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Editorial: Eutrophication, algal blooms, and hypoxia in lakes and reservoirs: perspectives on addressing water quality degradation

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Editorial on the Research Topic
Eutrophication, algal blooms, and hypoxia in lakes and reservoirs: perspectives on addressing water quality degradation

Introduction

Widespread water pollution problems, including eutrophication, algal blooms, and hypoxia, pose severe threats to aquatic environments and ecosystems. These complex and harmful processes can result in large-scale fish mortality, impair aquaculture production, cause economic losses, degrade water quality, and endanger human health. Moreover, driven by global warming and intensified anthropogenic activities, such water-related crises are occurring with increasing frequency in lakes and reservoirs worldwide. This Research Topic, *Eutrophication, algal blooms, and hypoxia in lakes and reservoirs: perspectives on addressing water quality degradation*, brings together interdisciplinary perspectives to elucidate key mechanisms and present innovative management approaches to address water pollution. The Research Topic features four innovative studies that address these challenges.

Discussion of the contributing articles

Rodal-Morales et al. explored how a hypolimnetic oxygenation system affected the cycling of nutrients, metals, and mercury in the hypereutrophic Hodges Reservoir in California, United States. The study emphasized that oxygenation caused substantial decreases in water column ammonia, phosphate, manganese, and methylmercury (MeHg) concentrations, but increased levels of iron and nitrate. Meanwhile, oxygenation can reduce algal productivity and its potential to produce potent tastes. However, the study also reported a loss of thermal stratification and the ongoing accumulation of reduced compounds (e.g., manganese and iron) in the bottom waters after oxygenation, illustrating both the promise and limitations of hypolimnetic oxygenation.

Similarly, Defeo et al. reported that the dissolved oxygen (DO) conditions at the sediment-water interface can affect the release of nutrients and metals from sediment to overlaying water, thereby influencing internal nutrient loading and algal bloom development. The authors compared the sediment release rates of nutrients and metals to the overlying water in shallow, hypereutrophic Lake Henshaw and moderately deep, meso-eutrophic Lake Wohlford. They observed that sediments released different nitrogen-to-phosphorus ratios under hypoxia (very low ratio plus iron) vs. anoxia (low ratio with high nutrient levels). The study also emphasized that effective water quality management in eutrophic reservoirs requires an integrated approach that considers biogeochemical processes and DO dynamics. The management plan involves using hydrogen peroxide to control algal blooms, applying sediment amendments to reduce internal phosphorus loading, and implementing water oxygenation systems to supply pure oxygen gas.

Besides mechanistic experiments and field observations, numerical modeling also plays a pivotal role in understanding and mitigating eutrophication and algal bloom problems. Julian et al. employed both a stage-based statistical algal growth model and a process-driven hydro-ecological model to assess algal bloom risk in different water management regimes and restoration infrastructures. Their results demonstrated that chlorophyll a (an indicator for algal biomass) concentrations in different parts of the lake can respond differently to nutrient reduction or water quality improvement scenarios. The study also emphasized that improving the lake's hydrodynamic conditions through the implementation of appropriate storage infrastructure can alleviate ecological stress associated with high water levels.

While understanding algal growth and nutrient dynamics within individual lakes or reservoirs is essential for local management, examining phytoplankton primary production (PP) at regional, national, or global scales provides a broader perspective on the overall extent and severity of algal blooms and eutrophication. Deng et al. compiled a 44-year (1980–2023) database of phytoplankton primary production (PP) from 165 reservoirs across China to examine its spatial and temporal patterns. Their analysis revealed that phytoplankton PP was significantly higher in reservoirs located within the Yellow River, Songhua River, and Liaohe River basins. Temporally, it peaked in the 1990s, declined in the following decades, and showed a rebound in the 2020s. Furthermore, they identified sunshine duration, water depth, and rainfall as the dominant environmental factors influencing phytoplankton PP.

Summary and broader implications

In summary, the articles in this Research Topic collectively deepen our understanding of the processes driving eutrophication, algal blooms, and hypoxia in reservoirs and lakes, while also advancing technologies for their mitigation. Drawing on mechanistic laboratory experiments, field observations, and advanced numerical modeling, these studies establish a comprehensive framework for understanding water quality problems and for designing effective management strategies. Moreover, the collective findings extend beyond specific case studies, contributing to a broader understanding of water quality degradation and the sustainable management of aquatic ecosystems and water resources.

Moving forward, advancing water quality restoration requires a new synthesis of science, technology, and governance. Emerging tools—ranging from sensor networks and machine learning to ecosystem modeling—offer unprecedented opportunities to monitor, understand, and predict water quality changes. By fostering transdisciplinary collaboration and adaptive, inclusive governance, the global research community can transform understanding into action and safeguard freshwater ecosystems for generations to come.

The Research Topic editors express their sincere gratitude to the authors for their valuable contributions, to the reviewers for their insightful feedback, and to the editorial board for their steadfast support throughout the publication process. These joint efforts drive innovation and advance research in the Research Topic field.

Author contributions

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