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Plastic debris in the coastal and marine ecosystem: a menace that needs concerted efforts

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Abstract
Plastics are versatile polymers and their application in variety of sectors has transformed day-to-day human life. Their use is increasing day-by-day. As a result, plastic debris is on the rise, and concerns the politicians, media, scientists, industry and the public. The plastic debris reaches coastal and marine environments as their ultimate sink and is accumulating around the world, even in the remote and uninhabited coastal environments. The marine organisms are facing the danger of possible entanglement, ingestion, habitat destruction and bio-invasion. The presence of debris affects the aesthetic and recreational value, causing considerable economic loss. The human health and safety is also threatened by the plastic debris. Considering the effect of plastics in the environment, a balanced approach should be followed in using the plastics. Educating the stakeholders for the wise and judicious use of plastics with appropriate disposal and cleanup strategies would help in managing the plastic debris to protect our coastal and marine ecosystem.

Keywords: Plastic debris, sources, distribution, entanglement and ingestion, invasion, stakeholder responsibilities

1. Introduction
Plastics are synthetic organic polymers prepared by the polymerization of monomers derived from oil or gas. About 8% of global oil production goes towards the production of plastics [1]. Different types of plastics are made by the addition of various chemical additives to the polymers. The most commonly used plastics are low-density polyethylene (LDPE), high density polyethylene (HDPE), polyethylene terephthalate (PET), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), nylon, teflon and thermoplastic polyurethane (TPU). The diversity of polymers and the versatility of their properties (low cost, excellent oxygen/moisture barrier properties, electrical and thermal insulation properties, bio-inertness, light weight, etc.) enabled them to be used in variety of applications to improve resource use efficiency in sectors ranging from packaging, appliance, agriculture, construction, automobile to healthcare and hygiene. Thus, plastics find an important role in transforming everyday human life and the usage is increasing markedly. The increase in the use of plastics has created waste management issues with the discarded end-of-life plastics accumulating in landfills and in natural habitats [2]. The very same versatile properties such as durability, bio-inertness, light weight and buoyancy are the major culprits for causing problems in the environment. As the plastics are made durable by adding different additives to the petrochemical compounds extracted from oil, the microorganisms do not recognize plastics as their food and do not degrade them. Physical forces such as winds, waves and ultraviolet radiation can disintegrate larger plastics to smaller fragments and monomers in the marine environment. The longevity of plastics is a matter for some debate, and estimates range from hundreds to thousands of years. It is considered that (with the exception of materials that have been incinerated) all of the conventional plastic that has ever been introduced into the environment still remains to date un-mineralized either as whole items or as fragments [3]. Highly buoyant nature of most of the plastic debris aids in transport of these debris along with the currents for thousands of miles, affecting the global environment, and can be rightly called as a trans-boundary pollutant. The global plastic consumption has been estimated at 260 million tonnes in 2008, and the consumption is to reach 297.5 million tons by 2015 [4]. The increasing demand for plastics is due to production of goods and its usage in packaging of various items. At present, plastic is the material of choice in nearly

half of all the packaged goods and packaging represents largest Single sector accounting for about 35 per cent of total plastic consumption. The demand potential for plastics in India is likely to double from current levels of about 10 million metric tonnes (MMT) to about 20 MMT by 2015. In terms of waste generated, plastics account for approximately nine per cent of 1.2 lakh tonnes per day of municipal solid wastes in India. The plastics are categorized into thermoplastics and thermoset plastics based on engineering behaviour. Thermoplastics form 80% of the plastic products in India and are easily recyclable. About 60% of plastic waste generated in India is recycled; the rest ends up in landfills or as stranded debris [5]. Although India stands first in plastic recycling, followed by South Africa (16%), Japan (12%), China (10%) and USA (10%), more emphasis must be laid on recycling of plastic wastes considering the rising demand.

2. Sources of plastic debris

Plastics are dumped into the environment intentionally or unintentionally. Thus, the quantity of plastic debris entering the marine environment is almost parallel to their level of production over the last half century [6]. Such plastic debris composed of fragments of manufactured plastic products (user plastic) and pre-production plastic pellets (industrial pellets, virgin pellets, plastic resin beads or nurdles). Plastic debris on beaches and in coastal waters originates from a wide and diverse range of sources. The sources of plastic debris can be broadly classified into land-based sources and sea-based sources. The land-based plastics include tourism-related and sewage-related debris. The tourism-related debris, mainly consists of direct discard by beach users such as food and beverage packaging material, beach toys and recreational articles. The sewage-related debris includes the garbage from domestic and street discards that enter the sewer or drains. Land-based debris can enter the beach and coastal environment through drains, or can be blown, washed or discharged directly from the land.

The sea-based debris include fishing-related, and ship or boat-related. Fishing lines, nets and ropes, floats and bait packaging material, those are lost accidentally or dumped intentionally into the ocean, constitute fishing-related debris. The ship- or boat-related plastic debris includes the garbage such as food and beverage packaging, toiletries, etc. used in the ship or boat. Apart from the above debris, large quantity of plastic pellets (Fig. 1) lost from container ships, down-drains, and through other shipping and production mishaps have been reported to be floating in coastal surface waters, in the open ocean and on beaches throughout the world and in sediments [7, 8]. Ocean Conservancy (2010) [9] reported that the debris of shoreline and recreational activities dominated the list with 65.31% of the total coastal debris, followed by the smoking-related activities (23.31%) during the International Coastal Cleanup Programme 2009 (Fig. 2).

3. Distribution of plastic debris

Although, mass production of plastics started in 1950s, in a shorter timescale of less than a century, plastics debris is distributed everywhere, both vertically (sea surface to deep seafloor) and horizontally (poles to equator). The development of recycling technologies and management strategies has not kept the pace with the increase in the use of plastics worldwide and resulted in increased pollution by plastic debris. Plastics account for approximately 10% of discarded waste all over the world, and comprise 50–80% of the waste stranded on beaches, floating on the ocean surface and on the seabed [8, 10, 11, 12]. Carpenter *et al*. (1972) [13] first reported the plastic and other man-made litter at sea. Classification of beach litter into groups based on the material made up of has demonstrated that plastic litter predominates. The decomposition of the most plastic debris found on coasts such as plastic grocery bag, foamed plastic cup, disposable diaper and plastic bottle, and fishing line requires 1-20, 50, 450 and 600 years, respectively, and decomposition rate depends on the composition of plastics and environmental conditions [14]. These organic polymers degrade slowly and thus, stay in the environment for a long period of time. As a consequence of accumulation of plastic debris on the beaches, the aesthetic appeal of the beaches is compromised apart from affecting the organisms.

During cleanup under the International Coastal Cleanup Operation – 2012, more than 10 million pounds of trash were picked up by 560000 volunteers from beaches and waterways in 97 countries and locations. 6,271 boaters picked up 109,253 pounds of debris from 905 miles of waterways. The quantity of debris collected in the land-based cleanup operation was predominant over the quantity of debris collected from waters. It is understandable that the number of volunteers participated in land-based collection was far more than that of water-based collection. The cigarettes/cigarette filters topped the list with 2,117,931 items in the collection. Plastic beverage bottles and bags accounted for over one million items each. In India, 16,756 volunteers picked up 147281 pounds of debris from 275.4 miles [15].

Indian beaches are no exception to the accumulation of considerable quantities of plastic debris (Fig. 3). India has a long coastline of 5423 km along the mainland with 43% sandy beaches [16]. However, there are no published reports in respect of beach litter in Indian coast except by Reddy *et al*. (2006) [17] on the accumulation of small plastic debris in the intertidal sediments of the world's largest ship-breaking yard at Alang-Sosiya; Ganesapandian *et al*. (2011) [18] along a 50-km stretch of shoreline in the northern Gulf of Mannar region on southeast coast of India, and by Jayasiri *et al*. (2013a, b) [19, 20] on accumulation of plastic litter on high-water strandline of beaches in Mumbai. The abundance and distribution of litter in Mumbai coast seems to be especially influenced by recreational visitors reflecting inadequate disposal practices and littering behaviour [19].

Fig 1: a) Plastic resin pellets found in Mumbai beaches

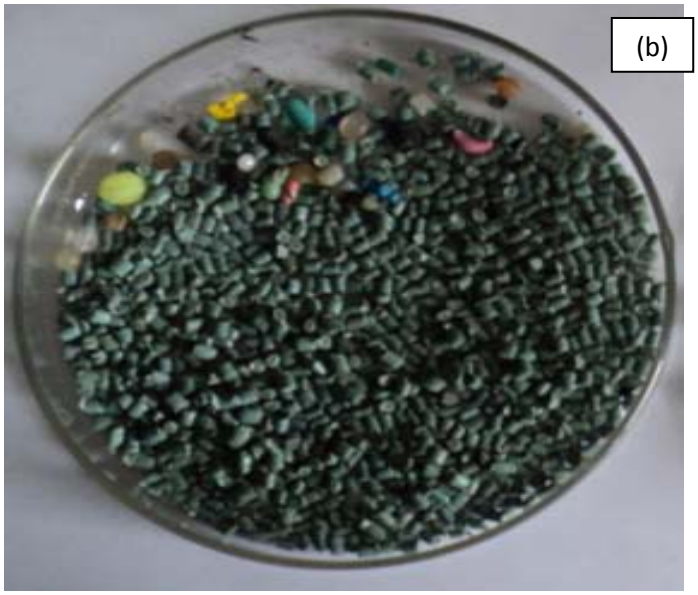

Fig 1: b) Unidentified micro-plastics in Juhu Beach, Mumbai

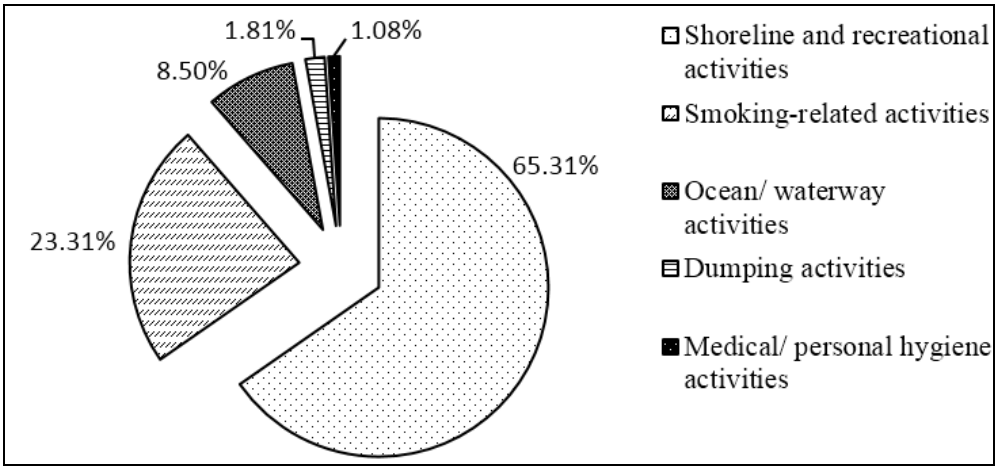

Fig 2: Sourcewise distribution of coastal debris collected in 2009 by International Coastal Cleanup Programme [9]

Fig 3: a & b) Debris in coastal area of Mahim bay, Mumbai; c): Debris in sewage outlet entering a creek in Mumbai

4. Impacts of plastic debris

The plastic debris in the coastal and marine environment affects the ecosystem and human population in numerous ways such as destruction of habitat and introduction of alien species, entanglement and ingestion by marine biota, carrier of toxic organic and inorganic chemicals, dangerous to human safety and health, damaging the vessel, aesthetic value and economy.

The coastal environment and seafloor are important habitats for benthic organisms. The accumulation of plastic debris on the floor smothers the benthic habitats, damaging biota of both soft sediment and rocky substrates at all depths from inter-tidal to the abyss. The smothering affects gas exchange between pore water and sea water [21] and thus makes the habitats unfit for benthic organisms. The plastics especially floating debris act as potential vectors for the sessile organisms and aid in their invasion into newer habitat causing threat to native biodiversity.

The large-size plastic debris such as abandoned fishing nets and lines in the ocean entrap large animals and indulge in ghost fishing (i.e. discarded fishing gear continue to catch fish). Entanglement restricts the mobility of the animals which reduces the ability to obtain food and escape from predators; potentially resulting in serious injury or death by starvation, drowning or suffocation. Ingested materials (either directly as mistaken prey items or indirectly by bioaccumulation through the food chain) tend to damage and block the digestive tract, and reduce feeding activity due to a false sensation of satiation, potentially resulting in starvation and death [22, 23, 24, 25]. At least 267 species worldwide, including 44% of all seabirds, 43% of all marine mammals, 86% of all turtles as well as fish species were affected by marine debris [23]. The underestimation of total number of species affected is certain as some affected species may either sink or be eaten by predators and hence, remain undiscovered [26].

Plastics are known to adsorb hydrophobic pollutants and hence a potential danger of bio-magnification along the food chain apart from the additives added to the plastics during manufacturing process. The investigation of potential bioavailability of compounds added to plastics at the time of manufacture, as well as those adsorbed from the environment is needed [6]. The toxic chemicals and pathogenic organisms carried by plastic debris not only affect marine organisms but also human beings. The plastic debris, resulted from medical and hygiene products, cause infectious diseases through direct or indirect exposure. The safety of the swimmers, divers and snorkelers is under risk due to the possible entanglement of floating and submerged plastic debris such as discarded ropes, nets and lines.

The beaches offer immense value in terms of recreation and tourism. The mere existence of plastic debris on beaches cause annoyance and reduce the aesthetic value, thereby lead to loss of tourism and recreational activities. Apart from this, the derelict nets and ropes damage seagoing vessels by entangling the propellers and clogging of water intake systems. The repair works of such damage are very expensive. The fishing gears also get entangled by plastic debris and cause considerable economic loss to the fishers.

5. Suggestions

The impact of plastic debris is far reaching than that is previously thought. The present widespread use of plastics as an alternative to wood or metal packing allows no room for a complete ban of plastics around the world. Therefore, the option available is to find innovative solution for the collection, segregation, recycling and reuse of plastics to reduce environmental pollution. A number of national and international regulations for preventing pollution in general and plastics in particular exists, such as Annex V of International Convention for the Prevention of Pollution from Ships (MARPOL) prohibits dumping of rubbish at sea from ships, UNEP Global Programme of Action for Protection of the Marine Environment from Land-based activities and the EU Marine Strategy Framework Directive (MSFD). The worrying fact is the extent of implementation of such regulations. Plastics being one of the most persistent pollutants, the strict implementation of the regulations to prevent such pollution, and management of plastic debris in a non-detrimental manner is essential at this juncture. Both prevention and cleanup aspects need to be considered in addressing the problem of plastic debris in the coastal and marine environment. As plastic debris of land- and sea-based sources are prevalent, the management plans of both marine and terrestrial environments should be integrated.

The plastic industries (manufacturing, packaging and processing) shall accept the responsibility of minimizing the plastic pollution by funding to create awareness among consumers for the reduced use of plastic materials and proper disposal of plastic debris, sorting and collection of plastic debris. The industries should also profusely fund to research programmes on developing ecofriendly alternatives to plastics, efficient plastic recycling technologies, and also research on methodologies to monitor and assess the impact of plastics on ecosystem and human beings.

Retailers can encourage the consumers to bring their own reusable items, bags, etc. and also have incentive-linked collection point for the discarded packaging material and other plastic debris at each retailer shops to bringing back the discards from the households to the recycling chain. Retailers should be accountable for the quantity of plastic bags and packaging material moved to the consumers and back to the retailers. The retailers who are efficient in bringing back the plastics for recycling should be rewarded.

Littering is a behavioural issue of the consumers. The change in littering behaviour can be brought out primarily through education. Educating the consumers on the environmental consequences of litter, would result in generation of less plastic waste as well as proper disposal of the debris. The efforts should be made to bring consistent and sustained behavioural changes among consumers to reduce, reuse, recycle, refuse and rethink to manage the problem of plastic debris.

Researchers should involve themselves in developing eco-friendly alternatives, environment-friendly recycling and energy recovery technologies. In addition, the methodologies for effective monitoring and impact assessment should be researched too. The Governments should effectively implement the regulations and also formulate pro-environment policies with the active participation of the stakeholder to address the menace of plastic debris.

The efforts of all the stakeholders (plastic industries, retailers, consumers, researchers and governments) should be harmonized for the effective management of pollution by plastic debris.

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