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MICROPLASTICS IN OUR OCEANS AND MARINE HEALTH

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KEYWORDS

- MICROPLASTICS
- MICROBEADS
- MARINE BIOTA
- MARINE HEALTH

If the 20th century was the revolution era of plastic industry for manufacturing too many plastic based products starting from bucket to car, then the 21st century is the time to face its consequences. Improper management, lack of information about its negative effect and irresponsible use as well as dumping of plastic products turns this planet into “plastic planet”. Besides emerging as solid waste, these plastic materials also appeared as a great threat for human and animal health. It not only polluted the roads, forests, mountains but also polluted our oceans. Ignorant human populations always throw the plastic waste into water bodies and most probably the “out of sight out of mind” thought leads them to do so. This is why the problem of microplastics in the marine ecosystem is an issue of great concern nowadays.

Here we discuss the different sources of microplastics in the oceans and their harmful impacts on the marine organisms. The microscopic size of these plastic fragments gets them easily available for ingestion by an array of marine habitants, causing adverse effects on their health. The potential of microplastics to absorb various harmful hydrophobic pollutants from the surrounding environment indirectly transfers these contaminants in the food chain. Thus to tackle this serious issue of microplastic pollution in the marine ecosystem, various policies and rules must be formulated. To avoid future threat, it is important to stop producing it further and replace the plastic with alternative eco-friendly materials.

INTRODUCTION

The fabrication and utilization of plastic over the last few years have been drastically increased due to its cost benefit nature and this has resulted in the increased disposal of these non recycled (treated) synthetic plastic polymers in the terrestrial and aquatic ecosystem¹. The small plastic fragments disposed in the marine habitat having dimensions ≤ 5 mm are defined as microplastics². These tiny plastics can be consumed by different marine biota including corals, planktons, marine invertebrates, fish and whales and are ultimately transferred along the food chain³. These plastic polymers directly pose a great threat to marine organisms and also indirectly affect the ecosystem by adsorbing other marine pollutants. Due to its large area to volume ratio, microplastics are readily absorbing hydrophobic pollutants from the aquatic system. Thus microplastic pollution is becoming an issue of concern because of its detrimental effect mainly on the marine health and biota.

MICROPLASTICS

Plastics are synthetic polymers which are supple or malleable (flexible) in nature and can be transformed in different shapes. Plastic is composed of long chains of polymers which are composed of carbon, oxygen, hydrogen, silicon and chloride and are acquired from natural gas, oil and coal⁴. The most prominent synthetic plastics are polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), polyvinyl chloride (PVC), low density polyethylene (LDPE) and high-density polyethylene (HDPE) and constitute 90% of the worldwide plastic production⁵. The properties of plastics such as flexibility, durability, low cost, easy to handle (lightweight) and resistant to corrosion makes it a widely acceptable compound. Plastic can withstand high rate of electrical and thermal insulation and thus have tremendous industrial and commercial usage⁶. There has been an exponential increase in plastic production from 1950 (1.5 million tons) to 2015 (322 million tons)⁷. The disposal of plastic materials is an issue of concern these days because of its durability and corrosion resistance. Plastic compounds take up to years to get degraded in smaller fragments⁸. Larger plastic debris slowly degrades into small fragments with various size ranges extending from meter to micrometer due to changing environmental conditions. This fragmented plastic with size smaller than 5 mm are known as

microplastics⁹ and are highly persistent in the ecosystem. Based on shapes, sizes and chemical composition, microplastics can be differentiated as follows.

TYPES OF MICROPLASTICS

On the basis of origin, microplastics are categorized in two types: primary and secondary microplastics¹⁰. Primary microplastics are micro-sized synthetic polymers and used as exfoliates of various processes such as chemical formulations, sandblasting media, maintenance of various plastic products and also in the manufacturing of synthetic clothes. Microbeads are another type of primary plastics (size < 2 mm) composed of polyethylene (PE), polypropylene (PP), polystyrene (PS) beads and are used in cosmetic and health care products. Secondary microplastics are the fragmented product of macro or meso plastics and mostly generated under the effect of various environmental processes such as biodegradation, photodegradation, thermo-oxidative degradation, thermal degradation and hydrolysis³ (Figure 1). Further nanoplastics are plastic fragments with < 1 µm size, and all these microplastics and nanoplastics have potential implications for the bioamplification and bioaccumulation of various chemicals and pollutants due to their large surface to volume ratio¹¹.

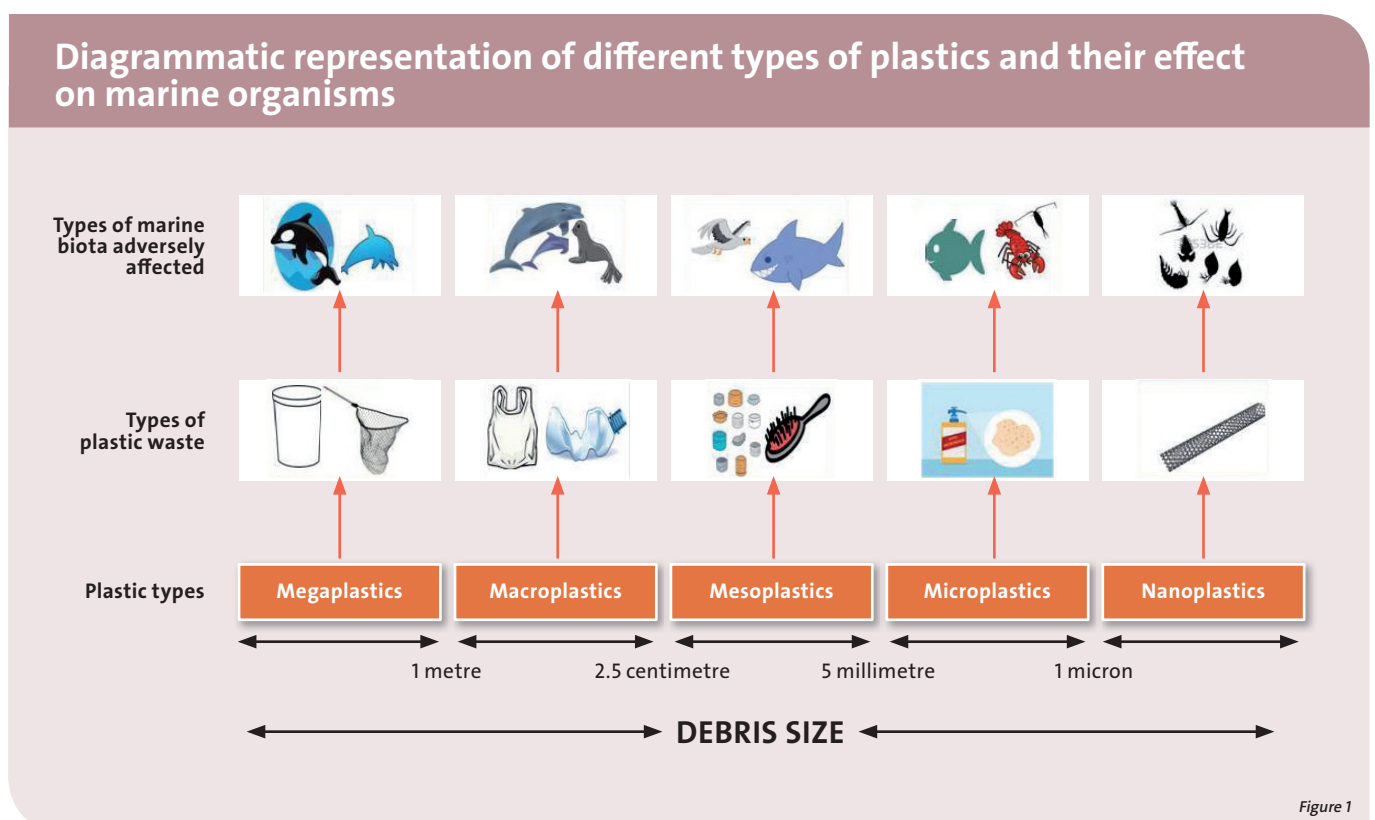


Figure 1



SOURCES OF MICROPLASTICS

The presence of these hazardous plastic fragments in the ecosystem (terrestrial and aquatic) is due to different anthropogenic activities which include domestic, industrial and coastal activities. The introduction of microplastics in the aquatic ecosystem is mainly because of the domestic runoff which contain microbeads and microplastic fragments (used in cosmetic and other consumer products) and also from the fragmentation of the large plastic trash¹². The plastic manufacturing industries release plastics in the form of pellets and resin powders produced from air-blasting¹³ which ultimately contaminate the aquatic environment. Also the coastal activities which include fishing practices, aqua tourism activities and marine industries are the sources of microplastic pollution in the marine ecosystem.

Microplastics once entered in the marine habitat are exposed to different physic-chemical processes such as biofouling and leaching or incorporation of secondary pollutants. Microplastics have different shapes, size and density, and according to these features, plastic fragments have distributed in different compartments of the marine ecosystem (finally settle down to benthos) and are available for the marine biota³.

The pelagic marine biota which consists of planktons and crustaceans are exposed to low density microplastics whereas benthic organisms such as polychaete and tubifex worms, amphipods and mollusks are known to encounter with dense microplastics¹⁴. The settling rate of microplastics through the water column varies depending

on different factors such as polymer type, biofouling and surface chemistry of the particles¹⁵. In most of the studies, microplastics have been detected in benthic environments and sediments. Benthic environment is one of the significant feeding ecosystems for a range of marine biota. Recent studies have shown that marine benthic biota ingest microplastics which is present in the sea in the form of microbeads and microfibers¹⁶.

EFFECT OF MICROPLASTICS ON THE HEALTH OF MARINE BIOTA

These tiny plastic fragments are persistent in the marine ecosystem and due to their micron sized particle nature, these fragments are mistaken as food and ingested by a range of marine biota which includes corals, phytoplanktons, zooplanktons, sea urchins, lobsters, fish etc. and ultimately get transferred to higher tropic level. The impact of microplastic on marine biota is an issue of concern as it leads to the entanglement and ingestion which can be lethal to marine life. The microplastic fragments mainly arrive from terrestrial source and thus coastal ecosystems which comprise of coral reefs are in great threat due to microplastic pollution. Corals survive in a symbiotic association with single celled algae which is present in the tissues of corals cavity. The algal association is a source of energy through the process of photosynthesis. Also corals obtain energy by feeding on planktons to acquire important nutrients which are essential for their growth, development and reproduction³. The 'microplastic feeding' mechanism of corals involves ingestion, retention

of plastic fragments and digestion¹⁷. The harmful effect of microplastics on corals involves retention of plastic fragments in mesenterial tissue which leads to reduction in feeding capability and lowering in energy reserves¹⁸.

The microbial biofilms associated with microplastics may also negatively regulate coral reef by promoting pathogen transmission¹⁹. The first report of presence of microplastics in scleractinian

corals was detected in the Australia's Great Barrier Reef. The experiment of feeding trials of corals revealed that corals when exposed to microplastics consume these tiny fragments at a rate of $\sim 50 \mu\text{g plastic cm}^{-2} \text{ h}^{-1}$. These ingested plastic fragments were detected in the mesenterial tissue within gut cavity of coral which have negative effect on coral's health²⁰.

Microplastics also adversely affect planktons which are most essential component of the marine habitat. The penetration of microplastics along the cell wall of phytoplanktons results in the reduction of chlorophyll absorption²¹. Also the heterotrophic plankton when exposed to microplastics undergoes the process of phagocytosis and retains these tiny plastic fragments

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in their tissues²². Zooplankton (a class of marine invertebrates) have essential role in marine ecosystem as these microorganisms are basic primary consumers of aquatic food chain. Zooplanktons have a range of feeding mechanisms and utilize the mechanism of chemo-mechano receptors for prey selection²³. The omnipresent nature of microplastics in marine habitat results in the interactions of microplastics with these zooplanktons as both of these are of same dimensions ($> 333 \mu\text{m}$) resulting in highly possible interactions²⁴. Experimental studies revealed that zooplankton were found to ingest latex beads when exposed to microplastic²⁵. In another study, it was found that zooplankton has the tendency to ingest polystyrene beads of dimensions of $1.7\text{--}30.6 \mu\text{m}$. The *Centropages typicus*, a well known copepod was known to ingest microplastics (of size $7.3 \mu\text{m}$) and ultimately lost their feeding ability which consequently has negative effect on their health²⁴. The effect of microplastics on *Gammarus fossarum* leads to decrease in the growth of this organism when exposed to poly (methyl methacrylate) (PMMA) and polyhydroxybutyrate (PHB)²⁶. Also, the ingestion of polyethylene (PE) microplastics in benthic organism *Hyalella azteca* leads to decrease in the growth and reproduction process²⁷. The microplastics uptake in the marine lugworm *Arenicola marina* caused reduction in feeding capability and ultimately weight loss²⁸.

Certain features of microplastics such as microscopic size, attractive colors and their high buoyancy makes these tiny

fragments easily available for fish. Fish ingest microplastics by mistaking these fragments as planktons or other natural prey. In a study, the microplastic ingestion was found in the planktivorous fish *Acanthochromis polyacanthus* where microplastics of the dimensions $< 300\mu\text{m}$ was present in the gut cavity of individual fish²⁹. In one of the experiments, ingestion of microplastics by fish showed that exposure of these plastic fragments causes histopathological modifications in the intestine, resulting in the detachment of mucosa epithelial lining from the lamina propria and causing its widening, reduction and puffing of villi, increase in number of goblet cells and certain alterations in the normal structure of serosa of fish³⁰. The effect of polystyrene on a European fish (*Perca fluviatilis*) was studied in which eggs and larvae of *Perca fluviatilis* were exposed to different concentration levels of microplastics found in the Swedish coast, namely $10,000$ particles per m^3 and $80,000$ particles per m^3 . It was found that eggs which were exposed to high concentration of microplastics had a comparative slower hatching rate when compared to control. Also the larvae exposed to microplastics were smaller and slower in comparison to normal larvae. The responsive ability of microplastics exposed *Perca fluviatilis* larvae to the chemical alarm (existence of predator) was found to be very low and thus it has a deleterious effect on the survival rate of fish. Other study also showed that microplastic ingestion in fishes cause metabolic alterations which include up-regulation and down-regulation of fatty



acids and amino acids respectively³¹. The ingestion of micro and nano plastics causes alteration in the ratio of triglycerides and cholesterol in the blood serum level of fish and also causes variation in the delivery of cholesterol between muscle and liver of fish³².

The harmful effects of microplastic ingestion is an issue of concern specially in case of sea birds as half of the species are endangered and the toxic effect of plastic fragments has negative effects on their body which could cause alteration in the feeding behavior, reproduction and mortality³³. It was found that six species of sea birds, *Phalacrocorax bougainvillii*, *Pelecanoides garnotii*, *Pelecanoides urinatrix*, *Pelecanus thagus*, *Spheniscus humboldti* and *Larus dominicanus* have the plastic fragments in their stomach region and maximum ingestion capacity was detected in case of *Larus dominicanus* which commonly feeds upon fishing nets, waste disposal products and plastic containers³⁴. The ingestion of plastic debris by these species mainly depends on certain factors such as size, weight and habitat of the sea birds; e.g. the species of sea birds *Spheniscus penguins* and *Thalassarche albatross* have small body size and thus ingestion rates were lower in comparison to large sea birds. The species such as *Fulmarus fulmars*, *Cyclorhynchus auklets*, *Oceanodroma*, *Pachyptila prions* and *Pelagodroma* have higher ingestion rate of plastic debris due to their large body size and weight³³. The large creatures of marine biota which includes sharks, whales, seals, sea turtles and polar bears are

The large creatures of marine biota which includes sharks, whales, seals, sea turtles and polar bears are also vulnerable to microplastics ingestion in the oceans throughout the world.

also vulnerable to microplastics ingestion in the oceans throughout the world; e.g. the presence of microplastics was detected in the stomach and intestine of harbor seal, *Phoca vitulina*³⁵. This class of marine mammals is filter feeders and thus ingests substantial amounts of microplastics either directly swallowing from ocean water or indirectly by consuming prey containing microplastics in their body cavity. The presence of the microplastics in the stomach of sharks of Sea of Cortez and whales of Mediterranean Sea proved that most of the littered plastic waste worldwide ultimately ends up at sea³⁶ and imposed a great threat to marine animals. In a study done on Mediterranean fin whale (*Balaenoptera physalus*), high concentration of phtalates were detected in these baleen whales which indicates the severity of microplastic pollution in world ocean³⁷.

CONTROL MEASURE

The worldwide record of plastic litter entering in the ocean gyres was estimated to be 4.8 to 12.7 million metric tons, and with the increased use of plastic and its products, the total amount of plastic litter available to marine ecosystem is expected to increase substantially by the end of 2025³⁸. This major issue was also raised in the “16th Global Meeting of the Regional Seas Conventions and Action Plans” which was held to literate nations regarding worldwide threat of plastic pollution in the marine habitat, and financial damage

of approximately US\$13 billion per year to the marine ecosystem was estimated³⁹. Considering this recent trend of ocean pollution by plastic litter, there is a pressing need to carry out some dedicated research which could help to restrict plastic pollution and could clean different water bodies worldwide. Certain innovative measures should be taken by states to literate the society about the harmful effects of plastic debris in the marine ecosystem. It is very essential to introduce certain strong legislative rules and policies which could monitor the excessive use of plastic items, otherwise the health of ecosystem will worsen in the coming span of time³. There should be a well established waste collection system which could check the collection of waste containing plastic litter. Efficient management, recycling and finally environment friendly disposal system would help in making environment free from plastic. Substantial policies are formulated in developing countries

against the use of plastic and its product such as complete ban on plastic bags and plastic bottles and imposing fine on usage of plastic⁴⁰. However, unfortunately FMCGs are still using plastic packets for selling their products. There should be a complete ban on microbeads in cosmetic and other personal care products such as toothpastes, face wash and shampoos. The waste management schemes such as EPR (extended producer responsibility) which promote the use of manufacturing packaging materials other than plastic for food and other beverage packaging should be encouraged. Various campaigns should be organized by various governmental and nongovernmental organizations for the public consciousness against the nocuous and chronic effects of microplastic pollution. Apart from that, more scientific innovation should be encouraged which will facilitate to produce environment friendly derivatives instead of plastic materials (Figure 2).

Overall representation of sources and deleterious effects of microplastics on marine biota and control measures for this problem

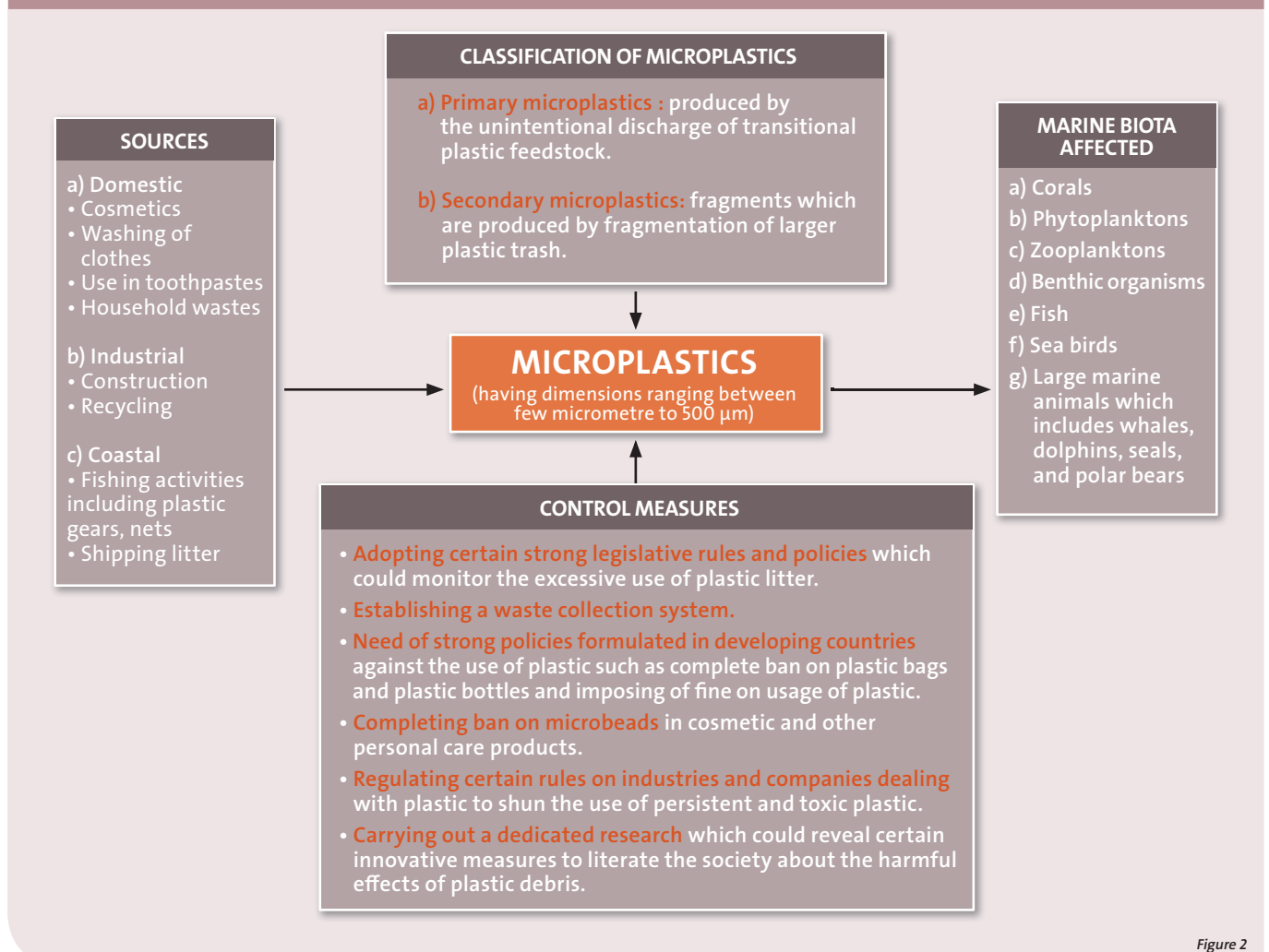


Figure 2

CONCLUSION

The problem of plastic pollution in the marine ecosystem is an issue of concern nowadays because of its deleterious effects on marine biota. Due to the size of microplastics, their bioaccumulation potential is very high. They are ingested by an array of marine habitants like corals, planktons, fish, seabirds and marine mammals and are transferred along the food chain. Also plastic polymers have different chemical additives and stabilizers due to which it absorbs various toxic contaminants and pollutants from the surrounding environment. Thus these harmful contaminants adhere to the microplastics which act as a vector. The problem of microplastics has been ignored for a long time and this threat has been recognized only recently. At present, drinking water, table salt and other daily used food items are contaminated with microplastics. There are various social active platforms such as *Plastic Pollution Coalitions*, *Plastics for change*, *Plastic Oceans*, *Surfers Against Sewage*, *Greenpeace*, *By the Ocean We Unite*, *One More Generation*, *One Green Planet*, *Surf Rider Foundation*, *Earth Guardians* who are working on the issue of microplastic pollution and contributing substantially. The adverse effects of microplastics pollution in the marine environment spans from molecular level of organism to its physiological actions and include poor health of organisms and poor economic services. Thus immediate actions are urgently required against the unnecessary use of plastics and its products. Strict measures must be enforced at national and international levels against the use of plastics. New scientific studies are required to elucidate various

factors which influence the presence of microplastics in marine ecosystem and its biological impacts on marine biota. New research methodologies must be developed for conservation management and supporting different educational programmes for the protection of ecosystem against these harmful polymers. The very urgent call in this field is to spread awareness among the general public regarding the nocuous effects of microplastics. This would stimulate various innovations to reduce the utilization and consumption of plastic and its products. To minimize the plastic input into the ecosystem the most important approach is to collect and reuse of plastic fragments. To avoid future threat, the best solution is to stop producing it further and find out the alternative of plastic products.

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Compliance with Ethical Standards

Conflict of interest: Authors declare no conflict of interests

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