



A Review on the Impact of Plastic Debris on Marine Environment

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Abstract

Marine plastic debris is increasing day by day resulting negative impacts on the marine biodiversity. Therefore, this review article summarizes the types of marine debris, sources of marine debris, impacts of marine plastics, and global initiatives for reducing plastic pollution in the marine environment. Both macro and micro plastics are coming from two sources including land (e.g. home, industry) and ocean (e.g. fishing). Plastics pose a great threat to organisms in the marine environment, for example, through ingestion or entanglement in the plastic. For addressing the issue of plastic pollution in the marine environment governments have formulated several laws and legislation and taken different approaches as well.

Keywords: Plastic debris; Marine environment; Ingestion; Entanglement; Government

Introduction

There are two types of plastic debris followed by macro, and micro are found in natural environment. About 50% plastic products such as utensils, and plastic bags are intended to disposal [1]. Therefore, marine environment is continuously polluted by plastic debris originate from different households, industries and so on. Humans are dumping, disposal, and discarded of plastics which have reached all the oceans of the world causing adverse effects on marine organisms and their food web. Moreover, livelihoods of the human and their economy also adversely affected by marine debris. Hence, pollution from plastic has now become a global concern [2]. Plastics are made by synthetic or semi-synthetic organic polymers that are very difficult to biodegrade resulting persist in the environment for up to a century [3-5]. Firstly, plastics tend to become break down into small pieces then degrade when exposed to UV radiation either direct sunlight or in sea water [6].

There is an increasing trend of plastic production around the world, for example, in the 1950s the annual production of plastic was about 1.5 million tons whereas in 2013 the annual production of plastic was about 299 million tons [7]. Though macro plastics have been reported in the marine environment since the early days of production, but micro plastics have been recently attention because they are ingested by marine organisms very easily. Thus, macro plastics act as vectors for the chemical transfer of pollutants within the food chain [3,8]. Plastic debris is very hazardous to the entire marine ecosystem because marine organisms can ingest the debris or become entangled in plastic debris [9]. This article reviews the types of marine debris, sources of both macro and micro plastic debris, impacts of marine plastics, and global initiatives for reducing plastic pollution in the marine environment as well. This study will be helpful for the policy maker and environmentalist as well.

Distribution of Plastic Waste in the Marine Environment

There are numerous plastic debris found in the marine environment followed by food wrappers, cigarette filters, fishing line, rope and gear, baby diapers and nappies, six-pack rings, beverage bottles, disposal syringes, and resin pellets as well [10]. There is a distributional variation of plastics in the marine environment. On an average plastic are covered 1000- 4000 km⁻¹ on the surfaces of North Atlantic, South Atlantic, and Pacific Oceans. These areas have shown greater concentration of plastics as most of the plastic manufacturing and processing companies are situated there [11,12].

Plastics in the form of sheets and pellets up to 14 m⁻³ were present in continental shelf waters between Virginia and Rhode Island [12]. On the other hand, an average concentration of micro plastics were found in the surface of Sargasso Sea about 3500 pieces' km⁻¹ over a lateral distance of 1300 km [11]. In Europe about 0.1-4.1% of marine micro plastics come from cosmetic product that is equal to 2461-8627 tons of plastic per year [13]. On the other hand, micro plastics from tire abrasion contribute to 5-10% marine plastics globally [14].

Types of Plastic Debris Found in the Marine Environment

There are two types of plastic debris found in the marine environment including microplastics and macroplastics.

Micro debris

Micro plastics were firstly identified in the North Atlantic [11]. These plastics are small in size viz. <1mm in diameter. Micro plastics consist of nylon, polyester, acrylic, polypropylene, polyethylene, poly(ethylene-propylene), polyvinyl chloride, polyvinyl alcohol, polystyrene, polyester, polyurethane, poly acrylonitrile, alkyd, alkyd resin, and polyamide fibers [15]. In 2004, Micro plastic is firstly coined by Thompson et al. [16]. Micro plastics are comprised of primary, and secondary micro plastics that are degraded from macro plastics e.g. plastics bags [17].

There are variations of concentrations of micro plastics considering water depth i.e. concentrations of micro plastics are higher at the high level water than the low level water (highly dynamic zone). It is evident from the recent studies that risk of micro plastics are more than the macro plastics in the marine environment [18]. Micro plastics are applied in cosmetics formulations like makeup, sunscreen, nail polish, hair coloring, eye shadow, shower gels, and personal care products such as toothpastes, facial cleansers, and air blasting [19]. These micro plastics are hardly visible to the naked eye and likely to flow from washroom drain into drainage systems [20].

Macro debris

Macro debris (>5mm) enter into the marine environment through the dumping of waste [21]. There are spatial variations of

concentrations of macro debris. Lower quantities of macro debris are found in the USA about 45 kgkm⁻¹, on the Falkland Islands about 18.3 kg km⁻¹ [22], and in Oman nearly 29.7 kg km⁻¹ [23]. On the other hand, much higher quantities of macro debris are found in Indonesia, and in Belgian beaches e.g. about 1000 kg km⁻¹, and about 64290 kgkm⁻¹ respectively. Influence of plastic is very usual in the marine environment because of their persistence [24].

Source of Plastic Debris Found in the Marine Environment

The source of plastic debris in the marine environment are mainly the discharge of waste water and runoff water by the river systems followed by proximity of outfalls from the waste water treatment plants, and the fragmentation of rejected plastic products from domestic and industrial wastes [25]. However, it is troublesome to detect the actual sources of marine plastics because of the fragmentation and degradation of the debris in small and heterogeneous assemblages. In addition, the investigation of micro plastics floating just under the surface of the ocean water which is quite impossible to observe through satellite. Consequently, there is no actual information of global plastic input into the ocean [2]. There are some causes of spatial variations of marine plastics including function of the coastal populated areas, popular tourist spots, occurrence of heavy rainfall, floods, speed and direction of the surface current that controls transport path way and accumulation of plastics [18].

Land based debris sources

Land based source is the main source of plastic debris in the marine environment and contribute to 80% of the plastic particle [3]. Land based plastics are coming from streets, parks, parking lots and what not. Then the debris is discharged into nearby waterways by rain, snowmelt, and wind also. Moreover, sources including unlawful dumping of domestic and industrial garbage (Figure 1), public littering, weakly covered dumpsters and dump trucks, manufacturing sites, processors and transporters, overflow of sewage, beachgoers, fisherman, beach based solid waste disposal, landfills, and water transports. All these practices of waste set to marine debris due to careless discharge of debris. Further, packaging and wrapping of food items, beverage containers, and other materials laid the foundation of marine pollution [10]. It is predicted that the majority of marine plastics come from land based sources followed by urban and storm runoff, sewer overflows, beach visitors, inappropriate waste disposal and management, industrial activities, construction, and illegal dumping as well [26].

Ocean based debris sources

Ocean based source is the remaining source of plastic debris in the marine environment and contribute to 20% of the plastic particle, where commercial fishing (Figure 1) is the main human activity [27]. Ocean based debris is also produced by the people at sea. People's actions and activities are responsible for producing ocean based debris. These debris are coming from commercial

fishing vessels, military, merchant, and research vessels; recreational boats and cruise ships; offshore petroleum platforms and associated supply vessels. More importantly, accidental loss or system failure of vessels also generate some debris. Again, poor waste management practices, and inappropriate discharge of debris from the vessels produce some debris. Commercial and

recreational fishermen produce ocean debris when they throw away ship generated trash overboard or fail to regain nets, ropes, trawl floats and other fishing related equipment [10]. Finally, it is said that ocean based source mainly comes from the fishing industry, nautical activities and aquaculture.

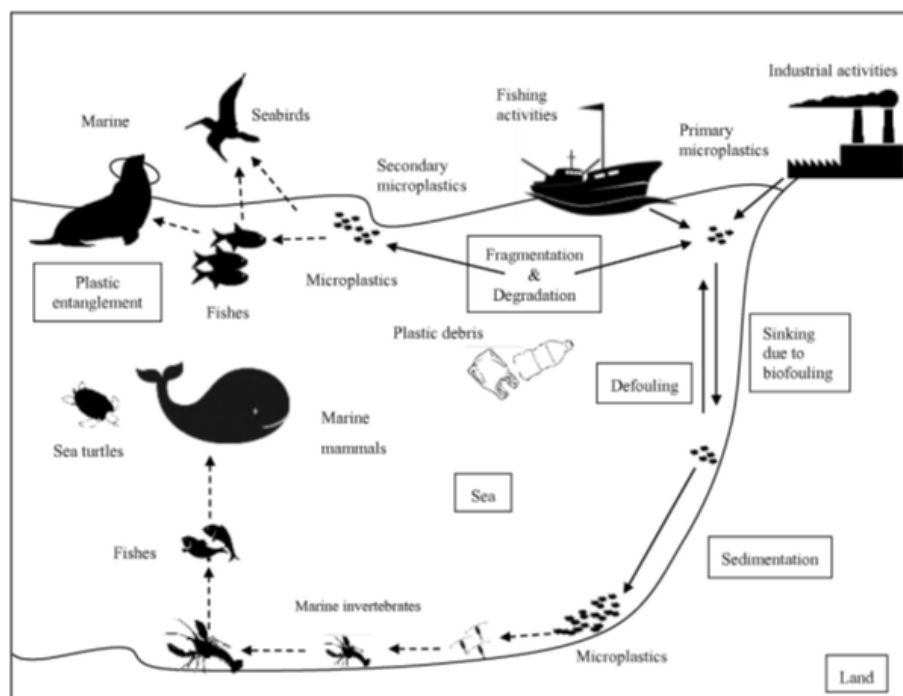


Figure 1: Potential pathways of plastic debris transportation and its biological interactions Source: [17, 39].

Impact of Marine Plastic Waste

At present, marine plastic is a global issue because it is affecting major waterbodies i.e. marine. Therefore, this debris can pose negative impact on humans (coastal communities), wildlife, habitats and so on. Plastics both macro and micro has negative impacts on marine environment. Macro plastics (fishing rope, nets) can cause entanglement of birds, mammals, invertebrates, and turtles. Again, micro plastic also causes negative impact on fish because the plastic is white or opaque in color as a result surface feeding fish commonly mistaken for plankton. Hence, ingestion of plastics is harmful for aquatic organisms [28]. Over and above, these micro plastics can enter the human food chain by the ingestion of fish, and shellfish which is detrimental to human health [29]. Macro plastic sometimes change the biodiversity of ocean by altering the availability of refugia. Moreover, large plastics provide hard surface for taxa as a result the surface would be unable for settle down of taxa [30]. Likewise, deep sea would not be typical habitats for the marine organism [31].

Marine sediments

Marine sediment is suffering from plastic debris. Nearly 258408 plastic particle m⁻² was found at fan Lau Tung Wan, Hong Kong. The highest number of plastic (e.g. polystyrene) found on the

beaches in Hong Kong due to population density and their lifestyle, for example, the use of insulated boxes for food transportation [32]. At the Belgian coast, concentrations of micro plastic on beach sediment was about 92.8 particles kg⁻¹ and are continuously increasing. Concentrations of plastic debris on the marine sediment at Groenendijk increased three times over the time period of 1993-1996 to 2005-2008, with 54.7 ± 8.7 and 156.2 ± 6.3 particles kg⁻¹, respectively [33].

Marine waterbody

Personal and medical debris followed by condoms and tampon applicators which enters waterways via direct sewage outflows or inappropriate sewage treatment systems poses serious water quality concern. Therefore, these debris can affect whole ocean water. The availability of these plastics items are indicating bacterial contamination include *E. coli*, other harmful bacteria, and viruses. When water contact with these contaminants and pathogens can cause infectious hepatitis, diarrhea, bacillary dysentery, skin rashes, typhoid, and cholera also [10].

Marine animals

Pollution from plastic affects marine species from zooplankton to whales. Both macro and micro plastic can affect individual

species either through entanglement or ingestion (Figure 1). Large plastic debris are responsible for entanglement while fragmented macro and micro plastic is ingested by 170 marine vertebrate and invertebrate species as well. Plastic especially micro plastic enter into every marine food web followed by invertebrates, fishes, turtles, and mammals too [34]. Recent studies have identified that zooplankton ingest plastic [5]. Ingested micro plastics can bridge trophic levels into crustaceans and other consumers [35].

At present, pollution from plastic provide more or less negative impacts on the marine habitat. These negative impacts are not uniform and depend on the type, size, accumulation and degradation rates of plastic [36]. Besides, plastic in the coastal areas alter the physico-chemical processes including light and oxygen availability, temperature, and water movement. Alteration of temperature of sediments also bring some harmful effect to reptiles as their sex determination depend on temperature [37]. This leads to the interruption of foraging patterns of key species [38].

At the tropical and subtropical shallow water coral reef has been entangled by fishing nets. Therefore, there is ecological shifting from heavily affected area and might affect their integrity, longevity, and resilience also [40]. Entanglement by the marine debris or plastic (e.g. ribbons on balloon, six-pack rings, rope, hair bands, hats, nets, and lines) is a well-known threat to marine taxa including northern fur seal, Hawaiian and Mediterranean monk seals [41] with at least 135 species are recorded as ensnared in marine debris, for example, snakes, turtles, pinnipeds, cetaceans, and sirenians [42]. Ocean plastics can impede animal's mobility, impose cuts and wounds, prevent from eating. Besides, debris can cause suffocation or drowning.

The effects of entanglement include abrasions, constriction, scoliosis, loss of limb, and increased inability to avoid predators [43]. Rates of entanglement depend on the age of the marine mammals. Generally, younger and immature animals are more entangled. Again, younger animals (e.g. seal pups and juveniles) may be more likely to become entangled in nets, whereas sub adults and adults are more likely to become entangled in fishing line [44]. On the other hand, ghost nets also ensnare cetaceans, turtles, sharks, crocodiles, crabs, lobsters etc. [45].

Diet or ingestion of plastic by animals is another threat to coastal animal. Plastic pellets can appearance like fish eggs, and plastic shopping bags can appearance like a jellyfish to a hungry sea turtle. Consequently, sea turtles are more vulnerable to the ingestion of ocean debris because of their feeding strategies [46]. There are large number of animals who confuse about debris for food and cannot bring up again to the mouth an item once it has been swallowed. This debris often becomes lodged in their throat and digestive tracts. Debris that will not pass out from the stomach gives a false sense of cessation, resulting some animals to stop eating and slowly starve to death. According to the U.S Marine Mammal Commission, 6 of 7 species of sea turtles, and 26 species of marine mammals are facing ingestion problem [47].

Marine birds

Sea birds have been entangled by abandoned fishing nets around the world (Figure 1). About 99 sea birds were entrapped in a 1500 m gill net [48]. Sometimes, sea birds encountering discarded fishing nets face possible drowning. Sea birds are more likely to be injured through ingested plastic debris. Moreover, eating of plastic could result in blockage or internal injury [49]. According to the U.S Marine Mammal Commission about 111 marine species of sea birds are facing ingestion problem due to marine debris [47]. In Alaska 15 out of 37 species of marine birds seized with plastic debris [50].

Sea birds in Gough Island, and South Atlantic Ocean are mostly contaminated with marine debris i.e. 53 debris per bird. About 96% white-faced storm-petrels and 81% greater shearwater contaminated with marine plastic [51]. birds that do not bring back plastic again to the mouth which can interfere directly with their digestion. Therefore, these non-food items cause gastrointestinal blockage. Large quantities of plastic in the stomach of a bird could bring down feeding activity by sustaining stomach swellings. More than that, the availability of large quantities of debris in the stomach hamper the secretion of gastric enzymes. Plastic ingestion may also be harmful to reproduction [50].

Tourism

Tourist, swimmers, divers, and snorkelers of a beach can be harmed by the broken glass, medical waste, fishing line, and, discarded syringes. Sometimes, they can be entangled by the submerged or floating debris. Marine environment always provides economic advantages to nearest people and government through the tourism industries. However, debris makes coastal area unattractive and potentially risky for the tourists. Marine plastic particle discourages people from fishing, boating, swimming, diving, and visiting coastal areas [10].

Global Initiatives to Reduce Marine Plastic Pollution

The International Coastal Cleanup (ICC) tries to involve other NGOs and volunteer groups for reducing marine plastic pollution by cleaning up coastal area over the world. The Honolulu strategy provide some outlines for prevention and management of marine plastic [52]. Two strategies were taken by Honolulu including market-based instruments (e.g. taxes on new plastic bags) for lessening waste, and creates policies, regulations, and legislation to minimize marine plastic or debris [53].

Formulation of law & legislation

Several laws and international agreements regulate litter and debris on both land and sea. The current laws relevant to the marine debris issue include the 1972 London Dumping Convention (LCD) and the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), which provides a comprehensive approach to dealing with ocean dumping by creating international guidelines to prevent ship pollution. MARPOL prohibits the disposal of plastic materials at sea and regulates the disposal of

other garbage at sea. MARPOL also requires ports and terminals to provide garbage reception facilities for boats and ships. There are also regional agreements to govern marine debris, including the 1987 Convention for the Protection and Development of the

Marine Environment of the Wider Caribbean Region—known as the Cartagena Convention [10]. Moreover, there is a Chronological plastic bag policy intervention were developed across the world (Table 1).

Table 1: Chronology of global plastic bag policy interventions.

Country (Jurisdiction)	Date of Ban (Introduction)	Policy Framework
Bangladesh	2002	Legislation passed to ban the manufacture and use of plastic bags. One of the major drivers of the ban was the tendency of submerged plastic bags to exacerbate major floods. While the ban has been in place, it has not been strictly enforced [54].
South Africa	2002 (2003)	Legislation passed to place a ban on plastic bags b30 μ m thick. Plastic bags N30 μ m were subjected to the imposition of a levy. Enforcement of the plastic bag ban has been poor. Acceptance of the levy by consumers has seen high levels of consumption continue [55].
Kenya	2007 (2011)	In 2007, a ban to plastic bags b30 μ m, and a levy was imposed on bags N30 μ m [56] (Earth Policy Institute 2014). Legislation passed to ban plastic bags b60 μ m and continue with a levy for thicker bags [57].
China	2008	Legislation passed to ban shops, supermarkets, and sales outlets from providing free plastic bags that are b25 μ m thick. For bags N25 μ m, a levy was put in place. Exemptions from the ban were in place for hygiene reasons in the handling and storage of fresh food. Adherence by retailers has not been widespread. N80% of retail stores in rural regions have continued to provide plastic bags free of charge. Suiping Huaqiang Plastic, a 20,000-employee plastic bag manufacturer, experienced the ban's economic effects almost immediately. The company went out of business soon after the government announced the plastic bag policy [58].
U.S. (Washington D.C.)	2009 (2010)	Legislation passed to help protect the Anacostia River, and money raised from the plastic bag levy is helping to clean up the river [59].
Australia	(2009, 2011, 2013)	The states and territories of South Australia (2009), Tasmania (2013), Australia Capital Territory (2011), and Northern Territory (2011) have all introduced bans on plastic bags [60].
Argentina (Buenos Aires)	2012 (2017)	In Argentina, Buenos Aires Province implemented a plastic bag ban in supermarkets in 2012 and full ban of plastic bags in supermarkets and hypermarkets, commencing 1 January 2017 [61].
Italy	2013	A ban on the sale of non-biodegradable plastic bags. This ban has not been fully implemented due to disputes regarding EU trade laws [56].
England	2015	Legislation passed by British parliament to place a levy of 5 pence per plastic bag. The levy applies at large retail businesses, which are businesses with 250 or more employees. Smaller businesses can also charge the levy on a voluntary basis [62].
Canada (National)	2016	In February 2016, Walmart Canada began charging customers a 5 cent fee for all shopping bags [63].

Hands-on approach

Educating the public: Everyone needs to take responsibility for their actions and keep their trash out of the marine environment—from school children, to people who eat fast food; recreational boaters and commercial fishermen; beach visitors and marina operators; waste management workers, and workers in all industries that transport or manufacture resin pellets. Every piece of debris and litter found in our waterways at one point involved a person who made an improper decision. In a way, it can be said that every piece of debris has human fingerprints on it. Knowledge is key for consumers to make appropriate choices when it comes to using and disposing of waste items.

There are many marine debris and litter-prevention activities and lesson plans available by various government agencies and school systems. In many cases, the manufacturers of plastic items have participated and supported their creation and dissemination. For example, the company that manufactures six-pack rings, ITW Hi-Cone, created an educational video, lesson plan, and a recycling program for schools. In addition, they modified the resin to increase photo-degradability. A critical part of successful education includes a complete understanding of the problem. In the 1980s, Ocean

Conservancy began its work on marine debris resulting in the development a public education and monitoring program targeting marine debris [10].

Gathering Data—International Coastal Cleanup and National Marine Debris Monitoring Program: Ocean Conservancy and its international and domestic partners have grown the International Coastal Cleanup (ICC) into a global annual volunteer effort devoted to the marine environment. The ICC engages schools, marinas, civic organizations, government agencies, and businesses as volunteers to conduct local cleanup events. One of the ICC's primary goals is to trace pollution to its source and work to prevent it from occurring. Volunteers record debris information on standardized data cards that identify the types, sources, and activities that produce the debris found along the world's beaches and waterways. Information on the data card is grouped by the behavior associated with the debris, including recreational, beach-going activities, smoking-related activities, ocean and waterway activities, activities associated with legal or illegal dumping, or activities resulting from improper disposal or handling of medical or personal hygiene materials. The result is a unique global database of debris information. Data from the

Cleanup provides the framework for government action to limit marine debris and to educate the public about litter and pollution prevention [10].

Business or Industry Involvement: The plastic industry has taken steps to understand the true nature of durable and degradable plastic materials and their behaviors in the environment. For more than 20 years, the plastics industry has joined forces with Ocean Conservancy regarding the presence of plastic materials and their impacts on the marine environment. The result was the formation of a triple alliance between industry, the conservation community, and government agencies with the mission of educating industry employees and consumers about the problems of marine debris. A national ad campaign was developed to help build awareness of boating and fishing groups about the impacts of fishing gear and packaging materials that are allowed to enter the marine environment [10].

The Dow Chemical Company provides an example of a company actively supporting the efforts to decrease marine debris. Dow has sponsored the International Coastal Cleanup for the past 20 years, has aided efforts in the Northwestern Hawaiian Islands for Monument designation, and has worked with Ocean Futures and Jean-Michel Cousteau on an education campaign on marine debris. Other companies, like ITW Hi-Cone and Philip Morris USA have directly approached their customers with litter prevention messages. Philip Morris has mailed pocket ashtrays to their customers as part of a campaign to decrease the number one type of litter—cigarette filters [10].

The Society of the Plastics Industry in partnership with the American Plastics Council (now the American Chemistry Council) developed “Operation Clean Sweep,” a program to train employees to prevent resin pellets spills and raise awareness for industry-based responsibility for the raw plastics materials that are being introduced into the environment. Pellets, the raw material for most plastic items, can be accidentally introduced into the environment by pellet manufacturers, by those who transport pellets, and by the end user. Most litter prevention programs target the consumer — but this program is focused on employees of the companies that manufacture products from plastics. Zero pellet loss is key to the industry’s ability to conserve resources, promote plant safety, and ultimately protect the environment [10].

Conclusion

Plastics debris originates from both land and ocean which is usually found in marine environment (e.g. water bodies, beach sediment). It is very difficult to biodegrade the debris resulting persist in the environment. These debris bring negative impacts on the marine biota and their food web through plastic ingestion or entanglement. There are some marine organisms followed by fish, sea birds, or sea lions have settled ingested plastic that is often associated with hydrophobic contaminants in their bodies. Moreover, these organisms may also become entangled in the plastic which can be dangerous. At last, it is found that governments

introduce laws to control the sources of plastic debris and the use of plastic debris. In parallel, plastics industries should take responsibility for the end-of-life of their products by introducing plastic recycling or upgrading programs.

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Conflict of Interest

No conflict of interest.

Reference

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