Review Article

Marine Debris: A Global Environmental Challenge to Coastal Diversity

Abstract:
Marine debris is an alarming issue for the marine environment and impacts the coastal and marine life by causing severe injuries, reduced health, decreased reproductive output and mortality. It also results in ingestion, entanglement, kill, maim and drown marine animals due to increased transport of pollutants into food chains. Over 400 million tons of plastic are produced every year for use in a wide variety of applications. At least 14 million tons of plastic end up in the ocean every year, and plastic makes up 80% of all marine debris found from surface waters to deep-sea sediments. Plastic pollution threatens food safety and quality, human health, coastal tourism, and contributes to climate change. Due to its durability, society's adoption of plastics as a substitute for traditional materials has expanded almost exponentially as a result, large-scale plastic production began. Therefore, there is an urgent need to explore new and existing legally binding agreements to address management of marine debris. This study aimed to review the marine debris with respect to types, sources, decomposition rate, impacts, and strategies for management of marine debris. The result showed that to reduce the impacts of marine debris, it is necessary to change mind-set and habits of people about waste disposal, and to avoid production and use of single-use plastics by producers and consumers. It is suggested that, input prevention should be the major objective during management efforts of marine debris. Reduction measures such as proper waste management, plastic recycling, and stringent penalties for illegal waste dumping are essential to reduce the marine debris.
Keywords: Biodegradation; Diversity; Entanglement; Ingestion; Marine debris; Plastics

1. Introduction

Any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment is referred to as "Marine debris" (DB)/Marine litter" (Walker et al., 2021). It largely consists of plastic materials which poses environmental, economic, health, aesthetic and cultural threats, including degradation of marine and coastal habitats and ecosystems and cause socioeconomic losses in marine-based sectors (Ministry of Environment and Water Malaysia, 2021; NOAA, 2024).

MD primarily consists of plastic, food cover, glass, rubber, tyre, household material, disposed, discarded or abandoned in coastal and marine environments or brought indirectly to the sea by inland waterways and winds. In the seas, MD either floats or sinks, and can be transported to other areas by currents, washing up onto the shoreline and beaches, or drifting offshore and sinking to the deepest ocean trench (Kannan et al., 2023). Shipping, fishing, aquaculture, tourism and recreation are directly affected by the pollution resulted from MD. It also causes risks and possible adverse effects on marine organisms and on human health (Lohr et al., 2017).

Plastic debris has now become the most serious problem affecting the marine environment because slowly degrading large plastic items generate microplastic (particles smaller than 1 to 5 mm) particles which spread over long distances by wind driven ocean surface layer circulation (Thevenon et al., 2014). It affects the oceans and inland waterways,

and also the economics and health of coastal and waterside communities. MD cause unsightly inconvenience for beach-bound vacations or pleasure boaters (Sheavly, 2005).

MD is a key environmental issue at the global level and a major threat to marine and coastal biodiversity. It has affected the world's oceans, coastal ecosystems, rivers, and also the livelihood of fishers (Naik et al., 2021). MD can impact organisms through entanglement, ingestion, chemical and microbial transfer, and by altering or modifying assemblages of species. It also carries a risk to human health and welfare by affecting tourism, fisheries, aquaculture, energy supply and economic losses to individuals, enterprises and communities (Werner et al., 2016).

STAP (2011) stated that; MD is unsightly, damages fisheries and tourism, kills and injures marine life, causes navigational problems, transport potentially harmful chemicals and invasive species, and represents a threat to human health. It is contaminated with man-made items of debris, and plastic items represent the major category of MD by material type (Scottish Government, 2012; CBD, 2016). MD is a significant stressor on the marine and coastal environment and impacts on marine biodiversity. It has socioeconomic impacts with health and safety hazard along with negative effect on commercially significant resources (UNEMG, 2021).

MD is a trash (articles that have been made or used by people or discarded) entered into the marine environment due to careless handling or disposal. It comes along with industrial waste, raw sewage overflows, runoff from cities, and mining operations. Plastic is the most prevalent type of marine debris, and comes in all shapes and sizes, such as microplastics (Project Oceanography Fall, 1999). Items that are most frequently collected from MD include: cigarette butts, foamed plastic cups, foamed plastic pieces, glass beverage bottles, glass pieces, metal beverage cans, paper pieces, plastic beverage bottles, plastic caps and lids, plastic food bags and wrappers, plastic pieces, and plastic straws (Schnurr et al., 2018).

Human-made refuse affecting marine ecosystems worldwide include glass or plastic bottles, cans, bags, balloons, rubber, metal, fibreglass, cigarettes, and other manufactured materials that end up in the ocean and along the coast. It also includes fishing gear such as line, ropes, hooks, buoys and other materials lost on or near land, or intentionally or unintentionally discarded at sea (Acampora et al., 2014). MD extends to every ocean and coast and causes enormous economic cost, ecological damage and social impact. It poses one of the biggest threats to marine species and marine ecosystems (Lusher et al., 2017).

CSIRO (2014) noted that; MD is an increasing issue for the integrity of marine ecosystems and impacts the wildlife especially marine turtles and seabirds by ingestion, entanglement, drowning, and also results in reduced health, decreased reproductive output and mortality (Hardesty and Wilcox, 2011). Plastics made up 79% of the total MD because the amount of waste entering the oceans on a yearly basis is immense. The impact of plastics and microplastics remains subject to investigation. Also, the potential of impacts of marine plastic debris on human health is also attracting attention (Bouwman et al., 2016).

According to IUCN (2021); over 400 million tons of plastic are produced every year, of which, at least 14 million tons of plastic end up in the ocean every year. Further, plastic makes up 80% of all marine debris found from surface waters to deep-sea sediments (Kripa et al., 2016). Plastic pollution threatens ocean health, the health of marine species, food safety and quality, human health, coastal tourism, and contributes to climate change. It also causes negative impacts on the marine biodiversity because marine environment is continuously polluted by debris originated from households, industries and other sources (Romana et al., 2021).

Pawar et al (2016) stated that; MD in oceans and seas is an aesthetic problem; it incurs considerable costs and can have severe impacts on marine organisms and habitats. MD

is more than an unsightly inconvenience for beach-bound vacationers or pleasure boaters; it is one of the world's most pervasive pollution problems affecting our waterways (Tekman et al., 2022). Every piece of MD is generated by the human activity, which affects the coastal ecosystem (The Ocean Conservancy, 2003). Along with land-based sources, MD results from sea based activities, such as fishing, aquaculture, shipping, ocean dumping and other ocean-based activities (GESAMP, 2021).

Perumal et al (2021) demonstrated that; MD (solid waste), marine litter (discarded man-made), and microplastics have been affecting and threatening marine life, hinder navigation safety, and throws human health at risk (UNEP, 2016). Further, storm drains, sewers, shorelines, and outdoor events contribute to the bulk of the garbage and debris that litter the beaches. Extensive use of plastic releases which cannot be decomposed and eventually carried away into the sea is estimated to cause more plastic than fish in the ocean in near future (Sari et al., 2021).

The aim of this review is to update recent information from the available literature relating with 'Marine Debris: A Global Environmental Challenge to Coastal Diversity' with respect to types/categories, sources, decomposition rate, impacts, and strategies to be adopted for the management.

2. Materials and Methods

This review was carried out by collecting information on relevant research findings with the help of Internet search engines like Google, Google Scholar, PubMed, ScienceDirect, and ResearchGate and other published articles, reports, and monographs. A total of 40 published articles have been reviewed and the related information was gathered for this current study with respect to types/categories, sources, decomposition rate, impacts, and strategies to be adopted for the management of marine debris.

3. Types/Categories of marine debris

Galgani et al (2010) and UNEP (2016) stated that, depending on material types, MD can be classified into several distinct categories such as: Clothing and textiles (furnishings, shoes, and towels); Glass (bottles, bulbs); Metal (aerosol cans, disposable barbeques, drink cans, and foil wrappers); Paper and cardboard (cartons, cups and bags); Plastics (synthetic polymeric materials: fishing nets, ropes, buoys and other fisheries-related equipment; consumer goods: plastic bags, plastic packaging, plastic toys; tampon applicators; nappies; and smoking-related items: cigarette butts, lighters and cigar tips; microplastic particles, plastic resin pellets); Processed timber (crates, pallets, and particle boards); and Rubber (balloons, gloves, and tyres) (CBD, 2016).

According to Naik et al (2021), MD can be categorized into two broad types, non-plastic debris (consumer and manufactured items: glass bottles, cans, bags, rubber, metal, fiberglass, cigarettes, fishing gears etc.) and plastic debris with polymers like polyethylene terephthalate (PETE/PET), high density polyethylene (HDPE), polyvinyl chloride (PVC), low density polyethylene (LDPE), polypropylene (PE), polystyrene (PS), polyamide/Nylon, acrylonitrile butadiene styrene (ABS) and polyurethane (PU). It also includes clothing, glass, industrial chemicals, metals, microplastics, paper, persistent pollutants, pharmaceuticals, plastic litter, rubber, and wood (Ministry of Environment and Water Malaysia, 2021; UNEMG, 2021).

4. Sources of Marine Debris

Ministry of Environment and Water Malaysia (2021) noted that; sources and pathways of marine litter are diverse and include land-based sources, shipping, fishing, aquaculture, tourism and recreation. Marine debris originates primarily from two distinct sources, the sea (and inland waterways) and the land (The Ocean Conservancy, 2003; Gunsilius and Frommann, 2015). The land-based sources account for around 80% of MD

globally. Human behaviour and storm-related events also contributes as the other sources of MD (Ashish and Sanhar, 2023).

Hardesty and Wilcox (2011) concluded that; in Australia, domestic sources are the major contributor to marine debris and large quantity of debris is released in areas of intense human activity. KASA Malaysia (2021) described that; MD arises from aquaculture and fisheries (accidental loss, intentional abandonment and discarding of fishing gear), shipping (ship-generated waste, plastic blasting in shipyards, and others), cosmetics and personal care products (use of microbeads), textiles and clothing (including synthetic fibres released during washing), retail and tourism (including plastic bags, bottles, packaging materials, disposable tableware and cutlery).

Department of Environment, Parks and Recreation, Ministry of Development, Brunei Darussalam (2021) stated that; main activities generating the MD under various groups include:

- **Human behaviour:** Accidental or intentional Hall (2000).
- **Land-based sources:** Agriculture, beachgoers, fisherman, beach based solid waste disposal, landfills, manufacturing sites, overflow of sewage, processors and transporters, public littering, unlawful dumping of domestic and industrial garbage, water transports, and weakly covered dumpsters and dump trucks (Romana et al., 2021).
- **Ocean-based sources:** Aquaculture installations, commercial shipping, cruise liners, fish farming, fishing vessels, military fleets, offshore oil and gas platforms and service vessels, passenger ferries, recreational boats, and research vessels (GESAMP, 2021).
- **Storm-related sources:** Floods, flushing of waste, and ocean currents (IUCN, 2021).

5. Decomposition rate of most common marine debris

According to Department of Environment, Parks and Recreation, Ministry of Development, Brunei Darussalam (2021); MD can stay in the environment for a longer time. Plastics do not biodegrade and they break down into tiny pieces called ‘microplastics’. The decomposition rate of most common marine debris is: aluminium can: 80-200 years; bottle cap: 100-500 years; cigarette butt: 10-15 years; fishing line: 600 years; paper cup: > 20 years; plastic bag: 10-100 years; plastic bottle: 450-1000 years; plastic cup: 450-1000 years; plastic cutleries: 100-1000 years; plastic straw: 100-500 years; snack packaging: 80-100 years; and styrofoam cup: 50-500 years (UNEP, 2016).

6. Impacts of Marine Debris

KASA Malaysia (2021) stated that; MD is transboundary in nature and cause poor aesthetics, marine pollution and serious threats to the ecosystem, human health, economy and overall quality of life (KASA Malaysia, 2021). Sheavly (2005) described that; impacts of MD can be categorized as: aesthetic and economic impacts, damage to vessels, destruction of habitat, human health and safety, ingestion and entanglement in wildlife, and introduction of alien species (UNEP, 2016).

Thevenon et al (2014) noted that; impacts of plastic debris on marine organisms include physical effects of plastic ingestion, transport of invasive species, and chemicals associated with plastics. MD cause adverse impacts on the environment, ecosystem functions and services, communities, and on economic activities at large. MD causes physical harm and mortality to marine life, resulting in direct economic losses to coastal and marine industries such as fisheries and aquaculture, tourism and shipping sectors (KASA Malaysia, 2021).

Werner et al (2016) noted that; impacts caused by MD include:

6.1. Impacts on biota

6.1.1. Affects animal welfare

Animal welfare refers to the physical and psychological wellbeing of animals and means how an animal is coping with the conditions in which it lives. MD can be regarded as harmful and has impact on animal welfare. Animals which are entangled by, trapped in, or ingest marine litter often experience trauma, damage, infection and compromised ability to feed, move and carry out their normal behaviour. The resulting suffering and pain, suggests that MD represents not only a serious environmental, conservation, human health and economic issue, but also as a significant global animal welfare issue that requires urgent action (Werner et al, 2016).

6.1.2. Affects levels of biological organization

MD has harmful effects on individual organisms of many species. It negatively affects population of some species and can modify marine assemblages. Marine debris in combination with other anthropogenic stressors represents a substantial additional challenge to marine biodiversity. It alters the levels of biological organization of wild marine animals, especially the marine turtles. One of the factors responsible for turtle declines is entanglement in litter and ghost-nets. The frequent ingestion of plastic litter by turtles contributes to population decline of marine turtles (Ryan, 2015).

6.1.3. Alter/modify assemblages of species

MD is an important contributor to the anthropogenic stresses acting on habitats and biodiversity. Pollution due to MD introduces additional hard surfaces into the marine environment. Especially when litter sinks to sedimentary seabed it can create an artificial habitat, which can be colonised by organisms that would not normally occur there. Depending on the size of MD items, they can provide habitat for faunal assemblages with taxa typically found in rocky environments. Habitat change has the potential to influence the relative abundance of organisms within local assemblages (Wang et al., 2016).

MD also cause the `smothering`, where litter covers bottom sediments or sedentary organisms such as corals and sponges. Smothering leads to reduced fitness and even death of the organisms lying under the plastic through reduced oxygen levels and reduced photosynthesis which alters the habitats and communities.

6.1.4. Entanglement in marine wildlife

Werner et al (2016) stated that; marine organisms are entangled in discarded or lost fishing gear or rope. Entanglement is the most visible effect of MD causing external injuries resulting in death. If entanglement is acute, it causes an immediate and severe welfare problem and death is reported in 80% of reports of entanglement. Tissue damage, skin lesions with ulceration, and death of muscle tissue are the widespread result of entanglement.

Naik et al (2021) pointed that; threats of plastics are mechanical due to entanglement to various species of seabirds, marine mammals and sea turtles. Frequency of entanglement in selected species of Brown Pelican, Grey Seal, Northern Elephant seal, Common Bottlenose dolphin, Green turtle, Leatherback turtle, Olive Ridley turtle etc (Adimey et al, 2014).

6.1.5. Ingestion

Marine animals may ingest different types of litter such as paper, processed wood, synthetic materials etc. Ingestion of MD occurs mainly as a intentional, accidental or secondary in many species of marine wildlife. Among marine biota, the most prominent group ingesting MD, particularly the plastics is the marine mammals (whales, toothed whales, true seals, eared seals, etc.); seabirds (waders, skuas, gulls, terns and auks); marine turtles, fish (pelagic and demersal fishes such as lantern fish, tuna, albacore, swordfish) and invertebrates (Werner et al, 2016).

Ingestion of MD is reported in all groups of marine organisms, especially in air-breathing marine life, mammals, birds and turtles. Ingested MD with plastic may cause direct physical damage to the various components of the intestinal tract (i.e. oesophagus, stomach,

gut); blockage of stomach or intestine; perforation of stomach wall; and finally leads to rapid death.

6.1.6. Transfer of chemical substances

MD also acts as a vector for the transport of chemicals to organisms upon ingestion. Plastics containing harmful chemicals such as plasticisers, antimicrobials and flame retardant chemicals can be released to organisms upon ingestion. Such transferred chemicals also have risk of transfer directly to human also. Many seabirds and invertebrates retain MD for a long time and gradually grind them down in their muscular stomachs, with the potential for leaching and transfer of chemical additives. Such transferred chemicals cause sub-lethal chemical effects in some wild animals as a consequence of MD ingestion (Werner et al, 2016).

6.1.7. Vector for transport of biota

Thevenon et al (2014) noted that; natural debris (dead wood, ash) acts as transport media for the non-indigenous invasive species; which are the greatest drivers of biodiversity loss and pose a threat to ecosystems integrity and functions. It also cause the alteration of habitats, changing native species dynamics, killing native species and/or competing with them, and acting as vectors of diseases. These species can alter the composition of ecosystems and also the genetic diversity through breeding with local varieties or species. Kannan et al (2023) showed that; MD acts as a vector for species dispersal in with the increasing risk of invasions by non-indigenous organisms attached to debris along the southeast coast of India.

6.2. Socioeconomic effects

According to Werner et al (2016); MD affects the human welfare by exerting negative impacts on economic sectors such as tourism, fisheries, aquaculture, navigation and energy and bringing economic losses to individuals, enterprises and communities. Socioeconomic effects of MD include: Implications on maritime sectors, impacts on coastal communities and tourism, perceptions of society about marine litter, human health risks, and effects of marine litter on ecosystem services.

6.2.1. Implications on Maritime Sectors

- Impacts on fisheries and aquaculture: Potential impacts of MD on fisheries includes contamination of fish and shellfish with ingested plastics, lost and damaged fishing gear, reduced earnings and lost fishing time, restricted catch due to litter in nets, and vessel damage and staff downtime (Kannan et al, 2023).
- Impacts on shipping and ports: Potential impacts of MD on shipping industry includes additional dredging in harbours and marinas, cost of coastguard rescues, ISO Awards and Golden Anchors, negative publicity, removal of debris from harbours and marinas, statutory duties, and vessel damage and incidents (Werner et al, 2016).
- Clean-up costs of floating or seafloor litter: Large amount of financial provision should be made for the clean-ups of floating MD or debris deposited on the sea-floor. It is noted that clean-up of the floating debris inside the port of Barcelona is conducted daily throughout the year (KASA Malaysia, 2021).

6.2.2. Impacts on coastal communities and tourism

Galgani et al (2010) noted that; potential implications of MD on coastal municipalities includes beach awards, beach cleansing costs, disposal costs, hidden costs, legal action, negative publicity, Public health risks, and statutory duty,

- Reduction of aesthetic value and beauty of the coast: Some of the economic costs to coastal municipalities include the direct costs of keeping beaches clear of debris and its wider implications for tourism and recreation. Potential impacts of MD on tourism include area promotion and branding, loss of aesthetics and reduced amenity, negative publicity and reputation, reduced recreational opportunity, and reduced revenue.

- Costs of beach cleaning: Direct costs of beach cleaning include the collection, transportation and disposal of debris, and administrative costs such as contract management. Debris should be removed from the coast either beached or floating, or left behind by beach users.

6.2.3. Perceptions of society about marine litter

The perception of the society about MD indicates a high concern on the issue. It poses a serious problem for coastal communities, impacts the marine environment and the appearance of the coast are the issues that raise more concern. MD was shown to reduce the restorative value and the presence of packaging related debris was perceived as stronger negative effect than the presence of fishing related debris. Further, the debris on beaches and at sea is often associated with waste issues and may be considered as a hygiene problem (CBD, 2014).

6.2.4. Human health risks

Marine litter, beached or floating, is considered a public health issue. Large sized debris may typically affect humans to an individual level. Pieces of glass, metal fragments, discarded syringes and medical waste may harm beach users. Entanglement can also pose a threat to maritime workers, swimmers, and divers who can become entangled in submerged or floating debris such as fishing nets and ropes. The presence of microplastics in food (fish and shellfish) could potentially increase direct exposure of plastic-associated chemicals to humans and may pose considerable risk to human health (Werner et al, 2016).

7. Strategies for Management of Marine Debris

CBD (2016) have stated that; for sustainable management of MD and to minimize its adverse effects, adopted strategies should include: bans for plastic bags and micro-beads; develop fully biodegradable alternatives to plastics; eco-labelling /certification schemes; economic instruments such as fees for single-use items; encouraging reuse and reduction; engaging with industry and corporations on sustainability; improved product and packaging design; improving awareness of marine debris; improving waste management infrastructure to prevent debris inflow; packaging and plastics reduction; potential use of waste as a resource; regulatory measures to prevent marine debris; and use of bio-plastics and natural compounds (Avallon and Henry, 2014).

8. Conclusion

Overall, the results from this study suggest that marine debris is recognized as a globally significant stressor on the marine and coastal environment. It has socioeconomic impacts and also impacts the marine biodiversity. Marine debris affects the health and safety hazard and significantly affects the commercially important resources. Control of domestic inputs of marine debris is potentially a very important source of debris along the coastal environment worldwide. Further, understanding the risks and uncertainties with regard to the harm caused by marine litter is closely associated with the precautionary principle. Proper waste management, plastic recycling, and stringent penalties for illegal waste dumping are essential to reduce the marine debris.

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