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Editorial: Emerging contaminants and aquatic ecosystem health

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Editorial on the Research Topic

Emerging contaminants and aquatic ecosystem health

Aquatic ecosystems are fundamental to sustaining life on Earth, possessing irreplaceable ecological, economic, and social value. However, these systems are highly sensitive to external disturbances and exhibit a vulnerability characterized by a “low threshold and difficult recovery.” (Baskar et al., 2022; Agathokleous et al., 2023) Maintaining the health of aquatic ecosystems is not only essential for ecological security but also serves as a safeguard for human health and a cornerstone of global sustainable development. In recent years, emerging contaminants (ECs) frequently detected in aquatic environments have been recognized as a new threat to ecological health, with potential hazards that cannot be overlooked. These substances pose relatively concealed risks to both the environment and human health. Even at low concentrations, they may introduce dangers to public health, environmental quality, and ecosystem safety. For instance, herbicides classified as ECs can persist in both water and sediment, where sediments act as significant reservoirs, presenting long-term potential health risks (Peng et al.).

ECs exert multi-level effects on aquatic ecosystems, ranging from molecular to community-level impacts. Notably, endocrine-disrupting chemicals can induce abnormal gonadal development in aquatic organisms even at very low exposure concentrations. Shaalan et al. investigated the effects of four common pharmaceuticals—bromazepam, naproxen, metoprolol, and sotalol—on common carp (*Cyprinus carpio*), underscoring the adverse impacts of pharmaceutical contaminants on aquatic species (Shaalan et al.). Li et al. studied the toxic effects of triphenyltin (TPT) and microplastics (MPs) on carp, providing valuable insights into the individual and combined toxicities of TPT and MPs, and revealing their potential synergistic or antagonistic effects on aquatic organisms (Li et al.). Daniel Elías examined the impacts of microplastics, ibuprofen, and their combination on the growth, locomotion, and reproduction of *Physella acuta*, highlighting the need for further research to understand the chronic and long-term ecosystem effects of these pollutants (Elías et al.). A growing body of evidence points to the “cocktail effect” among pollutants, indicating that the ecological risk of compound pollution exhibits nonlinear amplification.

In response to the technical challenges of monitoring emerging pollutants, analytical tools have shown three major development trends in recent years. First, highly sensitive non-targeted screening techniques based on LC-QTOF-MS enable full-spectrum analysis of up to 5,000 compounds per run, with detection limits reaching the femtogram level. Second, in the field of in-situ monitoring, graphene-based field-effect transistor biosensors have

improved the real-time detection sensitivity of bisphenol A (BPA) by two orders of magnitude compared to conventional ELISA. Third, intelligent early-warning systems that integrate passive sampling (POCIS), toxicity identification evaluation (TIE), and machine learning algorithms—such as the QSAR model—can predict ecological risks for up to 85% of new pollutants (Merlot, 2010; Slavov and Beger, 2020).

Current treatment technologies for ECs in water bodies primarily include advanced oxidation processes, adsorption, membrane separation, biodegradation, and ecological remediation. Future measures should focus on enhancing monitoring systems, strengthening source control, developing low-energy and high-efficiency treatment processes, and establishing a multi-level barrier-based prevention and control framework. According to Ji et al., mechanically processed nano-activated carbon (NAC) has been identified as an effective strategy for capturing trace pollutants—such as pesticides, dyes, and pharmaceutical residues—in saline-alkaline waters, owing to its high adsorption capacity and environmental compatibility (Ji et al.). Zhou et al. evaluated the efficacy of various methods in removing ECs, with particular emphasis on sustainability and economic viability (Zhou et al.). Their findings reveal that integrating these technologies can significantly improve removal efficiency, offering promising directions for environmental policy and practical applications.

Research on the environmental fate of ECs is shifting from single-medium studies to multi-interface processes, ecological risk assessments are expanding from acute toxicity to transgenerational effects, and monitoring technologies are evolving toward intelligence and miniaturization. Establishing an ecological integrity-based risk management framework and developing a comprehensive technological system that encompasses source control, process intervention, and end-of-pipe treatment will be key to safeguarding aquatic ecosystem health. This requires interdisciplinary collaboration across environmental science, ecotoxicology, and information technology, as well as the joint development of global-scale monitoring standards and governance mechanisms.

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