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Case studies of lake restoration in NE Germany

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In past and recent years quite different attempts were made to restore various highly eutrophied lakes in NE Germany. Preferentially, in-lake measures were conducted aiming at the lowering of the concentration of phosphorus (P) in the lakes.
In **Lake Jabel** ($V = 12.9 \times 10^6$ m^3, $A = 2.44$ km^2, z_{max} 23 m, $z_{mean} = 5.3$ m) the Al application in 1975 and the hypolimnetic withdrawal in 1989 failed. The diversion of the major tributary, delivering 80% of the external P and 94% of nitrate loading, as intended in 1996, was given up because of far-reaching ecological consequences. The second Al application in 2005 could lower the P concentration, however, because of a still high external P loading only short-term improvements are to presume.
In **Lake Arendsee** ($V = 147 \times 10^6$ m^3, $A = 5.13$ km^2, z_{max} 49 m, $z_{mean} = 29$ m) the hypolimnetic withdrawl in 1978 was inefficient since not enough P could be eliminated. Also the mechanical resuspension of autochthonous calcite for sediment capping in 1995 failed to control internal P loading. More effective and more costly restoration measures such as an Al application are currently considered. However, because of open issues pertaining sources and dues of external P loading and the huge water volume to treat by Al application, this measure is still under examination.
The basic principle of the respective restoration technique and the reasons for their failure were presented and discussed. For more details, please see the following literature sources.

References

Lake Jabel

Kleeberg, A., R. Hämmerling & B. Nixdorf (2001): The effect of hypolimnetic discharge on the faster deprivation of phosphorus from lake sediment using Lake Jabel (NE Germany) as an example. Lakes & Reservoirs: Research and Management 6: 289-295.

Abstract

After the reduction in external phosphorus-load (P-load), in-lake measures became practicable for eutrophic Lake Jabel. The benthic release of phosphorus (P) is efficiently suppressed by a significant nitrate supply via its main tributary. The *in-situ* stimulation of P-release as a result of the temporary decrease in this nitrate load, and the simultaneous P-removal by deep-water siphoning and external P-elimination was primarily designed for the faster deprivation of P from lake sediment. This new strategy was aimed at exhausting the 'P-surplus', that is, the mobile redox-sensitive iron-bound P-portions of the uppermost sediment layers, where a re-supply from deeper layers is needed within the stratification period of 2 consecutive years of operation of the P-elemination system. By studying early benthic P-diagenesis it remains to be demonstrated whether this procedure can contribute to a re-availability of P-binding sites to guarantee the long-term effect of the measure.

Kleeberg, A., B. Nixdorf & J. Mathes (2000): Lake Jabel restoration project: phosphorus status and possibilities and limitations of diversion of its nutrient-rich main inflow. Lakes & Reservoirs: Research and Management 5(1): 23-33.

Abstract

External and internal P-loading was studied in 1996 in the anthropogenically eutrophicated Lake Jabeler See located in Mecklenburg (northern Germany). It has a dimictic 23 m deep northern basin (JABN), a 19 m deep middle basin (JABM) and a 3.5 m deep polymictic southern basin (JABS). As the major nutrient discharge (80 % total P-loading) into JABN the main tributary Grabowhöfer Grenzgraben (GHGG) coming via a leaching field from a wastewater treatment plant has been identified. The sediments are the second largest source of P for Lake Jabeler See, contributing 25.7 % (JABN), 27.4 % (JABM) and 2.4 % (JABS) of the overall P-load to the respective basin. Although the favoured diversion of the GHGG would contribute to an exonoration of 1.22 t P and 20.94 t NO_3^--N per year, it is to reject mainly for following reasons. If the extreme monthly NO_3^- supply between 4.84 - 189.6 mg N m^{-2} d^{-1} would cease, the release of redox-sensitive P in JABN would enhance by a factor of 0.54, which is with 41.1% TP two times higher as in JABM. In addition, the NO_3^--supply can substantially lower the seasonal precipitation of stable iron sulfides, which otherwise would lower the portion of redox-sensitive P, however, can not change the P-retention in long-term. Due to internal P-sources the diversion of GHGG would result in no substantial changes in level of trophy.

Lake Arendsee

Hupfer, M., R. Pöthig, R. Brüggemann & W. Geller (2000): Mechanical resuspension of autochthonous calcite (Seekreide) failed to control internal phosphorus cycle in a eutrophic lake. Water Research 34: 859-867.

Abstract

The attempt to restore the highly eutrophic Lake Arendsee (Germany) by means of artificial resuspension of calcareous mud (Seekreide) and capping of the natural bottom sediments in 1995 did not show the expected effects of decreasing the phosphorus (P) content in the water body. To understand this, the sorption characteristics and the mechanisms of P uptake of Seekreide were studied with laboratory experiments. These experimental results were combined with model simulations at field conditions to evaluate the efficiency of Seekreide for controlling the P cycle in the lake. The littoral deposits of Seekreide in Lake Arendsee mainly consist of calcite (70-87% dw) and are characterised by low contents of organic matter (5-8% dw), total P (0.13-0.47 mg g^{-1} dw) and iron (3.2-3.8 mg g^{-1} dw). Phosphorus uptake under laboratory conditions could be described with Langmuir sorption isotherms. A substantial portion of this uptake was not due to sorption to the $CaCO_3$ surfaces but to iron oxihydroxides, since most P was found in the reductant-soluble fraction (BD-P). Although the theoretical maximum of sorbed P ranged between 0.19 and 0.22 mg g^{-1} dw, no substantial P uptake occurred under held conditions. The model predicted that resuspension of about 25,000 tons of littoral sediment would transiently remove not more than 0.3 tons of P from the water column (1.3% of TP_{lake}) during sedimentation. After deposition of resuspended Seekreide, anaerobic conditions prevented any additional P retention. The close agreement of laboratory based simulations with field observations indicates: (1) capping of the lake sediments did not significantly prevent P-release, and, therefore (2) the -negligible- total effect of the large scale treatment and the failure to decrease P concentration in Lake Arendsee may be explained by and predictable from P uptake experiments only.

Hupfer, J. & J. Lewandowski (2005): Retention and early diagenetic transformation of phosphorus in Lake Arendsee (Germany) - consequences for management strategies. Archive für Hydrobiologie 164: 143-167.

Abstract

Repeated sediment core investigations over one decade, mass balance calculations, and vertical flux measurements by traps and dialysis samplers, were used to determine P retention rates, release potential, and early diagenetic transformation processes in the sediment of Lake Arendsee (Germany). Sediment cores were dated by varve Counting, by 137 ceasium, and by a distinct layer originating from a restoration attempt in 1995, which involved the capping of the sediment with calcium rich material from the lake shore. P retention rates and the internal P cycle have not been altered by the sediment capping. The sharp decline of total P content within the first two centimeters of the sediment shows that diagenetic P mobilization is a rapid process. The temporary P pool in the sediment, calculated from core analysis (mean SE: 709 82 mg m^{-2}, n = 7), was small compared to the rates of hypolininetic SRP increase (10.7 +/- 0.45 mg m^{-2} d^{-1}, 1992-1997) and total P losses in the epilimnion caused by sedimentation (11.7 +/- 0.53 mg m^{-2} d^{-1}, 1992-1997), both of the latter calculated by mass balances during summer stratification. Without additional supply of freshly settled material, the temporary P pool in the sediment would be exhausted in less than three months. The fast P release of freshly settled material was also demonstrated during summer by the three times higher vertical P sedimentation rates calculated on the basis of mass balance data, compared to rates determined on the basis of cylindrical traps, in which some P was released during four weeks exposure time. The driving process for the rapid P release in Lake Arendsee is the remineralisation of organic P. This study demonstrates that high hypolimnetic P accumulation rates are not always correlated with a large total or potentially mobile P pool in the sediment. In lakes with small temporary P pools in the sediment, a decrease of P in the water body would immediately decrease the hypolimnetic P accumulation in summer; capping or dredging as in-lake measures are ineffective in such lakes.