

Precipitation of lakes

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Method

Precipitation as a restoration method was developed in Sweden during the 1960's and 70's. It was then used incorrectly with low dosage or in lakes mainly dominated by external loads. Because of this the method wasn't successful.

In USA the method has been applied since the late 70's and has since then been used as a restoration method in several lakes with good results.

The American authority US EPA has in its manual about restoration of lakes judged the method as being cost effective with both long

and short-term positive effects at a low risk. This makes it the most effective restoration method for eutrophic lakes. The American method is rougher, because you apply the alum as sulphate from the surface, which affects the whole volume of water and the organisms within. The dosage is designed to lower the pH to 6-6,5.

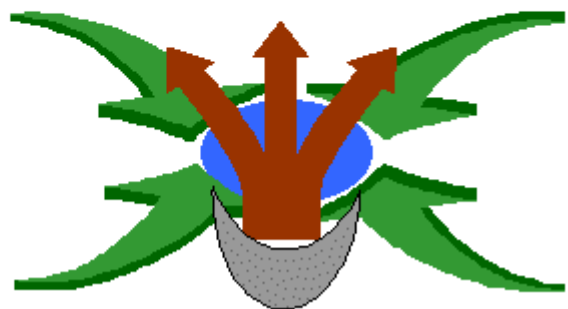
In Sweden precipitation has been used in *Lake Lejondal*. Here *Vattenresurs AB* developed a high precision technique where only the bottom water was treated resulting in just a slight pH decrease. It was important not to affect the shallow bottom areas and the surface water. This method has also been used in *Bagarsjön* in *Nacka*.

This method uses alum chloride intended for purification of drinking water. This only lowers the pH 0,3 units at the most. The only areas treated in *Lake Lejondal* were the bottom areas affected by oxygen depletion. In effect the parts deeper than 10 meters covering 1/3 of the total lake area was treated. *Lake Lejondal* is a secondary water supply with a great natural and recreational value. The lake is also rich in crayfish - *Astacus astacus*. (Crayfish is very important in Swedish gourmet culture and thus presents a high economic value. Crayfish is also sensitive for acidification).



What controls the Lake?

- External phosphorus load?
- Internal phosphorus load?



Nature's chemistry

The earth's crust contains a great deal of silicon and alum. Alum alone stands for 8%. Also iron and calcium are common minerals. That is why these earth metals are so abundant in soil, water and sediments. These are water-soluble and can therefore be transported from land with

surface water and ground water to watercourses and are finally deposited in sediments. Here they are important components and are also vital for the living organisms.

In all waters earth metals like iron, manganese, alum and calcium naturally precipitate phosphorus. The phosphorus binding to iron/manganese is broken when the oxygen level is low and henceforth the iron binds mostly to sulphide, which has a very low solubility. This leads to a lack of phosphorus binding metals and an increased level of phosphorus in the water. Calcium demands extremely high pH to be able to precipitate phosphorus effectively. Alum binds strongly to phosphorus and is not soluble when oxygen is scarce. This is why alum operates well for treating bottom waters where oxygen depletion occurs.

Chemistry of alum

In water alum occurs in many different forms. In an acid environment (pH <5,5) alum is soluble as Al³⁺-ions. At a higher pH (up to pH 9-10) alum is attached to different complexes with for instance phosphorus and hydroxides. At very high pH alum is soluble as ions. In acidified lakes alum is always soluble. Waters that is not acidified contains only small amounts of free alum because of the attachment to different complexes. The Al³⁺-ion is toxic in an acid environment. When the pH

is over 5,5 alum attach to and form complexes. This is a momentary reaction and that is how flock occurs when alum is added to water. These complexes are not toxic.

An example from daily life is when you are boiling food in a saucepan made of alum. If you cook something that is acid like jam, the saucepan becomes shining. This is because the oxide layer is dissolved.

Eutrophic lakes mostly have a pH and an alkalinity equivalent to that of Lake Lejondal. These types of lakes are well buffered and have a big tolerance towards pH-changes. The occurrence of alum is illustrated in figure 1.

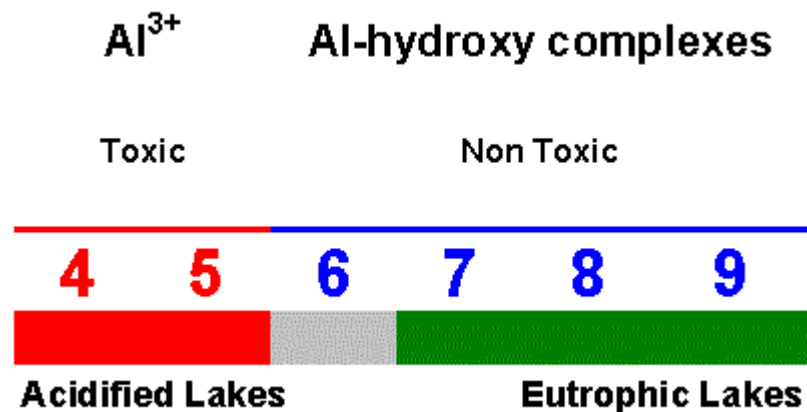


Figure 1. The occurrence of alum at different pH

Alum in sediments before and after treatment

Alum is as said earlier one of the most common metals in the earth's crust, in soils and in sediments. The sediment of eutrophic lakes in Sweden is known to have a rate of 2-4 % alum in the dry matter. This means that the surface layer of the sediment (0-10cm) hereby contains tons of alum or several hundred g Al/m². A treatment with 25-50g Al/m² gives an addition that is comparatively low.

Environmental impact

How come that a method that lowers the pH to 6-6,5 and precipitates the whole volume of water is considered as not likely to have negative consequences?

The immediate development of different alum complexes guarantees that the alum levels never increases enough to create disturbances. In USA scientists have studied consequences of alum treatment. They have studied plankton, bottom fauna and fish. You have a temporary influence on plankton that is caught in the flock when it settles. The bottom fauna copes with the new environment and larvae uses the flock to dig paths in. Effects on the fish fauna are not very well studied. The changes that are accounted for are generally the positive development of the lake ecosystem.

In Sweden there is experience on effects of alum on fish from acidified lakes. Swedish scientists have studied alum and fish in acidified lakes and found toxic effects however not at higher pH-values.

The collected experience from USA and Sweden shows that it is crucial that the pH value is between 6 and 9 otherwise you will have negative effect on the environment.

The risk of negative effects on crayfish and fishes are small because these animals don't normally inhabit those areas that are affected by the precipitation. The treatment makes the water clearer so that the vegetation can grow deeper down in the lake and this benefits crayfish and fishes. This is what happened in Lake Lejondal and Lake Flaten.

A common question is what will happen if the lake is acidified? The addition of alum from the surrounding areas will increase. Leaching from sediments will increase. The added amount of alum from the treatment is insignificant in this scenario.

Positive and negative effects are often compared in Sweden if an acidified lake should be treated with lime. This is because of the shock that the lake suffers when treated. When the lake after some time is in balance its conditions will be much improved.

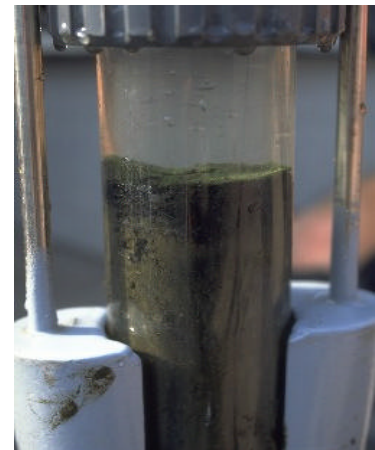
Other restoration methods as i.e. the removal of sediments involve a lot of influence on big volumes of water when transparency disappears.

It is necessary to compare the influence from the treatment with the negative effects of annual lack of oxygen during summer and winter in the lake. It is during these periods of oxygen depletion that toxic hydrogen sulphide is formed and kills organisms.

The conclusion is that the organisms, which survive the oxygen depletion in the deeper parts, may be disturbed in their habitat because of the treatment. These organisms will recolonise the bottom after the treatment. This is what happened in Lake Lejondal.

In the long run the added amount of alum will be just a marginal addition to the natural amount in the sediment.

It is always necessary to compare the positive and the negative effects when deciding how and if a lake should be treated



Sedimentcore

What will happen to a treated lake?

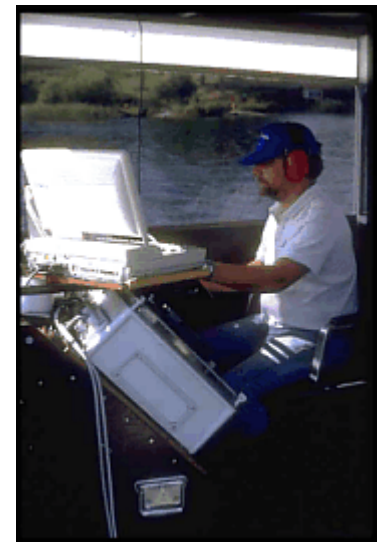
During the treatment plankton will suffer from the precipitation. Also the bottom fauna will be affected. Fishes and crayfishes will go unharmed. This is because the lake has a good pH value and alkalinity and therefore the effects are only mechanical.

After the treatment plankton has less nutrients to feed. This changes both the production and composition of species. This is one of the treatment goals.

The treatment also reduces the leaching of phosphorus from the sediment. This lowers the concentration in the whole water column. The addition of phosphorus from the surroundings will be crucial for how long the treatment will be effective. All external phosphorus sources must be taken care of in order to get a long-term benefit from the treatment.

As a result of reduced phosphorus content the production of phytoplankton will decrease and this increases the Secchidepth.

A decreased production leads to less sedimentation, which means that less amounts of organic material will be decomposed and less oxygen will be consumed during summer and winter. This gives the whole lake a better oxygen situation. It will take some years before the oxygen level in the bottom water is enough throughout the whole summer period but the anoxic period and areas will decrease considerable.



The pilot house on the precipitation vessel

Submerged vegetation will probably gain from the increased Secchidepth. This feeds the crayfish and along with the increased oxygen levels it provides much better living conditions. The ecological balance will thus improve.

The composition of fish species in a lake depends on its trophic level. Low Secchidepth usually favours carp fishes like roach and bream. More transparent water usually favours pike, perch and pikeperch. The treated lake's populations of pike and perch should consequently benefit from the improved water quality.

The recreation value during winter will not change. But during summer a better Secchidepth, bigger populations of crayfish, pike and perch will however considerably increase the recreation value for both swimmers and fishing. A lake in balance is also of great importance for the landscape.

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Beach at Lake Bagarsjön.
The treatment vessel in the background.