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Microplastics And Its Menance In The Environment

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Abstract:

The widespread presence of tiny plastic particles, specifically microplastics (100 nm–5 mm) in various ecosystems is becoming a significant environmental issue. Adding to these worries is the fact that microplastics (MNPs) possess different characteristics compared to their larger counterparts; therefore, their complete biological and ecological effects remain largely unknown. Currently, evidence suggests that these small plastic particles can release harmful plastic additives and can absorb a variety of chemicals, acting as reservoirs for various toxic substances, which increases their bioavailability, toxicity, and movement. Additionally, there is a potential risk of MNPs transferring through the food chain to humans and other higher organisms after being consumed by lower life forms. Additionally, there is a risk that microplastics (MNPs) could be transferred through the food chain to humans and other higher organisms after being consumed by lower species. Consequently, this paper provides a thorough evaluation of our present understanding of the environmental repercussions associated with MNPs. In this context, the characteristics, origins, and harmful effects of MNPs on various ecosystems, especially concerning living organisms, were explained. Likewise, the negative impacts of these particles on humans, along with ongoing and future initiatives aimed at reducing these harmful effects, were examined. Lastly, the planet's natural self-cleansing mechanisms involving a variety of decomposer organisms in relation to these synthetic particles were also emphasized.

INTRODUCTION

Microplastics are smaller plastic waste fragments. They are one of the factors affecting the balance of aquatic ecosystems due to their toxic compounds which endanger many aquatic organisms. It is estimated that the amount of micro plastics waste that pollutes the aquatic environment will reach 250 million tons in 2025 (Mrowiec, 2017). Micro plastics are plastics that range from 0.1 µm to 5000 µm. Micro plastics waste that can be found in marine water are in the form of fragments, fibres/filaments, beads/spheres, films/sheets, and pellets (Lusher et al., 2015). There are two kinds of micro plastic, namely primary microplastic and secondary microplastic. Primary microplastics are micro-sized plastic particles that are commonly used in various industries such as cosmetics. Meanwhile, secondary micro plastics are microplastics produced from the fragmentation of macroplastic waste.

Microplastics result from macro plastics that are degraded by UV light into small fragments (Morohoshi *et al.*, 2018). They also produced many cosmetic products. Besides, microplastics are also widely produced as cleaning agents such as toothpaste and facial wash soap. Plastic particles can be found in various parts of the ocean or waters. It depends on the relative density of plastic particles to the seawater. They can be found on the surface of the water and in the water column (Harrison *et al.*, 2018 and Oberbeckmann 2020). Plastic types of polyolefins, PE, PP, and PS are the most common plastic groups found as micro plastics on the surface of marine water (Galgani *et al.*, 2018). The existence of plastic waste in the aquatic environment is determined by its buoyancy. The larger plastic waste will have a higher buoyancy and be scattered over the surface or water body. Meanwhile, smaller plastic waste such as fragments has lower buoyancy, therefore it's easily sinking in the sediment due to biofouling. Microplastics are one of the main factors contributing to environmental issues (Oberbeckmann and Labrenz, 2020).

IMPACTS OF PLASTIC ON ENVIRONMENT AND HUMAN HEALTH

Effects of plastics on the environment

Throughout the entire life cycle of products, from the extraction of raw materials to waste management, plastics pose threats to environmental health. The extraction and transportation of fossil fuels needed for plastic production releases considerable quantities of chemical pollutants imposing risks to the ecosystem and air quality (Hamilton and Feit, 2019). Workers in the petrochemical industry and people living in the vicinity of oil plants are particularly vulnerable to being exposed to these environmental pollutants (Colborn *et al.*, 2011). The production of plastics contributes significantly to climate change. Throughout their lifecycle, plastics produce 3.4% of global greenhouse gas emissions, of which 90% are emitted during the production phase (Hamilton and Feit, 2019). Once products are used, poorly disposed plastics accumulate in the environment leading to contaminations of the marine and terrestrial environments. In terrestrial environments, plastic pollution affects water infiltration, the microbiome and the structure of soils, with possible implications for agricultural productivity (Ng *et al.*, 2018; de Souza Machado *et al.*, 2019). Burning plastics, a common means of managing waste around the world, emits toxic smokes and ashes. These emissions also impact the environment through contamination of soil, water and accumulation on the food chain (plants and animals)(Cormier *et al.*, 2006; Verma *et al.*) .

While dumping plastic on open landfills, Microplastics (MPs) get formed with the surrounding environmental factors (pressure, humidity, temperature, etc.) MPs can easily be passed and mixed with the environment (soil, water, storm) and get accumulated in the human body by various exposures like consumption of food, dust inhalation, water contamination, etc. As MP's pollution in soil results in health and ecological risk, it has become a serious concern and needs to be addressed properly (de Titto and Savino, 2019).

Effects of plastics on humans

There is no gainsaying that plastics have contributed immensely to the rise of human civilization; however, the distribution of plastic debris (macro-, micro-, and nanoplastics) in the environment and its entrainment into biological systems has become a serious issue (Fadare *et al.*, 2020). Humans are exposed to plastics from several sources, including food, water and consumer products through three main routes: ingestion, inhalation and dermal contact.(Prata *et al.*, 2020; Rahman *et al.*, 2021; Yee *et al.*, 2021) Recent evidence indicates that humans consume on average 0.1–5 g (or 0.004–0.18 ounces) of micro- and nano-plastics (smaller than 100 nm) weekly, but the exposure–outcome relationship is yet to be characterised and fully understood.(De Wit and Bigaud, 2019; Senathirajah *et al.*, 2021; Yee *et al.*, 2021)

There is some evidence suggesting that plastics are toxic through their chemical properties. Plastics are composed of chemicals added in their manufacturing process such as bisphenol A, phthalates, brominated flame retardants or plasticizers, most of which are recognised as priority pollutants by the US Environmental Protection Agency (Bucci *et al.*, 2020).Besides the toxicity from the chemicals primarily used in plastic manufacturing, plastic waste can also bind to other chemicals in the environment resulting in more complex toxic compounds (Coffin *et al.*, 2021). Plastics pose further health threats through the misuse of non-food grade packages for food products, a practice increasing exposure to chemical pollutants and prevalent in some settings (Hennebert, 2020). Overall, exposure to these chemicals contained in plastics could lead to a wide range of diseases and health conditions of public health relevance. These effects include chronic diseases such as cancers, diabetes, obesity, fertility problems (sterility), gastrointestinal problems (liver and microbiome), neurotoxicity and chronic inflammation (Vethaak and Leslie, 2016; Prata *et al.*, 2020; Rahman *et al.*, 2021; Yee *et al.*, 2021) In addition, micro-plastics and nano-plastics could have additional toxic properties because of their ability to cross biological membranes such as the brain or the placenta given their small size (Vethaak and Leslie, 2016; Yee *et al.*, 2021).

A growing body of evidence shows that macro and microplastics debris are favourable breeding environments for vectors and pathogens, especially in populated areas with poor sanitation (McCormick *et al.*, 2014; Vethaak and Leslie, 2016). Pathogenic organisms carried by plastic on land and in water include human pathogenic bacteria, mosquitoes transmitting Zika and dengue and schistosome-carrying snails (Vethaak and Leslie, 2016).

Various health conditions such as thyroid dysfunction, obesity, diabetes, and reproductive impairment have been attributed to plastic pollution. For example, it has been shown that nanoplastics impact negatively the composition and diversity of microbial communities in the human gut, which, considering emerging research evidencing the strong relationship between the gut and neural networks in the brain, could negatively impact the endocrine, immune, and nervous systems (Teles *et al.*, 2020).

The genotoxicity of micro- and nanoplastics to DNA has been established. It has been demonstrated that if the plastic matter is small enough to cross the nuclear membrane surrounding the DNA, damage can occur, impairing the DNA structure or forming lesions, which, unrepaired or miss repaired, can cause mutagenic processes that are considered to play a role in the carcinogenesis of cells. Additionally, it was found that the type and level of damage of DNA depend on the shape, functional groups, and chemical composition of the plastic debris (Rubio *et al.,* 2020).

The human airway is a key pathway for plastic fiber entrainment into the lungs, and biopersistence of the fibers depends on their length, structure, and chemical composition. Moreover, at certain exposure limits, all plastic fibers are likely to produce inflammation, which can lead to lung challenges such as the formation of reactive oxygen species with the potential to initiate cancerous growth through secondary genotoxicity (Gasperi *et al.,* 2018; Rubio *et al.,* 2020). It has long been established that constituents of plastic packaging chemically interact with or migrate into fat-containing foods; typical interactions include the migration of antioxidants from the plastic packaging into the food, sometimes bonding to the food surface. Such transfer of packaging additives from the packaging material to its food content is a potential health risk. Furthermore, PET, a common plastic employed in the food and beverage industry, is a source of endocrine disruptors, these endocrine disruptors leach from the plastic packaging into the consumables that it contains. Even at standard room temperature, phthalates (potential endocrine disruptors) are known to leach from PET packaging into various food contents in the presence of water (Sax, 2010). The low thermal conductivities of plastic materials, although considered advantageous in certain applications (e.g., heat insulation) (Andrady and Neal, 2009), contribute to global warming when these plastics are distributed in aquatic environments; they displace equal volumes of water and restrict heat flow from the sun to the aquatic environment, leading to a rise in sea levels and the dissipation of energy into the immediate environment (Iroegbu *et al.*, 2020).

In this dynamic, the burden of pollution is the highest among the least powerful and most vulnerable groups, such as children, workers in the informal waste sector, communities living near burning sites and marginalised communities who are at the receiving end of most unmanaged plastic wastes and their polluting effects (Vethaak and Leslie, 2016; Landrigan *et al.*, 2020).

MARINE PLASTIC POLLUTION

Marine and coastal environment acts as a highly productive zone that consists of different kinds of subsystems, such as coral reefs and seagrasses. It is a complex environment with rich biodiversity ranging from various primitive (horseshoe crab) to the advanced organisms (dolphins). The marine environment is the vast body of water that covers 71 percent of the earth's coverage. However, the global ocean system divides into five major oceans and many seas based on historical, cultural, geographical, scientific characteristics, and size variations. All ocean basins act as ecologically and economically important systems for the betterment of humans. Freshwater lotic systems connect with oceans and seas, creating unique, transitional ecosystems like lagoons and estuaries (Thushari and Senevirathna, 2020). The continental shelf of the marine environment is the mixing place of seawater and freshwater; therefore, this area creates a unique coastal ecosystem.

Marine ecosystem plays a vital role in supplying the world wealth of ecosystem services such as food security, carbon storage, waste detoxification and cultural benefits (e.g., recreational opportunities and spiritual enhancement)(Liquete *et al.*, 2013).Human threats such as disposal of plastic waste directly or indirectly into the marine ecosystem have negatively impacted the wellbeing of both human and marine ecosystems (Liquete *et al.*, 2013; Naeem *et al.*, 2016; Galloway *et al.*, 2017). In fact, as time goes by, these plastic wastes may fragment into smaller pieces of around 0.1 mme5 mm (i.e., microplastics) scattered in the environment over geological timescales, leading to the need of time intensive, high cost and laborious management in removing these marine plastics (Jambeck *et al.*, 2015).

Aquatic ecosystems are interconnected with the terrestrial environment; therefore, changes in one system have impacts on another (Adams, 2005). These include pollution and the physical destruction of the environment. Debris or litter accumulation is one of the human-created severe threats on marine and coastal systems due to unsustainable development and construction activities. Compared with other categories of debris such as glass, cloth, paper, food waste, metal, rubber, medical/personal hygiene-related items, smoking/firework items, and wood (Rosevelt *et al.*, 2013), plastic litter is persistent in the ocean basins due to unique characteristics of plastics. Plastic debris with counts of five trillion, weighing more than 260,000 tons, is floating over the world's ocean surface as a result of improper waste disposal. Currently, plastic pollution has become a serious concern over almost all parts of ocean basins irrespective of developed or underdeveloped regions in the world. There are a variety of potential impacts plastic can have within the marine environment. The European Union Marine Strategy Framework Directive (MSFD) expert group on marine litter recently concluded that plastics present a "large scale and serious threat to the welfare of marine animals."(Werner *et al.*, 2016) More than 700 species of marine organisms have been reported to encounter plastic debris, which can result in severe physical harm or death, or more subtle effects on behaviour and ecological interactions (e.g., the ability to escape from predators or migrate) (Gall and Thompson, 2015; Kühn *et al.*, 2015).

The accumulated plastics in the ocean basins can be broadly classified into four levels based on their sizes: mega plastics, macro plastics, meso plastics, and microplastics. Microplastics are mostly abundant in marine and coastal systems, while synthetic pollutants chemically interact with organic pollutants and metals (Guo and Wang, 2019). The density of microplastics also affects the distribution of microplastics in the water column. Polypropylene (PP) and polyethylene (PE) float in water due to low density of plastics, while polystyrene (PS), polyvinyl chloride (PVC), polyamide (PA), and polyethylene terephthalate (PET) with higher density do not float in water, but deposit by inclination through the water column(Guo and Wang, 2019). Accordingly, microplastic pollutants are widely distributed in every sub-zone/layer (pelagic and benthic) of coastal and marine systems. Salinity is one of the key factors affecting the chemical degradation of plastic. Hence, coastal and marine systems, which range at approximately 0.5–35/00 (ppt: parts per thousand) of salinity, are highly susceptible to the formation of microplastics.

Plastic pollutants are abundantly accumulating in these zones with adverse effects on ecological aspects, including biodiversity, economic activities, and human health (Wang *et al.*, 2018). Microplastics are ingested by different kinds of marine organisms (Cole *et al.*, 2013; Galloway *et al.*, 2017; Leslie *et al.*, 2017). Evidence on microplastics in the aquatic environment (Cózar *et al.*, 2014; Martin *et al.*, 2017) signifies the alarm on environmental issues caused by plastic pollution.

The most visible effect of plastic pollution on marine organisms is entanglement of organisms in marine debris, often in discarded or lost fishing gear and ropes (Baulch and Perry, 2014). Entangled organisms can be hindered in their ability to move, feed, and breathe. In addition, many marine organisms mistake litter for food and ingest it(Lazar and Gračan, 2011; Wright *et al.*, 2013; Kühn *et al.*, 2015; Lusher *et al.*, 2015). Ingestion of plastics by sea turtles (Shomura, 1985) and seabirds (Shomura, 1985; Harper and Fowler, 1987) was first documented in the 1960s. Recently, microplastics were reported in all digestive tracts of ten species of marine mammals stranded around the British coast (Nelms *et al.*, 2019).Laboratory studies predict uptake of even smaller particles, in the nano-size range, may be rapid. Laboratory experiments have shown that ingested plastics may accumulate in the stomach of organisms and affect individual fitness, with potential consequences for reproduction and growth (Wright *et al.*, 2013; Avio *et al.*, 2015).It was also observed that microplastics 31.5 µm in size, in the digestive systems of planktonic crustacean were alternated to <1 µm in diameter

Dawson *et al.* (2018) suggesting that secondary nanoplastic could also be produced by fragmentation of microplastic inside the digestive organ of animals after ingestion (Wagner *et al.*, 2014). Plastics may transfer contaminants sorbed from surrounding water, such as endocrine disruptors and persistent organic pollutants (Teuten *et al.*, 2007; Rochman *et al.*, 2013; Napper *et al.*, 2015; Wang *et al.*, 2016).Additive chemicals can be present in high concentrations and it is considered their release could provide an important pathway for chemical transfer to biotab (Oehlmann *et al.*, 2009; Tanaka *et al.*, 2013).For example, a recent study in Korea demonstrated that potentially harmful flame retardants could be released from buoys used in an aquaculture facility, leading to elevated concentrations of flame retardants in the surrounding environment(Al-Odaini *et al.*, 2015).Marine plastics may also cause more greenhouse gas emissions due to impacting ecosystems responsible for the gas exchange and circulation of marine CO_2(Shen *et al.*, 2020).

The substantial quantities of plastics that are entering aquatic habitats daily can present a range of negative economic and environmental consequences (Mouat *et al*., 2010; Jambeck *et al.*, 2015). Plastic debris can have negative economic consequences on navigation, aquaculture, tourism, and fisheries. Stranded plastic along shorelines creates an aesthetic issue, which has negative impacts for tourism (Jang *et al.*, 2011). In terms of fisheries, plastic litter can reduce or damage catches and vessels. There is also emerging EVIDENCE that even small quantities of litter on beaches may have a negative effect on human well-being (Wyles *et al.*, 2016).

SOURCES OF PLASTIC ACCUMULATION

Plastic wastes are accumulated in the aquatic ecosystems directly and indirectly by different kinds of sources. Land and ocean-based sources are critical sources of plastic pollution in coastal and marine ecosystems through in-situ and ex-situ pathways. Major land-based plastic pollution sources are freshwater input, residential & domestic activities, tourism, and other economic actions, including harbor operations. Over 75% of marine plastic litter items are accumulated from land-based sources (Andrady, 2011). Coastal zone is a highly residential, urbanized, and industrialized area. Air blasting and cosmetics used by coastal residents could directly discharge into the coastal zone. In some cases, these plastic containers are released into the wastewater treatment systems or drainage systems. (Browne et al., 2007) revealed that a significant amount of plastic debris release or escape even from the treatment systems. After that, such plastic debris accumulates into the natural freshwater ecosystems such as rivers and streams or subject to leachate into the groundwater and finally end up in the ocean. However, lotic freshwater ecosystems with directional, fast flow rates mainly lead to the accumulation of plastic debris in coastal areas (Browne et al., 2007; Moore, 2008). Plastic debris in beaches carries into the ocean as microplastic fragments and secondary plastics (Cole *et al.*, 2011). The main source of those fragments was the breaking down of larger size plastic debris accumulated on the beach, while the major sources of plastic pellets were from the operational activities of nearby port facilities (Costa *et al.*, 2010). Another potential cause of plastic pollutants is persistent fishing fleets, based on the literature records (Ivar do Sul *et al.*, 2013).

The plastic accumulation rate in the ocean also enhances from land based sources with prevailing extreme climatic conditions such as storms, hurricanes, and flooding (Thompson *et al.*, 2005).

Plastic debris from the beach enters the ocean through coastal water currents. Sometimes, monofilament and nylon fishing nets are disposed of at harbour operations in the shore area and float over the ocean surface. Floated nylon debris drifts over the ocean at different locations by the effect of ocean currents (Cole *et al.*, 2011). Offshore activities such as commercial fishery, navigation actions, waste disposal, and shellfish/fish culture are key ocean-based sources that contribute to plastic debris accumulation into the marine and coastal zones. Offshore fishing and aquaculture-related operations have been identified as a significant source of plastic pollution into the ocean basins and coastal ecosystems by the number of literature records. Damaged fishing nets and abandoned, lost, or discarded fishing nets can enter the offshore by fishers during fishing operations

Maritime and navigation activities are also another source of plastic accumulation in the offshore area of the sea. Marine vessels, intentionally or unintentionally, dump plastic litters into the ocean, with an accumulation rate of approximately 6.5 million tons per year into the deep sea by early 1990 (Derraik, 2002; Cole *et al.*, 2011).Accidental disposal of plastic litter items during transportation through a terrestrial environment or ocean can cause the flowing of plastics into the sea directly or indirectly. In Particular, improper use of plastic packaging materials causes the accumulation of plastic litter into the aquatic environment and the ocean systems (Cole *et al.*, 2011). Synthetic polymers have also been recorded in sub-surface plankton samples around Saint Peter and Saint Paul Archipelago in the Equatorial Atlantic Ocean with an increase in average plastic densities. Plastic materials can be transported over vast distances by ocean currents (Ivar do Sul *et al.*, 2013).

Plastics can enter the marine ecosystems as primary and secondary plastics. The larger plastic fragments sometimes directly release as megaplastic and/or macroplastic debris and convert into microplastics within the environment. Primary microplastics are the plastic debris manufactured with a microscopic size range, whereas secondary plastics are formed after exposing larger plastic debris for different forces and break down into tiny plastic debris. A fraction of the above light weight larger plastics floats on the sea surface, while the remaining portion with high density sinks into the benthic environment of the ocean due to higher molecular weight. Macroplastics are highly susceptible to degradation into micro size plastics by subjecting to different processes such as degradation; photo-degradation, mechanical degradation, and hydrolysis. Biodegradability of plastics is also essential to understand their fate and destination in the respective environment and identify size variations of plastic pollutants accordingly after subjecting to degradation.

In the open environment, macroplastic fragments are exposed to chemical, biological, physical, and mechanical processes and change the typical properties of plastics such as structure and integrity. As a result, large plastics degrade into minute plastic fragments in the environment (Barnes *et al.*, 2009; Andrady, 2011). Fundamental forces leading to degradation of macroplastics are ultra-violet (UV) radiation (Photo-degradation) and wave abrasion physically. During photo-degradation of plastics, sunlight with UV rays is subject to degradation of large plastics through oxidation of polymer plastic and breakdown of structural integrity. In the beach ecosystem, macroplastic fragments are directly exposed to the sunlight, and the degradation rate is higher with the presence of more Oxygen (Barnes *et al.*, 2009; Andrady, 2011). The plastic fragments with reduced structural integrity are further exposed to the physical and mechanical forces such as wave turbulence and abrasion (Barnes *et al.*, 2009). Finally, macroplastics rapidly convert into minute particles during the degradation process. This process continues until plastics become microscopic in size, and microplastic fragments further cleavage into nano-plastic particles in some cases (Fendall and Sewell, 2009). Oxidative characteristics in the atmosphere and hydrolytic properties of seawater (salinity) profoundly affect the degradation rate of plastics (Webb *et al.*, 2012), and a saline environment with prevailing lower temperature reduces the photo-degradation rate of plastics(Cole *et al.*, 2011; Webb *et al.*, 2012).

CONCLUSION

Since microplastics have unique qualities including buoyancy, resilience, lightweightness, and forms, they have been seen to travel great distances around the earth. Nonetheless, it has been determined that the primary sources and transport routes of MNPs into aquatic environments and the atmosphere are terrestrial ecosystems. The increased concentration of MNPs in these settings, reinforced by their unique properties, has made it possible for them to enter microorganisms and other lower-level organisms, particularly marine biota like phytoplankton, and eventually move up the food chain. They penetrate these organisms and build up in their different organelles and organs, causing oxidative stress and other harmful effects.
Nonetheless, it has been determined that the primary sources and transport routes of MNPs into aquatic environments and the atmosphere are terrestrial ecosystems. The increased concentration of MNPs in these settings, reinforced by their unique properties, has made it possible for them to enter microorganisms and

other lower-level organisms, particularly marine biota like phytoplankton, and eventually move up the food chain. On entering these organisms, they accumulate in their numerous organelles and organs, eliciting varied harmful effects largely via oxidative stress. However, because MNPs are growing in the environment at a faster rate than anticipated, the various scientific initiatives to lessen their detrimental impacts on living forms have not been as successful as anticipated.

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