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Editorial

Micro(nano)plastics in Aquatic Environments: State of the Art and Beyond

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1. Introduction

The significance of water resources cannot be overstated, as they are vital for human survival and the economic and social development of societies. Estimates suggest that by 2050, there will be a 55% increase in global water usage compared to levels recorded in 2000. As a result, approximately 3.9 billion people are anticipated to face difficulties in accessing water of sufficient quality [1]. Water pollution can arise from both natural phenomena and human actions. However, the rapid pace of industrialization has significantly magnified the impact of human activities on the degradation of water quality, resulting in increasingly complex and severe instances of water pollution. The pollutants that contaminate water can be categorized into four main types: microbial contaminants, inorganic compounds, organic pollutants, and emerging contaminants (such as microplastics, MPs). MPs have increasingly been recognized as a significant environmental concern due to their widespread presence in water bodies and their persistence in the environment.

Plastics are widely used in various products due to their cost-effectiveness, lightweight properties, and remarkable durability. According to Geyer et al. [2], about 80% of marine pollution comes from discarded plastic, with an estimated annual input of 13 million tons of plastic into the ocean. Microplastics (MPs), particles usually smaller than 5000 µm, are common and can further degrade into even smaller particles known as nanoplastics (NPs). Micro/nanoplastics can be classified into primary and secondary types based on their origin [3]. Primary micro/nanoplastics, such as beads, pellets, and nurdles, are intentionally manufactured for various commercial applications, including industrial abrasives, synthetic textiles, and personal care products. Secondary micro/nanoplastics, on the other hand, are formed through the fragmentation of larger plastic pieces due to physical, chemical, and biological processes, such as abrasion, exposure to ultraviolet light, high temperatures, and microbial degradation. Due to their small size, micro/nanoplastics pose challenges for removal using conventional wastewater treatment technologies and often end up being directly discharged into aquatic environments [4]. Furthermore, MPs/NPs can serve as carriers for various contaminants, including polybrominated diphenyl ethers (PBDEs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), heavy metals, poly-fluoroalkyl substances (PFAS), and pharmaceuticals. When MPs and NPs are laden with these additional contaminants, they can induce synergistic toxic effects, posing a significant threat to organisms and human health [5]. Existing water and wastewater treatment techniques have shown limited effectiveness in eliminating MPs/NPs. As a result, wastewater treatment plants (WWTPs) have been pinpointed as notable sources of the dissemination of MPs/NPs into aquatic ecosystems, including drinking water reservoirs, rivers, and seawater [6]. Therefore, monitoring, measuring, and removing MPs/NPs from water bodies is incredibly important.

The rising prevalence of these issues led to the creation of this Special Issue, titled "Micro/nanoplastics in Aquatic Environments: State of the Art and Beyond". This Special Issue explores the occurrence and removal of MPs/NPs from water bodies, offering insights that could guide the development of sustainable treatment methods in the future.

2. Summary of the Special Issue

We received 15 review and research papers for this Special Issue. Each submission underwent a rigorous peer-review process, leading to the selection of six original research and review papers focusing on the occurrence and removal of MPs and NPs from water bodies. The below section contains the list of contributions.

Contribution 1 presents a study of the implementation of a two-stage removal process for MPs and chemical oxygen demand (COD) in industrial wastewater streams. The results demonstrated average decreases in MP levels of 98.26 $\pm$ 2.15%, as measured via total suspended solids (TSS), and 97.92%, as measured via particle count. This effectively prevents the emission of 1.1 kg of MPs per cubic meter of water, equating to an estimated reduction of 2.7 tons of microplastics per year. Furthermore, the COD was efficiently reduced by 94.3%. In addition to MPs and COD, this treatment process enables water and agglomerates to be reused, reducing the overall CO_2 footprint.

Contribution 2 presents a study to assess the current level of MP contamination at two popular recreational beaches in Malaysia: UMS ODEC and Tanjung Aru Beach. Tanjung Aru Beach exhibited a higher concentration of MP particles at all monitoring sites, with 857 MPs/kg of dry sediment and a total mass concentration of 57.72 g/kg. In contrast, UMS ODEC recorded 160 MPs/kg of particles, with a total mass concentration of 17.96 g/kg. The predominant size range for MPs was <1 mm, with a significant portion displaying white or transparent coloration. Through Micro Fourier-Transform Infrared Spectroscopy (FTIR) analysis, the researchers identified polypropylene (PP) and polyethylene (PE) as the most prevalent plastic polymers at both beaches, comprising 60% and 43%, respectively, followed by polyethylene terephthalate (PET), with polystyrene (PS) being the least frequently observed.

Contribution 3 investigates the individual and combined toxic effects of nano-ZnO and PE-MPs on mosquito fish (*Gambusia holbrooki*) over a 14-day period. The study observed a significant increase in the activity levels of catalase, glutathione peroxidase, superoxide dismutase, and glutathione reductase in fish exposed to ZnO-NPs alone and in combination with PE-MPs (100 and 200 μg/L). Elevated levels of malondialdehyde were detected in fish exposed to both ZnO-NPs alone and in combination with PE-MPs. Additionally, the total antioxidant (TAN) levels exhibited notable decreases in all experimental groups compared to the control group. The accumulation study of microplastic particles indicated the liver-targeted accumulation of PE-MPs, while ZnO-NPs demonstrated the facilitated accumulation with the assistance of PE-MPs. The study confirmed the induction of oxidative stress and ZnO-NP-induced toxicity facilitated by PE-MPs in fish.

In a review paper designated as Contribution 4, the types, fates, and biotoxicities of MPs are examined. The review emphasized the significant reproductive toxicities of MPs in wildlife, highlighting the potential implications for human health.

In a separate study designated as Contribution 5, the characteristics, detection, and fates of MPs in landfill leachate during advanced oxidation processes (AOPs) are investigated. Their findings revealed the presence of over forty types of MPs in the leachate, exhibiting diverse shapes and a wide size distribution, with concentrations ranging from 0 to 25 items per liter. Furthermore, their study demonstrated that MPs undergo decomposition into smaller molecules, such as ketones and aldehydes, and some may ultimately degrade into CO_2 and H_2O during AOPs. These findings suggest potential applications for AOPs in the treatment of leachate in landfill treatment plants.

Contribution 6 presents a study to investigate the presence of pharmaceuticals and microplastic pollution in groundwater, wastewater, and surface water both before and during the COVID-19 pandemic. Their study identified 43 different types of pharmaceutical products across 25 countries, with sulfamethoxazole, acetaminophen, ibuprofen, caffeine, and carbamazepine being the most commonly found pollutants. Additionally, they detected 32 types of polymers in 13 countries, with polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS), and polyethylene (PE) being the most prevalent. Microplastic particles ranging from 1 to 2.5 mm and 2.5 to 5 mm in size constituted half of the microplastics discovered in the 13 countries. This investigation underscores the significance of emerging contaminants in aquatic environments both before and during the COVID-19 pandemic, providing valuable new insights.

In summary, this Special Issue not only explores the ubiquitous presence of MPs/NPs in aquatic environments but also delves into innovative strategies for their efficient removal and associated implications. Contributions within the Special Issue offer a range of multi-faceted approaches, ranging from novel treatment processes for industrial wastewater and landfill leachate to comprehensive assessments of MPs' and NPs' abundance, distribution, and biotoxicity in natural ecosystems. By expanding on the discussion of MPs removal technologies and their broader implications, this Special Issue significantly contributes to advancing our understanding and management of microplastic pollution in water bodies. However, further research is needed to identify more comprehensive and efficient methods for removing MPs from water bodies.

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