

# Aquaculture Fundamentals

## The use of lime, gypsum, alum and potassium permanganate in water quality management

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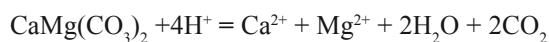
It is desirable to provide cultured fish with conditions that are within their favoured range for optimum growth and production. However, local environmental conditions may make a pond unfavourable or completely unsuitable for fish culture. Problems that are frequently encountered include soft acidic waters, low natural productivity, high clay turbidity, oxygen depletion and acid sulfate soils. In such circumstances it is desirable to adjust the water chemistry of a pond in order to bring it back into the favoured range of the culture species.

Lime, gypsum, alum and potassium permanganate are all chemicals frequently used in aquaculture to regulate water quality and the conditions described above. The usefulness of these chemicals in water quality management for fish culture is reviewed below.

### Lime

Pond waters with pH of 3.6-5.4 have been reported to exert toxic effects on a range of fishes including mortality, reduced growth and poor reproduction. Waters with a pH of less than 6.0 have also been associated with poor productivity<sup>1</sup>. Freshwater ponds with acidic waters may therefore be unsuitable for use in fish culture without remedial action. Total hardness and total alkalinity are normally within acceptable limits in brackish or marine ponds<sup>2</sup>.

Liming materials contain calcium, or calcium and magnesium in combination with an anionic radical capable of neutralising acidity<sup>2</sup>. Common liming materials include agricultural limestone and liquid lime, calcium hydroxide, calcium oxide and basic slag. Liming materials react with acidity as follows for dolomite<sup>3</sup>:



This reaction neutralises acidity, increases pH and total hardness of water, and results in an increase in total alkalinity. The addition of lime can be used to increase these properties to levels favoured by culture species<sup>4,5</sup>.

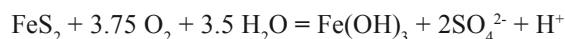
Rapid pH changes, even within the range normally tolerated by a species, may also cause the death of fishes<sup>1,6</sup>. Some liming materials such as calcium oxide and calcium hydroxide can result in a pH increase above 11, which is considered to be the alkaline death point for pondfishes<sup>1</sup>. However, these materials will react with atmospheric carbon dioxide (CO<sub>2</sub>) to form less hazardous carbonates if applied to empty ponds several weeks before refilling<sup>1</sup>. This will prevent such excessive increases in pH occurring from the use of these materials.

Ponds with substantial populations of phytoplankton or aquatic plants may also experience wide diel fluctuations in pH. This is caused by fluctuations in CO<sub>2</sub> concentration due to respiration and photosynthetic activity<sup>7</sup>.

The addition of liming materials to increase the total alkalinity of ponds has the desirable effect of increasing buffering capacity and pH stability<sup>1,7</sup>.

### Liming to reclaim acid-sulfate soils

Acid-sulfate soils contain iron pyrite, (iron sulfide) which is oxidised to sulfuric acid if the soils are exposed to air<sup>3</sup> as per the following reaction<sup>2</sup>:



Drainage from acid sulfate soils can cause extremely low pH in ponds outside the tolerable range of most species<sup>3</sup>. Acid sulfate soils within a pond or its watershed must therefore be treated if the pond is to be used for production. However, large amounts of lime are typically required and the technique may not be economically feasible unless used in conjunction with other methods<sup>2</sup>.

### Liming to increase the effectiveness of fertilisation programs in soft acidic waters

Fertiliser is often added to ponds to increase fish yields by increasing the availability of food organisms for fish. However, fertilisation programs are usually ineffective in ponds with acidic waters and sediments<sup>3</sup>. This reduced response is caused by two factors. The first is a deficiency of carbon in the alkalinity system, which cannot support high rates of photosynthesis by phytoplankton and plants<sup>8</sup>. The second is the increased adsorption of dissolved inorganic phosphorus by sediments<sup>9</sup>. Phosphorus is a key nutrient for phytoplankton growth and its availability limits phytoplankton production<sup>8,10</sup>. Liming materials may be used to support fertilisation programs or to improve productivity in acidic waters by addressing both of these factors. Lime is generally recommended as a treatment for ponds when total alkalinity and total hardness are below 20 mg/litre<sup>11</sup>.

Heavy phytoplankton growth can deplete free CO<sub>2</sub> which is required by phytoplankton and aquatic plants for photosynthesis<sup>4,5</sup>. Bicarbonate ions provide an alternative carbon source for photosynthesis in the absence of free CO<sub>2</sub><sup>1</sup>. The increase in total alkalinity resulting from properly applied liming materials is primarily by bicarbonate ions<sup>3</sup>. Liming can therefore favour greater rates of photosynthesis at times when the availability of free CO<sub>2</sub> is limited, leading to substantially higher phytoplankton densities<sup>4,5</sup>.

Phosphorus added to ponds rapidly disappears from solution. Some of this dissipation is due to adsorption by phytoplankton, but most phosphorus is removed through reaction with the sediment to form iron and aluminium phosphate compounds. This process is pH dependent<sup>9</sup>. Applying lime to neutralise the

acidic muds of ponds to pH 6.5 has been shown to increase soluble phosphorus concentrations. This reflects the greater solubility of phosphorus from muds at this pH<sup>5</sup>. This may enhance phytoplankton productivity and substantially increase fish yields in limed fertilised ponds relative to unlimed fertilised controls<sup>4</sup>.

Agricultural limestone cannot be applied simultaneously with phosphate fertilisers as this will cause phosphorus to precipitate<sup>12</sup>. This is due to the high calcium concentrations from the limestone reacting with phosphate to form tricalcium phosphate<sup>18</sup>. It is therefore desirable to add liming materials well in advance of fertilisers.

Liming is not usually considered to be a form of fertilisation<sup>13</sup>. However, liming increases the concentration of calcium and/or magnesium, which can be limiting nutrients, for phytoplankton, at low concentrations<sup>5</sup>. These nutrients are most likely to be limiting in waters of low total hardness.

Lime must be periodically reapplied to remain effective. Ponds treated with approximately 1000kg/ha agricultural limestone or hydrated lime have been reported to show increased productivity for two to four years<sup>3</sup>. The effective period of an application, as indicated by water hardness, is determined by the rate of water loss to seepage and overflow from ponds<sup>3</sup>. Liming has been reported to be ineffective in a pond with a water retention time of less than three weeks<sup>12</sup>.

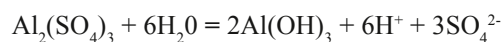
### Alum (Aluminium sulfate)

Clay turbidity restricts light penetration in ponds. This reduces the depth to which photosynthesis can occur and reduces primary productivity<sup>14</sup>. Clay turbidity is caused by ultra-fine colloidal particles, 1-10µm in diameter. These particles carry a negative charge which maintains them in suspension.

Positive ions react to reduce the negative charge of colloids, causing them to coagulate into larger particles and settle out<sup>2</sup>. Electrolytes with appropriate positive ions can therefore be added to water to remove colloidal particles. Alum (aluminium sulfate), hydrated lime (calcium hydroxide) and gypsum (calcium sulfate) are often used as sources of electrolytes for reducing turbidity<sup>14</sup>.

Liming materials increase the concentration of calcium and magnesium ions, which flocculate colloidal particles<sup>14</sup>. Gypsum can also be used to flocculate colloids by increasing the concentration of calcium ions<sup>7</sup>. However, in one comparative study, alum was found to be more effective than lime or gypsum in the reduction of turbidity. Alum reduced turbidity by 89-97% within 48 hours at doses of 10-30 mg/litre<sup>14</sup>. The cost of treatment with alum is significantly lower than for gypsum<sup>7</sup>.

Alum is acid forming and can substantially reduce total alkalinity and pH as per the following reaction<sup>14</sup>:



This effect makes alum unsuitable for use in ponds with low total alkalinity as it may lower pH to the point where it is toxic to fish<sup>14</sup>. Alum also reduces dissolved inorganic phosphate levels through the precipitation of insoluble aluminium phosphate, reducing phytoplankton growth<sup>14</sup>. The use of alum may therefore necessitate the addition of lime to correct total alkalinity and pH if these parameters fall below acceptable levels. Fertilisation to increase dissolved phosphorus concentrations may also be necessary to maintain productivity.

### Gypsum (calcium sulfate)

Gypsum (calcium sulfate) is more soluble than liming materials and can be used to increase the total hardness of waters beyond that possible with lime, although it does not neutralise acidity<sup>7</sup>. The low cost and high solubility of gypsum makes it ideal for use in the maintenance of calcium levels in hatchery situations. Adequate levels of calcium are critical for bone formation in fish and exoskeleton formation in crustaceans<sup>7</sup>.

The increased calcium concentrations associated with the addition of gypsum to ponds may cause a gradual, but substantial, decline in total alkalinity, pH and phytoplankton abundance<sup>7,15</sup>. The increased concentration of calcium associated with the addition of gypsum has been shown to reduce total alkalinity through the precipitation of calcium carbonate<sup>15,16</sup>. High calcium concentrations have also been shown to limit the concentration of dissolved phosphorus through precipitation of insoluble tricalcium phosphate<sup>10</sup>. The reduction in phosphorus in this manner is not normally enough to make ponds unproductive<sup>7</sup>. However, phosphorus concentrations are normally low in acidic waters due to the exchange acidity of sediments<sup>4</sup>. The use of gypsum may therefore reduce the productivity of acidic ponds. It may be necessary to correct total alkalinity with lime and increase phosphorus levels with fertilisation if treatment with gypsum causes these parameters to fall below acceptable levels.

The calcium ions supplied by gypsum act as electrolytes in the flocculation of colloidal particles. For example, gypsum applied at rates of 100-500 mg/litre substantially reduced turbidity in one study. However, similar reductions in turbidity were achieved using 20-25 mg/litre of alum, which is a more cost effective treatment<sup>7</sup>.

### Potassium permanganate

Potassium permanganate (KMnO<sub>4</sub>) is an oxidizing agent, which is sometimes used as a pond treatment for oxygen depletion. It is also sometimes used as a disinfectant or treatment for fish<sup>8</sup>.

The addition of potassium permanganate at concentrations above 4mg/litre has been reported to reduce the biological oxygen demand of water in plastic pools<sup>17</sup>. The effect lasted for one to two days post-treatment and was attributed to reduction in the abundance of aerobic bacteria. However, treatment also reduced daylight rates of oxygen gain by suppressing photosynthesis and reducing algal abundance. This technique may in fact be detrimental since it is only useful if potassium permanganate is added in advance of oxygen depletion occurring<sup>17</sup>. However, this technique might possibly be of some assistance as an emergency measure if combined with additional supplementary aeration to increase dissolved oxygen levels. This would be of particular benefit at night when dissolved oxygen levels are at their lowest.

The use of potassium permanganate appears to be incompatible with the application of fertilisers to enhance primary productivity of ponds. Treatment of ponds with potassium permanganate has been reported to substantially reduce the concentration of dissolved orthophosphate concentrations<sup>17</sup>. The loss was attributed to the formation of insoluble precipitate formed upon the oxidation of ferrous iron by potassium permanganate. Phosphorus is a key nutrient for phytoplankton and its availability limits phytoplankton growth<sup>18</sup>. Fertilisation with phosphorus may be required after treatment

with potassium permanganate in order to maintain the primary productivity of ponds.

Potassium permanganate may also be used to oxidise the piscicides such as rotenone and antimycin<sup>7</sup>. However, potassium permanganate has been shown to be toxic in itself, with adverse effects observed in some fish at concentrations of 2mg/litre in tap water<sup>17</sup>. The toxicity of potassium permanganate, and its effectiveness as a treatment appeared to be reduced by the presence of organic matter in ponds.

## Conclusion

Liming materials may contribute substantially to fish yields by improving conditions for fish, and by enhancing the primary productivity of the pond. Alum is an effective flocculant for reducing clay turbidity. Gypsum is less useful in this regard, but is better suited to raising hardness than lime or alum because of its greater solubility. Potassium permanganate is a useful disinfectant, but may actually be detrimental if added to ponds suffering from oxygen depletion.

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# The utilizations of heterosis in common carp in China

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Common carp *Cyprinus carpio* is one of the principal cultured species in China. The production of cultured common carp reached 2.05 million ton in 1999 and accounted for 20% of total freshwater fish production. Since the farming of this fish extends back to ancient times, common carp has a wide distribution in China. As a result of long-term selection (both natural and artificial), common carp populations have acquired a great deal of genetic diversity – there is a great deal of polymorphism in its phenotype and genotype and its genetic structure has high heterozygosity. This heterosis provides the opportunity to improve the productivity of carp through selective breeding.

The utilization of heterosis in selective breeding is an effective way to improve fish quality and increase fish production. Since 1970s, Chinese fisheries scientists have made broad studies on the utilization of heterosis in common carp and achieved significant results. Traits in which crossbreeds express heterosis include improved survival, growth and tolerance to cold and specific diseases. The followings are some hybrids of common carp that have been successfully extended to the practice.

## Applications of heterosis in common carp

### Feng carp

This hybrid comes from the combination of Xingguo red carp × scattered mirror carp, first developed by staff at the Hubei Institute of Hydrobiology. At the fingerling stage, the growth rate of Feng carp is typically 1.5-1.6 times of that of maternal fish, and at the adult stage, 1.32 times.

### Heyuan carp

This crossbreed is obtained from the hybridization between purse red carp × Yuanjiang carp. It has some advantages included a high growth rate, good body shape, high feed conversion rate and a high capture rate.

### Yue carp

These are the first generation offspring (F1) of the hybridization combination of purse red carp × Xiangjiang carp. Their growth rate is 50-100% more than the paternal fish and 25-50% than the maternal fish. Field trials have shown that they can reach market size after 200 days culture in the Hunan area (central China).

### Triple-hybrid carp

The maternal and paternal fish of this hybrid is Heyuan carp and scattered mirror carp, respectively. The growth increment of the hybrid is 15% and 50% greater than the maternal and paternal fish, respectively.