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Micro and Nanoplastic Pollution in Water

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In today's scenario plastic pollution has become the major societal issue. Plastic waste is a widespread and persistent global challenge with negative impacts on the environment, economy, human health and aesthetics. Plastic pollution has been a focus of environmental research over the past few decades, particularly in relation to macroplastics that are easily visible by the naked eye. More recently, smaller plastic waste at the micro- and nanoscale has become of increasing concern, resulting in extensive investment in research to advance knowledge on the sources, distribution, fate and impact of these materials in aquatic systems. However, owing to their small sizes and a lack of unified methods, adequate quantitative and qualitative assessment has been difficult. Furthermore, most of the microplastic surveys available to date have focused in the marine environment. Because the majority of marine debris originates on land, the role of wastewater treatment systems and natural fluvial vectors in delivering these emerging contaminants to the environment should be explored. Considering fundamental aspects pertaining to microplastic sources, distribution, mobility and degradation in these systems is crucial for developing effective control measures and strategies to mitigate the discharge of these particles to the sea. Hence the growing concern of plastic among the citizens reflects the accentuated efforts by the scientists to study the new type of pollution which is obtained through plastic. Plastics are used in almost all areas of social production and daily life. The plastics discharged into environment during production or use are broken into microplastics (<5 mm) or even nanoplastics (<1000 nm) over the time by UV radiation, mechanical degradation, chemical degradation and biodegradation, which are often ingested by various creatures from the lowest in food chains such as plankton to the highest levels of invertebrates or vertebrates. While during the comparison with microplastics researchers found that nanoplastics are more hazardous to creatures due to their smaller particle size, allowing them to cross through cell membranes randomly. The internalization rates of 100 nm nanoplastics in blue mussel larvae is 6–10 times higher than that of 2 μm microplastics. Polystyrene microbeads of 50 nm present more obvious toxicity to rotifers than that of 6 μm, displaying retarded growth, reduced fecundity and shortened lifespan. Thus the existence of nanoplastics in environment posing an obvious threat to creatures should be paid more attentions. Noticeably, nanoplastics have already been separated from North Atlantic Subtropical Gyre by ultrafiltration at molecular weight cutoff of 10 kDa, the polymer types of which were identified to be polyethylene terephthalate (PET), polystyrene (PS) and polyethylene (PE). Thereafter the polymer types of nanoplastics were found in Alpine snow, sand and agricultural soil sample.

Micro- and Nanoplastics

Plastic litter can occur in a wide range of sizes. The literature commonly distinguishes between two broad classes of plastics: macroplastic (>5 mm) and microplastic (<5 mm) but different terms and size ranges have been used across. A unified lower limit for measurement

for microplastics has not been defined but for practical purposes 333 µm (~0.3 mm) is often used when sampling with neuston nets. Nevertheless, because a lower cut-off has not been established, the term microplastic has often been used to encompass pieces ranging from millimetre to nanometre dimensions. More recently, the term "nanoplastic" has been introduced as a separate category. This size class has been defined as particles smaller than 0.2 mm based on the WG-GES size classification and smaller than 100 nm according to the general definition used for nanomaterials. Mostly, nanoplastics have been overlooked in the literature and are the least-studied size class, as evidenced by a lack of discussion of its definition and quantification. Nevertheless, it has been suggested that these nanoscopic plastics may be the most hazardous yet due to their high potential for bioaccumulation and biomagnification, thus requiring further investigation. For purposes of this review, for ease of reference the rest of the discussion will focus on micro- and nanoplastics (MNP) jointly as one single size class.

Classification

Micro- and nanoplastics are classified into two general categories according to source: primary and secondary. Their source of origin determines their shape and composition. Primary MNP are intentionally manufactured in small sizes for different applications, including personal care and cleaning products, and pre-production pellets for fabrication of other plastic goods.The manufacture of **primary nanoplastics** will likely increase with their use in electronic devices, medicines, cars and airplanes.

Primary MNP are likely to be collected mostly intact in industrial and household sewage, and go through wastewater treatment (WWT) facilities before being discharged into the aquatic environment.

Secondary MNP originates from the breakdown of larger plastic pieces due to weathering by UV-radiation and physical defragmentation by mechanical forces. Thus, macroplastics will breakdown into microplastics, and these will further break down into nanoplastics. Their abundance and production rates will depend on environmental characteristics and polymer type, making secondary MNP input to oceans harder to trace, quantify and control than primary sources.

Emerging technologies for MNPs removal

MNPs enter the environment mainly through wastewater treatment plants (WWTPs), making it a priority to monitor MNPs in different wastewaters released along with the various kinds of sludge produced after wastewater treatment. In the aquatic environment, MNPs act as transmitters for the detrimental contaminants transferred in the planktonic food cycle and ultimately affect the fate of the environment. Different techniques have been employed to remove MNPs from wastewater. It can be performed by Raman spectroscopy and pyrolysis–gas chromatography/mass spectrometry (py-GC–MS) are the most popular analytical methods. However, the current spectroscopic methods are time-consuming and cannot cover the whole nano-range due to the detection limit of particle size; determination of the mass concentration of nanoplastics by the mass spectrometry methods are destructive, thus requiring extra/subsamples to obtain physical information of nanoplastics. The major caveat is that the quantification is often conducted without chemical confirmation of polymer types, raising concerns about the reliability of current results. It is also worth noting that recovery tests and blank controls, both of which are general steps in the quantification of conventional chemical pollutants, are rarely reported in nanoplastic studies. Therefore, more efforts should be made to enhance the reliability and accuracy of nanoplastic analysis in environmental samples, which can only be achieved with strict chemical confirmation and adequate quality assurance along with the whole analytical process.

Conclusion

The main reasons behind the release of MNPs in the environment include extensive use, inadequate management, and mishandling of disposed plastics. Ships, fisheries, shoreline activities, untreated sewage, and treated effluents from municipal and industrial wastewater treatment plants are routes of how primary and secondary microplastics enter the environment. Storms, accidents, and unprofessional or illegal disposal of plastic waste are possible pathways for the entry of MNPs into the environment. Three factors determine the dispersion of MNPs including transport mechanisms, distance between source and sink, and type of polymer released. Recent detections of MNPs in the atmosphere of metropolitan, suburban, and even remote areas suggest that MNPs may be transported long distances by the atmosphere. Road traffic, vehicle movement, tire friction, and road surface are major sources of atmospheric MNPs. As well as wind removing MNPs from large cities, soil dust from agricultural processes is another means of introducing MPs to the atmosphere. The abundance of MPs in terrestrial environments is increased with the use of plastics in agricultural processes and the use of biosolids as fertilizers; however, very little information regarding their fate and transport is available. PP, low-density polyethylene (LDPE), high-density polyethylene (HDPE), and PS, a polymer commonly used for packaging, were the most common polymers identified in the aquatic bodies investigated. Plastic pellets primarily came from plastic-processing plants in the vicinity of the study sites. Low specific density microplastics are positively buoyant, which means they can potentially be transported a long distance at the ocean's surface (or in its water column). In sub-tidal sediment, high-density microplastics are accumulating because they are negatively buoyant and sink rapidly to the seafloor. Micro- and macro-organisms overgrow and increase specific density, resulting in MPs losing buoyancy and sinking. Pellets are transmitted over oceans depending on their buoyancy, weight, and ocean tides.