Heavy metals and rare earths in lake sediments

Tracing the Trace Elements

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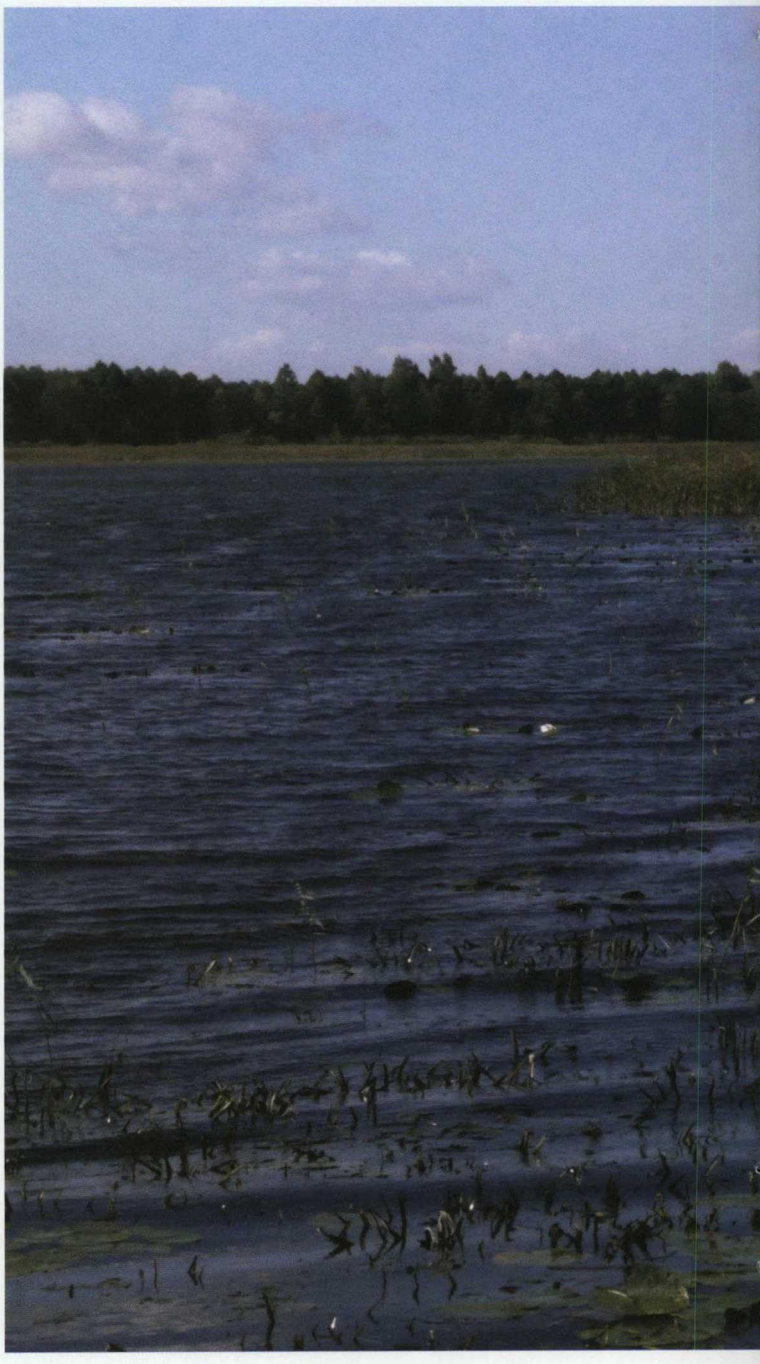
For decades, geochemical studies of lake and river sediments have been widely used in prospecting for mineral deposits. Nowadays they are also commonly used to assess the degree to which surface waters are polluted with heavy metals and harmful organic substances

The sediments currently being formed in Polish lakes are largely a result of allochthonous sedimentation, that is, deposits brought in from outside the reservoir. Sediments are formed as a result of catchment runoff and erosion of lake shores. Other, autochthonous materials (formed within the lake itself) also contribute to sedimentation in the form of biogenic deposits, mainly mollusk shells, diatoms, ostracods, and amorphous organic matter. Lakes are also the site of crystallization of minerals such as calcite, vivianite, pyrite, and iron and aluminum hydroxides. The presence of such organic matter, silt minerals, and ostracod shells can affect the retention of trace elements in sediment. Anthropogenic factors also play a big role, in particular, the discharge of municipal and industrial wastewater into lakes and rivers located within the catchment area of the lake. The use of organic and chemical fertilizers in cultivated areas surrounding the lake also has an impact.



Overgrown Łukie Lake in the Poleski National Park

Complex factors

In fact, the composition of lake sediments is influenced by a complex array of factors, all of which should be taken into account when assessing the degree of contamination with heavy metals and other harmful substances. The distribution of trace elements in lake sediments is strongly dependent on the type of geological formations on which the lake developed. The elements present in the ground as well as areas around the lake are often activated by rains and by migrating along the surface runoff, they become deposited in the lake. The formation of the bottom of the lake is also significant: the more complex its shape, the easier elements are retained in the sediment. Other important factors are the physicochemical environment and the utilization of land adjacent to the reservoir.

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Moreover, we have found that concentrations of elements present in deposits may also depend on which sedimentation zone is looked at. Our research at lakes in northeastern Poland has measured the content of heavy metals and rare earth elements (REEs) in coastal (littoral) zones and the deepest (profundal) zones. The lake basins studied were situated on substrata of uniform geological structure, half of them on highly permeable soils such as sand and gravel, and the other half on poorly permeable soils such as clay and silt.

Geochemical variation

This study found that the concentrations of individual elements, including arsenic, cadmium, mercury, lead, and REEs, were close to the values of the geochemical background, that is, their natural content in northern Poland. It also showed that lake sediments collected from the profundal zone contained higher quantities of heavy metals than littoral zone samples. Moreover, sediments in lakes situated on sandy strata were found to be characterized by lower content of trace minerals than for in lakes whose drainage basin is formed on poorly permeable soils rich in silt minerals (glacial till, varved clay). For example, concentrations of cobalt, nickel, and vanadium in lake sediments were found to depend in this way on the geological structure of the land where the lake is situated, indicating that the erosion of post-glacial material here results in the runoff of the compounds so released into lakes together with surface water. The presence of these elements is moreover correlated with the occurrence of iron. In littoral zones they mainly bind to iron hydroxides, while in profundal zones their occurrence is more likely to be linked with iron sulfides. Analysis of the content of heavy metals and elements forming phases that participate in the reten-

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Księże Lake in the Tuchola Forest

tion of metals in sediments (incl. aluminum, iron, manganese, calcium, magnesium, sodium, potassium) illucidates the existing relationships between those elements and the rare earths. Lake sediments in Poland had not yet been studied in terms of their REE content, meaning that there is no data available on natural REE levels in Poland. Lakes with a higher content of heavy metals were generally found to also contain higher REE concentrations. However, there are certain instances where low content of heavy metals collected from the profundal zone of a lake does not correlate with minimal REE content in the same sediment. Such cases are usually associated with the presence of zirconium (Zr), ubiquitous in sediments - it shows a close affinity with the rare earths, frequently forming minerals such as zircon (zirconium silicate) usually containing admixtures of these elements.

Natural relationships

Overall, we found that sediments from profundal zones are characterized by higher content of heavy metals in comparison to those found in littoral zones. In turn, rare earths occur in higher concentrations in littoral zone sediments than in profundal zones. This distribution of heavy metals and REEs between different sediments results from their differing affinities to mineral phases. For trace elements, an important role is played by the amount of organic matter and silt elements occurring in the profundal zone, while REEs are as-

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Wspólne Lake

sociated with clastic materials present in the littoral zone.

Another general finding is that concentrations of trace elements in lake sediments largely depend on the type of geological formations where the lake is situated, and on the lake's sedimentation zone that is being tested. Heavy metals reach higher concentrations in the profundal zone, where their accumulation is due to not only the reducing environment, but also the high content of organic matter and the presence of silt minerals. Occasionally human activity plays the most important role in determining their concentrations in sediment. Rare earths, in turn, are present in larger amounts in littoral zone sediments and are mostly associated with the presence of clastic material (primary minerals, most likely monazites) where anthropopressure (human impact) plays a less significant role. As such rare earths can be useful in defining the natural concentrations of elements in sediments, although it must be remembered that lake sedimentation is a complex process affected by various natural factors. ■

Further reading:

Bojakowska I., Gliwicz T. (2003). Wyniki geochemicznych badań osadów wodnych Polski w latach 2000-2002. [Results of Geochemical Studies of Polish Water Deposits in 2000-2002]

Bojakowska I., Sokołowska G. (1997). Akumulacja pierwiastków śladowych w osadach jeziornych w zależności od strefy ich sedymentacji [Accumulation of Trace Elements in Lake Deposits Depending on Sedimentation Zone] *Przegląd Geologiczny, 45 (5): 50 - 08.*