Global analysis finds too much phosphorus in lakes, too little in the soil

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Over-fertilized waterways, impoverished soils: the use of phosphorous in

agriculture is creating a dilemma, and it all began thousands of years ago. This has been verified by an analysis published in *Global and Planetary Change*.

It is well known that phosphorous from agricultural fertilization and wastewater is harmful to lakes. But the entry of phosphorous into water is also contributing to the scarcity of this substance, which is essential for agriculture.

An international team including the University of Bern has now made a reconstruction of how much phosphorous around the world has been washed from soils into lakes and stored there over the last few thousand years. The researchers found a significant increase in phosphorous entry, which provides evidence of very early human intervention in the global phosphorous cycle. To this end, they used the sediments that build up on the bottom of lakes. The composition of the layers allowed them to read what had happened in the past, much like an archive.

Thousands of years of human influence

For their study, the researchers consolidated sediment analyzes from 108 lakes around the world, together with a team from the UK and China. The layers of the core samples they investigated were up to 12,000 years old. "These data enabled us to make a global projection of phosphorous entry into lakes for the first time," says senior author Martin Grosjean, Director of the Oeschger Centre for Climate Change Research at the University of Bern.

The analysis revealed that phosphorous entry into lakes in Central Europe increased considerably even at the beginning of the Bronze Age, around 4,000 years ago. Severe deforestation and intensification of land use took place in this region—including Switzerland—at this time. This led to increased soil erosion and phosphorous runoff into lakes.

"Discernible human intervention in large- scale biogeochemical cycles thus dates back to the Bronze Age and did not just begin with industrialization," says Grosjean. The researchers found a similar increase in other regions in the northern hemisphere, albeit later on—around 2,000 years ago in China, and around 400 years ago in North America. This correlates with the later onset of population growth and the intensification of land use in these regions.

However, these earlier changes were nothing compared to what came later: from the 19th century, the researchers recorded a tremendous jump in phosphorous entry into sediments—caused by industrialization and the use of phosphorous fertilizers in agriculture.

Annual global phosphorous entry into lake sediments increased sixfold compared to the pre-industrial period, from around 240,000 tons per year to around 1.5 million tons per year in the present day. Over the last 12,000 years, huge phosphorous reservoirs have built up in lake sediments around the world. The research team estimates that this amounts to 2.7 billion tons in total.

Phosphorous can be recycled

The huge loss of phosphorous from soils poses a threat to food security in the long term, according to Grosjean, because there is a lack of this element as an agricultural plant nutrient: it is only found in limited quantities in rocks, or has to be recovered from domestic wastewater and agricultural waste.

"The high level of phosphorous entry is also extremely hazardous to aquatic ecosystems," says Grosjean, whose research focuses on the cycle of the nutrient in lakes. "The consequences are well known: eutrophication, fish deaths, toxic algae, loss of biodiversity."

But he can also see a positive side to the phosphorous deposits: "It seems that the sediments on the bottom of lakes can be very effective traps under certain conditions. If phosphorous is tightly bound in sediments instead of dissolving from them, then at least it cannot contribute to the further eutrophication of lakes." The chemical conditions that must exist in a lake to ensure phosphorous remains in the sediment in the long term are currently the subject of research.

More information: Luyao Tu et al, Anthropogenic modification of phosphorus sequestration in lake sediments during the Holocene: A global perspective, *Global and Planetary Change* (2023). DOI: 10.1016/j.gloplacha.2023.104222

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