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EMERGING POLLUTANTS: PROTECTING WATER QUALITY FOR THE HEALTH OF PEOPLE AND THE ENVIRONMENT

THEME I

# Emerging Pollutants: A Growing Threat to Aquatic Ecosystems

Urban river

## KEY POLICY MESSAGES

- Specifics differ from place to place, but pesticides, disinfectants, pharmaceuticals, microplastics, and engineered nanomaterials pose increasing risks worldwide to water quality and thereby to human health and ecological systems.
- Challenges for addressing these emerging pollutants include lack of transparency, difficulty in monitoring, and uncertainty regarding the risks they pose.
- Water quality standards set for individual chemicals do not adequately account for synergistic effects of multiple contaminants.
- Efficient control measures, such as source controls or wastewater treatment, are needed to mitigate the risks posed by emerging pollutants.
- In less developed regions, emerging contaminants compound the risk posed by traditional pollutants such as *E.coli* or nitrates.

*Increasing economic growth and urbanization around the world create opportunities but also drive a vast and increasing consumption of chemicals, many of which are directly or indirectly discharged into the environment.*

## EMERGING POLLUTANTS AND THEIR TRANSFORMATION PRODUCTS ARE UBIQUITOUS IN AQUATIC ECOSYSTEMS, AND MANY ARE TOXIC

Emerging pollutants are being detected in urban and ambient waters from different regions globally and can be considered a worldwide problem. Emerging pollutants are contaminants detected in water bodies that may cause ecological or human health impacts and are typically not regulated under existing environmental law. The concentrations of chemicals and other compounds of concern differ depending on the use of the compounds in each region and the level of wastewater treatment available or required, but pesticides, disinfectants, pharmaceuticals, microplastics, and engineered nanomaterials all pose increasing risks to water quality. Understanding the sources and behavior of emerging pollutants is key to addressing their ecological and human health impacts on aquatic ecosystems. Research linking physical and chemical tracers to trace specific pollution sources in groundwater and surface water, improve understanding of pollutants' pathways, understand connections between components of the water cycle, and identify biological processes that impact pollutants in water is key to efforts to limit the proliferation of emerging pollutants.

Some emerging pollutants and their transformation products can be persistent, bioaccumulative, and toxic to humans and biota in various ways. Per- and polyfluoroalkyl substances (PFAS) are "forever chemicals" that can bioaccumulate and transfer from one trophic level to another in aquatic food webs, triggering multiple toxicity endpoints, such as endocrine, neurotoxic, carcinogenic and immunotoxic effects, and impairing growth and reproduction of aquatic organisms. Another example is 6PPD-Q (2-anilino-5-[(4-methylpentan-2-yl)amino]-cyclohexa-2,5-diene-1,4-dione), a globally widespread tire rubber–derived oxidation product of 6PPD. 6PPD-Q induces death of adult coho salmon when the salmon migrate to urban creeks contaminated with the substance, and it can also induce acute mortality in juvenile coho salmon at trace levels (LC50 = 95 ng/L). Yet another threat is found in the waste residues from human and animal consumption of antibiotics that are increasingly present in aquatic systems around the world, contributing to antimicrobial resistance—a top global public health threat.

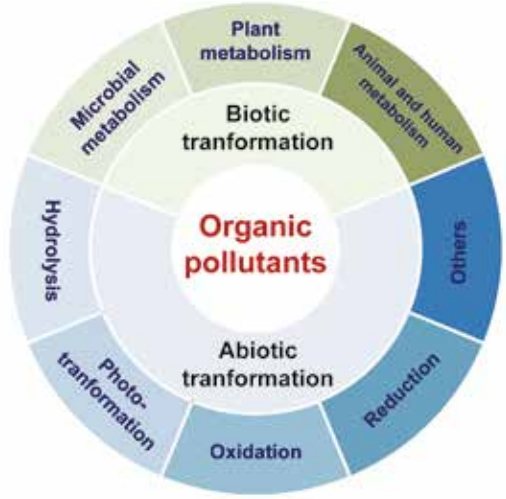
## THE MONITORING AND MANAGEMENT OF EMERGING POLLUTANTS FACES NUMEROUS CHALLENGES

At present, most emerging pollutants are not monitored and, for some, hazard information is still limited. This lack of information makes understanding the pollutants' environmental behavior and assessing the risks they present very challenging, impeding decision making and practices for their control and management by the commercial/industrial sectors, as well as regulatory initiatives by governments. To protect and maintain the health of aquatic ecosystems and the sustainability of urbanization, it is imperative to scrutinize emerging pollutants in the environment. Efforts to date have enriched our knowledge of emerging pollutants. However, there are still three major challenges in monitoring and managing emerging pollutants:

1/ The lack of transparency around emerging pollutants and related products within their life cycles. The production and application of compounds are often considered commercial secrets and are thus not publicly available, which makes it difficult for would-be monitors and regulators to identify and understand the impacts of the compounds in the environment. Consequently, the management of emerging pollutants usually lags decades behind their

*Emerging pollutants are typically not yet regulated.*

*Transformation process for organic pollutants*




discovery and use. For example, while liquid crystal monomers have been used in liquid crystal displays since the 1990s, environmental monitoring of liquid crystal monomers began only in recent years due to the confidential nature of their makeup among manufacturers. Further, the transportation and disposal of those new compounds is not well documented, which may contribute to unintentional discharge and improper disposal or accidental release. A lack of transparency also complicates the practical management of emerging pollutants and research on treatment options.

2/ The difficulty in monitoring emerging pollutants. Routine chemical analyses can be used to identify a narrow portion of emerging pollutants. However, this approach is restricted to compounds with reference standards. When reference standards are not available, suspect (evaluating the presence of a list of suspected pollutants) and non-target analyses with high-resolution mass spectrometry (HRMS) provide extensive information (e.g., accurate mass and retention time) about known and unknown chemicals. However, only a fraction of HRMS information is well analyzed and interpreted, preventing the discovery of some new emerging pollutants. Further, due to the properties of some emerging pollutants, the signals are masked thus preventing detection with HRMS .

3/ Identifying the hazard that emerging pollutants present. Although they have been identified as distinct compound-classes, the toxicities and ecological risks of emerging pollutants for aquatic species have not been systematically studied, which impedes the enactment of regulations for emerging pollutants. Further, emerging pollutants often are present in the environment as mixtures, which makes their regulation even more challenging. The co-exposure of multiple emerging pollutants may cause adverse outcomes even when the concentrations of individual chemicals are below the regulatory dose. Further, the transformation products of emerging pollutants may be even more toxic than the parent compound. Investigating the toxicity of thousands of emerging pollutants is time, labor, and cost consuming, making it impractical to determine the multiple toxicity endpoints of each emerging pollutant.

## RECOMMENDATIONS TO IMPROVE THE MANAGEMENT OF EMERGING POLLUTANTS

Addressing the threats that emerging pollutants present for aquatic ecosystems across the globe is essential to protect and ensure the quality of urban water, the sustainability of urbanization, and the achievement of United Nations Sustainable Development Goals (e.g., Goal 3: Good health and well-being, Goal 11: Sustainable cities and communities, and Goal 12: Responsible consumption and production). Recommendations to improve the management and oversight of emerging pollutants are given below:

1/ Increase and improve information available about emerging pollutants at each stage of their life cycles. Better and more extensive information about the synthesis, application, and effluents in which emerging pollutants are present would reduce unintentional discharge and inadequate treatment, facilitate understanding of their physico-chemical properties and environmental fate prediction, boost their replacement with alternatives, and facilitate remediation of affected environments.

2/ Strengthen the analysis of emerging pollutants. The integration of all the viable methods for chemical analysis in a systematic approach would enable discovery of more emerging pollutants

***The transformation products of emerging pollutants may be even more toxic than the parent compound.***

and the subsequent clarification of their persistence, environmental fate, and levels of exposure (e.g., the transfer from one trophic level to another in aquatic food webs) in urban aquatic ecosystems. Meanwhile, the development of data-mining programs, effective sample pretreatment methods, and advanced detection techniques would further decode emerging pollutants in complex aquatic samples.

3/ Accelerate toxicological testing for emerging pollutants. High throughput tests, which use robotics, high-speed computing, and other advances in technology to allow a researcher to conduct millions of chemical, genetic, or pharmacological tests quickly, can be applied to speed up the toxicological profile of individual emerging pollutants and mixtures of emerging pollutants, disclosing their adverse effects and improving the understanding of the quantitative structure-toxicity relationship for new emerging pollutants. The latter can be used to estimate the toxicity of untested emerging pollutants. It is known that the co-exposure of multiple contaminants may cause adverse outcomes even when the concentrations of individual chemicals are below the already-defined water quality criteria. However, methods to assess the effects of mixtures are currently inadequate and require further development. Risk assessment of emerging pollutants and chemical mixtures in urban and ambient waters is only in the early stages of development.

4/ Establish national or regional regulations for emerging pollutants. Source controls to eliminate or reduce the use of emerging pollutants are the most effective control measure, where feasible. The emission of emerging pollutants in urban areas can differ depending on population size, human activities, urban development levels, and the usage of chemicals, as well as wastewater treatments available. Therefore, in addition to the international conventions (e.g., the Basel, Rotterdam, Stockholm and Minamata conventions), a series of national or regional regulations should be established considering specific risk scenarios of exposure to emerging pollutants.


Lake Guiers, Senegal

## EMERGING POLLUTANTS IN LAKE GUIERS, SENEGAL

**Growing anthropogenic pressures combined with climate change are threatening the Lake Guiers basin in Senegal. To understand the impact of human activities on the lake's water quality, researchers undertook a spatio-temporal evaluation of pesticide and land use in the basin. The study found an increase in pesticides in water samples, including organochlorines and organophosphates. It also demonstrated that pesticide use and the occurrence of new molecules were increasing annually, although there was a decrease in agricultural land use during the COVID-19 pandemic period. High to moderate pollution levels were detected at some sites for most of the targeted parameters. The study highlighted that the environmental degradation of the lake basin requires the monitoring of chemicals and emerging pollutants while integrating management practices, involving multiple stakeholders, and increasing awareness to avoid the d Emerging Pollutants: Protecting Water Quality for the Health of People and the Environment eterioration of the ecological environment.**

5/ Develop and implement other control measures when source controls are not feasible. Collaborations in technology transfer and knowledge among less and more developed regions should be encouraged to mitigate the risks of emerging pollutants and to promote global health and equality. Emerging contaminants that respond to wastewater treatment technologies should be identified. For most countries around the globe, sanitation is still a big challenge. To improve this situation, efficient, low-cost wastewater treatment options should be developed and urgently implemented to mitigate the risks of emerging pollutants that compound those of old contaminants (e.g., *E. coli*, nitrate).

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