METU Environmental Engineering
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From Wastewater to Agricultural Soils: Tracking Microplastics Quantities, Types, Fate and Impact with Innovative Approaches

Plastic production continues to increase exponentially and is on track to double by 2040 and triple by 2060 (UNEP, 2021). Plastics degrade very slowly and remain in the environment for hundreds of years. As a result, plastic pollution continues to increase and accumulate, with an estimated 6 billion metric tons of plastic waste currently polluting the environment. Human exposure to microplastics (<5 mm) and nanoplastics (<1 µm) is also increasing, and these particles have been found in almost all human organs. Chemical additives, stabilizers, and functional agents added to polymers during production can leach out and inhibit key enzymes, genes, and intracellular reactive oxygen species, causing damage to ecological and human health. Currently, there is limited literature on the quantities, characteristics, and chemical contaminants of micro- and nanoplastics (MNPs) across all environmental matrices, as well as their impacts on the environment and human health.

This presentation will cover a wide range of topics related to plastic pollution studied in our research lab, starting with new technologies and approaches for detecting and quantifying microplastics across different environments, including real-time methods such as AI-assisted micro-flow imaging for water samples and hyperspectral imaging for biosolids and agricultural soil samples. The methods were challenged by testing a wide range of plastics in different sizes, shapes, and colours, coated with organic materials and treated with chemicals, to establish their sensitivity, selectivity, and limitations. The results clearly illustrated that quicker, easier detection of environmental microplastics is possible with the support of new technologies. The presentation will also include results on the formation and detection of nanoplastics resulting from UV exposure, shear, and erosion of microplastics in aquatic environments.

Using improved detection and quantification methods, results on microplastic abundance and types in wastewater sludges will be presented, along with seasonal fluctuations in microplastic concentrations and characteristics. Several other contaminants, including fertilizers and pharmaceutical drugs, were found adsorbed onto MPs, often obscuring their underlying material properties and potentially leading to an underestimation of MP abundance in sludge samples. Seasonal dynamics at wastewater treatment plants play a crucial role in assessing microplastic (MP) emissions into aquatic and terrestrial ecosystems. Understanding these fluctuations enables the development of more targeted and effective intervention strategies that are responsive to periods of heightened risk and that mitigate their environmental impacts.

Microplastics also impact biological treatment processes, including anaerobic digestion. Our results show that different types of microplastic polymers have distinct impacts on microbial communities and treatment performance, and that the shape of microplastics (i.e., fibres versus fragments) also plays a key role. Exposure to microfibers consistently inhibited methane production during anaerobic digestion; however, the MP fragments enhanced the methane yield at higher concentrations. To bring our research full circle, the impact of microplastics on agricultural soils following simulated land application of anaerobically digested sludge was investigated, and the results confirmed negative effects on soil microbial populations and plant uptake of microplastics, particularly in smaller size ranges. Finally, simple and affordable approaches to better microplastic removal from liquid and solids streams at wastewater treatment plants were investigated, and the results showed that adjusting the polymer dose can significantly improve both microfiber and fragment removal during sludge dewatering.

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