

A Systematic Review of Emerging Contaminants in Surface Waters: Sources, Impacts, and Monitoring Approaches

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Emerging contaminants (ECs) such as pharmaceuticals, personal care products, endocrine-disrupting chemicals (EDCs), microplastics, and industrial additives are increasingly being discovered in surface waters globally. These unregulated and persistent pollutants originate from diverse sources including urban wastewater, agricultural runoff, and industrial effluents. Even though there have been extensive studies on ECs in marine and soil matrices, their presence, migration, and monitoring in surface freshwater systems remain a growing concern. The aim of this systematic review is to identify the major sources and types of ECs in surface waters, summarize their ecological and health impacts on humans, and assess conventional and emerging methods for monitoring ECs. The PRISMA guideline was used to ease the review process. Forty peer-reviewed papers between 2010 and 2024 were examined, selected from Scopus, ScienceDirect, SpringerLink and Wiley Online Library databases using keywords including "emerging contaminants," "surface water," "monitoring techniques," "ecological impacts," and "wastewater pollution." The findings highlight wastewater outfalls, agricultural pesticides, and industrial effluents as dominant sources. ECs enter water bodies via runoff, leaching, sewer overflow, and atmospheric deposition. ECs pose grave health issues such as hormonal interference, reproductive disorders, and antibiotic resistance in human beings, as well as endocrine dysfunction and death in aquatic organisms. Classical methods such as gas chromatography-mass spectrometry (GC-MS) and liquid chromatography (LC-MS/MS) are precise and costly and require a lot of time. New technologies such as biosensors and remote sensing approaches using UAVs are being developed as potential alternatives for bulk, real-time surveillance. EC pollution control requires a multi-dimensional approach, including regulation, technological advancement, and awareness among the public. This review necessitates the construction of sustainable water monitoring systems to ensure the integrity of aquatic ecosystems and human health.

Keywords: Biosensors, Emerging contaminants, Monitoring techniques, Remote sensing, surface water, Wastewater pollution