiently, and minimise the potential for losses to the environment. Some products already exist. Slow- and controlled-release fertilizers as well as nitrification and inhibitors can considerably reduce nitrogen losses to water and to the atmosphere while at same time significantly improving fertilizer efficiency. However, there has been little significant change in the fundamental nature of fertilizer products for decades. Due to economic constraints, these more costly products are used primarily in horticulture at this time. (Rice production in Japan is a notable exception.)

Several obstacles must be overcome if product research and development is to take off. Fertilizers are mostly priced as commodities, which means that manufacturers are subject to unpredictable and normally low prices for their products. Therefore the costly investment in research and development is relatively more risky than in a high-growth industry.

Demand for these products also remains limited. This is probably influenced both by the higher price of speciality products and a lack of appreciation on the part of farmers as to the real economic and environmental costs of fertilizer inefficiency. Public policy may help overcome this stumbling block. For example, restrictions on the quantities of nitrogen that farmers are allowed to apply could incite them

to seek a better return per kilogram used, rendering the costlier but more efficient products more attractive.

It is a chicken-and-egg situation. Co-operative approaches for product development at industry level are not feasible because they would produce unfair market advantages for some members of industry associations. State agencies no longer carry out this type of research in the name of policy goals. This poses a fundamental dilemma about how to achieve this important step.

One caveat remains, however; no matter how well formulated the products are, they must still contain the basic plant nutrients: nitrogen, phosphorus and potassium as well as a number of secondary and micronutrients. There are no other substances that can be substituted. This means that even extremely sophisticated products may be misused. Technology innovation is a necessary, but insufficient step towards sustainability.

Another key issue for research is the presence of naturally-occurring contaminants in fertilizer raw materials. Most of the concerns about such unwanted substances are related to the environment. Processes exist for the removal of some impurities, but solutions to others remain out of reach. The industry needs to carry out more research to develop innovative new processes for removing these impurities and disposing of them in an acceptable manner.

At first glance, this type of research is purely a cost centre, but the reality is more complex and should figure into industry thinking. The first producer who finds a way to remove some of the impurities that cause concern will have a market advantage for its products. The technology itself could be licensed to other companies to generate income. Furthermore, finding uses for these waste products would turn them into resources and improve the overall efficiency of the production process.

5.3.2 Ongoing support for agronomic research

Mindful that adjustments in the factory can never address all sustainability issues, the industry needs to continue fostering research on how to best use mineral fertilizers under a wide range of conditions. The industry also needs to offer guidance to researchers on where there are gaps in scientific knowledge about the impact of fertilizers or on how to improve their performance. Stakeholder input will also be important when designing research questions.

5.3.3 Education, training and information

Training programmes alone will not overcome the sustainability challenges facing the fertilizer industry, but ongoing industry involvement in farmer training, education and information is indispensable. Because of the nature of plant nutrition and soil science, fertilizers must be used in a very site-specific way. Bridging the gap between industry expertise, scientific understanding of soils and plant nutrition, and farmers' knowledge is therefore vital for achieving sustainable use of mineral fertilizers.

Farmers do not just need training on the effective use of fertilizers. They need product and market information that allow them to make intelligent decisions which are appropriate for their situation. They also need channels for feeding their ideas and concerns back into the product development process.

As farmers' organisations become stronger and more common in developing countries, they could also play a valuable role in ensuring the flow of information in both directions. The fertilizer industry must continue to build relationships with these groups. In some areas where the distribution system is poor, these farmers' groups may even help ensure better access to necessary input.

Large farmer co-operatives which produce fertilizers in the United States and India do provide crop nutrition services rather than acting simply as bulk commodity sellers. In both cases, subsidies currently play a large role in the viability of providing this value-added service.

The retailer is well placed to give advice, but needs to be informed, trained and motivated and supported by appropriate policies. This is particularly important in view of today's liberalised markets. Certification may also be an important step to give a farmer an objective way to recognise the legitimacy of the advice. In fact, it is probably a key way forward. Such certification schemes already exist in several mature fertilizer markets, and have been set up with the support of the fertilizer industry. The fertilizer industry should undertake an initiative to generalise certification throughout the world in coming years.

Annexe 1: Abbreviations and acronyms

ADAS	Agricultural Development Advisory Service (UK)
AFA	Arab Fertilizer Association
AICC	Association of Independent Crop Consultants (UK)
ANDA	Associação Nacional para Difusão de Adubos (Brazil)
BAT	Best Available Technique(s)
BFDP	The Balanced Fertilization Demonstration Programme
CCA	Certified Crop Adviser (United States and Canada)
CFI	Canadian Fertilizer Institute
CDM	Cleaner Development Mechanism
COMIFER	Comité français d'étude et de développement de la fertilization raisonnée (France)
DEFRA	Department for Environment, Food, and Rural Affairs (UK),
EFMA	European Fertilizer Manufacturers Association
EMAS	Environmental Management Assessment System
EU	European Union
FACTS	An independent certification scheme for sellers and advisers on fertilizers. Established in the UK in 1993
FADINAP	Fertilizer Advisory, Development and Information Network for Asia and the Pacific
FAI	Fertilizer Association of India
FAO	Food and Agriculture Organisation of the United Nations
Fert Research	The New Zealand Fertilizer Manufacturers' Research Association
FMA	Fertilizer Manufacturers' Association (UK)
GMI	Global Mining Initiative
ha	Hectare
ICRAF	International Centre for Research in Agroforestry
IAFN	International Agri-Food Network
IFA	International Fertilizer Industry Association
IFAD	International Fund for Agricultural Development
IFDC	IFDC – An International Centre for Soil Fertility and Agricultural Development
IPNS	Integrated plant nutrient system(s)
IPPC	Integrated Pollution Prevention and Control Directive
IFPRI	International Food Policy Research Institute
ISO	International Organisation for Standardisation
ISFM	Integrated soil fertility management
IMPHOS	World Phosphate Institute
Mt	Million tonnes
NAAC	National Association of Agricultural Contractors (UK)
NAPAE0	The National Association of Principal Agricultural Education Officers (UK)
NFU	National Farmers' Union (UK)
OECD	Organisation for Economic Co-operation and Development
PDA	Potash Development Association (UK)
PPI	Potash & Phosphate Institute Potash & Phosphate Institute of Canada
PPIC	Phosphate Institute of Canada
QAFCO	Qatar Fertilizer Company
RTOP	Reaching Towards Optimum Productivity project (Asia)
SCODP	Sustainable Community-Oriented Development Programme (Kenya)
TFI	The Fertilizer Institute (United States)
UKASTA	UK Agricultural Supply Trade Association
UNEP	United Nations Environment Programme

Annexe 2: Research institutes affiliated with the fertilizer industry

FADINAP
 ESCAP Population, Rural & Urban
 Development Division
 UNITED NATION Bldg, Rajdamnern Avenue
 Bangkok 10200
 Thailand
 Tel: +66 2 288 1394
 Fax: +66 2 288 1056
 Web site: <http://www.fadinap.org>

Florida Institute of Phosphate Research
 1855 W. Main Street
 Bartow FL 33830
 United States
 Tel: +1 863 534 7160
 Fax: +1 863 534 7165
 E-mail: kstewart@helios.acomp.usf.edu
 Web site: <http://www.fipr.state.fl.us>

IFDC
 P.O. Box 2040
 Muscle Shoals AL 35662
 United States
 Tel: +1 256 381 6600
 Fax: +1 256 381 7408
 E-mail: general@ifdc.org
 Web site: <http://www.ifdc.org>

Institute of Plant Nutrition and Soil Science
 Federal Centre
 Bundesallee 50
 38116 Braunschweig
 Germany
 Tel: +49 531 596 2104
 Fax: +49 531 596 2199
 E-mail: pb@fal.de
 Web site: <http://www.pb.fal.de>

Instituto de Pesquisas Tecnológicas (IPT)
 Avenida Prof. Almeida Prado, 532
 Cidade Universitaria, Butanta
 05508-901 Sao Paulo, SP
 Brazil
 Tel: +55 11 376 74 252
 Fax: +55 11 376 74 052
 E-mail: sac@ipt.br
 Web site: <http://www.ipt.br>

International Fertilizer Society (The)
 P.O. Box 4
 York YO32 5YS
 United Kingdom
 Tel/Fax: +44 1904 492 700
 E-mail: secretary@fertilizer-society.org
 Web site: <http://www.fertilizer-society.org>

International Food Policy Research Institute
 (IFPRI)
 2033 K Street, N.W.
 Washington DC 20006 – 1002
 United States
 Tel: +1 202 862 5670
 Fax: +1 202 467 4439
 Web site: <http://www.ifpri.org>

International Potash Institute (IPI)
 Schneidergasse 27
 P.O. Box 1609
 4001 Basel
 Switzerland
 Tel: +41 61 261 2922
 Fax: +41 61 261 2925
 E-mail: ipi@iprolink.ch
 Web site: <http://www.ipipotash.org>

Nutrient Management Institute B.V. (NMI)
 Agro Business Park 20
 6708 PW Wageningen
 The Netherlands
 Tel: +31 317 479 620
 Fax: +31 317 479 621
 E-mail: nmi@nmi-agro.nl
 Web site: <http://www.nmi-agro.nl>

Potash & Phosphate Institute (PPI)
 655 Engineering Drive
 Suite 110
 Norcross, GA 30092-2837
 United States
 Tel: +1 770 447 0335
 Fax: +1 770 448 0439
 E-mail: ppi@ppi-far.org
 Web site: <http://www.ppi-ppic.org> or
<http://www.ppi-far.org>

Potash & Phosphate Institute of Canada (PPIC)
 Ste 704, CN Tower
 Midtown Plaza
 Saskatoon, SK S7K 1J5
 Canada
 Tel: +1 306 652 3535
 Fax: +1 306 664 8941

The Sulphur Institute (TSI)
 Suite 612
 1140 Connecticut Avenue N.W.
 Washington DC 20036
 United States
 Tel: +1 202 331 9660
 Fax: +1 202 293 2940
 E-mail: sulphur@sulphurinstitute.org
 Web site: <http://www.sulphurinstitute.org>

World Phosphate Institute (IMPHOS)
 3, rue Abdelkader Al Mazini
 3e Etage
 Casablanca
 Morocco
 Tel: +212 22 484 124
 Fax: +212 22 484 121
 E-mail: imphos@casanet.net.ma

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Isherwood, KF, 2000b

Mineral fertilizer use and the environment
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UNEP contribution to the World Summit on Sustainable Development

The mission of the United Nations Environment Programme (UNEP) is to provide leadership and encourage partnerships in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations. The UNEP Division of Technology, Industry and Economics (DTIE) contributes to the UNEP mission by encouraging decision-makers in government, business, and industry develop and adopt policies, strategies and practices that are cleaner and safer; make efficient use of natural resources, ensure adequate management of chemicals, incorporate environmental costs, and reduce pollution and risks for humans and the environment.

This report is part of a series facilitated by UNEP DTIE as a contribution to the World Summit on Sustainable Development. UNEP DTIE provided a report outline based on Agenda 21 to interested industrial sectors and co-ordinated a consultation process with relevant stakeholders. In turn, participating industry sectors committed themselves to producing an honest account of performance against sustainability goals.

The full set of reports is available from UNEP DTIE's web site (<http://www.uneptie.org/wssd/>), which gives further details on the process and the organisations that made it possible. The following is a list of related outputs from this process, all of which are available from UNEP both in electronic version and hardcopy:

- industry sectoral reports, including
 - accounting
 - advertising
 - aluminium
 - automotive
 - aviation
 - chemicals
 - coal
 - construction
 - consulting engineering
 - electricity
 - fertilizer
 - finance and insurance
 - food and drink
 - information and communications technology
 - iron and steel
 - oil and gas
 - railways
 - refrigeration
 - road transport
 - tourism
 - waste management
 - water management

- a compilation of executive summaries of the industry sectoral reports above;
- an overview report by UNEP DTIE;
- a booklet including an extended version of the executive summary of the UNEP overview report;
- a CD-ROM including all of the above documents.

UNEP DTIE is also contributing the following additional products:

- a joint WBCSD/WRI/UNEP publication entitled *Tomorrow's Markets: Global Trends and Their Implications for Business*, presenting the imperative for sustainable business practices;
- a joint WB/UNEP report on innovative finance for sustainability, which highlights new and effective financial mechanisms to address pressing environmental, social and developmental issues;
- two extraordinary issues of UNEP DTIE's quarterly *Industry and Environment* review, addressing key regional industry issues and the broader sustainable development agenda.

More generally, UNEP will be contributing to the World Summit on Sustainable Development with various other products, including:

- the Global Environmental Outlook 3 (GEO 3), UNEP's third state of the environment assessment report;
- a special issue of UNEP's *Our Planet* magazine for World Environment Day, with a focus on the International Year of Mountains;
- the UNEP photobook *Focus on Your World*, with the best images from the Third International Photographic Competition on the Environment.