Fertilization, soil and water quality management in small-scale ponds

Part II – Soil and water quality management

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Suitable bottom soil condition and high quality water are essential ingredients for successful pond aquaculture. Some problems with pond soil and water quality are related to site characteristics. Bottom soils may have undesirable properties such as potential acid sulfate, high organic matter content or excessive porosity. The water may be of poor quality, viz, highly acidic, rich in nutrients and organic matter, high in suspended solids or polluted with industrial or agricultural chemicals. However, even if a good site is available large inputs of nutrients and organic matter as a result of feeding very often lead to poor water and bottom soil conditions. Therefore, soil and water quality problems are common in aquaculture ponds, and many methods are used for the purpose of improving pond soils and water.

Water quality management

Fish are in equilibrium between potential disease organisms and their environment. Changes in this equilibrium such as a deterioration in water quality (environment) can result in fish becoming "stressed" and vulnerable to disease. It is, therefore, very important to know something of the water quality parameters and their management that have influence on growth and survival of aquatic organisms.

Dissolved Oxygen

The optimum dissolved oxygen (DO) content of pond waters should be in the range of 5 mg/l to saturation level for good growth of fish. Aeration is a proven technique for improving dissolved oxygen availability in ponds. However, in heavily aerated ponds where aerators are positioned around the edges to create circular water flow, strong water currents can cause severe erosion of pond bottom. Mineral soil and organic matter particles eroded from peripheral areas settle in the central part of the pond where water currents are weaker. Therefore, a method of aeration that does not erode soil and produces water movement over the entire pond bottom instead of just around the periphery is needed.

Temperature

Temperature sets the pace of fish metabolism by controlling molecular dynamics (diffusibility, solubility, fluidity) and biochemical reaction rates. Under otherwise favorable conditions, the optimum temperature range for many 'coldwater' and 'warmwater' fishes are 14-18C and 24-30C, respectively. Water temperature can be adjusted to optimum levels in controlled systems such as hatcheries. It is difficult to adjust water temperature in large water bodies. Operation of aerators during calm and warm afternoons helps to break thermal stratification of ponds by mixing warm surface water with cool subsurface water. The planting of trees on pond banks to give shade will reduce stratification but at the same time, reduces the beneficial effects of wind mixing and restricts sunlight needed for photosynthesis, which can reduce the productivity of the pond.

Turbidity

Turbidity is the result of several factors including suspended soil particles, planktonic organisms and humic substances produced through decomposition of organic matter. Turbidity is measured by Secchi disk visibility. Optimum Secchi disk visibility of fishponds is considered to be 40-60 cm. Turbidity resulting from plankton is generally desirable. However, heavy blooms limits heat and light penetration thus reducing the effective volume of the productive zone. Turbidity due to suspended soil particles can be controlled by manure application of 500-1000 kg/ha, gypsum application of 250-500 kg/ha or alum application of 25-50 kg/ha.

Ammonia

Fish are very sensitive to unionized ammonia (NH_3) and the optimum range is 0.02-0.05 mg/l in the pond water. Normally in the case of high dissolved oxygen and high carbon dioxide concentrations, the toxicity of ammonia to fish is reduced. Aeration can reduce ammonia toxicity. Healthy phytoplankton populations remove ammonia from water. The addition of salt @ 1,200-1,800 kg/ha can be used to reduce the toxicity of ammonia in water. Formalin may also be used to reduce ammonia. Biological filters may be used to treat water for converting ammonia to nitrite and then to harmless nitrate through nitrification process.

Nitrite

Under normal conditions the nitrite concentration of fish ponds is negligible as the ponds are kept well oxygenated. In hatcheries, control may be accomplished by installing biological filters and addition of chloride ions (through addition of salt). Effective removal of organic wastes, adequate aeration, and correct application of fertilizers are the methods to prevent the accumulation of nitrite to toxic levels in pond culture.

Hydrogen sulfide

Freshwater fish ponds should be free from hydrogen sulphide. Fish lose their equilibrium and become to sublethal stress at concentrations of 0.01 mg/l of hydrogen sulphide. Frequent exchange of water is practiced to prevent building up of hydrogen sulphide in the water body. Also, if the pH of water is increased by liming the toxicity of hydrogen sulphide is reduced. Potassium permanganate is also used (6.2 mg/l) to remove hydrogen sulphide (1 mg/l) from water.

[*Editors note:* Care is required in application of potassium permanganate as excessive amounts can kill phytoplankton leading to oxygen depletion as it decomposes. For more information on use of potassium permanganate see 'Aquaculture fundamentals' in the April-June 2002 edition of Aquaculture Asia – or you can download the back issue from the NACA website www.enaca.org].

pH

pH is a measure of hydrogen ion concentration in water and indicates how much water is acidic or basic. Water pH affects metabolism and physiological process of fish. pH also exerts considerable influence on toxicity of ammonia and hydrogen sulphide as well as solubility of nutrients and thereby water fertility. The generalized effects of pH on fish is generalized below.

The best way to counter water pH problem is to lime the pond to increase the soil pH to greater than pH 6, total alkalinity and the total hardness to greater than 40 mg/l as calcium carbonate.

Calcium carbonate (calcite) $CaCO_3$, Dolomite-$CaMg(C0_3)_2$, Calcium hydroxide (slaked lime)-$Ca(OH)_2$ and Calcium Oxide (quick lime)-CaO are the liming materials generally used. Liming should be carried out a few weeks before addition of fertilizers and stocking of fish. Agricultural gypsum ($CaSO_4$) is applied, to correct total hardness without affecting total alkalinity when total hardness is low and total alkalinity is high to control very high afternoon pH. It may also be applied to correct alkaline pH.

pH	Effect
4	Acid death point
4-6	Slow growth
6-9	Best for growth
9-11	Slow growth, lethal to fish over long period of time
11+	Alkaline death point

Total alkalinity

Pond waters with a low alkalinity (less than 20 mg/l) as $CaCO_3$, have a very low buffering capacity and consequently are very vulnerable to fluctuations in pH, for example, during rainfall and phytoplankton blooms. Such fluctuations may be directly harmful to fish populations. Ponds with alkalinity greater than 300 mg/l may also be unproductive because of limitation to carbon dioxide availability at such high concentrations. The ideal range of total; alkalinity for freshwater fish is 60-300 mg/l as $CaCO_3$. Low alkalinity ponds can be treated with lime.

Total hardness

Total hardness for freshwater fishponds should be greater than 40 mg/l as $CaCO_3$. This concentration of hardness helps to protect fish against harmful effects of pH fluctuation and metal ions. Ponds with low hardness can be treated with lime.

Carbon dioxide

Freshwater fishponds should contain a low concentration of free CO_2 (<8 mg/l). However, repeated aeration of water and increasing the pH of water by hydrated lime (calcium hydroxide) can control high carbon dioxide concentration. Experiments have shown that 1.0 mg/l of hydrated lime can remove 1.68 mg/l of free CO_2.

Bottom soil management

The role of bottom soil in determining productivity of a pond is well documented. The production of various primary food organisms depends largely on the availability of different nutrients. Dynamics of availability of most of these nutrients, in turn, is determined by the condition prevailing in the bottom soil. Considering this significance bottom soil is designated as the chemical laboratory of a pond. However, suitable soil quality problems are common in aquaculture ponds, and therefore, many methods are used for the purpose of improving pond soils.

Texture

The nature and the properties of the parent material forming the soil determine the soil texture. Many important physico-chemical properties influencing the fertility of fishponds are influenced to a great extent by the relative proportion of the different size fraction of the soil. An ideal pond soil should be too sandy to allow leaching of the nutrients or should not be too clayey to keep all the nutrients adsorbed in it. When the pond is constructed on sandy soils, then heavy doses of organic manure are essential to control seepage loss of water. In general, the dose of raw or composted farmyard manure varies from 10,000-15,000 kg/ha/yr.

Soil acidity

Soil may be acidic, alkaline or neutral. The ideal range for soil is pH 6-8. The water passing over acid soil tends to be acidic with low alkalinity and hardness. High concentration of metal ions particularly aluminum and iron also may be present. Acid ponds do not respond well to fertilization.

Liming is the only way to improve water quality in ponds with acid soils and it is the pH of the soil that must be corrected for lasting effect, rather than the pH of the water. Recommended rates of application of lime ($CaCO_3$) at different soil pH is given below.

Soil pH	Lime (mt/ha) $CaCO_3$
6.0-7.0	0.3-0.5
5.0-6.0	0.5-1.0
4.0-5.0	1.0-1.5
3.0-4.0	2.0-4.0

Acid sulfate soils

Acid sulfate soils from mine spoils and coastal mangroves contain high levels of pyrite (FeS_2 1-6%). As long as sediments containing pyrites are submerged and anaerobic they remain reduced and change little. However, as they are drained and exposed to the air, oxidation results and sulfuric acid is formed.

Sulfuric acid reduces the pH of the water when pond is filled. In ponds the problems with acid sulfate soils usually originate in pond dykes. Pond bottoms are usually flooded and anaerobic, so sulfuric acid does not form. However, dykes dry and sulfuric acid formed during the dry period enters pond in run off water after rains. Acidity on dykes can be controlled by liming (0.5-l.0 kg/ square meter) and establishing good cover with an acid resistant grass species.

A procedure for rapid reclamation of ponds with acid sulfate involves drying and filling of the soil to oxidize pyrite, filling the pond with water and holding till water pH drops to below 4 and then draining the pond, repeating the procedure until the pH stabilize at a pH above 5 and then liming the pond with 500 kg of calcium carbonate per hectare.

Bottom soil oxidation

Dissolved oxygen cannot move rapidly into water-saturated soil, and pond soils become anaerobic below a depth of few millimeters. Aeration and water circulation are beneficial in improving bottom soil oxygenation, but the surface layer of soil may still become anaerobic in intensive fish culture ponds. When the redox potential is low at the soil surface (anaerobic conditions), hydrogen sulfide and other toxic microbial metabolites diffuse into the pond water. Sodium nitrate can serve as a source of oxygen for microbes in poorly oxygenated environments the redox-potential will not drop low enough for the formation of hydrogen sulfide and other toxic metabolites.

Drying pond bottoms

When pond bottom are dried between crops, evaporation of waters from soil pores and cracking of the soil enhances aeration and favors microbial decomposition of soil organic matter. Excessive drying makes soil too dry for microbial activity, so a drying period of 2-3 weeks usually is adequate. Tilling of dry soil with a disk harrow also can improve aeration, but tilled bottoms of aerated ponds should be compacted before refilling to reduce the tendency for erosion.

Some other treatments for sustainable pond productivity

Nutrient removal

It is possible to precipitate phosphorus from pond water by applying sources of iron, aluminium or calcium ions. These ions precipitate phosphate as insoluble iron, aluminium or calcium phosphates. Alum (aluminium sulfate) and ferric chloride are commercially available sources of aluminium and iron respectively. Alum is cheaper and more widely available than ferric chloride. Gypsum (calcium sulfate) is a good source of calcium, because it is more soluble than liming materials. Treatments rates of 20-30 mg/l of alum and 100-200 mg/l of gypsum have lower phosphorus concentration in pond waters. Alum is acidic and more suitable for use in waters of 500 mg/l total alkalinity and above. Gypsum is better for use in low alkalinity waters.

Phytoplankton removal

Algicides are used to reduce the abundance of phytoplankton in intensive fish culture ponds. Copper sulfate is recommended for reducing phytoplankton abundance and the abundance of blue green algae in particular. The usual recommendation is to apply a dose to copper sulfate equal to 1/100 of the total alkalinity. The best approach to phytoplankton control is to regulate nutrient inputs by moderate stocking and feeding rates, but it may feasible to use alum or gypsum to precipitate excessive concentrations of phosphorus.

Chlorination

Hypochlorus acid and hypochlorite (free chlorine residuals) are responsible for the disinfecting power of chlorine products in pond water. But, chlorination of waters containing fish or prawn is both dangerous and unbeneficial. It is possible to disinfect bottoms of empty ponds and water in newly filled but unstocked ponds by applying chlorine products. When this is done, enough chlorine should be applied to overcome the chlorine demand and provide 1 mg/l or more of free chlorine residual. The residuals will detoxify naturally in a few days so that ponds can be stocked safely.

Water exchange

There are reasons to exchange water in specific instances, such as to reduce salinity, to flush out excessive nutrients and plankton or to reduce ammonia concentrations. However, daily water exchange usually does not improve water quality in ponds, and pumping costs are a liability. Ponds are highly efficient in assimilating carbon, nitrogen and phosphorous inputs not converted to fish or prawn flesh, but if water exchange is great, these substances are discharged from ponds before they can be assimilated. Thus, the pollution potential of aquaculture ponds increases as a function of increasing water exchange. From both economic and environmental perspectives, water exchange should only be used when necessary.

The best method for preventing soils and water quality problems in aquaculture ponds is to select a site with good soils and an adequate supply of high quality water and to maintain moderate levels of prawn and fish production. If this is done, liming, fertilization and aeration can prevent most soil and water quality imbalances. However, in some instances, sedimentation basin may be needed to prevent ponds from filling in and water exchange may be required periodically. In intensive aquaculture ponds, bottom soil treatment such as drying and liming between crops, phosphorous precipitation, turbidity removal and oxidation of bottom soils with sodium nitrate may be beneficial. Some treatments are either ineffective or potentially hazardous to the stock.

Therefore, proper pond management is the key to sustainability in aquaculture, and enhancing sustainability of pond aquaculture can improve soil and water quality in ponds and reduce the volume and pollution potential of pond effluents. Proper procedures for pond management will improve environmental conditions, sustainability and profits.