IFA CROSSROADS ASIA-PACIFIC 2006

Growing markets, nurturing success

Chiangmai, Thailand
13-16 November 2006

THE USE OF FERTILIZERS ON AQUACULTURE IN CHINA

Zhiping PENG, Shaohai YANG and Junxi CAO

**Soil and Fertilizer Research Institute,
Guangdong Academy of Agricultural Sciences
CHINA P.R.**

Soil and Fertilizer Research Institute,
Guangdong Academy of Agricultural Sciences
Wushan Road
Guangzhou, Guangdong 510640
China P.R.
Email: ytifei@yahoo.com.cn

All the papers and presentations prepared for the 2006 IFA Asia-Pacific Crossroads in Chiangmai are compiled on a cd-rom released in December 2006.

The Use of Fertilizers on Aquaculture in China

Zhiping PENG, Shaohai YANG and Junxi CAO
Soil and Fertilizer Institute
Guangdong Academy of Agricultural Sciences

Abstract

The aquaculture industry in China has enjoyed fast growth in the last three decades. The use of fertilizers has contributed to the fast growth of aquaculture. The technology of fertilizer use for fish farming has received unprecedented attention. This paper discussed the roles of fertilizers, the history and current situation of fertilizer use in aquaculture in China.

Key Words: Fertilizers, Aquaculture

China is the largest country in the world for aquaculture in terms of both aquatic farming areas and aquatic product varieties. It is reported that the total output of aquatic products reached 49 million tonnes in China in 2004, of which 32 million tonnes, or 65% of the total output production came from aquaculture fish farming. This accounted for 70% of the world total. There are over 160 different fish species in China's aquaculture fish farming, of which 100 are marine species and the remaining 60 species are raised in fresh water [1].

Since the founding of People's Republic of China, China has made great achievements in the development of fish farming technology, especially during the past 20 years of economic reform. The use of fertilizers for fish farming has grown dramatically in the fast-growing aquaculture industry in China. It has been a common practice that farmers apply fertilizers together with feedstuff as an economical means to raise fishing yield. As a result, fertilizers, both organic and inorganic fertilizers, have become a major input for fishing farm in China. This paper is prepared to address the use of fertilizers in aquaculture in China.

I. Principles and functions of fertilizer use in fish farming

1. Use of fertilizers to control the water fertility for fish farming

Water quality is an important factor in relation to the yield and quality of fish. There is an old Chinese proverb saying: "The fish cannot survive without the water", indicating the importance of water quality to the fish farming. The water quality parameters include the nutrient contents, depth, temperature, pH value, oxygen and the types of salts and their concentrations in the water. The control of water quality is an important process for high-yielding fish farming. One of the goals of applying fertilizers to the fishponds is to enrich the "poor water" to become "fertile water" suitable for the growth and reproduction of planktons as the feeders of fish.

Biography: Zhiping Peng, male, born in 1964, associate professor, dealing with the research of plant nutrient and fertilizer.

The aquatic animals are heterotrophic organisms, which are dependent upon heterotrophic nutrients for energy and growth. The feedstuff is the major source of food for fish. However, dietary balance for fish farming is critical to maintain balanced nutrient supplies for high fish yield and quality. Therefore fertilizers (both organic and in-organic) are generally used in fish farming to enrich the water fertility, the growth of planktons and to achieve dietary balance for fish.

In summary, the use of fertilizers in fish farming plays the following roles:

1) To enrich the water fertility by increasing the nutrients and organic matter in the water, some of which can become the feeders for fish directly.
2) To stimulate the growth and reproduction of planktons, algae, and zoobenthos, etc. in the water, which form the natural diets for fish.

2. The function of the fertilization for fish farming

Under the natural conditions, the nutrients in the water and from fertilizers are absorbed by the green plants, such as phytoplankton, algae, autotrophic bacteria, etc. and assimilated to form organic substances. Lower-grade animals and fish in the water consume these green plants. Ultimately, most of the low-grade animals become the food of fish. The fish is the final step of the food chains. All of the cadavers of livings and the organic matter in the water are decomposed by bacteria and broken down into simple organic matter or minerals and biologically recycled in the water [2]. But as a general practice, the fish is usually captured commercially for the food of human, removing the organic substances and minerals from the water. The organic substances and minerals need to be supplemented in order to maintain the balance of the nutrients in the water and the productivity of the water.

The functions of the fertilization for fish farming are summarized as the following three aspects:

1) Some organic and inorganic nutrients from the fertilizers become the feeders of the fish;
2) The majority of the nutrients from fertilizers provide nutrient source for green plants, algae, and autotrophic bacteria etc., which are among the direct sources of food for fish [3] [4].
3) The green plants become the food of lower-grade animals, which in turn is the food for fish.

II. The history of the fertilizer use and its consumption in fish farming in China

1. The history of fertilizer use for fish farming in China

China has a long history in the use of organic fertilizers in fish farming, dating back to more than 3,000 years ago in the Ying Dynasty when the fish farming in the pond began. A book entitled as “The Scriptures of Fish Farming” written by Fan Lu 2,400 years ago was the earliest available literature featuring fish farming. In late Tang Dynasty, Liu Xun’s book entitled “The Records in Ling Nang” described cleaning of weeds in the paddy field by raising fish witch eat up the weeds as food. These are the earliest records of fish farming in China’s history.

Since the 1950's, the technology of fertilization for fish farming has received vigorous developments. Traditionally, the organic fertilizer, grass and the other plants were used to feed the fish. The history of the use of chemical fertilizers in fish farming is relatively short. In the 1970s, China started the research and development in the use of fertilizers for fish farming. In 1972, Institute of Hydrobiology under the Chinese Academy of Sciences studied the use of fertilizers for fish breeding. In the 1980's, research in the development of fertilizers for fish farming has been expanded to many Chinese provinces, and as a result, the use of fertilizer in efficient fish farming has been a major practice generally accepted by fish farmers in China since the 1990's.

2. Estimated consumption of fertilizers in aquaculture in China

The quantity of fertilizers used for fish farming was relatively small compared to the fertilizers consumed in agriculture. There are no official statistics of fertilizer consumption in aquaculture industry in China. Therefore we estimated the consumption of chemical fertilizers in fish farming based on the areas of fish farms and fish output.

Because marine fish culture rarely uses fertilizers, only the fertilizer consumption in fresh water fish farming is estimated. We categorize the fresh water fish farming in four groups, i.e., fish farming in ponds, lakes, reservoirs, and rivers. The areas (S in ha) and fish yield (M in t/ha) of the above four fish farming from 1990 to 2004 are available in the China Agriculture Yearbooks. Our fertilizer consumption estimation also considers the fertilizer requirements (r) and benchmark fish yield per ha (b in t/ha). The fertilizer requirement (r) is defined as 0.14 kg N for kg of fish products. The Benchmark fish yield (b) is defined as the maximum fish yield when fertilizers are not applied as follows: 2 t/ha for fish farming in pond, 0.35 t/ha for fish farming in lake, 0.25 t/ha for fish farming in reservoir and 0.6 t/ha for fish farming in rivers.

The annual N consumption (EAN in 10,000 t) is estimated as $EAN = S * (M - b) * r/10^4$.

The annual P2O5 consumption (EAP in 10,000 t) is estimated as EAP = EAN/3.5 * 2.29 of which 3.5 represents the average application ratio of N to P and 2.29 the coefficient for P converting to P2O5.

Then the estimated annual fertilizer consumption can be calculated by adding the N and P numbers (Figure 1).

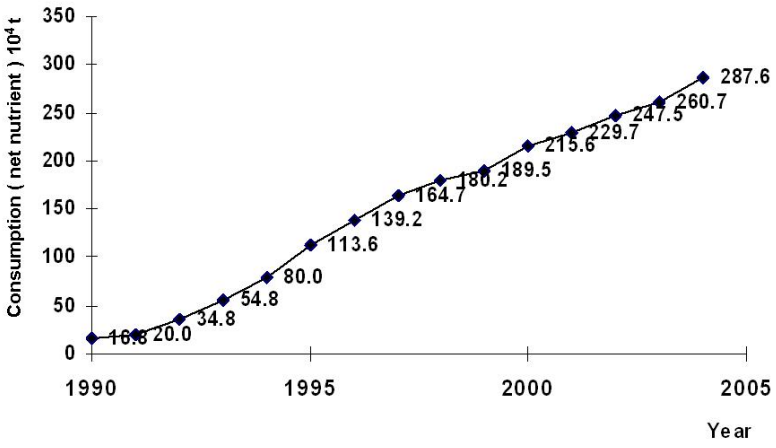

Figure 1. The estimation for the nutrient consumption in aquaculture

The timeframe from 1970 to 1989 was the research and development phase for fish fertilizers and little is known about fish fertilizers during this period of time. Fish farmers used primarily farmyard manures and green manures. During this timeframe, fertilizers consumed in fish farming were less than 150,000 tonnes.

Fertilizer consumption in fish farming during the period from 1990 to 1997 enjoyed a rapid growth. In 1997, nearly 1.65 million tonnes of fertilizers were consumed in fish farming, 10 times of the number in 1990, an increase by 40% year on year. From 1998 to 2004, the growth of fertilizer consumption in fish farming slowed down with an annual increase by 8.2% on the average. It is estimated that the fertilizer consumption in fish farming in 2004 was 2.87 million tonnes, which accounted for 6.1% of the total fertilizer consumption (47 million tonnes) in China.

3. The forecasts of fertilizer consumption in aquaculture in the future

It is estimated that the consumption of chemical fertilizers in fish farming will increase by 3% annually from 2005 to 2010, and the consumption will reach 3.43 million tonnes in 2010. From 2011 to 2015, fertilizer consumption in fish farming will increase by 2% annually and will reach 4.52 million tonnes in 2015. From 2016 to 2030, the fertilizer consumption will increase by 1% annually and reach 5.24 million tonnes in 2030.

III. The use of fertilizers in fish farming in China

1. The types of fertilizers used in fish farming

1.1. Nitrogen fertilizers

Nitrogen fertilizers are the major fertilizers used in fish farming in China. Nearly all different types of commercially available N fertilizers for agriculture have been used in fish farming, including urea, anhydrous ammonia, ammonium bicarbonate, ammonium sulphate, ammonium nitrate, ammonium chloride, etc. The application of N is important to influence the growth of phytoplankton. Nitrogen fertilizers are used to maintain N concentration at 1.0 mg/L in the fish water. It is cautioned that water quality should be taken into consideration when nitrogen fertilizers are applied to the water making sure the water is not under anoxic conditions to avoid toxicity of fertilizers. The maximum allowable concentration for NH4+ in the water for fish is 5 mg N/L, and 0.2-1.0 mg N/L for NH3•H2O. If lack of oxygen in water, the NH4+ will be converted NO2-, which is more toxic to the fish, especially if NO2- concentration reaches the level of 0.8mg/L [5]. In addition, the carbon contained in some nitrogen fertilizers such as urea and fish as the source of carbon can consume ammonium bicarbonate. Ammonium nitrate has functions to inhibit the parasites in fish.

1.2. Phosphate fertilizers

Phosphorus is an essential nutrient for algae. However, phosphorus is normally deficient in clean water, especially in the regions where the soils are acidic. The application of phosphorus can stimulate the reproduction and growth of algae, nitrogen-fixing microorganism and nitrifying bacteria, and will accelerate the cycle of nitrogen in the water. The types of phosphorus fertilizers for common use are single superphosphate (SSP), triple superphosphate (TSP), ammonium phosphates (AP), calcium magnesium phosphate (CMP) etc. Considering the solubility and availability of P in the water, the phosphorus fertilizers containing water-soluble P such as SSP, TSP, and ammonium phosphates are generally used to maintain the P concentration at 0.4 mg P/L in the water.

Nitrogen and phosphorus fertilizers are the major fertilizers applied in aquaculture. In general practice, N and P fertilizers are applied to the fish water at the ratio of 3-4:1. The balanced N/P ratio is critical to maintain the quantity of phytoplankton in the water body providing adequate food for fish.

In recent year, with the popularization of fertilizer use in fish farming, many specialty fertilizers have been developed for fish farming in China. These specialty fertilizers are easy to use and contain N, P and K, but also Ca, Si and micronutrients in soluble forms.

1.3. Other fertilizers

Potassium, calcium and silicon are the nutrients essential for fish growth. The commonly used potassium fertilizers are potassium chloride and potassium sulphate, which are used in the fishpond, of which the bottom beds are sandy or sandy loam in texture. Potassium is generally low in the reservoir or ponds in South China and potassium fertilization is required for fish farming.

The commonly used calcium fertilizers are lime and powder limestone, which are used to neutralize the acidity, supplement Ca and improve water quality. Ca deficiency will occur if Ca content is low in the water and humic acid content is higher. The Ca fertilizers also have disinfectant effects. If the total water hardness is below 10mg/L, Ca application is required. The Silicon is an element necessary for diatoms, which are an excellent source of food for fish, cowries and shrimps and a key indicator of water fertility. If the silicon content is below 0.1-0.4ug SiO2/L in the water, Si application is needed.

2. The usage of chemical fertilizers and its effect

The use of fertilizers in fish farming has been more standardized in recent years, with a series of relevant standards being enacted in China (Table 1). These standards play important roles in demonstration and extension for the scientific application of fertilizers in fish farming.

Table 1. The relevant industry standards to the fertilization for fish farming in China

The Standards	Serial Number
Technical regulations for fish culture in ponds: Breeding technique in northeastern China	SC/T 1016.1—1995
Technical regulations for fish culture in ponds: Breeding technique in Northwestern China	SC/T 1016.2—1995
Technical regulations for fish culture in ponds: Breeding technique in Northwestern China	SC/T 1016.3—1995
Technical regulations for fish culture in ponds: Breeding technique in Northwestern China	SC/T 1016.4—1995
Technical regulations for fish culture in ponds: Breeding technique in the downer region of Chang Jiang River	SC/T 1016.5—1995
Technical regulations for fish culture in ponds: Breeding technique in the Upper-middle region of Chang Jiang River	SC/T 1016.6—1995
Technical regulations for fish culture in ponds: Breeding technique in the delta of Pearl River	SC/T 1016.7—1995
Specification for fish culture in paddy field	SC/T 1009 —94
Specification for fish culture with chemical fertilizers	SC/T 1028—1999
Technical regulations for reservoir fish farming by fertilization	SL/T177-96

2.1. The conditions for fertilizer applications

It is necessary to determine whether the water conditions are suitable for fertilizer applications. It is required that the water pH value is in the range of 6.5-8.5 and soluble oxygen content >5 mg/L. If the water has adequate nutrients, then no fertilizer applications are recommended to avoid over-growth of phytoplanktons. The water testing is an important tool to determine the needs for fertilizer applications.

Weather is another factor to be considered when deciding fertilizer applications for fish farming. Rainy days and/or high temperature days are not suitable for fertilizer applications. Fertilizer applications will generate better results when N, P and K are appropriately balanced and when the water is clear.

2.2. Fertilizer application rate and application methods

The fertilizer application rates vary with the types of fish farming and are summarized in Table 2.

Table 2. Fertilizer application method for aquaculture in China

Type of culture	Rates of Fertilizer (kg/ha)	Application Methods
Pond culture (North China)	N 51－169.5, P2O5 16.5-57.0	Top-Dressing in Jun-Aug. once every 5-6 days
Pond culture (Southwestern China)	N 45－142.5, P2O5 30－97.5	Top-Dressing in Jun.Aug. once every 5-10 days
Pond culture (Nortwestern China)	N 75－150, P2O5 45-90	Top-Dressing in summer days of high temp. once every 5-6 days
Pond culture (Middle-upper of Yangtze River)	N 241－379, P2O5 157－247	Top-Dressing in May-Sep. once every 5-6 days
Culture in reservoir	N 300－450, P2O5 105－250	Once every 5-6 days – proper temp. 25-30°C
Lake Culture	N100－150, P2O5 75－115	Once every 10-15 days, not exceeding 15kgN and 10kg P205

As a general practice, fertilizers are usually dissolved in water followed by spraying to the fish farms. Phosphate fertilizers are usually first applied, followed by N fertilizers. The N and P fertilizers cannot be mixed together and applied at the same time to avoid the production of toxic $HPO4^{2-}$.

2.3. The benefits of fertilizer use in fish farming

- **Improving water quality and increasing the types and quantity of phytoplanktons.** Research on the fertilization for the lake fish culture indicated that after using ammonium bicarbonate, N concentration reached peak level in 2-3 days for NH4-N and in 4-5 days for NO3-N, with quantity of planktons reaching the peak level in 5-6 days. Wang et al (2005) [6] studied the effect of fertilization on phytoplankton succession in polyhaline water ponds and found that 42 species of plankton (33 of phytoplankton and 9 of zooplankton) were identified after using nitrogen and phosphorus, the phytoplankton biomass peaked at 288.2 mg/L. The content of chlorophyll reached peak 5-6 days after fertilization.

- **Improving water quality and increasing the types and quantity of phytoplanktons.** Pan et al (1994) studied the growth of silver carp and bighead fish cultured in ponds after fertilization with ammonium chloride [7].The result indicated that ammonium chloride applied promoted the growth and the best results were received when the N : P2O5 ratio was about 2:1.

- **Increasing fish yield and economic returns.** According to the data from the Research Institute of Aquatic Product, 1 kg of the mixed fertilizer of urea with SSP in ratio of 1:1 applied increased fish yield by 1kg. A fertilization experiment in reservoir indicated fish yield doubled to reach 1,045 kg/ha when fertilizers were applied, compared to those receiving no fertilizers.

IV. Impacts of fertilizer use in fish farming on environment quality

With the rapid development of aquaculture in China, the environmental problems have received serious attention from the government and public. In the Yangtze River Delta, for example, extensive aquaculture practice with heavy use of fertilizers and feedstuff has caused serious water pollution problems. This problem is particularly significant with the cage fish culture. The major sources of N pollution are from feedstuff, fertilizers and water pumped into the fish farms [8].

It is evident that the use of chemical fertilizers in fish farming could stimulate the eutrophication in the water. A research indicated that the content of phosphate and total phosphorus, the biomass of phytoplankton in the water in 1992-1993 increased by 1.4, 6.0 and 4.6 times compared to in 1992-1993 [9]. In 6 out the 9 reservoirs along the Yangtze River, middle to strong degree of eutrophication has been found. Local governments have vowed to stop the use of fertilizers in the reservoirs supplying water for human consumption.

Fertilizers are applied to the fish farms to enrich the water fertility as a practice to raise fish. It takes 2-3 steps before the benefits of fertilization are realized in the fish. However, over-fertilization will have negative impacts on water quality and the environment. The hazardous components in the fertilizers may potentially pollute the water and in turn affect the health of the fish. Fertilizer use in fish farming affects the environment in the following ways:

1. N Pollution toxic to the fish

Excessive application of N fertilizers directly contaminated the water. For instance, application of 1,500 kg/ha ABC to 2-meter deep water will generate N in the water higher than the allowable level, especially the NH3 concentration exceeding 14-120 times of the allowable level in the standard of water quality in fishery in China (0.02mg/L). The plankton normally released back to the water 20-60% of the assimilated nitrogen, which in turn is converted to NH3-N. A content of NH3 at 0.099 mg/L is considered toxic to fish, causing damage to the liver and lamella of glass carp.

2. Phosphorus Pollution

Application of P fertilizers significantly increases the phosphorous concentration in the water. The application of SSP at the rate of 1,500 kg/ha could increase P concentration by 35-36 times in 2-m deep water, much higher than the allowable level (0.1 mg/L). The plankton normally released back to the water about 54% of the assimilated P as soluble P.

3. Heavy Metal Pollution

Phosphate fertilizer applied is a major source of heavy metals. The analysis result showed that SSP contains 0.11 mg/kg Cd, 2.31 mg/kg Hg, and 8.35 mg/kg Pb. CMP contains 0.10 mg/kg Cd, 0.27 mg/kg Hg and 4.37 mg/kg As. Application of such fertilizers will surely pollute the water and the environment and be toxic to the fish. Although there have been no reports on excessive heavy metal levels in the water, the contamination of heavy metals to aquatic products is a potential risk.

In the last 20 years, the use of fertilizers has promoted the development of aquaculture in China and become a major practice to raise fish. However, heavy and over-fertilizations have caused negative impacts on the environment and the safety of water. Therefore, it is important that we develop technology and standards regulating the use of fertilizers.

Acknowledgement

Great thanks are given to Dr. David Zeng, the Asia Agronomy Manager of Mosaic company, for his great help for the improving works of this paper.

References

[1] J.H. Xie; Gao J, Analysis of supply characters of aquaculture products in China[J]. *Journal of Shanghai Fisheries University*. 2006, 15 (2) : 222 – 227 (in Chinese).

[2] B.T. Hu, Ecological basis of mixed breeding various species of fish with the application of fertilizers in ponds[J]. *Chinese Journal of Ecology.* 1983 (3) : 24-27 (in Chinese).

[3] K.M Qu; Chen B.J; Yuan Y.X. et al, A preliminary study on influence of N and P on population constituent of planktonic diatoms in seawater[J]. *Chinese Journal of Applied Ecology*. 2000, 11 (3) : 445 – 448 (in Chinese).

[4] B.K Zhu; Fan Q.X., The effect of fertilizing with ammonium chloride as nitrogen source on plankton in intensive fishpond[J]. *Journal Huazhong (Central China) Agricultural University*. 1995, 1 (1) : 73-78 (in Chinese).

[5] R.L.Yu; Nie X.P; Wei T.Li et al, Toxicity of molecular ammonia & nitrite to fishes and the control measures[J]. *Journal of Fishery Sciences of China*. 1999, 6 (3) : 73-76 (in Chinese).

[6] H.L. Wang; Zhao W.; LI X.D. et al, Effects of fertilization on phytoplankton succession in polyhaline water ponds[J]. *Journal of Fishery Sciences of China*. 2005, 12 (5) : 608-613 (in Chinese).

[7] Q.S. Pan; Fan Q.X.; Zhu B.K. et al, The growth of silver carp and bigheadin polycylture ponds fertilized mainly with ammonium chloride[J]. *Acta Hydrobiological Sinica*. 1994, 18 (2) : 116-126 (in Chinese).

[8] T.F. Shu; Wen Y.M; TANG Y.T., Cycle and Budget Balance of Nitrogen in the Cultivated Water[J]. *Fisheries Science*. 2002, 21 (2) : 30-34 (in Chinese).

[9] Q.J. Kuang; Xia Y.C., Community dynamics of algae and limiting nutrient in Taipinghu reservoir[J]. *Journal of Lake Science.* 1995, 7 (3) : 235-239 (in Chinese).