

EUTROPHICATION:
RESEARCH AND APPLICATION TO WATER SUPPLY

Edited by

DAVID W. SUTCLIFFE AND J. GWYNFRYN JONES

Published by the Freshwater Biological Association

Invited papers from a specialised conference held in London
on 10-11 December 1991 by the
Freshwater Biological Association,
The Ferry House, Far Sawrey, Ambleside, Cumbria LA22 0LP
and
International Water Supply Association,
1 Queen Anne's Gate, London SW1H 9BT

© Freshwater Biological Association 1992

ISBN 0-900386-52-5

Calcite covering of sediments as a possible way of curbing blue-green algae

HELMUT KLAPPER

GKSS Institute for Water Research Magdeburg, D-O-3010 Magdeburg,
Gouvernementsberg 1, Germany

Natural calcite precipitation in lakes is a well-known control mechanism of eutrophication. In hard-water lakes, calcite deposits on the flat bottoms of shallow lakes and near the shores of deeper lakes resulted from biogenic decalcification during the millenia after the last glacial period.

The objective of a new restoration technology is to intensify the natural process of precipitation by utilizing the different qualities of calcareous mud layers. In a pilot experiment in Lake Rudower See, East Germany, phosphorus-poor deeper layers of the sediments were flushed out and spread over the phosphorus-rich uppermost sediments, to promote the co-precipitation of calcite with phosphorus from the water-column.

Introduction: phosphorus elimination as a tool against blue-green algae

Several different methods have been used for curbing blooms of blue-green algae by drastically reducing the phosphorus concentration in the water column. From a series of field experiments on nutrient precipitation in lakes, using ferric or aluminium salts, the most promising so far is to seal the sediments with phosphorus-binding cations. To hinder the development of bloom-forming nitrogen-fixing species of Cyanophyceae, the ratio of N:P should be kept higher than 10 by low phosphorus concentrations. These conditions were achieved in a 100-ha lake near Magdeburg after application of 400 tonnes of aluminium sulphate in liquid form (5 grams Al^{3+} per m^3). Prior to the precipitation of phosphorus, *Aphanizomenon flos-aquae*, *A. gracile* and *Anabaena lemmermannii* formed water-blooms which polluted the bathing areas of the lake. Following the addition of aluminium sulphate, algal blooms have been absent for 5 years and only some colonies of *Microcystis* and *Limnothrix* in low concentrations were found at the end of the recreation seasons. Secchi-depth transparency of the water in summertime increased from year to year. Also, macrophytes were re-established in the lake and filter-feeding cladocerans are now able to eat and control the more digestible phytoplankton species. An overdose of aluminium (twice the amount needed to precipitate the phosphorus), formed a thin hydroxide layer on the sediment surface and prevented the re-solution of phosphorus into the overlying layer of water during anaerobic conditions (Roenicke 1991).

Calcite precipitation: a natural control mechanism

Despite its usefulness, from both ecological and economic standpoints the application of ferric or aluminium salts is a relatively difficult and expensive tool for improving water quality. Therefore we have tried to find a more natural, easier and cheaper technology for reducing the phosphorus concentrations in lake water. Hard-water lakes demonstrate such a natural process, in the form of calcite precipitation or biogenic decalcification. The main process of interest is a co-precipitation of phosphorus containing biological and colloidal matter.

Because of calcite precipitation in early spring, hard-water lakes may be more oligotrophic than soft waters containing similar concentrations of phosphorus. The aim of the new

restoration technology is to intensify this natural process by utilizing the different qualities of calcareous sediment layers to provide an artificially enhanced internal precipitation of phosphorus (Strong & Eadie 1978; Benndorf *et al.* 1983; Stabel 1986; Koschel 1989; Kleiner 1988, 1990)

Calcite flushing in a polymictic lake

Investigations were first made on Lake Rudower See in East Germany. This 170-ha shallow lake lies in a tectonic trench. The deeper parts of the lake basin have been filled up by lake lime, forming a flat surface at 5–6 m depth. Samples were taken at different points on the lake, both on the sediment surface, with an Ekman grab sampler, and in 2–3 metres of sediment with a chamber collector and a boring bar. Here the sediments have lower concentrations of phosphorus and organic matter but higher concentrations of cations with phosphorus-binding properties (see Fig. 1 and Table 1).

Table 1. Sediment quality (means of eight sampling stations, shown in Figure 1) in Lake Rudower See

Depth	PO ₄ ³⁻ (mg g dry wt ⁻¹)	Fe (mg g dry wt ⁻¹)	Ca ²⁺ (mg g dry wt ⁻¹)	Ignition loss (%)
Surface	4.2	7.28	175	28.6
2–3 metres	2.25	8.69	218	16.2
Difference (%)	-46.4	+19.4	+24.6	-43.4

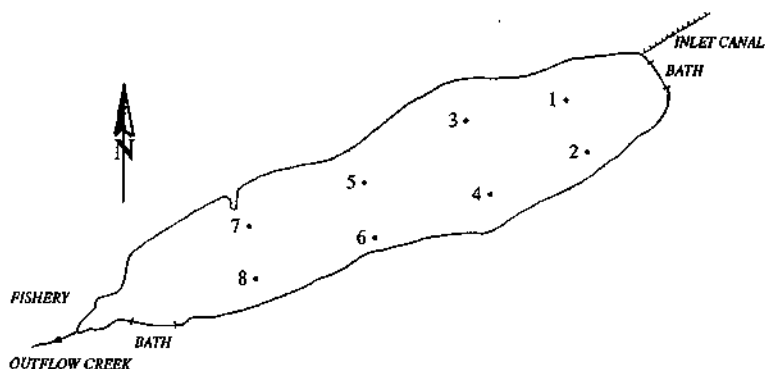


Figure 1. Eight sampling points for sediments in Lake Rudower See; BATH shows the bathing areas at each end of the lake.

The main constituent of all the samples is calcite (CaCO₃). The lake lime in deeper layers is very compact and cannot be pumped out directly. Therefore it was flushed out with the help of rinsing jet equipment and then the water–calcite suspension was pumped and spread over the phosphorus-rich youngest sediments (see Fig. 2).

The generation of some unevenness on the lake bottom, in the form of holes or trenches, is a wanted side-effect. These holes act as sediment traps, in which the newly-forming sludge from sedimented plankton collects and becomes locally concentrated, so adverse influences on water quality are localized and the re-solution of phosphorus is diminished (see Fig. 3).

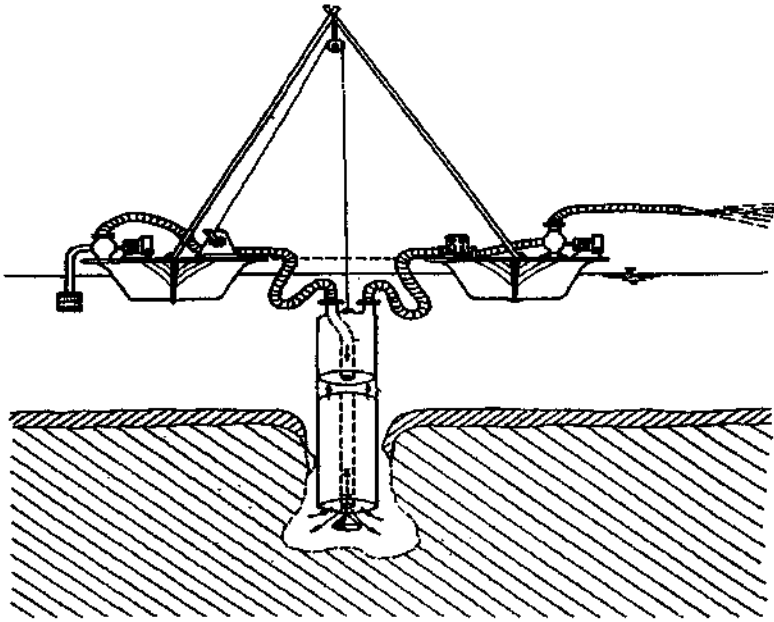


Figure 2. Drill-flushing method for covering phosphorus-rich recent sediments with a layer of calcite from deeper sediments.

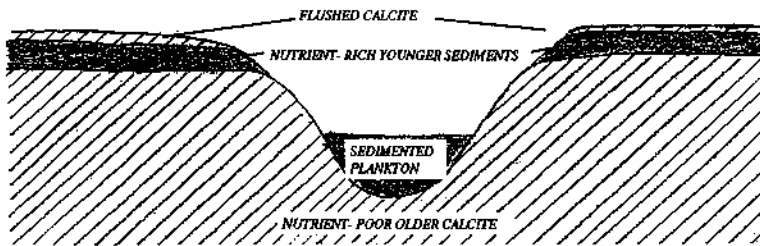


Figure 3. Diagram showing how plankton is trapped and concentrated in holes made in the sediments.

Results and further questions

In a pilot experiment started in 1989, during the initial flushing period there was an increase of orthophosphate in the free water above the sediment layer, because of nutrient release from interstitial solutions. In 1990 the phosphate dropped to about 50% of the values for 1988, the year prior to flushing with calcite, and in 1991 orthophosphate concentrations reached values near zero (Fig. 4).

So far the expected effects on blue-green algae have not materialized, although quantitative measurements of biomass in the lake are lacking for the period prior to flushing with calcite. *Microcystis* still forms water blooms, so the quality goal is not yet reached.

A series of theoretically possible mechanisms besides that of phosphorus limitation need to be investigated in the near future. (1), Is it possible to counteract a rise in pH caused by higher carbonate hardness and buffer capacity, and thus overcome the natural advantage of

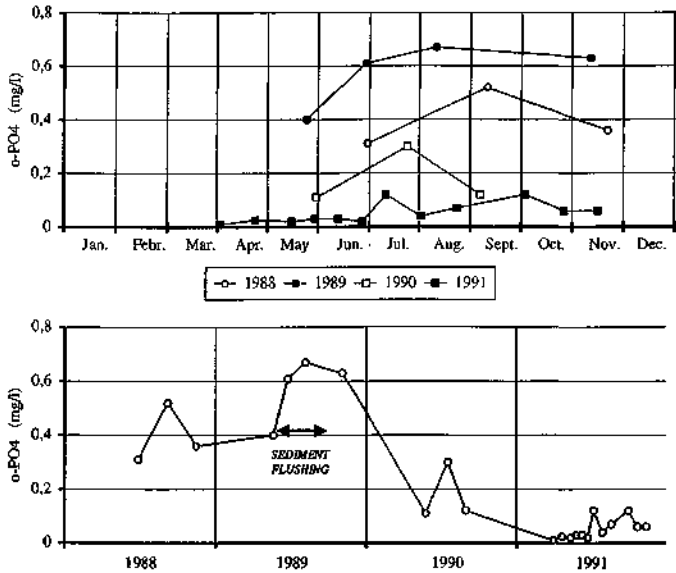


Figure 4. Orthophosphate concentrations (mg l^{-1}) in the free water of Lake Rudower See, shown chronologically (below) for 1988-1991, and compared between years (above) for \circ , 1988, \bullet , 1989, \square , 1990 and \blacksquare , 1991.

blue-green algae which can photosynthesise at high pH values? (2), Is there any evidence that carbon dioxide is increased by oxidation of methane when this is rinsed into the free water when flushing the calcite? (3), Can blue-green algae be curbed by covering or burying their bottom-resting cells with lime? (4), After calcite flushing, will the desired silicious algae compete more successfully with blue-green algae because of higher concentrations of liberated silicon? (5), Can other stabilization mechanisms be used for combatting blue-green algae, e.g. higher stocks of suitable herbivorous fishes and/or increased growth of macrophytes? (6), What can be done to prevent the dramatic retrogression of reed beds? (7), Is it in fact possible to curb blue-green algae in a polymictic lake that is no more than 6 metres deep and therefore has a high availability of phosphorus from the lake bottom?

Of course, observations on the effects of this first experiment will be continued. From other restoration experiments it is known that major responses occur mostly after a time lag of several years, when a new balance level is rather quickly achieved.

Preparation for the next application on a deep dimictic lake

In the meantime a second experiment is being prepared for the 50-m deep dimictic Lake Arendsee, for which good limnological data are available. Calcite deposition has been found in the littoral region of this lake. The aim is to flush this calcite from the littoral and spread it over the deepest parts of the lake, where there are soft, phosphorus-rich sediments.

The biological goal is to combat the frequent occurrence of *Oscillatoria rubescens*. A technical problem is how to transport the flushed calcite over distances of more than 1 kilometre to the required places. A large floating plastic tube, towed by boat, should be suitable for this purpose.

This report is the first on a new approach to restore hard-water lakes. If it is successful, some 100 similar lakes (in Germany) may be restored by this technology.

References

- Benndorf, J., Proft, G. & Recknagel, F. (1983). Calcite precipitation as a natural control mechanism of eutrophication. *Archiv für Hydrobiologie*, **98**, 380-408.
- Kleiner, J. (1988). Coprecipitation of phosphate with calcite in lake water: A laboratory experiment modelling phosphorus removal with calcite in Lake Constance. *Water Research*, **22**, 1259-1265.
- Kleiner, J. (1990). Calcite precipitation-regulating mechanism in hardwater lakes. *Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie*, **22**, 638-643.
- Koschel, R. (1989). Pelagic calcite precipitation and trophic state of hardwater lakes. *Archiv für Hydrobiologie, Beiheft Ergebnisse der Limnologie*, **33**, 713-722.
- Roenicke, H. (1991). Langzeiteinfluss einer Fällmittelapplikation auf die Nährstoffdynamik und Phytoplanktonsuccession in einem Magdeburger Baggersee. *Limnologentagung der SIL und DGL, Mondsee/Österreich, Tagungsband*, 205-209.
- Stabel, H.-H. (1986). Calcite precipitation in Lake Constance. *Limnology and Oceanography*, **31**, 1081-1093.
- Strong, A. E. & Eadie, B. J. (1978). Satellite observation of calcium carbonate precipitation in the Great lakes. *Limnology and Oceanography*, **23**, 877-887.