

## Distribution of sediment phosphorus fractions in hypertrophic strongly stratified Lake Verevi

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### Abstract

Lake Verevi is a hypertrophic and strongly stratified (partly meromictic) small temperate lake. Vertical distribution of sediment phosphorus fractions as well as iron, manganese, organic matter and calcium carbonate of the deep bottom sediment was determined. The study focused on the ecologically important layer of the sediment [ $<20(45)$  cm]. In the uppermost layers of the sediment, NaOH-NRP (organic P) dominated while HCl-RP (apatite-P) became dominant in some deeper layers below 7 cm. Extremely high concentrations of labile phosphorus fraction ( $\text{NH}_4\text{Cl-RP}$ ) indicated the low binding capacity of phosphorus by lake sediment. Due to sediment and hypolimnion anoxia, the internal load of phosphorus in this lake is most likely. Potentially mobile phosphorus fractions ( $\text{NH}_4\text{Cl-RP}$ , BD-RP, NaOH-NRP) formed 301 kg in upper 10 cm thick sediment layer of hypolimnetic bottom sediment (40% of lake bottom area).

### Introduction

Phosphorus is the key element of eutrophication processes in many lakes. Phosphorus supply to the euphotic zone depends on the external load and also on the tendency of sediments to retain or release phosphorus. The intensity of water mixing and stratification play an important role in this process. Stratification may lead to anoxic conditions, lowered pH and accumulation of nutrients in both hypolimnion and surface sediments of eutrophic lakes.

Total phosphorus concentration is a poor measure of the potential phosphorus release from sediments. Chemical fractionation of sedimentary phosphorus has served as a tool to predict the phosphorus binding capacity of sediments under different environmental conditions. In most cases, the potential internal load is the matter of interest.

The aim of present study was to determine the distribution of phosphorus fractions and other

chemical properties of surface sediments in hypertrophic strongly stratified and partly meromictic Lake Verevi. The special emphasis of the study was focused on the upper 20 cm of sediment, which could take part in nutrient exchange between the water column and bottom.

### Study site

Hypertrophic hard-water Lake Verevi is situated in South Estonia, within the borders of town Elva. General description of the ecosystem as well as detailed information on the location and bathymetry of the lake is presented by Ott et al., (2005a, 2005b). The lake has a surface area of 12.6 ha, maximum depth of 11 m, mean depth of 3.6 m and theoretical water residence time on an average 0.5 times per year. The deepest part of the lake is situated in the middle of the southern part of the lake while the narrow northern part

is shallow and largely covered by macrophytes. The lake is strongly stratified and during winter covered by ice. In early warm springs, the stratification may be formed so rapidly that the spring turnover is absent. The lake is sheltered from winds and no marked water mixing due to wave action occurs.

The lake, especially its shallow northern part is rich in springs. The upper layer of sediment in the northern part is soft greyish-green calcareous mud. In the southern part, the upper 30–50 cm thick sediment layer consists of  $\text{H}_2\text{S}$ -rich greenish-black mud, apparently being formed in anoxic conditions. In 1989, the phosphorus content of the surface sediment of Lake Verevi was determined with the depth resolution of 20 cm (Rummi et al., 1991). The lowest phosphorus value of  $0.4 \text{ mg g}^{-1}$  of dry sediment (DW) has been reported from the northern part of the lake, the highest concentration from the middle area of the southern part was  $1.4 \text{ mg g}^{-1}$  DW.

## Materials and methods

### *Field work*

Sediment samples were collected using Willner core sampler in four occasions: August 1994 (one core, length 45 cm), March 2001 (two cores, 15 and 25 cm long), June 2001 (two cores, both 4 cm long) and August 2001 (both cores 15 cm long). In March and June 2001, samples were collected from the eastern part of the lake's deepest bottom area at a depth of 6–8 m. In 1994 and August 2001, samples were collected close to the deepest point of the lake at the water depth of 9 m. Parallel cores were collected within the distance of 20 m.

The cores were sliced immediately after sampling. The slicing intervals were following: 0–2 cm, 2–5 cm, 5–10 cm in 1994, 0–2 cm, 2–5 cm, 5–7 cm, 7–10 cm in March 2001 and 0–1 cm, 1–2 cm, 2–3 cm, 3–4 cm, 4–5 cm, 5–7 cm, 7–10 cm in June and August 2001; deeper than 10 cm, all cores were sliced with 5 cm intervals. The samples were kept in closed plastic bags in an icebox until they could be stored at  $4^\circ\text{C}$  (normally within 1 h after sampling). The laboratory analyses began 1 week after sampling in 1994 and on the following day in 2001.

### *Laboratory analyses*

The concentrations of dry matter and phosphorus fractions in the sediment were analysed. Additionally, in 1994, the concentrations of organic matter, carbonates, iron, manganese and total phosphorus were measured.

The concentration of dry matter of the sediment was calculated from weight difference before and after drying of triplicate samples at  $105^\circ\text{C}$  for 24 h. The bulk density of the sediment was calculated according to Håkanson & Jansson (1983), enabling to determine the phosphorus amount in certain sediment volume.

The concentration of organic matter of the sediment was determined by the loss of weight during ignition at  $550^\circ\text{C}$  for 2 h. Ignition residue was further ignited at  $825^\circ\text{C}$  for 4 h. The loss of weight was ascribed to the emission of carbon dioxide serving as a basis for calculation of the carbonate concentration.

Manganese and iron concentrations were measured using Atomic Adsorption/ Flame Emission Spectroscopy (AA/FES, Shimadzu AA-670) after digestion of dry sediment in 7 M  $\text{HNO}_3$ . The content of total phosphorus was determined spectrophotometrically according to Murphy & Riley (1962) after boiling of dry sediment in mixed acids (conc.  $\text{H}_2\text{SO}_4$ ,  $\text{HNO}_3$ ,  $\text{HClO}_4$ ).

Sediment phosphorus fractionation was performed in triplicates according to Hieltjes & Lijklema (1980) at the first three sampling cases. Sediment was extracted in four following steps with three solutions:  $\text{NH}_4\text{Cl}$ ,  $\text{NaOH}$  and  $\text{HCl}$ . From these solutions, the concentration of soluble reactive phosphorus was measured according to Murphy & Riley (1962). The following fractions were gained:

1.  $\text{NH}_4\text{Cl}$ -RP (RP = reactive phosphate) – labile, loosely bound or adsorbed P.
2.  $\text{NaOH}$ -RP represents the phosphates adsorbed to metal (Fe, Al) oxides and other surfaces, exchangeable against  $\text{OH}^-$ , and phosphorus compounds soluble in bases.
3.  $\text{NaOH}$ -NRP (NRP = non-reactive phosphate) is calculated as the differences between total P in the  $\text{NaOH}$  extract, measured by peroxosulphate digestion, and  $\text{NaOH}$ -RP. It is assumed to represent the major part of organic and humic P.