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Viewpoint

Phosphorus Control: Inadequate Attention Was Paid in Eastern China

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Phosphorus (P) is a limiting factor of primary productivity in freshwater ecosystems and is an essential nutrient for the growth of aquatic organisms. However, it is also one of the leading causes of eutrophication.[1,2] In the past two decades, the booming economy, rapid population growth,[3,4] and agricultural and industrial activities have greatly increased the levels of generation and consumption of P and accelerated the rate of P bioactivity. Large volumes of wastewater containing P are directly discharged into rivers, wetlands, and lakes because of outdated and ineffective sewage treatment facilities;[5] this input of P has increased the risk of algal blooms in natural water bodies.

Although some studies have reported that total phosphorus (TP) in freshwater lakes is decreasing,[6] surface sediments still have active P biogeochemical cycling, where P-containing species are transformed or mineralized. In this study, we investigated P speciation and concentration in freshwater sediments in eastern China (Figure 1). More than 50% of the sediment samples had P concentrations of >500 mg kg^{-1}, indicating that the sediment was polluted by P and should be dredged or remediated.[7] The average TP in the sediment was 574 mg kg^{-1}. We also found the highest P concentrations in the upper layer of the sediment (~10 cm), which indicated that the surface sediment is an active zone for P cycling. On the basis of the average concentration of P and the area of freshwater sediment, we calculated that ~1.27×10^6 t of P is stored in the surface sediment of freshwater ecosystems in this region. Most of the P was present as HCl-Pi (Ca-bound P and apatite P), NaOH-Pi (P bound to Al, Fe, and Mn oxides or hydroxides), or organic P (Po), with concentrations of 320, 151, and 104 mg kg^{-1}, respectively. The excessive P stored in the surface sediments was from the input of untreated wastewater and agricultural non-point-source pollution. The P-cycling reactions led to a one-way flow of P and resulted in a pool of P in the limnetic ecosystem, a vital buffer area between the land and the ocean.[8−10]

There are many reasons for the accumulation of P in surface sediment. Incomplete drainage allows non-point-source pollution caused by storm runoff to flow into rivers, and inefficient sewage collection allows the discharge of sewage into rivers. The main water quality indicators [Secchi depth (SD), dissolved oxygen (DO), oxidation−reduction potential (ORP), and ammonia nitrogen (NH_3-N)] specified in the "Black and Odorous Water Treatment Project" (an important policy for controlling urban point-source pollution in China) do not include P concentrations, and these indicators neglect the effect of P on the aquatic environment. The disturbance of freshwater ecosystems by excessive anthropogenic activity is further intensified by the accumulation of P.

Large amounts of accumulated P in freshwater ecosystems can cause many social and environmental problems. Discharge of untreated wastewater not only introduces pollutants into the environment but also induces anaerobic conditions at the water−sediment interface. Anaerobic conditions will activate the sediment P and allow it to be released from the sediment.[11,12] Freshwater ecosystems act as a buffer between the land and ocean, and P released from freshwater sediments will flow to the coast through rivers or will be trapped at estuaries. Excess P entering the ocean can induce eutrophication and red tide, deteriorate the aquatic ecological environ-

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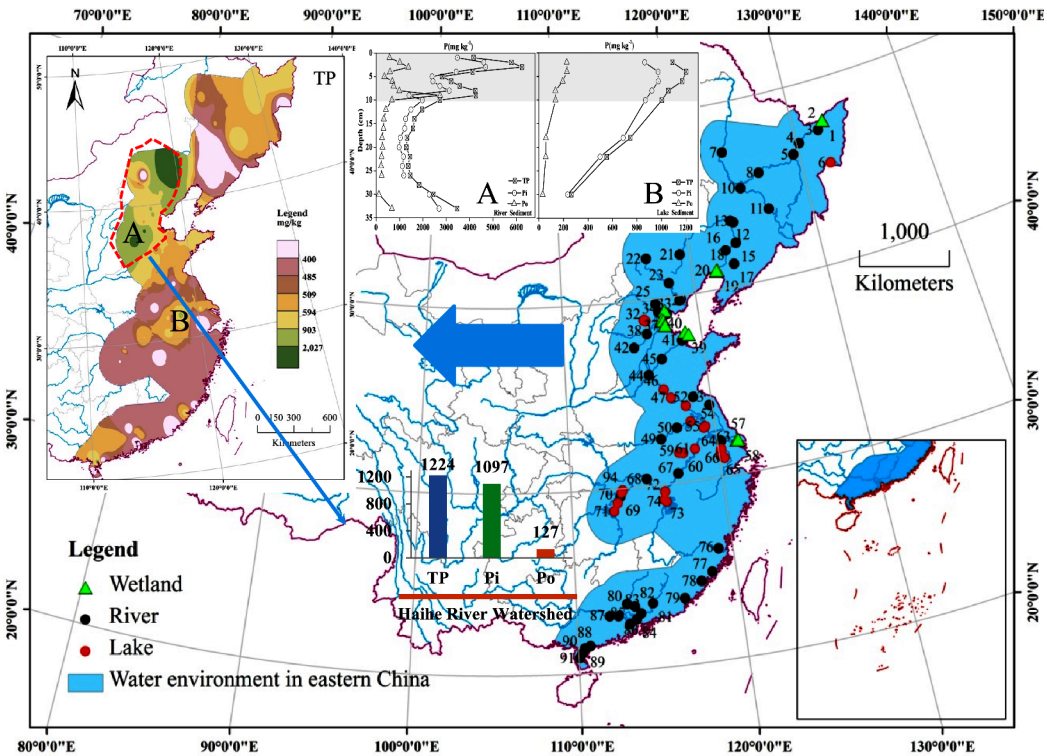

Figure 1. Research region distributed throughout the Heilongjiang, Liaoning, Hebei, Shandong, Jiangsu, Anhui, Hubei, and Guangdong provinces, as well as the Beijing, Tianjin, and Shanghai municipalities. River, wetland, and lake systems, which are prominent ecosystems in eastern China, are represented.

ment, and affect the normal development of a social economy.[13] Red tide can affect the health of marine ecosystems and the offshore aquaculture industry.

With increasing government awareness, a number of policies and projects have been proposed and implemented, such as the Chinese National Water Pollution Control and Technology Management project and the Water Pollution Prevention Action Plan. However, policy makers focus on the pollutants and ignore P control and management at the source. As P is an important biological nutrient, the scientific management and recycling of P through new technologies are critical and will not only solve environmental problems but also support the sustainable utilization of P.

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Author Contributions

W.Z. wrote the draft. X.M., X.J., and B.S. revised the manuscript. All authors contributed to the discussion of the results and revision of the manuscript.

Notes

The authors declare no competing financial interest.

Biography

Zhang Wenqiang, Ph.D., Associate Researcher at the Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences (CAS), and member of the Youth Innovation Promotion Association of CAS, is distinguished as a key member by the Chinese Academy of Sciences. His primary research interests encompass the analytical methods for forms of phosphorus in the water environment, biogeochemical cycles of phosphorus under the context of global change and its eco-environmental effects, and watershed water

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pollution control and aquatic ecological restoration. He has made significant progress in the optimization of solution ^{31}P nuclear magnetic resonance analysis methods, understanding the environmental behavior of phosphorus in freshwater ecosystems, foundational theories of water pollution control, strategies and planning for water pollution control, and technologies for aquatic ecological restoration engineering. He has led various projects, including those funded by the National Natural Science Foundation of China, national key research and development programs, and major science and technology projects for water pollution control and treatment. He has published mora than 70 papers and filed for 10 patents. He participated in the "Searching for China's Good Water" environmental protection campaign organized by the Chinese Society for Environmental Sciences, for which he was awarded the "Special Contribution Award".

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