IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

MICROPLASTIC: A CURSE TO MARINE ENVIRONMENT WITH SOLUTIONS

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Abstract: The discovery of Microplastics inside marine animals is no more surprising. Plastics' durability makes them very resistant to disintegration. This review attempts to provide information regarding the sources, kinds and properties of microplastics which makes them persistent in marine environment for longer duration. Recently discovered toxic effects of microplastics on various marine species have been discussed. Moreover, study also provides insight towards appropriate biodegradable solutions to minimize the environmental impact of plastics. Different microbial strains have been bound to degrade a variety of microplastic particles.

***Keywords*:** Microplastic, Marine environment, Pollutants, Toxicity, Bioremidiation.

INTRODUCTION

Plastic has become more popular as a result of the growing global population, but academics are still concerned about how to handle the plastics' trash. With a history of roughly 60 years, plastic materials are relatively new. Following that, they have almost completely covered all aquatic environments (Van Cauwenberghe et al. 2013). The discovery of minute plastic fragments in the open ocean was made by Carpenter and Smith in 1972, and the term "Microplastics" was first used to describe these fragments by Thompson in 2000 (Thompson et al. 2004).The term "Microplastics" (MPs) refers to small plastic particles having a maximum size range of less than 5 mm, with smaller being 1µm -1 mm and bigger being 1-5 mm (Barboza et al. 2019). The degree of MPs pollution is actually higher in less developed places because of improper waste management, which might result in a massive influx of plastics from land into the oceans by 2025 (Jambeck et al. 2015).MPs are a source of concern for people all over the world because of their propensity to interact with and adsorb other environmental pollutants, their propensity to be eaten by marine life, and their propensity to linger in the environment for a long time (Fonte, Ferreira and Guilhermino, 2016; Jabeen et al. 2017). The "Trojan Horse" effect, a phenomenon that affects the uptake of hydrophobic organic compounds, has led to the suggestion that MPs could act as contamination vectors. Because of their very little dimensions, significant surface area and hydrophobic characteristics, MPs are likely to adsorb various substances on their surfaces, which may change how other pollutants bioaccumulate on them (Sun et al. 2022). Also According to various studies (Wu et al. 2021), a range of environmental contaminants can attach to the surface of MPs through phenomena such as electrostatic interactions , hydrophobic association, vander Waals interactions, pore filling, h-bonding, and p-p interactions. MPs might have a big impact on the bioaccumulation of other pollutants in aquatic species by acting as a conduit or vector for their transmission (Sun et al. 2022). According to Sangkham et al. (2022), synthetic plastic fibres generally degrade extremely slowly and remain in the environment for a very long period, posing long-term danger to the ecosystem and public health .Neurotoxicity and behavioural abnormalities, histopathological damage, metabolic and haematological changes, and embryotoxicity are only a few of the negative impacts that MPs may have on aquatic species (Hamed et al. 2019; Li et al., 2020). Without other pollutants or contaminants, MPs as well poses a number of indirect and direct threats to a diverse range of organisms, including physiological stress, altered energy storage , abnormal metabolic activity, disturbed immune function, behavioral issues, decreased fertility, ineffective digestion, severe intestinal harm, and death (Amelia et al. 2021).The results of control studies performed in labs and on the ground have provided insight into the possible impacts of MPs on the marine organisms.

TYPES OF MICROPLASTIC

To reduce the social, environmental, and economic effects of microplastics, it is essential to identify their sources (Pettipas et al. 2016). Depending on their source, MPs in the environment can be categorised into the primary and secondary categories (Cole et al. 2011). The majority of principal sources of microplastics are cosmetics, industrial resin pellets, plastic pellets, abrasives, and synthetic clothes drilling fluids. (Alimba and Faggio, 2019; Xu et al. 2020)."Secondary microplastics" are made when bigger plastic fragments break down, shatter and gradually deteriorate (Anderson et al. 2016).Ocean pollution, according to Landrigan et al. (2020), " is a blend of plastic trash, toxic metals, chemicals, spillages, urban and manufacturing waste, pesticides, fertilizer, medicinal compounds, fertilizer runoff and sewage. Approximately 1.5 million tonnes of microplastic are released annually into the oceans on a global scale, according to estimates (Boucher and Friot, 2017). MPs may be categorised into five different categories: fragments (hard, sharp edged particles), micro-pellets (hard, spherical particles), fibres, films, and froth. However, six main kinds are polythene(PE), polypropylene (PP), polyamide(PA) , polyvinyl chloride(PVC), polystyrene (PS) , polyurethane and polyethylene terephthalate(PET) (Rezania et al. 2018).

SOURCES OF MICROPLASTIC

A number of sources, including as ground sources, atmospheric deposition, fertilizers, textile products, synthetic turf, roads, aeroplanes, textile, seaside and touristic activities, container ships, fishing industry, agriculture, and oil platforms discharge microplastic into the environment (Amelia et al. 2021). Marine species from every trophic level can now withstand ingesting plastic, either directly or indirectly through trophic transfer caused by microplastics (Samir Ali et al. 2021). According to research (D'etr'ee and Gallardo-Esc' arate, 2018; Kolandhasamy et al. 2018), the physiological processes of respiration, reproduction, nutrition, growth, and survival rate can all be significantly impacted after MP ingestion by marine biota. A plastic's hydrophobicity and surface area to volume ratio can influence how well it aggregates with other contaminants (Samir Ali et al. 2021). Nurdles, which are plastic pellets used to make plastic products, were also identified by Seltenrich (2015) as a land- and ocean-based source that leaked from ships and water treatment plants. The majority of MPs used in the treatment of sewage are found in the sludge. The concentration decreases until just 3% of MPs are present in the effluent at the end of the treatment phases (Li et al. 2019). The physicochemical properties of MPs may alter during the treatment process, which could increase the ability for metal contaminants to bind to them. Mechanical abrasion and microbiological activity during treatment are to blame for this (Li et al. 2019). Scratches and colour changes that appear on the top surface of microcapsules during the paddy runoff process indicate that secondary MPs were released (Katsumi et al. 2020). The majority of tyre particles go through the air or other rivers and end up in the ocean (Chen et al. 2020).Pollutant effects are less severe where there are less MPs and more severe where they accumulate. Microplastics are present in the ecosystem, seabed, water column, and bottom of the ocean. Different responses are taking place on the MPs in each section (Issac and Kandasubramanian, 2021). Therefore, knowledge of the distribution of MPs is essential to reducing the threats that lie ahead.

PROPERTIES OF MICROPLASTIC

Pollutant sorption capacity of MP is greatly affected by its physical and chemical properties (Huffer et al. 2018). Also it is influenced by no. of factors such as colour, age,type of pollutant ,its chemical properties, surrounding conditions like pH , salinity and dissolved organic matter (Fisner et al. 2017). Recent research in the field of microplastics claimed that the terms adsorb and absorb refer to substances that are separately adsorbed to the surface of and adsorbed into the bulk of MP (Amelia et al. 2021).Studies show that dark coloured microplastic were rich in PAH or PCB and contained PAH of higher molecular weight as compared to light coloured microplastic (Fisner et al. 2017). Ageing is the major factor that results in increase in surface area, porosity, roughness, charge, polarity and formation of oxygen groups (Fotopoulou and Karapanagioti, 2012) . Immature microplastic has a significantly lower adsorption capability than mature or weathered microplastic (Amelia et al. 2021).The crystallinity of PP and PE is increased by oxidation due to light and temperature. (Guo and Wang, 2019) claim that semi-crystalline materials are superior than amorphous materials in terms of strength and wear tolerance. Larger crystallinity ratios result in microplastics with higher densities, which sink, making crystallinity a key element in determining where an object is in the water column and what aquatic species it interacts with (Andrady 2017).Additionally, according to laboratory research, the surface of the microplastics develops tiny microcracks, cracks, and flakes following exposure to UV radiation (Hüffer et al. 2018).The prevalence of rubbery microplastic domains is crucial for the sorption of organic substances. PYR, PHE, lubricating oils, PCBs, PFOS, POSA, and 4, 4′-DDT have higher sorption capabilities on PE than other kinds of MPs, according to research (Guo and Wang 2019).

Not only physical properties, chemical properties like composition, crystallinity, stability, polarity, functional groups and type of bonds are also known to affect the adsorption properties of microplastics (Amelia et al. 2021). Chemicals to be gathered by plastic rely on the physical and chemical characteristics of the polymer including contact area, diffusivity, hydrophobicity and crystallinity (Issac and Kandasubramanian, 2021). Rubbery polymers made of polyethylene and polypropylene should absorb chemicals more readily than PET and PVC glass polymers. Microplastics absorb hydrophobic pollutants at different rates depending on their form and kind of polymer (Tourinho et al. 2019). Pollutants are drawn to microplastics due to chemical interactions such as, van der Waals interactions, electrostatic interaction, hydrophobic forces and h - bonding (Amelia et al. 2021). Hydrophillic antibiotics like amoxicillin (AMX), tetracycline (TC), trimethoprim (TMP), sulfadiazine (SDZ) and ciprofloxacin hydrochloride (CIP HCl), were sorbed by microplastics such as PE, PP, PS, PVC and PA (Jeyavani et al. 2021).According to (Huffer and Hofmann 2016) strong hydrophobic interaction is behind the greater affinity of microplastics for benzene derivatives instead of single benzene . Adsorption efficiency of PVC and PS for the antibiotic tylisin (TYL) rises with a reduction in pH, but adsorption efficiency of PP and PE shows very small variations. Also with the decrease in pH the sorption capacity of HDPE for Cr increases for Pb, Ni, Co, and Cd decreases, while for Cu remains constant(Jeyavani et al. 2021). Similarly, Increase in salinity increases the sorption capacities (Wang et al. 2015). However, increased salinity also shows a negative effect on sorption capacities, for dichlorodiphenyltrichloroethane (DDT) and ciprofloxacin as they compete for the for the sorption site (Li et al. 2018). In a ground-breaking study, Napper et al. (2015) showed that when microplastics from cosmetic products like facial scrubs were present in a binary combination, they could absorb more DDT than phenanthrene. Möhlenkamp et al. (2018) conducted a laboratory study to examine cosmetic microplastics' buoyancy and aggregation in water. They discovered that microplastics can collect quickly and flocculate swiftly as a result of seawater mixing. Both the density and the size of the microplastic particle affect buoyancy. The density of plastic particles are as follow: PP (0.83-0.92 g/cm3), PVC (1.16-1.58 g/cm3), PS (1.04-1.10 g/cm3), HDPE (0.9-0.98 g/cm3), PET (0.96-1.45 g/cm3), PA (1.02-1.16 g/cm3), PC (1.20-1.22 g/cm3) (Vo & Pham, 2021).The size, colour, and concentration of the PE microbeads in the facial exfoliating cleansers were described by Chang (2015). The findings revealed that microbeads ranged in diameter from 60 to 800 μm on average. Additionally, white and opaque microbeads were determined to comprise the majority. The majority of the microbeads in body washes and facial cleansers were less than 100 μm in size, according to a different study by Kalc'kova et al. (2017).The physical interactions between MPs and POPs or PPCPs were stronger than those between MPs and trace metals which caused them to have a higher affinity for MPs (Sun et al. 2022). Some of the studied tissues (hepatic) had a high lipid content, that may result in greater bioavailability of POPs /PPCPs in tissues (Sun et al. 2022). Positively buoyant plastics frequently only float on the water's top for a short period of time before becoming repeatedly contaminated and sinking to the bottom, where they become benthic. Plastics that are sinking may temporarily refloat if surface fouling on them is reduced as a consequence of grazing; however, this cycle of floating and sinking will continue until the plastics eventually sink to the bottom of the ocean (Alimi et al. 2021).Different polyethylene grades have varying densities, strengths, crystallinities, and weatherability, and each grade has a specific application. But their presence, decomposition, and propensity to bind or release persistent organic contaminants are all determined by the characteristics of the polymers that make them up (Andrady 2017). PE, PS, PP, PVC, and PC showed change in colour due to oxidation. This is typically due to the buildup of breakdown products or modifiers employed while manufacturing (Issac and Kandasubramanian, 2021). Factors that influence the impact of microplastic on organisms are its type , size , concentration, exposure period , but also gender, age, and reproductive potential of animals (Issac and Kandasubramanian, 2021).

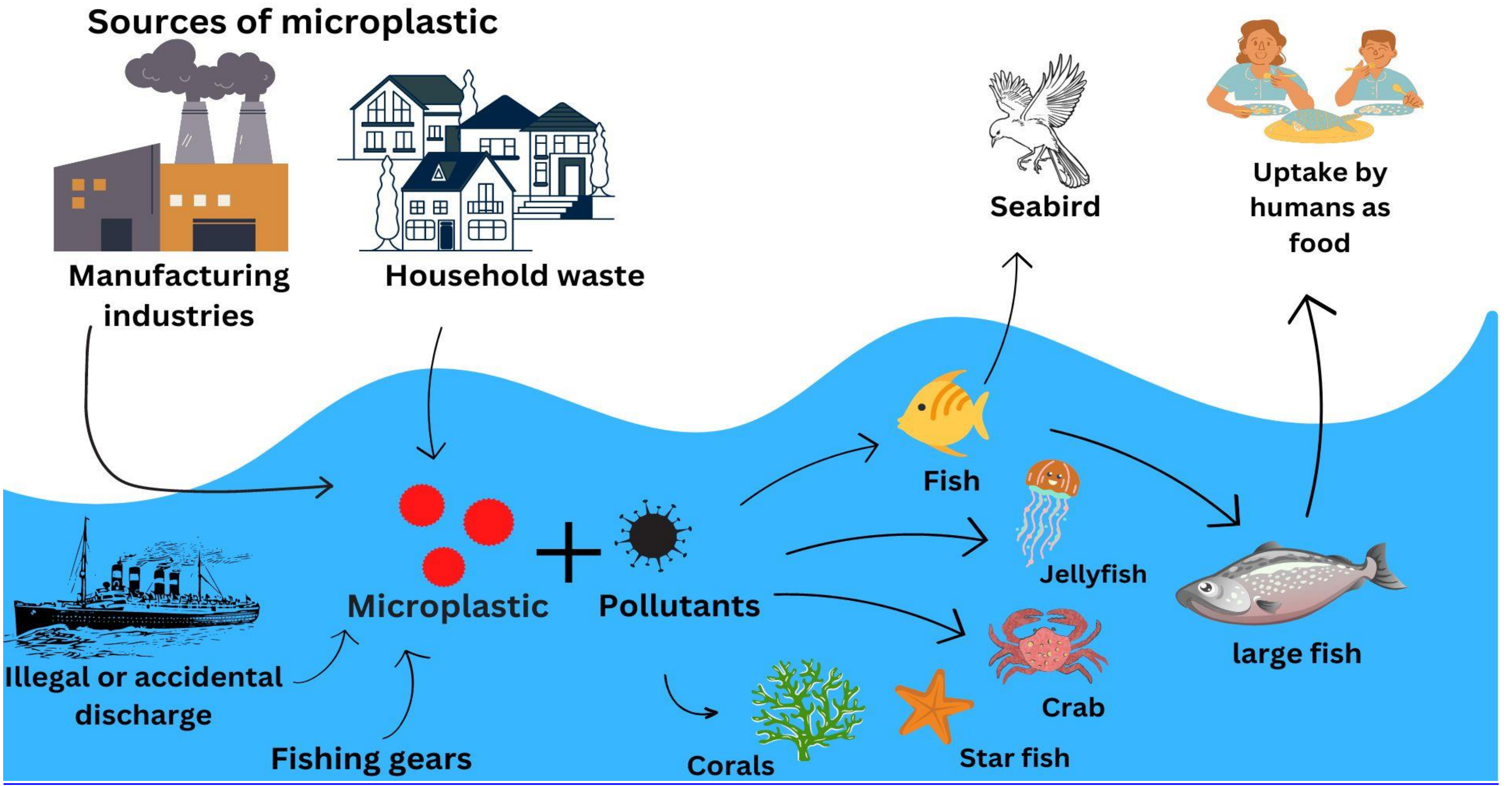

Fig. Ultimate fate of microplastics.

TOXIC EFFECTS OF MPS IN VARIOUS MARINE ORGANISMS

Table1. Toxic effects on corals

Coral species	Type of MP	Toxic effects
P. damicornis colonies	Polystyrene (PS) microplastics (diameter 1.0 µm)	Remarkable decrease in AKP and GST (glutathione S- transferases) and a remarkable increase in CAT (Catalase) and SOD(Superoxide dismutase) function . Moreover Changes in coral genes related to (zymogen granule ,coral stress, JNK and EGF-ERK1/2 signalling pathway. (Tang et al. 2018).
Tubastrea aurea	MPs (PE PVC, PET, and PA66) ,diameters ranging from 1 to 10 µm)	MPs significantly alters functions of alkaline phosphatase (AKP), catalase (CAT), Superoxide dismutase (SOD), Ca^{2+} ATPase, Na^{+}, K^{+}ATPase, $Ca^{2+}Mg^{2+}$ATPase and Mg^{2+}ATPase (Liao et al. 2021).
Acropora humilis, Acropora millepora, Porites cylindrical	PE (polyethylene)	Bleaching (Reichert et al. 2018).
Pocillopora verrucosa Pocillopora damicornis	PE (polyethylene)	Tissue damage (Reichert et al. 2018).
A. muricata and H. coerulea	High density polyethylene (PE)	They revealed Mp exposure led to reduction in growth ,tissue injury and bleaching mutually present algal partner faces difficulty in performing photosynthesis (Reichert et al. 2019)
Acropora Formosa	LDPE MPs sizes less than 100 µm,100-200µm and 200-500µm)	Researchers found coral necrosis and bleaching (Syakti et al.2019)
Acroporacervicornis and Pseudodiploriaclivosa	MPs (various)	Both Acroporacervicornis and Pseudodiploriaclivosa showed decreased mineralization and tissue surface area. (Hankins et al. 2021)
Acropora sp.	Polystyrene (PS)microfibres (size range of 0.05 to1 cm)	Decreased photosynthesis output and may result in Chronic effects such as decreased fertility , less growth and early death . . (Mendrik et al. 2021)
Goniopora columna	Polyethylene (PE)	Polyethylene microplastics (PE-MP) exposure decreased the polyp size ,alters the glutathione (GSH), superoxide dismutase (SOD) and catalase (CAT) activities . Also disturbs mutual association with algal partner(Chen et al. 2022)
Amphisteginagibbosa	Polyethylene terephthalate(PET) size range(150 to300 μm)	PET-MP exposure impairs food intake (Joppien et al. 2022)

Table2. Toxic effects on bivalves

Bivalve species	Type of MP	Toxic effects
Crassostrea gigas	Polystyrene (PS)-MP, size of 6µm	Observed reproductive stress : sperm motility lowered by 23%, egg count lowered by 38% , egg size lowered by 5%, along with this feeding and absorption were significantly affected (Sussarellu et al. 2016)
Corbicula fluminea	Florfenicol, Microspheres of size range(1-5 µm diameter)	MPs-florfenicolcombinely resulted in lowered activity of AChE (44–57%), reduced intake (57-83%),consequently lead to neurotoxic and oxidative damage. (Guilhermino et al. 2018)
Tegillarca granosa.	Polystyrene (PS) MPs size range 29.4 ± 0.8 µm, and Polycyclic aromatic hydrocarbons (PAHs)	PS-PAHs combinely resulted in genotoxicity ,decreased life span ,increased amount of ROS and rapid oxidative degradation of lipids .Moreover, expression of TRAF6 and NFκB1 was suppressed while that of Caspase-3, CYP1A1, ARNT , AHR and BAX was triggered (Sun et al. 2021)
Crassostrea gigas	Chlortoluron (Herbicide) , concentration of 85 µg/L and high-density polyethylene microparticles (HDPE) size range of 20-25 µm and concentration 112 MP./mL	HDPE-Chlortoluron coexposure lead to reduced VMC (Valve Micro-Closures) and shell development, while shows positive impact on VOA (Valve Opening Amplitude)(Bringer et al. 2021)
Perna viridis	Weathered Polyethylene (wPE) size size range of 32-43 µm and concentrations 1, 2 and 3 µm/L	wPE triggered oxidative damage, impaired filteration and detoxification (Hariharan et al. 2021),
Mytilus galloprovincialis	Polyethylene terephthalate (PET) MFs ,size of 100 µm, concentrations (0.0005, 0.1, 1, 10, and 100 mg/L)	Decline in amount of gonadotrophins, Long term exposure leads to rise in AChE activity , CAT (catalase) and SOD (Superoxide dismutase) activity (Choi et al. 2022)

Table3. Toxic effects on copepods

Copepod species	Type of MP	Toxic effects
Tigriopus japonicus	PS (polystyrene) microbeads with diameters of 0.05, 0.5, and 6 µm ,concentration (1.25-25 g/mL),	Negatively affects growth and production rate along with survival (Lee et al. 2013).
Calanus helgolandicus	PS (polystyrene) beads, size of 20.0 µm, concentration (75 particles/mL),	Disturbs energy storage that may lead to reduced ingestion and development rates, Reduced egg size and hatching failure were observed (Cole et al. 2015).
Calanus finmarchicus.	Nylon fibers size (10 × 30µm), concentration (50 particles/mL)	Triggered moulting, reduction in lipid buildups in body and ingestion, negatively affecting health of copepods (Cole et al. 2019).
Tigriopus japonicus	PS(Polystyrene) beads , Size of 6 µm,concentration (0.023 and 0.23 mg/L)	Microplastics concentration (0.23 mg/L) resulted in substantial decrease in fertility, nauplii counts and success rates (Zhang et al. 2019)
Tigriopus japonicas	PS (Polystyrene) microbeads , size range (0.05 and 10 µm), concentration 20 mg/L	Consumption of microplastics results in an excess of ROS (reactive oxygen species) and the activity of antioxidants was severely impacted (Choi et al. 2020)
Acartia tonsa	Polyethylene (PE) MPs of size range (1.4-42 mm) along with CPF (chlorpyrifos), concentrations (0, 0.1, 1, 10, 100 mg/L)	Negative impact on reproductive performance (reduced egg number, hatching failure) and impaired feeding (Bellas and Gil 2020).
Acartia tonsa	PS (polystyrene) particles , size range (6.0-8.0 µm)	Negatively impacted survivorship and development at initial stage,also resulted in production of smaller eggs (Shore et al. 2021)
Temora longicornis	PE (polyethylene) microplastic , size range (10-45 µm)	When treated to a variety of PE microplastic concentrations and the filtration rate fell by 50% at a concentration of 1956 ± 311 particles/ L(Everaert et al.2022)
Tigriopus japonicus	PS (Polystyrene)-microplastic , size of 10 µmdiameter,concentration (20 µg/L and 200 µg/L PS microplastic)	Exposure 20 µg/L and 200 µg/L PS -microplastic resulted in : decreased rate of oxygen uptake decreased rate of filtration decreased Hatching rate decreased rate of food uptake (Shi et al. 2022)

Table 4. Toxic effects on Fishes

Fish species	Type of MP	Toxic effects
Carassius carassius	Polyethylene microplastics (PE-MPs)	Lead to slower growth, hepatic and pancreatic injuries .Development of microbes was observed in the gut region (Hu et al. 2022)
Cyprinus carpio	MPs (various)	Hepatic stress was observed due to altered expression of genes associated with filtering toxins in the liver cells. Increased levels of lipids and glucose , while decreased levels of glycogen were identified (Banaei et al. 2022)
Marine medaka (*Oryzias melastigma*)	MPs(various)	Reproduction outcome lowered by 42%.(Cormier et al., 2022)
Zebrafish (*Daniorerio*)	MPs(various)	Reproduction outcome lowered by 70 % (Cormier et al. 2022)
Black Sea Bass(*Centropristis striata*)	LDPE microspheres and LDPE microfibers	LDPE microfibers intake lead to rise in breathing rate while LDPE microspheres intake suppressed the immune system(Stienbarger et al. 2021)
Oryzias latipes	Polystyrene (PS) MP	Changes in the fertility , reproductive outcome , count of egg laying females, inner tissues of the kidney and thyroid, fertility were observed (González-Doncel et al. 2022)
European sea bass(*Dicentrarchus labrax L.*)	Polyvinylchloride (PVC) and polyethylene (PE) MPs	PVC-MPs increased oxidative stress in leucocytes and PE-MPs affects immune response by overproduction of IgM (Espinosa et al. 2019).

Table 5. Toxic effects on sea birds

Seabird species	Type of MP	Toxic effects
Flesh-footed Shearwaters (*Ardenna carneipes)*	MPs (various)	Remarkably affected morphological characters, calcium measure in blood and raised levels of amylase, cholesterol and uric acid were observed (Lavers et al. 2019)

Morus bassanus and Greater Shearwater (*Puffinus gravis*).	MPs(various)	Mortality was observed as plastic material got stuck in the gut area caused lesions and blockage (Pierce et al. 2004)

STEPS TOWARDS CONTROL

Considering the negative effects of microplastic on marine species, an eco-friendly method is necessary to prevent microplastic pollution. Here, we'll concentrate on bioremediation, which is already used to get rid of pollutants like hydrocarbons or phosphates from WWTPs (Gargouri et al. 2014). By using pollutants and hazardous substances as food sources for growth, living organisms like bacteria carry out bioremediation. Through the metabolism of living things (a series of metabolic events), pollutants are entirely eliminated or changed into non-hazardous products (Horemans et al. 2017). Natural bacterial communities, primarily from contaminated locations, can be used to separate microbes for bioremediation. Following microbial communities were found to useful in degradation of various plastic materials.

Table 6. Microorganisms associated with degradation of various MPs.

Type of MP	Microbial species
LDPE(low density polyethylene)	*Pseudomonas putida*, *Pseudomonas fluorescence* and *Streptomyces sp*.(alkB gene) (Rani et al. 2019)
Polyethylene terephthalate (PET)	*Bacillus cereus* and *Agromycesmediolanus* (Torena et al. 2021)
Low-density polyethylene (LDPE) and Polypropylene (PP)	*Enterobacter sp. and Pseudomonas aeruginosa*(Skariyachan et al.2021)
Polyethylene terephthalate (PET)	*Ideonellasakaiensis* 201-F6 (Yoshida et al. 2016)
Polyethylene (PE)	Enterobacter sp.extracted from the Galleria mellonella (wax moth) (Ren et al. 2019)
Polyethylene (PE)	*Pseudomonas aeruginosa and Pseudomonas knackmussii*(Hou et al. 2022)
PE (Polyethylene), PET (Polyethylene terephthalate), and PS (Polystyrene)	*Bacillus cereus* (Auta et al. 2017)
PP (Polypropylene),PE (Polyethylene), PET (Polyethylene terephthalate), and PS (Polystyrene)	*Bacillus gottheilii*(Auta et al. 2017)
PP(Polypropylene)	*Bacillus* sp. and *Rhodococcus* sp. (Auta et al. 2018)
LMWPE (low molecular weight polyethylene)	*Pseudomonas aeruginosa* E7 (bacterial genes : AlkB, rubB and rubA) were responsible for bidegradation (Jeon& Kim, 2015).

CONCLUSION

In conclusion, home activities, manufacturing enterprises, fisheries, and marine activities are mostly responsible for MP pollution. It is becoming more and more serious with the growing population. Although, many studies have proved the negative impacts of MP on a wide spectrum of marine biota, still further research is needed in this sector. Regardless of the fact that soil-based activities are the primary source of the bulk of plastic waste in water, it is advised that this issue be addressed. Some waste management solutions include source management, product improvement, reuse, recycling, composting, turning trash into power, and avoiding debris at ocean entrance points. To lessen the hazardous impacts of MPs, more environmentally safe techniques are required .

ACKNOWLEDGEMENT: NIL

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