The Impact of Microplastics on Marine life and Human Health

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Abstract

Microplastics are up to 1 µm, whereas the size of nano plastics are less than 1 µm and widely used in daily life. More than 98% of the microplastics in the ocean come from land-based activities. In contrast, secondary Microplastics are formed from plastic bottles and breaking down of large Plastics. Microplastics, when combined with microbial toxic substances and chemical toxicity, can potentially have adverse impacts on life. It emphasizes the need for further investigation and proposes essential and analytical research that is crucial for policymakers and scientists. Government and funding organizations should allocate funds specifically for micro plastics research. To facilitate comprehensive research on microplastics, foster collaboration among governmental bodies, academic institutions, and non-governmental organizations (NGOs). The sources and effects of micro plastics give in Fig. 1.

Keywords: Nano particle, Cell Morphology, Chemical additives, Bio films. Hydro phobic, Genetic Material

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Introduction

Plastics are commonly used in everyday life due to their lightweight nature, long-lasting properties, and affordable cost (Meng et al., 2020). Since 1950, there has been a significant increase in worldwide plastic output, surpassing 2791 million tons as of 2022 (Cai et al., 2022). Assuming the current situation persists, wastage of plastics is projected to reach 12 billion metric tons by the year 2050, as stated by Sobhani et al. (2020). Microplastics are often characterized as particles 1 µm to 5 mm in size, exhibiting a solid state or polymeric matrix (not soluble in water) (Frias and Nash, 2019). On the other hand, plastics are 1 nm to 1000 nm classified as nano plastics. These nano plastics exhibit colloidal properties Gigault et al. (2018), and hazardous to fresh and marine water species (Gigault et al., 2021). Nano plastics may not be harmful directly for aquatic life however their negative impact is enhanced after being mixed with environmental pollutants. Microalgae, being primary producers are responsible for oxygen production in aquatic ecosystem and they are also associated with the presence of microplastics (Wu et al., 2019 Guschina et al., 2020; Wang et al., 2020; Su et al., 2022). Microplastics originating from land are primary contributors to the problem of aquatic plastic pollution (Li et al., 2016). According to Meijer et al. (2021), around 1.5% (with a range of 1.2-4.0%) of the total 67.5 million unmanaged plastic garbage produced worldwide enters the ocean annually. Hence, it is crucial to examine the impact of microplastics on microalgae. Table 1 provides evidence from considerable research indicating that microplastics (MPs) have a detrimental impact on microalgae, specifically resulting in growth suppression and damage to cell morphology (Wang et al., 2019).

What are Micro Plastics?

Micro Plastics are up to 1 µm, whereas the size of nano plastics are less than 1 µm (Gigault et al., 2018). Plastic's versatility makes them ideal for a broad variety of product transformations (Umoren and Solomon 2019; Wu et al., 2020; Wang et al., 2021; Yong and Zhang 2021). These include molded components, extrusion sections, fibers, films, sheets, and coatings. Adhesives, paints, and other polymers all contain plastics as one of their main ingredients. The most prevalent plastics are polyethylene, polyethylene terephthalate, polyester, polypropylene, and polystyrene, respectively (Andrady, 2011). Nanoplastics are synthetic polymers that have chemical additives or plasticizers added to make them more resistant, durable, and flexible (Rochman et al., 2013; Seyoum and Pradhan, 2019). Microplastics are widely employed in consumer items such medication, cosmetics, toothpaste, face cleansers, and waterproof coatings. The fact that the majority of plastics do not biodegrade has made plastic pollution an ever-present threat to ecosystems (Li et al., 2016). There have been reports of plastic pollution in several environmental compartments, including the Arctic (Halsband and Herzke, 2019), the Yangtze River (Xiong et al., 2019), and the Mariana Trench (Peng et al., 2018). Due to the far-reaching consequences of plastic pollution on aquatic ecosystems, the issue has garnered considerable international attention and concern.

Types of Micro Plastics

Primary and secondary microplastics are the two main types. Many different industrial and household processes contribute to the production of primary microplastics (Perumal and Muthuramalingam, 2022). More than 98% of the microplastics in the ocean come from land-based activities. In contrast, secondary Microplastics are formed from plastic bottles and breaking down of large Plastics. Microplastic enters in aquatic ecosystem via three main pathways, runoff from roads, treatment of polluted water, and wind transfer (Fiore et al., 2022). Natural light and oceanic currents are major factors, lead to Plastics breakdown and Production of Micro Plastics. Fishing nets only offer a 2% yield of Micro plastics (Boucher and Friot, 2017). The environmental exposure of microplastics, the development of bio films, and the absorption of chemical pollutants all contribute to their complexity (Burns et al., 2018). Some sources of Micro plastics are shown in Figure 2.

Fig. 1: Sources and effects of micro plastics

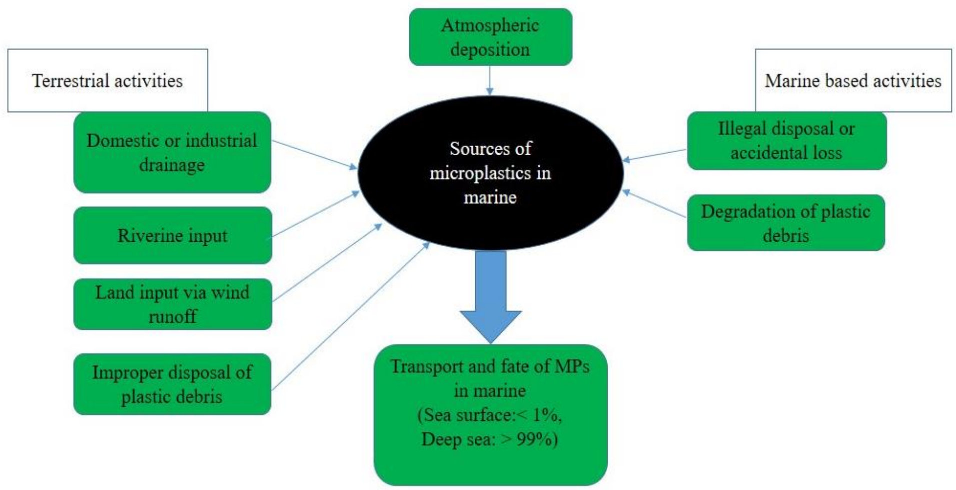

Fig. 2: Depicts the source of Micro Plastics in marine

Effects on Human Beings

Aquatic organisms are also important constituent of human diet which is important source of micro plastics and nano plastics also. Many authors reported the presence of considerable quantity of micro plastics in mussels (Nelms et al., 2016) Respiratory system is also responsible for the entrance of microplastics (Gasperi et al., 2018). Nano plastics enter in human blood stream through lungs and spread out in the whole body (Lehner et al., 2019).

Microplastics greatly affect the physiology and functioning of different organs. Human chemical coordination consists on endocrine and exocrine systems which secreted hormones and control the function of the different organs and systems. Urinary system, cardiovascular system, reproductive mechanism, liver and central nervous system affected greatly by micro plastics (Schubert 1972; Cingotti & Jensen, 2019). These substances affect the feedback mechanisms of hormonal system, mechanism of response of the different body systems and organs (Olea-Serrano et al., 2002; Miyagawa et al., 2016). Microplastics may cause cancer of breast and gonads, respiratory disorders and enhance the risk of diseases in many countries of Europe due effect on nervous and immune system of humans (Cingotti & Jensen, 2019).

Microplastics are found in digestive tract of humans especially in the lining intestine which cause the harms in cellular membrane system, transport mechanisms and placental structure and functions (Barboza et al., 2018). Micro plastics are hydrophobic, stable and more resistive, toxicity and hazards for human's increases due to these features (Wright & Kelly 2017). Micro plastics upset the biochemical process, enzymes kinetics, and uptake of food and bioenergetics (Bhuyan, 2022). Micro plastics affect the brain functions, neural transmission and cause acidity and toxic effects (Mohan-Kumar et al., 2008; Deng et al., 2017).

Prata (2018), reported that micro plastics severely damage the genetic material and oxidative stress which cause the different types of cancer. Microplastics are also carrier for pathogens, due to these pathogens serious infections are caused reported Prata et al. (2020) reported that the large surface area makes the micro plastics favorable for bacterial and viral attachment. Many authors reported that micro plastics more harmful when it contacts with pathogens and other pollutants (Bakir et al., 2014; Rodrigues et al., 2019). A number of pollutants and harmful chemicals with low molecular weight are attached with micro plastics and causing DNA damaging, toxicity.

Effects of Microplastics on Algae

Microplastics in aquatic ecosystem are quickly taken up by microalgae, resulting in movement along the food chain and effect the human health also. Microalgae serve as the base of aquatic food chains, the impact of micro plastics on these organisms could have cascading consequences for ecosystems (Pinto et al., 2023). A correlation exists between particle size and toxicity, with smaller dimensions being associated with increased toxicity in microalgae (Nava and Leoni, 2021). Microplastics inhibits the photosynthetic reactions of microalgae (Xu et al., 2023). Furthermore, MPs impede the proliferation of microalgae by many mechanisms, Firstly, MPs, when attached to the surface of microalgae or present inside the cells, damage the cell walls and membranes and effects the transport system (Nava and Leoni, 2021). Secondly MPs that attached to the surface of microalgae can impede the passage of light and effect the photosynthesis (Ye et al., 2023). Microalgae release exopolymeric substances (EPS) in response to stress caused by their interaction with plastic particles. This promotes the formation of hetero-aggregates, which reduce the availability of light.

Table 1: Toxic Effects of microplastics on Algae

Species name	Polymer type	Size of microplastic	Effect mechanism	References
P. tricornutum	Polymethyl methacrylate (PMMA) and Polystyrene (PS)	70–80 for PS and 40–60 for PMMA	Pigments, carbohydrates, and Biomass production severely decreased	(Cunha et al., 2020)
M. flosaquae and *C. pyrenoidosa*	Polypropylene (PP) Polyvinyl Chloride (PVC)	D_{90}: 21 D_{10}: 236	The presence of large amounts of microplastics hindered the process of photosynthesis in algae.	(Wu et al., 2019)
Chlorella. reinhardtii	v-PVC, a-PVC	50 to 100	Decrease in chlorophyll-a concentration; occurrence of oxidative harm	(Wang et al., 2020)
C. sorokiniana	Polystyrene	<70	PS caused a disturbance in the lipid composition by decreasing the levels of two important fatty acids, linoleic and linolinic.	(Guschina et al., 2020)
C. vulgaris	Polyethylene, polypropylene	77.75; 59.88; 57.41; 53.33	The presence of this molecule hinders the growth of microalgae, while also stimulating the production of photosynthetic pigments and the development of antioxidative compounds. diverse combination of microplastics (MPs) and microalgae	(Su et al., 2022)
Rhodomonas lens	HDPE + CPF + Hg	10–15	Influence the viability of cells, the rate of population increase, and the amount of pigment present.	(Pinto et al., 2023)

Effect of Microplastics on Fishes

There is evidence from scientific studies that micro plastics are harmful to fish because they can damage the digestive tract, change their feeding behaviour, and decrease nutrient absorption, influence immunological functions, growth rates, and reproduction (Lu et al., 2021). According to Koelmans et al. (2022), microplastics have the potential to bio accumulate in fish and pollute the whole food chain as well as human health also, which raises concerns about their long-term effects. Microplastics can also cause stress reactions, which have an impact on the physiology and general health of fish (Wright et al., 2013).

Effect on Mammals

Sharks can come into contact with micro plastics through their gills or by eating. Damage to their digestive systems, nutritional obstruction, and change their feeding behaviour might result from micro plastics. Break down of micro plastics in the digestive tract, they may release persistent organic pollutants (POPs), which can cause chemical toxicity. Microplastics and related chemical contaminants have the ability to bioaccumulate in whale tissues, which adds to their harmful effects. The presence of microplastics in seals' stomachs suggests that they may have come into contact with these particles. Toxins may be transferred to higher trophic levels and chemical toxicity can occur when microplastics are consumed (Siegfried et al., 2017).

Physical Method for Micro Plastics Removal

Studies reveal that adsorption, sedimentation, filtration, etc is categorized as physical approaches for removal of micro plastics. Utilizing a novel adsorbent is the most effective method for eliminating MPs through adsorption. Misra et al. (2020) created a composite material consisting of a magnetic polyoxometalate-supported ionic liquid phase. This composite was able to eliminate over 90% of PS beads that are1 to 10 µm in size (Misra et al., 2020). The details of physicals methods are given table 2.

Limitations and Future prospective

The examined articles all exhibit deficiencies that continue to restrict our understanding of the impact of MPs on ecosystems. The precise concentrations of micro plastics in the soil and water are currently unknown. This is a result of the limited occurrence of biodegradable polymers. Consequently, recent investigations employ either estimated quantities, including exceedingly high levels. Precise measurement of the levels of micro plastics (MP) in the environment is necessary in order to effectively replicate the actual pollution conditions in future studies (Malafeev et al., 2023).

Table 2: Removal of microplastics by physical methods

Methods	Principle of Technique	Efficiency	Microplastics type	Advantages	Disadvantages	References
Magnetic Polyoxometalate-Supported Ionic Liquid Phases	Physisorption	Almost 90 %	Polystyrene	1. The device has the capability to identify and eliminate contaminants in water, including organic compounds, inorganic substances, and microplastics. 2. Optimal effectiveness.	1. Only relevant for polystyrene (PS) microplastics ranging in size from 1 to 10 micrometers (µm).	(Misra et al., 2020)
Biochar adsorbents	Physisorption	100 %	All microplastics	1. Maximum adsorption capacity. 2. Highly efficient. 3. Very cheap.	1. Not effective for eliminating MPs that are of micrometer size.	(Siipola et al., 2020)
Zirconium metal-organic frame-work based foams	Filtration	96%	All microplastics	1. Efficient removal of MPs in both freshwater and marine water environments. 2. Applicable for the elimination of MPs in all types of suspensions, regardless of their concentrations. 3. Solar-powered automatic filtering system. 4. Recycleable	1. Large-scale filtration experiments, which are often conducted in laboratories, are essential for practical applications.	(Chen et al., 2020)
Rapid sand filter	Filtration	97.5 %	All microplastics	1. Very cheap 2. Easy to handle 3. Applicable for all types of MPs	1. Only effective on >20 µm size of MPs.	(Talvitie et al., 2017)
Disc filter	Retention	89.5 %	All microplastics	1. Highly efficient 2. Very cheap 3. Easy to handle	1. Not useful for smaller MPs 2. High maintenance required	(Talvitie et al., 2017)
Dissolved air flotation	Floatation	95.5 %	All microplastics	1. Highly efficient	1. Useful only for low density particles	(Talvitie et al., 2017)
Magnetic carbon nanotubes	Physisorption	99 %	All microplastics	1. Highly efficient	1. The efficiency diminishes with repeated use.	(Tang et al., 2021)
Coagulative colloidal gas aphrons	Physisorption	94. 5 %	Carboxyl-modified poly-(methyl methacrylate) (PMMA) and unsurface-coated polystyrene (PS)	1. Highly efficient 2. Efficiency not affected by salanity	1. Size dependent efficiency	(Zhang et al., 2021)
Non-fluorinated superhydrophobic aluminum surface	Physisorption	99.5 %	Polypropylene	1. Applicable in natural condition 2. Highly efficient	1. Efficiency only examined with 262 µm size of MPs	(Rius-Ayra and Llorca-Isern, 2021)
Graphene oxide and Chitin made up with sponges	Physisorption	The percentages for clean polystyrene, amine-modified polystyrene, and carboxylate-modified polystyrene are 9.8%, 88.9%, and 72.4% respectively.	Polystyrene, amine-modified polystyrene and carboxylate-modified polystyrene	1. The sponge's reusability, biodegradability, and biocompatibility enhance its suitability for removing MPs.	1. Complicated	(Sun et al., 2020a)
Magnetic micro-submarines	Induced fluid flow	70 %	All microplastics	1. Easy to handle 2. Environment friendly 3. No chemical required 4. High adaptability 5. Good efficient	1. Less efficient than other methods 2. Very expensive	(Sun et al., 2020b)

Retention of microplastics in a large-scale secondary wastewater treatment system	Sedimentation	91. 8 %	All microplastics	1. Low cost 2. Harmful chemicals not required	1. Not applicable for smaller MPs	(Gies et al., 2018)
The combination of chemical alum coagulant and alum with cationic polyamine-coated sand	Coagulation and flocculation	70.8 %–92.7 %	Polyethylene (PE)	1. MPs removal efficiency increased	1. Not applicable for smaller size MPs (10-30 µm)	(Shahi et al., 2020)

The existing research unequivocally demonstrates that the toxicological impacts of MPs on living species and ecosystems are contingent upon several elements, such as their composition, concentration, and size, in intricate ways. It is challenging to determine the specific impact of each component on the possible harms linked to MPs, as there is a scarcity of comparative laboratory studies that are capable of detecting the variations in these pertinent factors. Specifically, the surface-to-volume ratio of MPs greatly determines their degradation kinetics. In additions, analyses are necessary to close this gap in knowledge. Another constraint arises from the utilization of unaltered plastics, primarily inside tightly regulated environments (Wang et al., 2021).

An all-encompassing database is required to specifically address the relationship between microplastics, human and other animals, in order to elucidate the effects of micro plastics on animals and their ability to break down these pollutants. It is essential to investigate the molecular processes that explain how microplastics affect the functional genes and metabolism in mammals (Li et al., 2023).

Microplastics, when combined with microbial toxic substances and chemical toxicity, can potentially have adverse impacts on life. It emphasizes the need for further investigation and proposes essential and analytical research that is crucial for policymakers and scientists.

Future Studies should incorporate environmental scenarios that consider the concentration, shape, size, and aging of micro plastics. The existing research fails to provide a clear resolution to the ongoing dispute on the potential of micro plastics to serve as vectors for polluting aquatic systems (Avio et al., 2015). This is due to the fact that MPs micro plastics make up less than 3% of the diet in aquatic systems. It was also emphasized that the bioaccumulation of OCPs is low and does not generate any toxicological effects.

Now-a-days, there are no proper methods to quickly and accurately measure and identify pollutants that are attached to micro plastics and related groups. Hence, further investigations could prioritize this key domain. Scanning electron microscopy and high-throughput sequencing, along with techniques like DNA fingerprinting and gel electrophoresis have provided evidence that microbes and their appendages are connected to micro plastics. Nevertheless, further clarification is required about the specific manner in which the organisms are connected to micro plastics and the subsequent influence on genetic exchange (Tumwesigye et al., 2023).

Government and funding organizations should allocate funds specifically for micro plastics research. To facilitate comprehensive research on microplastics, foster collaboration among governmental bodies, academic institutions, and non-governmental organizations (NGOs). The utilization of open-access data repositories facilitates the seamless sharing of datasets and research findings pertaining to micro plastics. Develop workshops and training programs aimed at educating scientists on the techniques involved in sampling, analyzing, and identifying micro plastics (Thacharodi et al., 2023).

Conclusion

Micro plastics are used in a number of industries including cosmetics, medicines and packing industries. Occurrence of micro plastics in air, water, land and food items for human and animals are possible. The micro plastics in environments greatly affect the living organisms as well as whole aquatic and terrestrial ecosystems. Micro plastics hazardous for all type of life including plants, animals and human beings also. Micro plastics are more harmful when it combined with other pathogens and microbes. Micro plastics also affect the zooplankton, phytoplankton and fresh water organisms. It reduces the growth of organisms, metabolic reactions, reproductive mechanisms, nervous systems and sometimes deaths. Complete remediation of micro plastics from the environment is not possible but by using different strategies, the level of micro plastics can be reduced. So we need to investigate the new methods and strategies for the removal and remediation of micro plastic pollution Government and other funding agencies should allocate funds for micro plastics research, removal strategies and policies.

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