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VI. Applied Limnology

Hypolimnetic aeration as a means of controlling redox processes on the bottom of a eutrophic reservoir

Abstract

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With 1 figure in the text

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For the past 10 years we have aerated the Wahnbach Reservoir, which provides drinking water for the Bonn—Siegburg area in the German Federal Republic, because every year constant overloading with phosphate and nitrogen compounds causes a higher production of biomass than the reservoir can mineralize under aerobic conditions in the tropholytic zone. This has led to progressive eutrophication over the 20 years of the reservoir's existence. The development of anaerobic conditions on the reservoir bottom during summer stagnation and autumnal partial circulation can be successfully countered by pumping in air. For this purpose the Wahnbach Association developed the system of hypolimnetic aeration which provides oxygen enrichment of only the hypolimnetic waterbody and the sediment-water interface. Using the apparatus illustrated in Fig. 1, air blown in at the lower end of a vertical pipe constantly sucks in reservoir bottom water which is then enriched with oxygen from the air to circa 10 mg/l O_2 as it rises over a distance of 30—40 m. It then enters a chamber, the air escapes and the water

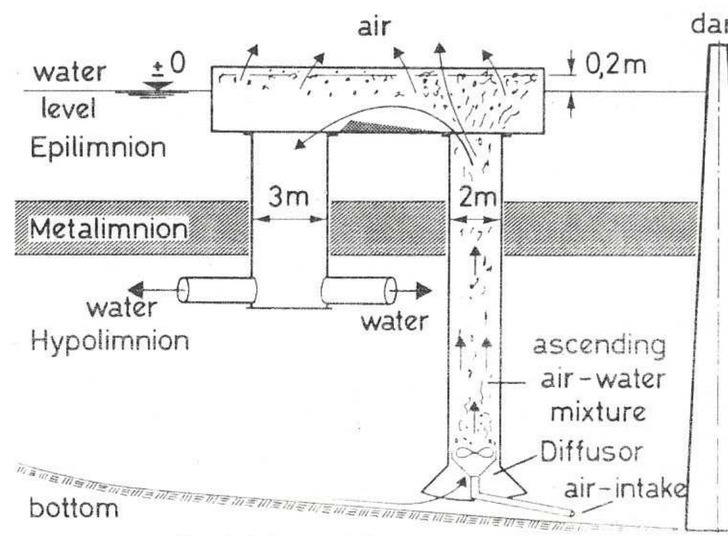

Fig. 1. Scheme of the hypolimnetic aeration

returned to the hypolimnion at a depth of 15 m, via the second vertical pipe. A detailed description of this process is given elsewhere (BERNHARDT 1967).

This aeration process is monitored every 1—3 days by taking samples from the microlayer (the layer of water 0—5 cm above the sediment) using a specially constructed sampler; these samples are then chemically tested. This paper discusses the result of 7 years of testing the water in the microlayer with special regard to the chemical reactions taking place in the sediment-water interface (BERNHARDT 1974).

The reservoir sediment is poor in calcium (0.2—2.2 % CaO; 0.2—1.3 % MgO) and consists chiefly of SiO_2 (47—87 %). The percentage of Fe_2O_3 is between 2.8 and 6.1 %, the fraction of MnO_2 is low at 0.2 %.

It has been observed that a rapid increase in the concentration of organismic and organic substance in the lake bottom, due to extensive planktonic production in the lake, leads to considerable benthic oxygen consumption. There is insufficient oxygen present in the water to fully oxidize the autochthonously produced biomass. There ensues a reduction of the manganese-IV-oxide-hydrate, the nitrate ions and the iron-III-compounds. Reduction of the manganese-IV-oxide-hydrate, as a result of the given relationships of redox- and pH-values, is very much more rapid than that the Fe^{3+}-compounds. Thus, in the presence of large amounts of dead biomass reaching the lake bottom through sedimentation, increased concentrations of Mn^{++} ions occur. After a period of about 8 days there is then an increase in concentration of ortho-PO_4^{3-} ions in the microlayer.

The release of ortho-phosphate ions from the reservoir sediment is 0.03 mg P/m²/day as long as less than 4 mg/l O_2 is present in the microlayer, and is thus lower by about one factor of ten than the release rate (0.3—0.5 mg P/m²/day) which we obtained in modelling experiments on reservoir sediment under anaerobic conditions. Nevertheless, this release is not zero when oxygen content in the water of the microlayer is less or about 4 mg/l. The findings of our modelling tests were borne out, in that the release of ortho-phosphate ions begins only after a certain period of adaptation to the anaerobic conditions.

We cannot confirm references in the literature which state that, under aerobic conditions in the sediment-water interface, depending on the difference in PO_4^{3-} concentration, phosphate ions become fixed in the sediment. On the contrary, long years of observing the conditions in the microlayer of the Wahnbach Reservoir have shown that release of Mn^{++} takes place as soon as the oxygen content in the microlayer drops below 4 mg/l, and that somewhat later ortho-phosphate ions are also released. This indicates the importance of supplying the microlayer with as much oxygen as possible all year round, by using suitable methods.

The increase in PO_4 ions results not only from the onset of the release of ortho-PO_4^{3-} ions from the sediment, due to reduction of the Fe-III compounds, but also from the release of the ortho-PO_4^{3-} ions from the cell substances.

An increase in the concentration of Fe^{++} ions, on the other hand, is not yet to be found in this initial stage of anaerobic conditions in the microlayer.

Thus the behaviour of the concentration of Mn^{++} zones can be used as an indicator for the start of increasing intensity of the reduction processes taking place in the sediment-water boundary layer. This is much easier to do and can be established more accurately than by measurements of the redox potential which would lead to the same results.

If apparatus is installed on a sufficiently large scale, hypolimnetic aeration can restore the balance between production and respiration capacity, a balance which has been upset by overloading of the reservoir. In this way, the reservoir contains a sediment in which, despite considerable productivity, enrichment of the organic matter does not occur.

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Discussion

BENGTSSON: Did you measure if there was any increase of Mn, P total amount within the hypolimnion during the hypolimnion aeration?

BERNHARDT: We do weekly tests on our reservoir from the surface to the bottom. We have not found any change in concentration of Mn^{2+} or ortho-PO_4^{3-}.

HORNE: FAST has shown decreases in epilimnial primary production after adding oxygen to the hypolimnion. Did you show a similar decrease over the 10 years at your hypolimnetic experiments?

BERNHARDT: We also observe a decrease but this is probably due to the general reduction in phosphate release over the year.