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Inorganic salts and other nutrients are continuously depleted in ponds due to removal of fish and through the hatching of aquatic insects. The purpose of fertilizing the pond is to replenish these nutrients thereby increasing productivity. When organic fertilizer is used, such as decayed plants, manure, sewage and mixed fertilizers, pieces of this organic matter can be eaten directly by fish. When it is acted upon by bacteria, the organic fertilizer

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) can also be broken up into inorganic salts which can be used by phytoplankton. If inorganic fertilizer is used, such as nitrogen, phosphorous, potassium and calcium salts, it will be directly available to phytoplankton.

After fertilization, the appearance of the first and succeeding dominant species of plankton depends upon the kind of fertilizer used, and the rate of maturity and reproduction of each species of plankton.

The plankton and other natural food organisms in a fish pond are controlled not only by fertilizer but also by physical and chemical factors, such as light, temperature, atmospheric pressure, etc. In addition, the kinds and quantity of fertilizer used must be considered so that contamination and/or oxygen depletion of the pond does not occur.

Chapter 10

POND FERTILIZATION

Phytoplankton are the primary producers in a fish pond. They continuously take in various essential inorganic salts from the water and assimilate them into their cells. Phytoplankton form the food for zooplankton and other aquatic animals. After organisms die, their bodies are disintegrated by bacterial action into simple mineral compounds, which are returned to the water for use by phytoplankton. This food relationship among the organisms is called food-chain. Fish are the last link of the food chain in the aquatic ecoysystem.

Every year inorganic salts are lost from the pond through the removal of fish and through the hatching of aquatic insects. If these salts are not replenished, the food chain will suffer and the productivity of the pond will be lowered. The purpose of fertilizing the pond is, therefore, to replenish the inorganic salts. When organic fertilizer is used, bits and pieces of the organic matter itself can be eaten by fish directly as food, and when it is acted upon by bacteria, it is broken up into inorganic salts, which are used by phytoplankton. Inorganic fertilizer will, of course, be directly available to phytoplankton for their growth and reproduction.

Kinds of Fertilizers and Their Composition

There are many kinds of fertilizers, such as human and animal manures, green manure, chemical fertilizers, burned ash, etc. These fertilizers are generally classified into organic and inorganic fertilizers. The former is called slow-acting fertilizer.

1. Organic fertilizers. The composition and effect of organic fertilizers are generally unstable. They vary according to kinds, to the way they are treated and prepared, etc. Tables 13-16 show the composition of various organic fertilizers.

2. Inorganic fertilizers. The composition and effect of inorganic fertilizers differ somewhat according to manufacturing methods. The major kinds are: (1) nitrogenous fertilizers, which include ammonium sulphate, ammonium nitrate, ammonium chloride, calcium ammonium nitrate, (2) phosphorus fertilizers: $Ca(H_2PO_4)_2$; (3) potassium fertilizers. These include potassium sulphate (K_2SO_4) and burned ash.

Methods of Fertilizer Application

1. Application of organic fertilizers.

(1) Application of decaying plants. Most commonly used plants include several species of compositae and some graminae and legumes. The method involves placing the plants in a corner of a fish pond and rotating them once every day or two. The decayed parts will disperse into the water. Undisintegrated parts are finally removed.

(2) Application of manure. the manure is usually diluted with two parts of water before using. It can be used once a day.

(3) Application of mixed fertilizers. These fertilizers are made of green plants, human and animal manures, and lime. After fermentation under sealed conditions they are ready for use.

(4) Application of sewage. City sewage contains rich nutrients which can fertilize fish ponds.

, Chemical composition of Tiensin City Sewage (ml/l).

pH------------8.1-8.5	Magnesium---------69.67
Oxygen--------3.52-6.74	Nitrous nitrogen- 0.663
CO ----------1.936	Ammonium nitrogen-0.45
B.O.D.--------9.52-12.24	Phosphates--------0.175
Salt content--1.86-1.92	Hardness ( )------28.48
Calcium-------88.78	

Solid debris in the sewage should be filtered out or settled out before using. They can be settled out in a settling pond. The size of the settling pond can be calculated according to the following formula:

$$V = QD$$

Where V is the volume of the settling poind, in cubic meters,

D is time in which sewage remains in pond, in hours,

Q is the amount of sewage added, in m /hour.

Because sewage water is heavily turbid and limits light penetration, the bottom layer of water will develop anaerobic conditions. Also, due to disintegration of organic matters, methane gas, hydrogen sulphide, and ammonia are produced. Therefore, in order to safeguard the fish, pond depth should not be over 3.3 ft.

Table 1 shows the proper amount of sewage to be added to a pond.

Table 1. Amount of sewage in application.

B.O.D. of sewage:	100 ml/l	150 ml/l	200 ml/l	250 ml/l
Sewage (tons/acre /day):	3.86	2.38	1.77	1.42

[1]6.6 mou = 1 acre.

If daily input of sewage is under 30 tons, a 30 flow structure can be used; if over 30 tons, use a 90 flow structure (Fig. 52).

The flow volume of a 30 flow structure can be found from Table 21; that of a 90 flow structure can be calculated by the following equation:

$$Q = 1.43 \times H$$

Where Q is the flow volume, tons/hour,

H is water level height, in cm.

If after fertilization, fish begin to surface, immediately add fresh water, or mass mortality will occur.

2. Application of inorganic fertilizers. Phytoplankton require various elements for their growth and reproduction, and, therefore, demand inorganic salts and nutrients. They are the primary producers, and are the foundation in the food chain. Therefore, addition of inorganic salts (principally nitrogen, phosphorus, potassium and calcium salts) can increase the production of food organisms, which in turn will increase the production of fish.

(1) Application of nitrogen, phosphorus, and potassium fertilizers. Nitrogenous fertilizers. Nitrogenous fertilizer is most important. Generally inorganic fertilizers have to be utilized by phytoplankton

first before becoming available to animal feeders. A good principle to follow is to apply a small amount at a time, but at frequent intervals. The fertilizer should be added to ponds 20 days before introduction of fish fry.

For best results of plankton culture, the proper proportion of N, P, and K is 8-8-4. For proper mix, use:

$(NH_4)_2SO_4$	(20% N)	----------40
$Ca(H_2PO_4)_2$	(17% P 0	-----------47.5
K_2SO_4	(33% K_2O)	---------------12.1
Limestone		------------------------ 0.4

(2) Application of lime. The major purpose of adding lime to a fish pond is to adjust the pH value of the water. It is usually used in conjunction with inorganic or organic fertilizers in a proportion of 1% of other fertilizers. In ponds with heavy sediments, add 870-1,090 lbs of lime to each acre of pond area; in ponds with light sediments, use 725-870 lbs of lime to each acre.

(3) Combined use of organic and inorganic fertilizers. Organic and inorganic fertilizers can be used either simultaneously or alternately. First, in late April apply lime, then one month later, apply both organic and inorganic fertilizers.

The Effect of Fertilizers on Plankton

After fertilization the appearance of the first dominant species of plankton depends much upon the kind of fertilizer used. When organic fertilizers are used, organic-matter-loving plankton will first appear in great abundance, such as Cryptomonas of phytoplankton and Urotricha of zooplankton. On the other hand, if inorganic fertilizers are used, Scenedesmus, Coleps, and Halteria become the dominant species. The amount of fertilizers used also affects the appearance of plankton. Heavy fertilization will favor green and blue algae; light fertilization will result in the dominance of diatoms.

Due to the increase of nutrients from fertilization, plankton will peak soon afterwards. Those phytoplankton that are easily digestible to the bigheads peak in about 4 days; those that are hard to digest peak in 5-10 days; zooplankton peak in 5-7 days.

Different species of phytoplankton peak at different times too. Those that prefer rich nutrient concentrations generally peak earlier than those that prefer less nutrient concentrations.

Among zooplankton, protozoans are the first to appear in abundance, next are the rotifers, then daphnias, and finally copepods. Protozoans multiply by division, therefore increase in number rapidly and reach peak abundance very quickly. Rotifers reproduce by parthenogenesis under normal conditions, and the number of eggs laid each time is relatively few. Brachionus, for instance, lays a total of only 3-4 eggs in its life time (7 days). It therefore requires a longer time to reach peak abundance. Daphnias also reproduce by parthenogenesis and require a long time to mature. Take Daphnia pulex, for instance, under 7 C, it takes 18.4 days to reach maturity and lays a total of 90 eggs: it reproduces once every 11 days. Under 18 C, maturity is reached in 7-8 days, and total egg deposition is reduced to 27 days, and eggs are deposited every 5-6 days. Under 25 C, it matures in 5 days, lays eggs every 2-3 days, and deposits a total of 13-14 eggs. Copepods vary a great deal from species to species in time of maturity. *Cyclops* requires 7-180 days; some *diaptomus* require one year. These forms therefore require a much longer time to reach peak abundance.

Some Problems in Applying Fertilization

Natural food organisms in a fish pond are controlled not merely by fertilizers but also by physical and chemical factors, such as temperature, light, soil, nutrients, etc. Therefore, in applying fertilizers, the following problems must be borne in mind:

1. Kinds of fertilizers. The composition and method of application of each fertilizer must be fully understood.

2. Quantity of fertilizers. Too much organic matter in the water will cause oxygen depletion and cause fish to suffocate.

Oxygen content of pond water is influenced by the following factors:

i. Temperature. Oxygen saturation in water is inversely proportional to temperature; the higher the temperature, the lesser amount of dissolved oxygen. (Table 2). This is why the low oxygen phenomenon occurs more often in summer time.

Table 2. Dissolved Oxygen Saturation Amount, 0-35 C.
(mg/l, Atmospheric Pressure 760 cm)

C	DO	C	DO	C	DO	C	DO
0	14.16	9	11.19	18	9.18	27	7.86
1	13.77	10	10.92	19	9.01	28	7.75
2	13.40	11	10.67	20	8.84	29	7.64
3	13.05	12	10.43	21	8.68	30	7.53
4	12.70	13	10.20	22	8.53	31	7.42
5	12.37	14	9.98	23	8.38	32	7.32
6	12.06	15	9.76	24	8.25	33	7.22
7	11.76	16	9.56	25	8.11	34	7.13
8	11.47	17	9.37	26	7.99	35	7.04

ii. Atmospheric pressure. Dissolved oxygen content is directly proportional to atmospheric pressure. During humid, hot summer days, atmospheric pressure may become quite low, and fish ponds may run low on oxygen.

iii. Organisms. Zooplankton, fish, and other aquatic animals remove oxygen from the water through their respiration. Therefore, when animal populations becomes too thick, oxygen may become deficient. Phytoplankton, on the other hand, releases oxygen due to photosynthesis during daytime. However, during night time when no photosynthesis takes place, phytoplankton also respire, therefore oxygen in the water depletes much faster during the night, and reaches the minimum just before dawn. This is the best time to determine whether a fish pond lacks oxygen.

For subsequent fertilization. It is best to apply a small amount at frequent intervals.

Fertilizing Lakes and Reservoirs

A. Method of Application

There are several ways of applying fertilizer into a lake. One is by building pits around the lake, and by filling the pits with fertilizer and draining it into the lake gradually. The other is by building holding pens in the shallow part of the lake to hold the fertilizer, or by placing the fertilizer in a bag or a basket and hanging it on a pole with its mouth above the water.

The Problem of Increasing the Fertility of Large Water Bodies

Most of the lakes in which freshwater fishes are cultured in China are located in relatively plain areas, and are often heavily populated and surrounded by rich farm lands. The lake water and especially the lake bottom mud are therefore usually rich in nutrients. This rich bottom mud should be utilized in fertilizing lakes.

1. Use of lake bottom mud. Lake bottom mud contains decaying aquatic plants, phytoplankton, and dead aquatic animals. Seepage from rich surface soil from the surrounding land is also drained into the lake. The lake bottom mud usually accumulates to 0.5 - 1.0 m deep, and is very rich. The nutrient value of the bottom mud is usually 2,000 to 3,000 times greater than the water itself in the lake. In 1,000 pounds of dried mud, there is nitrogen, 4-5 pounds; phosphorus, 0.3-1.0 pounds;   and organic

matter, 30-40 pounds. However, these materials usually cannot be directly utilized by phytoplankton. The pH value lies between 5.2 and 7.0. Analysis of the bottom mud of one Hupei lake shows results as listed in Table 3:

Table 3. Chemical Analysis of a Lake Bottom Mud (Except Water Content, the Rest are Based on Dried Mud).

pH --------------7.0	Inorganic p ---------0.006%
Total N ---------0.532%	Usable K ------------0.3065%
Inorganic N -----0.083%	Water content--------72.03%
Total P ---------0.032%	

According to experiments carried out by Academia Sinica, it was found that best results were obtained by the use of a mixture of lake mud and lime. Results are shown in Tables 4 and 5.

Table 4. Comparison of Experimental Lake and Control Lake Fertilizer Used in Mixture of Lake Mud and Lime.

Lake	Lake Volume m^3	Depth m	Amount lime used lbs	Amount mud use lbs
1 Control Lake	122.6	0.35-0.70	0	0
2 Exp'l Lake	48.5	0.35-0.70	40.6	11.6

Note: In both lakes, there was vegetation but no fish.

Table 5. Comparison of Water Chemistry and Amount of Plankton in Control and Experimental Lakes

Date	Lake	Air T. C	Water T. C	pH	Total N ppm	Inorganic N	Total P	Inorg. P	Phyto-plankton no. 1	Zooplank-ton no.1
Jan. 23	Control	7.0	5.5	9.0	2.296	0.972	0.070	0.0164	341,850	1,052
	Exp'l	7.0	4.2	9.1	1.757	0.872	0.072	0.0170	973,950	900
24	Control	13.0	7.5	8.9	2.421	0.664	0.111	0.0168		
	Exp'l	13.0	7.0	9.3	2.025	0.672	0.074	0.0237		
25	Control								709,500	2,103
	Exp'l								2,444,550	3,901
26	Control	9.0	9.4	8.9	1.695	0.731	0.092	0.0088	209,600	2,252
	Exp'l		9.3	9.2	1.816	0.842	0.119	0.0082	2,122,050	3,452
28	Control	9.0	9.0	8.5	1.652		0.121	Trace	638,550	2,403
	Exp'l	9.0	8.5	8.9		0.761	0.090	Trace	2,102,700	3,905
29	Control									
	Exp'l								2,044,650	5,288
30	Control	7.5	7.5	8.9	1.938	0.885		Trace	608,300	1,353
	Exp'l	7.5	8.3	8.9	2.293	0.902		Trace	2,547,750	9,011

In the experimental lake, the reproduction of phytoplankton is fast; the number of cells per liter increases to more than twice the original count within the first week. In the control lake, although there is also some increase, the increase is much smaller. Only in one instance does it reach twice as many as the original count. The increase of zooplankton in the experimental lake is even faster; the number is increased by 10-fold at week's end. On the contrary, the increase in the control lake is very insignificant, with the maximum reaching only twice the original count (Table 5).

Similar experiments were conducted, using lake mud only in the experimental lake. In this case, the phytoplankton cells in the experimental lake were 96% greater than in the control lake; but zooplankton cells were 11% less, demonstrating that without lime growth of zooplankton is poor,

In another instance, a fertilized bay in a lake is compared with a nearby bay that is not fertilized. Results are similar to those in the above experiments (Table 6).

Table 6 Changes in the Number of Plankton Cells in Fertilized and Nonfertilized Bays

		Dates
Control	Phytoplankton	
	Zooplankton	(See p. 5 for figures)
Fertilized	Phytoplankton	
	Zooplankton	

In the fertilized bay, total phosphorus, B.O.D., alkalinity, and total hardness are all larger than in the control bay. During the experiment, it was observed that phytoplankton bloom followed the peak of phosphorus and that the bloom caused phosphorus to decline rapidly. Total nitrogen in the fertilized bay was lower than in the control bay. Possibly this is due to the fact that inorganic phosphorus was extremely low in lake water (only trace or nil) - the N/P ratio was 35:1. Fertilization increases total phosphorus in the experimental bay and consequently enhances the assimilation of nitrogen of phytoplankton, thereby decreasing the total nitrogen in the fertilized bay.

Water temperature also plays an important role in affecting the quantity of plankton. With the rise of water temperature, plankton increases rapidly in quantity.

Zooplankton species are mostly protozoans, rotifers, and daphnias. Phytoplankton includes both those species that are easily digested by bigheads such as Chroomonas, Cryptomona, Navicula, Chromulina, Ochromonas, etc., and those species that are not easily digested by bigheads, such as Ankistrodesmus, Dictyophaerium, Ulothrix, Merismopedia, Phormidium, Oscillatoria, etc.

Lake mud is always neutral or slightly acidic. By adding lime (35 - 40 lbs/acre), lake alkalinity may be increased and pH may be maintained at 6.5 - 7.5. As a result, a large amount of phosphorus is released from the mud, enriching the water.

2. Utilization of sewage. Sewage can be used to fertilize lake and reservoirs just as it is used to fertilize ponds, and results are similar. The effect of sewage is fast and shortlived. It should be applied in small amounts, but at more frequent intervals. Usually it can be applied once a week and can be added throughout the year.