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Liming Acidified Lakes and Ponds

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What Is Liming?

"Liming," as the word suggests, is the addition of limestone (calcite), primarily calcium carbonate ($CaCO_3$), to neutralize acid waters and soils and buffer them from rapid fluctuations in pH. Limestone typically is applied to lawns, gardens, pastures, and croplands to supply calcium, an essential plant nutrient, and to decrease soil acidity.

Limestone can also be applied to lakes, ponds, and their surrounding watersheds to protect them from acidification, to add calcium, and to restore their important ecological, economic, and recreational values. Adding limestone to maintain a near-neutral pH (pH 7) keeps lake and pond water safe for aquatic life.

Advantages of Lime

- Inexpensive
- Available
- Non-toxic
- Natural mineral
- Easy to distribute
- Dissolves in water

What Is pH?

The pH of water is an expression of its acid or base content. The pH scale ranges from 0 (very acidic) to 14 (very basic). For example, battery acid has a pH below 1, and lye has a pH above 13; both are very caustic compounds, harmful to human and aquatic life.

Water with a pH reading of 0 to 6.9 is acidic; that with a pH of 7.1 to 14 is basic (alkaline). Most natural lake waters range from 6 to 9 in pH and are slightly basic due to the presence of carbonates and bicarbonates. Fish production generally is higher in alkaline (pH 7.1-9) waters.

What Is Alkalinity?

The alkalinity of water refers to its capacity to neutralize acids or to resist changes in pH. Alkalinity is a measure of the concentrations of three basic ions: carbonates (CO_3), bicarbonates (HCO_3), and hydroxides (OH) in water expressed as mg/L equivalents of calcium carbonate. In general, soft waters with low alkalinities (< 30 mg/L) contain few basic ions, have a low buffering capacity to resist pH fluctuations, and are more susceptible to acidification. Hard waters usually have high alkalinities (>100 mg/L), many basic ions, a high buffering capacity, and are less sensitive to acidification.

Why Liming?

Liming is one of the most cost-effective methods of slowing the effects of acidification, restoring acidic waters, and enhancing the abundance and diversity of aquatic life. It also reduces the toxic effects of metals, especially aluminum, copper, cadmium, lead, nickel, and zinc, which can threaten fish, other aquatic life, and human health.

Very acid lakes (i.e., pH below 4) often are devoid of fish, frogs, salamanders, crayfish, insects, and plankton. Certain sportfish, such as striped bass and salmonids, are sensitive to changes in pH and prefer lake waters with pH values ranging from 7 to 9. Because very acidic surface waters can have toxic concentrations of aluminum in solution, aquatic animals may be subjected to a potentially lethal double dose of poisonous acid and metals.

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By neutralizing acid waters and reducing toxic dissolved metals, liming can improve reproduction and survival of aquatic life and promote healthy, balanced fish populations. The calcium in lime dissolved in water is absorbed and used by mussels and crayfish to develop their protective shells and by young and adult fish for scale formation, bone development, and growth.

Does Liming Improve Sport Fisheries?

Liming benefits sport fish populations in many ways. Liming improves overall water quality and fish health in acidified lakes and ponds. Fish in acidic waters are stressed, have lower resistance to disease, and grow more slowly to a smaller maximum size than fish in alkaline lakes. High acidity and toxic metals kill fish eggs and larvae and reduce spawning success. Liming can neutralize acidic waters, minimize stress, and detoxify heavy metals.

Liming enriches a lake by adding calcium, an important nutrient, and releasing phosphorus, another important nutrient, from the lake bottom muds. Production within the entire food chain (plankton-insects-fish) is stimulated by liming, and the increased abundance of natural food items supports sport fish growth and reproduction. Enhanced growth of rooted aquatic plants that serve as nursery areas for young sport fish can result from liming.

What Are the Considerations Before Liming?

Make sure that acidification is the problem before adding lime. Symptoms similar to acidification may result from other problems. For example, poor fishing or declining numbers of fish may result from overfishing rather than poor reproduction caused by acid water.

Liming alkaline waters is unnecessary. Test the pH at different times of the day over several weeks to reliably determine the range of pH values. Generally, if the lake is an acidic or soft-water system with pH values less than 6.5 (and acid neutralizing capacity less than 50 microequivalents per liter), total alkalinity levels less than 20 milligrams per liter (mg/L), and total hardness concentrations below 25 mg/L, liming may be beneficial.

What Is Hardness?

Total hardness of water is a measure of its mineral content, expressed as mg/L equivalents of calcium carbonate. Calcium and magnesium are the primary cause of hardness in natural waters, but other metal ions (Al, Fe, Zn, Mn) also contribute to water hardness. Soft waters (hardness values < 100 mg/L) generally have low alkalinities and little calcium and magnesium, and consequently, are susceptible to acidification. Hard waters (hardness > 100 mg/L) usually have high calcium and are less prone to acidification.

Evidence of Acidification

- Is the lake acidic (pH < 6.5)?
- Does the daily pH fluctuate widely (2 units in 24 hrs)?
- Is this a soft-water lake (alkalinity <10 mg/L and hardness <25 mg/L)?
- Are metal (Al, Zn, Ni, Cu, Cd, Pb) levels increasing?

Lake or Pond Characteristics

- Is the residence time (retention time) of water) >3 months
- Is the surface area of the lake >1 acre?
- Is the average depth >8 feet?

Fish and Other Aquatic Life

- Is there a record of fish species and abundances?
- Is there an existing fish population (stocked or natural)?
- Are other aquatic animals (mussels, crayfish) present?
- Is sport fish growth slow and production limited?

What About Permits for Liming?

Liming public or private surface waters may require permits from state and federal agencies. Private lake and pond owners may or may not need permits, but they are liable for chemically altering downstream waters. Some states such as New York have adopted detailed policies and guidelines for liming surface waters. Others evaluate liming on a site-specific basis.

Permit applications and regulatory information usually are available from state water or natural resource agencies. Generally, the information required for a permit is similar to that needed for designing and defining the treatment, including (a) the proposed treatment material and application rate and (b) the data specific to that lake on baseline water quality, aquatic plants, and physical and hydrologic characteristics.

Liming may be harmful to naturally acidic wetlands (i.e., bogs, swamps, and marshes) and their associated acid-loving plants (sphagnum moss, black spruce, cranberry, leather leaf). Liming wetlands is not recommended because it can alter water chemistry, thereby permanently changing the plant and animal communities.

Public notification of the date, time, method of liming, and general precautions for recreational users is recommended on private lakes and typically required on public waters. Because liming may discolor the water temporarily, stimulate short-term algal blooms, and alter the taste and mineral content of drinking water, a pre-liming public education program is recommended when liming water-supply reservoirs.

What Is Residence Time?

Residence time (retention time) is the amount of time required to replace all of the water in the lake. For example, in small lakes (<10 acres) with a high flushing rate (large inflow and outflow), a residence time may be relatively short, perhaps weeks. Alternatively, in larger lakes with lower flushing rates (small inflow and outflow), residence time may be much greater, perhaps years. Clearly, liming is more lasting and effective in lakes with a longer residence time.

What Are the Sources of Acidity?

Acidification of lakes and ponds is not always caused by acid deposition. Some bog, swamp, and marsh waters contain high levels of naturally occurring organic acids. Pennsylvania, West Virginia, and Virginia are states where coal mine acid drainage can occur when sulfur-bearing minerals are exposed to air and water. Mine runoff typically is low in pH and can cause fish kills.

Timber cutting and forest regrowth, building and road construction, and other types of land-use modifications can influence the acidity of surface waters. Land use changes can increase or decrease the acidity of lakes by altering the chemistry (acid-base ratios) within the watershed.

Sources of Acidity

- Acid Rain and Snow
- Acid Mine Drainage
- Bog and Swamp Waters
- Natural Organic Acids
- Acid Soils and
- Geologic Strata

How Does Liming Improve Sport Fishing?

Soft water lakes and ponds seldom support abundant fish or plankton populations. Plankton, the basis of the food chain, often is limited in acidic waters with low alkalinities. Surface waters with low alkalinities typically are acidic and infertile; few dissolved nutrients are present and most nutrients are locked onto acidic bottom muds. Limestone neutralizes acidic bottom mud (i.e., increases soil pH) and promotes the release of phosphorus and other limiting nutrients needed for photosynthesis by green plants.

Liming surface waters neutralizes acidity and increases pH, alkalinity, and hardness to levels that encourage plankton and sport fish growth. Liming not only adds calcium, but releases absorbed elements (phosphorus and carbon) important to the growth and support of aquatic life.

Adding limestone and fertilizer are conventional fisheries management practices for enhancing sport fish production in ponds, even in those waters that are not impacted by acid. They should not be applied simultaneously because limestone may precipitate phosphorus and reduce its availability.

Protective or Mitigative Liming?

Protective (preventative) liming is, as the name implies, used to prevent a lake or pond from becoming acidic by fortifying the water's alkalinity (buffering capacity). Susceptible soft-water lakes and ponds that have little buffering capacity and are located in areas receiving strong acid deposition are good targets for protective liming. This type of liming may require only periodic additions of limestone to the surface waters or the surrounding watershed. It is generally more cost-effective to prevent a lake from becoming acidic than to restore an acidified one.

Acidified lakes and ponds can be restored by mitigative liming. The objective of mitigative liming is to restore and protect water quality and promote the recovery of aquatic life in acidified lakes and ponds. Applications of limestone on a sustained basis and the use of other fisheries management techniques, such as stocking, may be required to promote full recovery of lake resources.

What Type of Limestone Should Be Applied?

Finely ground (pulverized) agricultural limestone (calcite, calcium carbonate) is recommended for liming lakes and ponds. Agricultural limestone (aglime) is a relatively inexpensive, widely available, easy to handle, natural and nontoxic compound, that dissolves (although not readily) in water. Aglime can be purchased in many particle sizes ranging from fine dust to rock. Fine limestone particles (< 0.01 inches or 0.025 cm) will dissolve rapidly and are preferred over coarse materials.

Use high-quality, contaminant-free (< 5% of magnesium), and nutrient-free (low nitrates and phosphates) agricultural lime. Dolomitic limestone with high levels (> 5%) of magnesium carbonate ($MgCO_3$) may result in poor dissolution and neutralization. However, because dolomitic limestone may be the only neutralizing material readily available in your locality, it is an acceptable alternative to aglime.

The calcium content of the limestone relates directly to its capacity to neutralize acidity. Calcium content should be > 70% (preferably 90-100%) $CaCO_3$ by weight.

What Types of Limestone Should Not Be Applied?

Material	Comment
• Aglime ($CaCO_3$)	Recommended
• Dolomite lime ($MgCO_3$)	Impure
• Quicklime (CaO)	Caustic
• Hydrated lime ($CaOH_2$)	Caustic
• Soda ash (Na_2CO_3)	Expensive

Hydrated lime (calcium hydroxide, $Ca(OH)_2$) and quicklime (calcium oxide, $Ca(OH)_2$) generally are not recommended for treating surface waters because they are corrosive, difficult to control, and may not be legal to apply. Hydrated lime and quicklime have been used for acid neutralization because less is needed (they have higher neutralizing values than pure limestone), but both are caustic.

Hydrated lime applications can kill fish at rates in excess of 50 pounds per surface acre. In fact, hydrated lime and quicklime often are used to disinfect ponds from fish parasites and to sterilize ponds prior to stocking fish. Hydrated lime contains about 54% calcium whereas quicklime contains about 71% calcium. Agricultural gypsum (calcium sulfate, $CaSO_4*2H_20$) is not a liming material.

Soda ash or sodium carbonate (Na_2CO_3) has been used infrequently to neutralize acidified surface waters. Soda ash is three to five times more expensive than limestone and does not contribute beneficial calcium ions.

How Much Limestone Should Be Used?

The typical application rate for acidic waters is 1-2 tons of agricultural limestone ($CaCO_3$) per surface acre for the initial liming. If necessary, consultants can use computer models or small-scale laboratory tests to estimate limestone dosage rates for lake owners.

Relatively inexpensive chemical test kits are available to measure pH and alkalinity levels. In most states, the Cooperative Extension Service and the Natural Resources Conservation Service can provide information on soil acidity. Calculating exactly how much limestone to add to neutralize an acidic lake is complicated by many factors, including:

- existing pH, alkalinity, and hardness
- acidity and chemistry of lake bottom mud
- water quality and temperature
- desired pH and target water quality
- density and types of aquatic plants
- type, purity, and particle size of the limestone
- volume and flushing rate

Is Reliming Necessary?

One treatment may be sufficient if the lake is small, has a slow flushing rate, and is not very acidic. However, additional treatments may be needed for very acidic lakes or those with fast flushing times that may be reacidified quickly.

After liming, the pH and alkalinity of waters should be monitored, especially during the summer, by taking surface samples on a weekly basis. If pH and total alkalinity of the lake water are low a month after the initial liming, the treatment should be repeated.

The addition of 500-3,000 pounds of limestone per surface acre should be sufficient to neutralize most lakes, but those with very acidic soils, low alkalinities, high concentrations of organic matter, and quick flushing rates may require greater dosages and more frequent treatments.

Reliming should occur whenever pH values drop below 6.5, total alkalinities drop below 10 mg/L. Maintaining the pH near neutral (pH 7) and total alkalinities > 20 mg/L will minimize stress to fish and prevent the bioaccumulation of toxic metals, such as mercury, in fish tissue.

Bagged or Bulk Limestone?

Limestone can be purchased in bulk (truckloads) or in bags (50 pound bags) and can be applied as a dry powder or mixed with water as a wet slurry. A well-mixed slurry of lake water and fine-sized particles of limestone is more soluble than a dry powder.

Buy the smallest particle size of limestone available that is cost effective. The smaller the particle size, the better the rate of solution. Large limestone particles dissolve slowly. Finer limestone will cost more, but it generally is more cost-effective because greater amounts go into solution. Pulverized limestone particles that pass through a 200-mesh screen and are about 1 5-20 microns (0.00059-0.000079 inches) in size are ideal for liming lakes.

Generally, it is easier to handle, transport, and distribute bagged limestone. Volunteers can more easily lift and load bags of limestone from the shoreline staging area (boat dock) onto boats and barges for distribution. Stockpile limestone near the dock area to minimize handling time. Cover bagged limestone with plastic for rain protection if the application period is prolonged. Bulk limestone is much cheaper to buy, but requires special equipment to transport, unload, and distribute quickly and evenly.

Application Methods

- Boat or barge
- Surface ice (snowmobile)
- Shoreland (tractor)
- Feeder stream
- Air (helicopter, plane)

How Is the Limestone Applied?

Limestone can be applied to lakes and ponds using 4 methods: (1) broadcast by boat, (2) piled on winter ice, (3) spread by air, and (4) distributed upstream on the watershed or in tributary streams.

Application from a boat or barge is the most popular way to treat lakes and ponds. Shoveling limestone into the wake (prop wash) of a moving powerboat is a simple and cheap distribution method. Flushing limestone from a moving barge platform with a high pressure water hose is an alternative broadcast method that promotes dissolution of the limestone.

Using an on-board slurry box to mix the limestone and water solution before pumping the mixture into the lake helps ensure better solution and circulation. Applying limestone as a wet slurry increases its dissolution efficiency by 25% when compared to its application as a dry dust on the water or on surface ice in winter.

Spreading limestone by snowmobile, tractor/spreader, or truck directly on ice-covered lakes is a relatively easy and economical method to use in the northern U.S. where surface ice is prevalent in winter and thick enough to support heavy, loaded vehicles. At spring icemelt, the limestone dissolves with the surface ice and is distributed evenly into the lake.

Limestone applied by helicopter, truck, or hand within the lake watershed (lawns, fields, and forests) eventually will wash into the lake. Treatments can be applied to water pathways such as wetlands, headwater springs, tributaries, and other sources of water discharge.

Generally, watershed treatment is more expensive than direct lake application. The average cost of direct pond application is only about 20% of the cost of one average watershed treatment. However, watershed treatment may provide sustained neutralization. Watershed liming has been effective on small lakes with small tributaries. Reliable, easily implemented procedures for treating watersheds are not yet widely available in the U.S.

Limestone application by aircraft may be necessary on very large or remote lakes and ponds where road access and ground transportation are not available. This technique is expensive (often 4 times the cost of boat delivery methods).

Limestone should be spread over (blanketing) the entire lake surface. Areas of deep water have greater volumes and will require proportionally greater amounts of limestone. Consult a hydrographic (depth) map to determine dosage rates and limestone placement.

What Will It Cost?

Generally, liming is a relatively inexpensive restoration technique, and the material itself is the cheapest component. Agricultural limestone costs, for example, range from $10-50 per ton, depending on the quantity needed and the available supply. Bulk purchases are cheaper than bagged limestone, and finely ground limestone is more expensive than coarse limestone.

Much of the total cost of liming a lake or pond is attributed to transport, labor, and the application equipment. Of course, the more acidic the lake, the greater the amount of limestone required and the greater the cost of treatment. Moreover, complete restoration to the original pH and the maintenance of self-reproducing (rather than stocked) fish populations may require repeated treatments.

Annual treatments are more expensive than a single treatment, but the costs can be spread over many years. Annual treatments allow smaller dosages than the recommended rate of 1-2 tons/acre to be applied. For example, after the initial dose, smaller doses, usually 25% of the initial application rate, can be applied over 4 years.

When Should Lakes and Ponds Be Limed?

Lakes and ponds can be limed at any season of the year, but fall turnover (the time of complete water circulation, top to bottom) in October or November generally is recommended. If limestone is to be applied on surface ice, then January or February are optimal months. Fall and winter liming will buffer the lake from extreme acid inflows that frequently occur in March and April at ice melt and high spring rains.

Liming during the summer months may disrupt recreational activities and temporarily diminish water clarity, resulting in public inconvenience and displeasure. Additionally, the limestone may not be evenly mixed throughout the water column during the summer.

What Are the Effects of Liming?

Short-term effects of liming may include increased cloudiness or turbidity and reduced water clarity resulting from suspension of limestone particles in the water column, and a gradual increase in aquatic plant production as more phosphorous is released from the bottom muds. Lake and pond property owners and recreational users should be notified of the dates of liming treatments and informed of these short-term consequences through posters and newsletters.

The effects of liming on fish populations and aquatic life usually are slow and subtle. If an adequate number of adult spawning fish remain in an acidified lake, natural reproductive success may restore fish populations. Liming improves the survival of fish eggs and developing embryos, which are particularly sensitive to acidification. By stimulating the growth of plankton populations, liming provides prey items for young sport and forage fish.

Liming has been used for over a century to enable acidified and naturally acidic surface waters to support more productive fisheries. The objectives of protection and restoration of recreational fisheries can be achieved with a higher degree of certainty and rapidity by liming than by relying solely on emission controls limiting the release of sulfur dioxide (SO_2) and nitrogen oxides (NO_2). Even when emission controls are in place, liming achieves short-term fishery improvements until the controls are effective in reversing acidification processes in surface waters.

Restore Lake and Pond Values

- Water Supply
- Lakeshore Real Estate
- Swimming & Boating
- Fish & Wildlife Habitat
- Scenic Beauty
- Crop Irrigation
- Livestock Watering

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Reviewed by Michelle Davis, research associate, Fisheries and Wildlife