EMERGING ORGANIC POLLUTANTS IN AQUATIC SYSTEMS: ANALYTICAL METHODS, ENVIRONMENTAL FATE, RISK ASSESSMENT AND REMEDIATION TECHNIQUES

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HABILITATION THESIS
ABSTRACT

The habilitation thesis summarizes the main scientific, professional, and academic achievements in Environmental Engineering, highlighting original contributions to the investigation of emerging organic pollutants in aquatic systems. The research follows an integrated approach, encompassing the development and validation of advanced analytical methods, environmental monitoring, investigation of pollutant fate and behavior, ecological and human health risk assessment, and the evaluation of remediation technologies. The main classes of contaminants investigated include per- and polyfluoroalkyl substances (PFAS), bisphenol A and its analogues, organic UV filters, and organophosphate flame retardants (OPFRs).

The scientific contributions are organized into four complementary research directions. The first focuses on the development and validation of analytical methods based on liquid chromatography coupled with tandem mass spectrometry (LC-MS/MS), enabling the identification and quantification of emerging contaminants at trace and ultra-trace levels in complex environmental matrices, including wastewater, surface water, seawater, sediments, sewage sludge, and biota. The second direction addresses the occurrence and behavior of these contaminants in Romanian wastewater treatment plants through the investigation of influents, effluents, and sewage sludge. The findings reveal variable removal efficiencies and demonstrate that wastewater treatment plants remain important pathways for the transfer of emerging organic pollutants into aquatic ecosystems. The third research direction investigates the distribution of emerging contaminants in freshwater and marine ecosystems, including Romanian rivers, the Danube River, and the Romanian Black Sea coastal area. These investigations contribute to the identification of anthropogenic sources, the characterization of transport and accumulation processes, and the assessment of potential ecological and human health risks. The fourth direction explores remediation approaches based on adsorption and bacterial biodegradation, highlighting their potential to reduce contaminant concentrations while emphasizing the importance of evaluating treatment efficiency and transformation products.

Future research perspectives include expanding the investigation to additional categories of emerging contaminants, their interactions with microplastics and nanoplastics, bioaccumulation processes, and integrated risk assessment. Particular emphasis will be placed on implementing high-resolution mass spectrometry, suspect and non-target screening strategies, advanced microplastic characterization techniques, and statistical and artificial intelligence-based tools for interpreting complex environmental datasets. Academic development objectives include PhD supervision, establishing a competitive research team, and strengthening international scientific collaborations.

By integrating environmental analytical chemistry, contaminant monitoring, risk assessment, and remediation technologies, the research presented in this thesis advances the understanding of the environmental fate and behavior of emerging organic pollutants and provides a scientific basis for developing sustainable strategies to protect aquatic ecosystems and water resources.