MICROPLASTIC IN THE RIVERS AND OCEAN AND THEIR IMPACT: A REVIEW

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DOI: http://dx.doi.org/10.24327/ijrsr.2020.1102.5083

INTRODUCTION

For anyone living in the developed or developing country, it is impossible in 2020 to avoid plastic as besides basic needs as clothes, cosmetics, medical field as well as in rockets and aircraft, electronics, toys, shampoo, plastic is used from grocery bags to forks to wrappers of candy, chocolates. As plastic the long-chain synthetic polymers are composed of Carbon, hydrogen, oxygen, chlorine is pliable, lightweight, cost-efficient, durable and can be easily shaped have been widely used. After Second World War popularity and the production of the plastic polymers have been significantly increased. These polymers have replaced the limited natural products such as ivory, wood, stone, tusk, horn, bone etc.

The plastic material of < 5 mm size is called as microplastic which is highly persistent in the ecosystem and is hazardous to the environment, human health and to marine and aquatic organisms [1- 4]. Out of 5000 billion pieces of plastic floating on the surface of the ocean 90% represents microplastic. Approximately 380 million metric tons of plastic were used globally in the year 2018 [5] and approximately 100 million metric tons of textile fibres were produced, out of 100 million metric tons of textile fibres 60% were plastic fibres, 27% natural fibres and 6% cellulose fibres.

Globally every minute about one million plastic bottles are bought and it will be 20% higher by 2021. Ministry of Environment, Forest and Climate Change has reported that in India 25,000 tons of plastic are used per day and only 9000 tons are recycled.

Presence of microplastics have been reported in surface water of every ocean [6], the deep sea [7], deep-sea sand, coastal sediments, estuaries [8], storm water runoff, wastewater [9] and in almost all the freshwater environments including in the environments of the protected and remote areas [10]. The number of microplastic in the Oceans is 500 times than the stars in our Galaxy.

Marine pollution by plastic litter not only affects the ecosystem but also causes economic loss due to damage of fishing gear; vessels, negative impact on tourism and more efforts and labours are used to clean the shoreline. Microplastic also acts as a transporter of persistent organic pollutants and metals as microplastic particles have large

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surface area environmental contaminants like persistent organic pollutants (polycyclic aromatic hydrocarbons), potentially toxic metals and endocrine-disrupting chemicals are easily sorbed on the microplastic surface [11-13] which is ingested by marine biota and passes to the food chain.

The United Nations Environment Programme (UNEP) includes the issue of plastic waste present in our oceans and seas in the list of the six most pressing environmental issues globally, and World Health Organisation (WHO) has convened a meeting of Scientists on March 2-3, 2020 to discuss the impact of microplastic on human. If the present scenario continues by 2050 in the sea the number of microparticle will exceed the number of fish in the ocean.

The present review work was made to report the type and concentration of the microplastic in the different atmospheric compartments and their health impact on marine organisms and human.

Classification of Microplastic

Microplastic based on their production is classified as;

**Primary**: These are micro-sized particles which are released directly in the environment from domestic and industrial effluents, sewage discharge, spills etc. The primary microplastics includes pellets, film, fragments, microbeads, airborne microplastic from textile industries,

**Secondary**: The secondary microplastic is produced by the gradual degradation and/or fragmentation of larger plastic particles present in the environment by the environmental natural processes as photo-oxidation, thermal degradation, biodegradation, thermo-oxidation, mechanical transformation, hydrolysis, wind, wave action and abrasion [3, 14]. The wastewater from washing machines which contain synthetic fibres is another source of secondary microplastic.

Sources of Microplastic

Microplastic in the environment are due to anthropogenic activities including domestic, coastal and industrial activities.

The Major sources are

**Plastic Pellets**

Plastic pellets, the primary microplastic are of 2.5 mm diameter or in powder form and are transported to different industries to form plastic products. During these processes i.e. processing, transport, manufacturing, recycling these pellets are split in the environment. Several scientific studies have reported the presence of plastic pellets in the environment [15].

**Synthetic Textiles**

The primary microplastic is produced via abrasion and shedding of fibres during washing of synthetic textiles in industrial laundries and households. These fibres (polyester, acrylic, polyethylene or elastane) ultimately reach in the ocean via sewage water, river [16]. Number of Scientists [17, 18] has confirmed the presence of the fibres in the marine sediment, sewage water, river water and ocean.

**Abrasion of Tyres**

The outer part of tyres which are made up of Poly Styrene-buta diene rubber, polyisoprene and additives get eroded during use. Approximately 270,000 tonnes of tiny plastic particles per year are contributed by tyre dust to the ocean. As per the report of San Francisco Bay Microplastic project studies, the main source of microplastic pollution in California’s coastal waters seems to be originated from the erosion of Tyres [19].

**Abrasion of Road Markings**

Different type of markings as paint, thermoplast, polymer tape, epoxy resins are used during road infrastructure development and its maintenance. Due to weathering and by road vehicles abrasion of these materials occurs [20]. By rains and wind, these materials reach the ocean via surface waters.

**Weathering of Marine Coatings**

To protect different parts of marine vessels coating of Polyurethane and epoxy coatings and vinyl and lacquers plastics are applied on the different parts of marine vessels. These primary microplastics during maintenance, repair, use, and building, due to weathering and during disposal are released to the ocean.

**Personal Care Products and cosmetics**

Personal care products and cosmetics like facial cleansers, toothpaste, shower gels, scrubs, eye shadow, deodorant, make up foundation, mascara, hair colouring, shaving creams, nail polish, and sunscreen contain plastic microbeads as a major ingredient [14]. Some products contain these microbeads about 10% of the product weight, meaning by several thousands of microbead per g of the product. Due to these products plastic particles entered in the wastewater streams from households, hotels, hospitals, and sports facilities including beaches. Many researchers have reported the presence of the microbeads in wastewater.

**City Dust**

City Dust is mainly generated due to abrasion of infrastructure (households dust, building coating, and artificial turf), abrasion of objects like synthetic soles of footwear, synthetic cooking utensils and abrasion of detergents [16].

**Coastal activities**

Fishing practices, marine industries and aqua tourism activities occurring at coasts are also the sources of microplastic pollution.

**Table 1** Most commonly found plastic polymers and their application are given as

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Uses</th>
<th>Nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyester</td>
<td>Textiles, fibres, recording tape</td>
<td>Density is 1.24-2.3 so sink in water</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>Packing, in bags, wire insulation, and squeeze bottles</td>
<td>Density is 0.91-0.97 so floats on water</td>
</tr>
<tr>
<td>Polyethylene terephthalate</td>
<td>Soft drinks and other beverages, Packing, Fibres, indoor-outdoor carpets, bottles, Heavy-duty microwavable containers</td>
<td>Density is 1.37-1.45 so sink in water</td>
</tr>
<tr>
<td>Polypropylene</td>
<td></td>
<td>Density is 0.91 so floats on water</td>
</tr>
<tr>
<td>Material</td>
<td>Density</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------------------</td>
<td></td>
</tr>
<tr>
<td>Polypropylene</td>
<td>1.01-1.04 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Polyethylene</td>
<td>0.03-0.1 so floats on water</td>
<td></td>
</tr>
<tr>
<td>Polyvinyl chloride</td>
<td>1.16-1.584 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Alkyd</td>
<td>1.67-2.1 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Polyurethane</td>
<td>1.02-1.05 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Nylons (Polyamide)</td>
<td>1.17-1.20 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Polymethyl methacrylate</td>
<td>1.09-1.20 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Polycrylonitrile</td>
<td>1.19-1.31 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Polynyl alcohol</td>
<td>1.06-1.08 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Acrylonitrile-butadiene-styrene</td>
<td>1.20-1.22 so sink in water</td>
<td></td>
</tr>
<tr>
<td>High-density polyethylene</td>
<td>1.0-1.05 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>1.20-1.22 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Cellulose acetate</td>
<td>1.28 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Cellulose nitrate</td>
<td>1.35 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Polylactic acid (biodegradable)</td>
<td>1.38 so sink in water</td>
<td></td>
</tr>
<tr>
<td>Melamine</td>
<td>1.57 so sink in water</td>
<td></td>
</tr>
</tbody>
</table>

**Routes of Exposure**

Most commonly used synthetic plastics are polyethylene (low and high density), polystyrene, polyvinyl chloride, polypropylene, polyethylene terephthalate. The exposure of microplastic to human and other organisms is via:

i. **Ingestion:** It occurs via gastrointestinal route i.e. through the mouth by eating food, honey, beer, salt, vegetables, fruits, seafood including fish and by drinking water, beverages,

ii. **Dermal:** Dermal uptake means absorption through skin/gills, the aquatic animals' bioaccumulates microplastic or Nano plastic via dermal contact. Dermal uptakes by humans are during washing by contaminated water and/or via facial, body scrubs (which also contain microplastic particles) [21],

iii. **Inhalation:** Inhalation uptake occurs via inhalation of the polluted air containing micro and Nano plastics particles, dust fumes and through exposure at the workplace.

**Microplastic in the Marine Environment**

*As per reports* 3% of all the marketed plastic goes in the ocean [22]: In the marine environments plastic is present in the forms of microbeads, bags, packaging, construction coating, polystyrene containers, tape and fishing equipment and about 80% of the plastic debris comes from the dry land [23]. The survey of literature reveals that plastic in the ocean is mainly due to coastal mismanaged plastic waste (8.28-12.2 metric ton/year) [24]; due to rivers (1.15-2.41 metric ton/year) mainly from Asian countries [25] and due to loss of fishing gear (0.6 metric ton/year) [17].

Boucher and Friot [17] during their studies found that 8.0 million tons/ year of primary microplastic which is 15-31% of total microplastic is released per year in the ocean. Microplastic present in the ocean can either float or sink the microplastic with a density lower than water i.e. polypropylene floats and disperse in the oceans and due to ocean currents are accumulated in the gyre. Researchers [26] have estimated that approximately 260 k tons of such microplastic are floating in the oceans. The acrylic microplastics are heavier than seawater and accumulate on the floor of the ocean probably a major part of which is accumulated in the food chain.

Distribution of the microplastic in the ocean besides anthropogenic activities depends on environmental factors such as tides, cyclones, wave currents and wind directions [27] and river hydrodynamics [28].

According to the latest United Nations Environment Programme (UNEP) report, every squarekilometre of the ocean contains on average 63,520 microplastic particles, with significant variations on a regional level. For example, the levels in Southeast Asia are 27 times higher compared to others. The Mediterranean Sea contains 7% of total microplastic present in the ocean so the Mediterranean Sea is considered as one of the most polluted seas in the world. The concentration of the microplastics in the East Asian seas around Japan was 10 times higher than in the North Pacific Ocean while it was 27 times more than in the world oceans[29]. Furthermore, there are five oceanic regions (called gyres) where currents funnel the largest amount of debris.

Cheng and Fok [30] found 342.2 billion microbeads items in the Hong Kong marine water. Beaches of Goa contain 505-1655 pellets which were mainly due to unintentional spillage from ships [31].

Martin *et al.*, [32] found 40-280 microplastic particles /L in the Irish Sea, while the Mariana trench contains 200-2200 particles/L [33]. The concentration of the microplastic in the Cantabrian Sea, Alboran Sea, and the Catalan Sea, Levantine Sea and the Black Sea were 800-1400; 500-1200; 400-1500; 200-1200 and 400 particles /L respectively [34]. The Arctic sea contains 1304-3463 particles/ L was the findings of Bergmann *et al.*, [35].

**Impact on Marine Organisms**

**Microplastic in the ocean disturbs the ecosystem of the ocean**

Accumulation of microplastics in gills and intestine of marine organisms interferes in the feeding habits of these organisms resulting in the unnatural deaths, (ii) Microplastics in several
ocean animals disrupts the endocrine system causing abnormal growth and reproductive problems, (iii) Pesticides and potentially toxic metals like lead, cadmium, copper which are associated with microplastic leaches in the marine environment [36] affecting adversely the ecosystem.

When mistaken for food and eaten by marine species, microplastics have been shown to cause gut blockage and physical injury, alter feeding behaviour and affect energy levels, growth rates and reproduction [37]. For instance, microplastic ingestion has been found to decrease energy reserves and reduce feeding activity in marine worms, a keystone species inhabiting intertidal sediments in Northern Europe [38]. Rist et al., [39] reported that microplastic causes adverse effects on the physiology of D. magna and larvae of Mytilus edulis.

Setala et al., [40] reported that consumption of the microplastic by the marine organisms hinders the mobility, clogs the digestive tract, causes inflammation, hepatic stress and retards the growth. Cole et al., [41] reported that ingestion of microplastic by Copepod (Calanus helgolandicus) reduces feeding, decreases egg production; while in Mussel (Mytilus edulis), the microplastic forms granulocytes and destabilises the lysosomal membrane [42].

Microplastic is consumed by the number of marine organism’s viz., mussels, lugworms, sea cucumbers, amphipods, fish-eating birds, fishes, turtles etc.[14,43-44] and passes up to the food chain when lower trophic organisms are fed upon by higher trophic organisms [45].

Batel et al., [46] during their studies found that microplastic particles act as a vector to transfer associated persistent organic pollutant and potentially toxic metals to fishes causing pathological and oxidative stress and liver inflammation [47]; disturbs the lipid and energy metabolism [48].

**Plastic in rivers and freshwaters**

Rivers are the major route of passing inland generated microplastic to the ocean. Ebro River (largest rivers on the Iberian Peninsula, Spain) annually dumps 2.2 billion microplastic pieces in the Mediterranean Sea, and 2052 microplastic particles per kg of sediments of Ebro River [49].

McEachern et al [6] studied the concentration of microplastic in the Tampa Bay, Florida and reported that the average concentrations of the microplastic in the Tampa bay was 0.94 particles/L, while in Hillsborough bay was 0.68 particles/L and 76% of microplastic was fibres followed by fragment which were 17%, flakes 5% and 1% each of beads and film. They also reported that 4 billion plastic particles are present in the Tampa bay.

In the rivers of the United Kingdom, the average concentration of microplastic was 127.1 particles/ L of water [50]. River Thames, London (84.1); Chester Reedbed (7.6); Ullswater, Lake District (29.5); River Irwell, Salford, Greater Manchester (84.8); River Tame, Tameside, Greater Manchester (>1,000); River Blackwater, Essex (15.1); Falls of Dochart, Loch Lomond & Trossachs National Park (3.3); Loch Lomond, Loch Lomond & Trossachs National Park (2.4); AfonCegin - river; North Wales (76.9) and Llyn Cefni - reservoir; Anglesey, Wales (43.2). Out of total plastic particles present 46% were of polyethylene, 23% of polystyrene, 17% of polypropylene, 14% of ethylene-vinyl acetate, polyvinyl chloride and remaining were of polyamide and polyethylene terephthalate. The Huron River water (UK) contains microplastic in the forms of fibre 70%; fragments 17%; foam 7.6%; Film 3.3% and beads 1.05% [51].

Yin et al., [52] (2019) studied the concentration of the microplastic in the urban lakes of Changsha, China they found that the concentration of microplastic ranged from 2425 to 7050 items/m² in the surface water. They also reported that most of the microplastic was transparent and of the size less than 2mm, polypropylene was the dominant microplastic pollutant. Su et al., [53] found 3.4-25.8 particles of microplastic /L in the Taihu lake of China, Wang et al., [54] found 1.6-8.9 microplastic particles/L in the lakes and rivers of Wuhan City, China and 0.9-4.65 particles in the Dongting and Hong lakes of China. Di et al., [55] reported 1.6-12.6 particles in the Three Gorges Reservoir, China.

The number of microplastic particles in the Ganga, Brahmaputra and Indus was studied by Pendharkar [56] and reported 1494 particles/m².

Lahens et al., [57] found 172-519 particles /L in the Saigon river of Vietnam, while Teltow river Germany contains 0.01-95.8 particles/L was the findings of Schmidt et al., [58]. Lake Huvsogol, Mongolia on average contains 20264 particles km⁻² [59]. The microplastic concentration in the surface waters of San Francisco bay ranged from 15,000-2,000,000 particles km⁻² [60].

**Microplastic in the sediments**

In the sediments of Tampa Bay, the average concentration of the microplastic was 290 particles/ kg of dry sediment. Sarkar et al., [61] during their studies on the sediments of Ganga Basin of the eastern part found that 99.27-409.86 items/kg of the sediments.

A survey of literature denotes that number of microplastic particles in the sediments of different rivers per kg were as, Tames river UK 165 [62]; River Thames, UK 350 [63]; Mersey/Irwell, UK 2810-6350 [64]; Ottawa river (Canada) 220 [65], Rhine-Main area (Germany) 228–3760 [66]; Beijing River (China) 178–544 [67]; Bloukrans River (South Africa) 6–160 [68] and Elbe, Mosel, Neckar, and Rhine (Germany) 34–64 particles [69].

In the heavily impacted beaches, the concentration of the plastic is 3.3% of sediment weight [13]. The sediments of the Wadden Sea and Rhine estuary contain 700 and 3300 items kg⁻¹ dry weight respectively.

The concentration of microplastic in the beach sediments of South Africa ranged from 340.7-4757 particles m⁻² [70]; of Taiwan beach 800-40640 [71]; South Korea Beaches 473-27606 [72]; China 6700[73]; Italy 151-678 [74]; Spain 430-1656 particles/ m²[75]. The concentration of the microplastic at the Turkey beaches was 49 -279 items/ kg [76]; the Iran beaches contain 2-1258 items /kg [77]; the concentration of the microplastic in the Turkey beaches was 248 items/kg [78]. The beaches of North America contain 43-443 items/kg [79].
Impact on Human

Oral, dermal and inhalation exposure to microplastics and additive chemicals to the human body occurs not only via the food chain but also due to day-to-day life contact with plastic materials.

So, to understand the effect of microplastic on the human health it is important to study the interactions between microplastics and biological macromolecules [80]. According to industry estimates, an average Indian consumes approximately 11 kg of plastic products in various forms every year, while in the other Asian countries is approximately 36 kg per annum per person. In America and Europe, it is 140 kg per person annually. Though in India consumption of plastics it is much less than what an American or a Chinese does, it still is a problem. Cox et al. [81] have reported that a human consumes 39,000 – 52,000 plastic particles every year and inhale approximately 25000 particles every year. Besides it those who drink only bottled water ingest additional 90000 microplastic particles in a year (those who drink only tap water consumes 4000 particles per annum).

The potential hazards of the microplastics in the drinking water are due to three forms: physical particles, chemicals and microbial pathogens that are part of biofilms of the microplastic. The impact of the particles on the body depends on the shape, size and surface area of the particle, microplastics<150 µm are excreted directly through faeces. Small particles are more absorbed which may cause inflammation of the liver. Persistent organic pollutants, hydrophobic chemicals present in the environment are sorbed by the plastic particles which have adverse effects on human health.

When microbes grow on the drinking water distribution system/surface biofilms in the drinking water are formed, most of the microbes in the biofilms are non-pathogenic few pathogenic microbess viz., Pseudomonas aeruginosa, Legionella spp., non-Mycobacterium spp. and Naegleria fowleri has also been reported [82].

University Medical Centre (UMC) Utrecht during their studies reported that the mortality of immune cells in presence of microplastic is 2-3 times higher than in absence of microplastic, they also found that chemical additives to plastic viz., Bisphenol A (BPA), PFAS, phthalates affect hormonal activities in the body reduces fertility in men and women. Styrene an additive to the microplastic causes nervous system disorder, loss of hearing and cancer, Polychlorinated biphenyls which are accumulated on microplastic weakens the immune system, causes cancer besides reproductive problems [83]. Due to both hydrophobic and electrostatic interactions Bisphenol A is strongly adsorbed on the plastic fibres [84].

Some scientific studies have shown that microplastic via bloodstream can cross even the hardy membrane which protects the brain. Rutgers Centre for Urban Environmental Sustainability during their studies found that the microplastic is passed to the developing foetus from mothers via the placenta. Recent studies have found the microplastic in the faeces of human.

Researchers are studying the minimum dose of the microplastic which may cause health effects. Cox [81] has reported that those who are more exposed to plastic are less tolerant of plastic-like air pollution or harmful construction materials.

Bosker et al. [85] reported that presence of microplastic particles in the soil retards germination rate and root growth.

Small steps to curtail the risks of Plastic

It is impossible to completely avoid the microplastic or the chemicals associated with plastic. But a few small steps will help to non-essential exposure:

i. Drink water from your tap: As plastic is present in bottled water, beer, sea salt so if tap water is used for drinking the consumption of plastic can be reduced.

ii. Avoid plastic food containers and not to heat food in plastic: The recycled plastic containers contain phthalates, styrene and bisphenols which are known harmful chemicals so the use of these materials must be avoided. When food is heated in plastic material the harmful chemicals associated with plastic leaches to food so the use of plastic in food materials must be avoided. The American Academy of Paediatrics has recommended not washing plastic wares in the dishwashers.

iii. Eat more fresh food: Use of fresh food avoids exposure to plastic.

iv. Minimize household dust: Household dust contains several harmful chemicals such as phthalates, per- and polyfluoroalkyl substances so to avoid it regular and proper vacuuming are essential.

v. Think big picture: The use of single-use plastic must be minimized and opt for products packaged in glass instead of plastic.

CONCLUSION

Due to small size microplastics are very easily bioaccumulated and in the ocean number of marine habitats such as corals, planktons, fish, sea birds ingest the microplastic assuming as their food, from these marine biotas the microplastic enter the food chain. Besides it, the persistent organic pollutants and potentially toxic metals which are sorbed on the microplastic acts as a vector for the number of microbes also enter the food chain. The ingestion of the microplastic by marine biota hinders the mobility, clogs the digestive tract, causes inflammation, hepatic stress and retards the growth, retards the egg production, destabilises the lysosomal membrane.

According to industry estimates, an average Indian consumes approximately 11 kg of plastic products in various forms every year, while in the other Asian countries is approximately 36 kg per annum per person. In America and Europe, it is 140 kg per person annually. Globally a human consumes 39,000 - 52,000 plastic particles every year and inhales approximately 25000 particles every year. Microplastic and chemicals associated with the microplastic affect the immune system, affects hormonal activities, nervous system disorder, cancer etc.

So to minimize the adverse effect of the plastic there is an urgent need of awareness among the general public, to reduce the production and to minimise the input of microplastic into the ecosystem.
Acknowledgement
The author thanks to all the Researchers whose work has been reported in the review article.

Declaration: No original data have been used in this review all information is accessed from published work.

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