Liming as a Technique

in

Fisheries & Water Quality Management

A.G.A. GROUP
Consultancy Limited

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Education Series

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1. Introduction

The use of Calcium compounds, often referred to as Lime (Liming) in fisheries management circles is a long established method and indeed it could almost be described as a tradition in twentieth century rural aquaculture. Its effects have been well documented and without doubt the use of the correct compound in the right circumstances will serve valuable functions. The aim of this booklet is to give practical advice on the application of lime in fisheries as a management option, particularly when and where it is applicable.

The term ‘liming’ comes from the field of aquaculture where liming is used as part of the annual cycle to prepare ponds ready for the growing season. Where ponds are used for semi-intensive or intensive aquaculture it is a highly recommended procedure used as a precursor to fertilisation. The technique has since been transferred to still-water fisheries management where it can serve similar and other functions with the same associated benefits.

Liming is an effective tool in fishery management and can be applied to meet a number of objectives. However, lime is a casually used term to describe various types of calcium compounds, used for very different purposes *(Table 1)*.

It should be noted that not all waters will require liming or will significantly benefit from it. Indeed, in certain circumstances it can be harmful. It should also be noted that certain calcium compounds are extremely and alkaline (high pH) can be toxic to fish.

AGA Group promotes the use of lime only as part of a wider fishery management approach, as part of a management plan where all factors impacting on a fishery are considered holistically. The use of lime should not therefore be considered in isolation but rather as part of a coherent strategy to improve environmental parameters and fish health.

Liming can be carried out with four basic calcium compounds; all are used in freshwaters depending on the management objective of the application as shown in *Box 1.*

It should be acknowledged that trying to change the chemical composition of a water body is at best problematic, and the consequences, should it go wrong, can be severe. AGA would therefore only advise the use of lime after consultation with a professional consultant.

Table 1. Common Calcium compounds used for liming ponds and lakes.

Basic chemical	Common name	Toxicity to fish	Disinfectant properties	Cost	Effectiveness	Preferred when
Calcium carbonate $CaCO_3$ Aquatic chalk	Limestone (90-95% $CaCO_3$ Dolomite (double carbonate of calcium/magnesium) Marl (20-80% $CaCO_3$ others: basic slag, coral, shells etc.	Low	None	Low	Low and slow NV 100	water pH: >4.5 fish are present
Calcium Sulphate – dihydrate $CaSO_4 H_2O$ AquaBio	Gypsum	Low	None	Low	Medium	water pH: >4.5 fish are present
Calcium hydroxide $Ca(OH)_2$	Hydrated lime Caustic lime, Slaked lime Builders lime (approx. 70% CaO)	Medium	Strong	Medium	Medium 0.7 kg = 1 kg $CaCO_3$ NV 136	water pH: <4.5 no fish present pest control
Calcium oxide CaO Quick lime	Quicklime, or burned lime	High	Strong	High	High and fast 0.55 kg = 1 kg $CaCO_3$ NV 179	drained pond, pest control

NV = neutralising value of the pure salts, in percent, with reference to $CaCO_3$ (NV = 100%).

Taken from FAO (1997) and amended.

Box 1. The four basic liming compounds.

- Calcium carbonate, $CaCO_3$ – naturally occurring, quarried as limestone or chalk, also known as 'Aquatic Chalk' or 'Siltex' for aquatic use;
- Calcium hydroxide, $Ca(OH)_2$ – commercially manufactured as Hydrated or Slaked lime, also known as 'builders' lime;
- Calcium oxide, CaO – known also as Quick or Burnt lime:
- Calcium sulphate dihydrate, $CaSO_4 H_2O$ – commercially manufactured as 'Gypsum', also known as 'AquaBio' for aquatic use.

2.0. Potential benefits

Liming may benefit pond health and fish populations in recreational angling waterbodies in many ways depending on the objective of the application. It is best therefore to consider the potential benefits according to the objectives of the application.

2.1 Application of Calcium carbonate (Aquatic chalk) and Calcium sulphate di-hydrate (AquaBio)

The addition of Calcium carbonate or Calcium sulphate di-hydrate has benefits to both the hydro-soil and the water in terms of chemical quality. Using calcium carbonate or calcium sulphate di-hydrate acts to increase mineralisation, a vital biological process in the overall food web of a pond *(Figure 1)*. The addition of calcium - a vital nutrient, and the release of phosphorus as phosphates from the hydro-soil are both beneficial to the aquatic environment promoted by the application of lime.

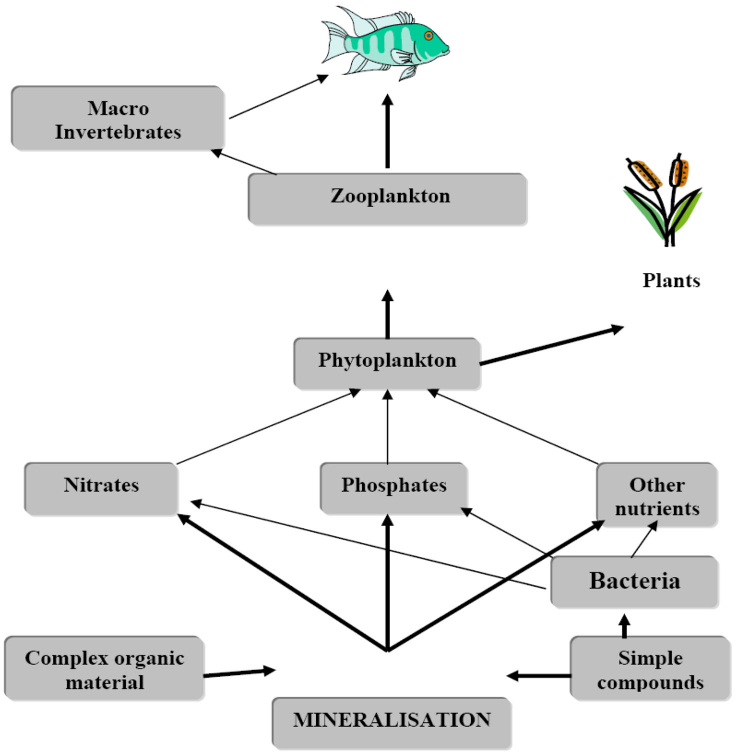
Calcium is an essential nutrient for many invertebrate organisms which provide the base of the food chain for fish. By increasing the number and diversity of invertebrates it is effectively providing the fish with a more stable source of food and nutrition.

Phosphates stimulate the growth of plankton and water plants providing increased food for the fish. This may have the effect of increasing the fish population and an improvement of environmental conditions. Biro (1995) states that "the exchange rate of nutrients, e.g. phosphorus, basically depends on the pH regime; higher pH results in more intensive release of P- forms (phosphate) as a result of heterotrophic activity, thus allowing increased primary production and energy flux".

However, if too much phosphate is released it can lead to eutrophication, a common problem in UK ponds and lakes. In such circumstances algae and water plants grow wildly, choke the water body, and use up large amounts of oxygen. This would be an instance where the application of lime might not be advisable in forms that elevate pH

Where it is applicable, the application of Aquatic chalk or AquaBio has numerous benefits to both the hydro-soil and the water of a pond.

Figure 1. Food web and mineralisation in a coarse fish (cyprinid) pond.



The key benefits to the hydro-soil are:

- Structure will be improved;
- Decomposition of the organic matter, particularly cellulose will be accelerated;
- pH of the hydro-soil will increase.

The key benefits to the water are:

- pH will increase and become more stable;
- Total alkalinity will increase, providing more carbon dioxide for photosynthesis;
- Calcium content will increase, to be used by plants;
- Certain toxic substances such as iron compounds will be neutralised and precipitated as pH increases;
- Excess organic matter will precipitate, decreasing the demand for dissolved oxygen in the pond water;
- Precipitating organic matter in suspension – colloidal clay.

Note: Where increasing pH is not desirable i.e. release of nutrients then there is a significant benefit in choosing Calcium sulphate di-hydrate (AquaBio) as the preferred liming compound.

One of the most important effects used as a measure to control the liming is the effect Calcium carbonate has on total alkalinity. Total alkalinity depends on local characteristics of the soil and water. Water with a high alkalinity will have a good buffering capacity; it will be chemically quite stable, with small diurnal variance (fluctuating pH). Increasing the alkalinity of a water body to a level where it is considered an acceptable range for fish (pH 6.5-9.0) will undoubtedly bring about and support improvements in fish health. Fish in acidic waters (pH below 6.5) are commonly stressed, have lower resistance to disease, and grow more slowly to a smaller maximum size than fish in alkaline waters. High acidity and toxic metals also kill fish eggs and larvae and reduce spawning success.

However, raising the pH in itself will have little effect without the chemical stability or buffering capacity which reduces the diurnal and seasonal fluctuations.

Liming can neutralise acidic waters, minimise stress, and detoxify heavy metals. It is worth noting that different species have different tolerance levels and whilst some species perform well in neutral pH waters, most notably cyprinid fish such as carp *(C. carpio)* pH 7.0-8.5, others may prefer a more alkaline environment.

The application of lime can help buffer against fluctuations of pH where due to environmental conditions it could potentially decrease to levels which are harmful for fish (diurnal variance). Using lime to increase the alkalinity to a level where daily fluctuations will not fall into this sub-optimal zone (<pH 6.5) will chemically stabilise the pond and bring about benefits for the health of the fish.

2.2. Chemical de-silting of lakes

The use of lime to chemically de-silt lakes has several benefits; not least it is a lot cheaper than mechanical removal and can be carried out without harming the fish so negates their removal which is often not the reality with mechanical silt removal if harm to the fish stock is to be avoided.

Where there are deep layers of organic rich hydro-soil potential nutrients are stored where oxygen cannot penetrate, so they are consequently dormant. This stops the facultative (beneficial) bacteria from efficiently decomposing the material and promotes poor environmental conditions.

In waterbodies with fish populations only the application of Calcium compounds in the form of Aquatic Chalk and AquaBio should be used as they are the only two forms of Calcium compounds that can be used in the required quantities and remain safe for use with fish in the water. Both Aquatic Chalk and AquaBio encourage a greater abundance and diversity of bacteria which can then break down the organic matter. The re-vitalisation obtained through the application of Calcium carbonate or Calcium sulphate dihydrate will kick-start the facultative fauna. This is critical to the efficient operation of the natural mineralisation cycles that drive the aquatic ecosystem of lakes and ponds, as the facultative fauna break down the material so the silt content is reduced and the lake deepened to some extent. This technique will only be effective where the hydro-soil contains a partially decomposed element and that there is sufficient oxygen to allow aerobic decomposition. This fact should not be passed by and is one of the main reasons why the chemical de-silting of stillwaters is a slow process and oxygen does not penetrate down very deep into the hydro-soil.

There is little or no scientific evidence to support many of the claims made about Aquatic Chalk for reducing silt that has no organic component. This claim is not made for the other 'fish safe' Calcium product AquaBio, which is used in similar situations. Both can have a modest effect on reducing existing silts that are built up, providing there is a partially decomposed organic component. Both these products can perhaps be most useful in stopping the build up of silt in the future whilst having the benefit of revitalising the hydro-soil if used annually as a conditioning treatment for the hydro-soil and water quality more generally.

The cost of Aquatic chalk and AquaBio is prohibitive when compared to ordinary quarried Calcium carbonate; however, a comparison of the two products is not on a like for like basis as the Aquatic chalk and AquaBio undergoes a much finer milling and quality process and is therefore much more effective.

The increased effectiveness over other forms of calcium carbonate for silt reduction is due to its very small particle size (a teaspoon will have in the region of 500 million particles (Needham 1997). It is therefore very efficient in its mode of action in comparison with other forms of calcium carbonate; it appears exceptional in its ability to form a colloidal mass with suspended particles of sediment.

When applied, Aquatic chalk and AquaBio will gradually sink through the water body binding on to any suspended fine particulate matter. This often will cause the water to go temporarily clear. The clarity even in the short term is desirable as the increased light is an important part of the mineralisation process. However, the clarity may also increase the growth in a response to increased light, of submerged macrophytes. It should also be considered that the Calcium will also encourage those macrophytes that are calciferous by nature (*Ceratophyllum, Chara, and Elodea*).

If the objective is to use lime to sterilise a water body prior to stocking (empty of fish), then a different type of lime is required. In this instance the lime used is either Calcium hydroxide (Hydrated lime) or Calcium oxide (Quick lime) which is significantly more potent (caustic) than Calcium carbonate or Calcium sulphate di-hydrate used in the above applications.

Calcium hydroxide and Calcium oxide are more expensive than the other Calcium compounds but act as very effective disinfectant and steriliser, raising the pH quickly and dramatically above tolerable levels for most aquatic organisms.

They should be used very carefully, avoiding contact to the person carrying out the application; and never used in water bodies containing desirable fish *(Health and Safety, Section 8.0).*

These very strongly alkaline products can be used within a drained pond or lake to kill many fish pathogens that have part of their life-cycle away from the fish host. When carrying out such an operation the lime needs to be introduced to all areas including the aquatic margins and plants. A lake being limed to control the external fish parasite *Argulus spp.* by AGA is shown in *Plate 1*.

Plate 1. Lake liming with hydrated lime.

3.0 History and effectiveness

Liming lakes and ponds is a tried and tested method for treating acidified surface waters, with notable studies in Sweden in the 1980's (Nyberg). The aim of Nyberg's studies was to investigate whether lime treatment was a possible method of protecting waters of special value for fisheries, nature conservation or recreational uses. In all waters where liming was tested it resulted in a sufficient and durable pH increase, the fish started to reproduce again, even if the populations were composed of very few and old individuals at the time of treatment. Lime treatment is not however a definite cure all for acidified waters but may protect fish populations in lakes with long turnover times in areas with relatively low acid deposition. Areas of high runoff in streams, rivers and lakes with short turnover times are a lot more difficult to treat with lime and the application is not recommended.

In areas with a high acid load and acidified watersheds, liming of lakes and running waters will not prevent acidic groundwater with elevated concentrations of toxic metals from entering surface waters.

Identifying liming needs can be accomplished by taking either water and/or soil samples from the water body over a period of time (ideally over a few months). Measuring the total alkalinity of water over such a period is the most effective way to determine if liming is necessary.

Production within the entire food chain (plankton-insects-fish) is stimulated by liming, and the increased abundance of natural food items. The increase in natural feed item production supports fish growth and reproduction can also often be accompanied by enhanced growth of rooted aquatic plants, that serve as nursery areas for juvenile fish.

Adding Calcium compounds and fertiliser are conventional aquaculture practices for enhancing fish production in fish culture ponds. The addition of the Calcium compound and the fertiliser should not be applied simultaneously however because Calcium may precipitate phosphorus and reduce its availability. The calcium and magnesium components of lime raise the hardness of water, essential to the health of many aquatic species. The carbonate component raises the alkalinity and the pH.

Buffering daily fluctuations in pH increases microbial activity in the hydro-soil and increases the availability of phosphorous to phytoplankton. It is accepted that water with total alkalinity less than 20 ppm can potentially benefit from liming (Nyberg, 1984).

4.0 When should lime be used

Lime is most commonly used when fisheries experience periods of depleted nutrients. This is especially common in older, established lakes where nutrients necessary for plant growth become locked within the sediments causing a decline in productivity. This can result in the sediment becoming increasingly acidic, slowing the breakdown of organic matter such as plants and leaves, and releasing fewer nutrients into the water for use by plants.

Caution must be taken however as there may be a different reason for the problems attributed to acidification. Similar symptoms to that of acidification may result from other problems so make sure acidification is responsible before applying lime. The pH should ideally be tested at various times of the day over several weeks.

This process of monitoring will allow for reliable decisions to be made regarding a representative range of pH values. In addition, seek advice of a professional consultant before adding lime.

New lakes created in rich soil are generally considered to be productive but lakes in gravel pits, clay pits and sandpits contain few nutrients – they are therefore not productive to begin with. Nutrients may also be lost from lakes if a stream or groundwater flows through them.

Fertiliser can be also added to enhance the productivity of stillwaters as with intensive aquaculture, but care must be taken to avoid pollution, damage to protected species or rapid removal or outflow taking place (Environment Agency, 2006).

Making chemical improvements to a water body is perhaps one of the easiest fishery management strategies to get wrong! If in doubt always seek professional advice. Mineralisation is a natural biological process with facultative bacteria preferring to work in alkaline conditions. Most soil however is slightly acidic, so the application of lime can help to change the chemical composition to more favourable alkaline conditions. There are conditions where the application of lime is unadvisable however and generally ponds should not be limed if:

- Fertilisers will not be used subsequently, unless the water is very acidic
- Natural food is not important – intensive system (supplementary feeding)
- The water pH reaches more than 8.5 by the end of the day

5.0 Lime application in river catchments

The benefits of liming in river catchments are mixed and depend heavily on catchment characteristics. Some success has been achieved in the River Tywi catchment, with pH rising from 5.1 to 7.0 (neutral), with associated recovery of previously impoverished juvenile salmonoid stocks.

However, there are questionable aspects to this technique. Water chemistry is not restored to pre-acidification conditions; rather, pH and calcium concentrations are often much higher than previously, with some aquatic organisms such as mosses and liverworts being negatively affected. Additionally, responses by invertebrate communities have been slow and partial, with limed streams gaining only a fraction of the communities found in streams that are naturally circum-neutral (National Trust, 2004). The applicability of liming and the alteration of natural systems must therefore be questioned, especially if the effects are negative for some aquatic organisms. Management decisions should be based on the best course of action for all species and as such caution shown in the approach.

This cautionary approach is also supported by Weatherly (1988) who suggested that while there are undoubtedly benefits in the application of lime to freshwater ecosystems there may also be unforeseen consequences. The benefits supported by his research included population expansion of acid-sensitive plant and animal species, and restoration of fisheries. However, no ecosystems have so far been returned to pre-acidification status. He concludes that if the long-term ecological consequences of liming are to be predicted, further understanding of these limitations and the stability properties of aquatic communities is necessary.

6.0 Application methods

Calcium carbonate is ideally applied directly to the bottom of the pond prior to filling with water and should be spread evenly over the entire base. It is acknowledged however that in fishery management the focus is on improving existing water bodies and it is often impractical to apply the lime in this fashion as perhaps would be the situation in aquaculture following annual ‘drain down’.

Applying Calcium carbonate or Calcium sulphate di-hydrate to lakes which are full of water is more difficult but can be achieved without fear of harming the fish. Depending on the size of the water body the application of lime should be a staged process with no more than a quarter of the area being treated at one time; this allows the fish to adjust to the changes in environmental conditions and reduces the chance of stress.

The efficiency of liming materials increases as their individual particle size decreases. The powder to be used should ideally pass through a 0.25mm sieve (FAO 1997). Granules and larger particulates can be used for the disinfectant of drained pond bottoms (Calcium oxide, Calcium hydroxide) if this is the objective of the application.

The rate of application is determined by many of the factors discussed, and with the consideration of the aims and objectives of the specific management plan. Bulk application can be carried from a boat or work pontoon, a commercial application is shown being undertaken in *Plate 2*.

Plate 2. Installation of AquaBio.

It will be apparent form the text that the only entirely suitable (safe) forms of Calcium for the liming of ponds with fish present is Calcium carbonate (Aquatic chalk) or Calcium sulphate di-hydrate (AquaBio). The application of the more concentrated and toxic forms requires more gradual application and careful monitoring of water chemistry during and after application. Dosage rates are shown in *Table 2*

Table 2. Dosage rates for pond liming.

Form of lime	**Dosage – kg/ha**
Calcium Carbonate $CaCO_3$ Aquatic Chalk	1st dose 1000 - 1500kg 2nd dose.1000 - 1200kg
Calcium hydroxide $Ca(OH)_2$ Hydrated lime	750 - 1000kg (thick mud) 300 - 450kg (thin mud) 1500 - 2250kg (disinfectant)
Calcium oxide CaO	500 - 750kg (thick mud) 200 - 300kg (thin mud) 1000 - 500kg (disinfectant)

Calcium sulphate-dihydrate $CaSO_4 \cdot H_2O$ AquaBio'	1st dose 350 - 500kg 2nd dose 250 - 400kg

Adapted from Girdler *et al* (2010).

7.0 Further considerations

When undertaking the liming of a pond it should be noted that the whole area should be treated, not just those areas perceived to be 'silty'. It is suggested to those using any form of liming in an aquaculture setting that there may also be significant benefits to be gained in pond production by carrying out a fertilisation programme.

Fertilisation should however only be carried out if there is a clearly identified management objective. It should be noted that inappropriate fertilisation can increase population densities of nuisance alga such as blue/green species and lead to eutrophic conditions. This is a subject however that is beyond the remit of this document.

The pH, organic content and aerobic status of the hydro-soil are critical factors in deciding upon whether to lime a pond or lake, without this knowledge it is difficult to estimate the appropriate dosage and almost impossible to predict the outcome.

To ensure a beneficial, controlled and measured outcome consult a professional with regard to the suitability of any pond or lake for treatment with a Calcium-based product.

8.0 Health and Safety

The application of all forms of liming material should be subject to health and safety considerations. Whilst Calcium carbonate and Calcium sulphate di-hydrate are not caustic in their action, their granular form can be a mild irritant to the eyes, so the use of goggles is recommended. An eye bath should be part of the first-aid equipment on site for all liming operations.

Hydrated and Quick lime can cause serious burns to the skin and eyes. A one-piece cover-all, face mask and goggles should be worn when applying this product.

COSHH and/or the Material Safety sheets should always accompany the Risk Assessment and the Method Statement (RAMS) for the work to be undertaken.

9.0 Conclusion

The use of lime in fishery management is now commonplace and can be extremely beneficial to both water quality and fish health. By applying lime in the correct quantities, the environmental parameters of inland waters can be improved to encourage more diversity of both plant life and aquatic organisms.

These improvements are brought about by changes in the chemical composition of the hydro-soil and the water by stimulating aerobic micro-organism activity.

Many still-waters in the UK suffer from deep layers of oxygen depleted organic hydro-soil and the application of lime has proved to encourage the breakdown of these layers by promoting facultative bacterial activity. Nonetheless with all aspects of the natural environment there is a fine balancing act between nutrient deficiencies and nutrient excesses which can lead to eutrophication.

There must therefore be a clear understanding of the issues facing a Stillwater based on monitoring and a comprehensive management plan before action is taken.

Liming methodologies have the following advantages:

- Decreases organic matter;
- Increases oxygenation by stimulating of aerobic micro-organisms;
- Improves water clarity by settling suspended solids;
- Reduces methane production in silt bodies;
- Counteracts acidity in water and hydro-soil;
- Provides essential calcium, increases alkalinity and conductivity;
- Increases water transparency;
- Reduction of orthophosphates, and iron ammonia salts;
- Reduction of disease in aquatic organisms.

As this booklet has highlighted, liming can be used to fulfil a number of fishery and water management strategies depending on the objectives of the overarching plan. However, whilst its applications can be beneficial in the right circumstances, caution must be taken when utilising liming as a management technique.

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