Chapter

Sources, Fate, and Impact of Microplastics in Aquatic Environment

Sukanya Mehra, Khushboo Sharma, Geetika Sharma, Mandeep Singh and Pooja Chadha

Abstract

Over the past decade, enhanced scientific interest has produced an expanding knowledge base for microplastics. The highest abundance of microplastics is typically associated with coastlines and oceans but the fate of these microplastics is elusive. Microplastics sink following fragmentation which is further ingested by marine biota thus imposes threat to them. Thus, the present review focuses on properties and sources of microplastics, its impact on environment, the bioaccumulation and trophic transfer of microplastics and its impact on living biota. This study would be helpful for the development and implementation of risk management strategies for managing the disposal of microplastics.

Keywords: microplastics, sources, accumulation, toxicity, aquatic organisms

1. Introduction

Due to the permanence and robustness, plastic has infiltrated every aspect of life like in clothing, electronics, cleaning products as well as in building materials [1]. World production of synthetic organic polymer plastic has skyrocketed from 1950 to 2013, showing an escalation from 1.5 to 299 million tons. Around 8-16 million tons plastic waste invades sea and oceans annually, substantial section of which comes from land borne sources [1, 2]. In the very beginning more attentiveness was towards large plastic debris; however prevalence of smaller plastic particles in the marine environment elucidated in early 1970's [3, 4]. Due to minuscule proportion of microplastics they are ingested by protozoans to marine mammals and by many filter feeders [5]. Amphipods, polychaete worms, barnacles and sea cucumber ingest microplastic which gets accumulated in food web [6]. According to Setälä et al. [7] and Green et al. [8] microplastics are omnipresent in nature and possess high potential to interrelate with environment (biotic and abiotic) thus menacing with biogenic domain of flora and fauna. Presences of microplastics were perceived more in aquatic ecosystems, surface waters, sediments and water column. Deep seas and mountain lakes were also sullied by the presence of microplastics and thus scrutinized as global pollutant [9, 10]. Worldwide pollution provoked by plastic is dispersed maximum across seas and oceans. Longevity and buoyancy are some properties that have led these pollutants fall under the category of hazardous waste [11–13]. In the environment microplastics are present in heterogeneous group, according to varying size and shape, specific density and composition. Prodigious plastic wastes are easily perceptible [14, 15]. Although microplastics are inconspicuous, their dissemination into the oceans has profound repercussions leading to cumulative effect in the food chain [16].

Microplastics may pose a risk to aquatic environments due to their documented ubiquity in marine ecosystems, long residence time, and propensity to be ingested by biota. As Microplastics from different sources ultimately reaches water bodies and from here microplastics disperse into surface water, underground water, and benthic sediment, etc. and their bioavailability gets affected [17]. After consumption or ingestion, microplastics can remain in the digestive tracts of aquatic organisms for periods of days to weeks before excretion. The more time of excretion likely allows the transfer of microplastics both up the food web and to new geographic locations. Exposure of individual aquatic organisms to microplastics may negatively impact feeding, growth, reproductive capabilities, or survival [18]. While studies and reviews on plastic pollution in the marine environment are increasingly common, to date, few studies have assessed the sources, fate and impact of microplastics in freshwater as well as marine environment. Thus, the present article has been made in order to fill the lacuna in this regard.

2. Types of microplastics

Two primary or foremost types of microplastics are: primary and secondary microplastics. According to Sundt et al. [19] plastics that are instantaneously propagated into the environment compose primary microplastics. They are produced in relatively micro size. Secondary microplastics pioneered from the deterioration or fragmentation of larger plastics.

2.1 Primary microplastics

Plastic ranging between size of 1 μm and 5 mm are considered primary microplastics. Microplastics are affixed to certain products due to their discrete functions. They are also operated as mordant in cosmetics and soap products and also act as conveyor of pigments. Plastic powder, granulates, pellets are some examples of primary microplastics [1, 20]. Primary microplastics are also used as exfoliates. They are the main protagonist of several day to day products like hand cleaners, toothpastes, face washes [20]. Primary microplastics are also used in dental polishes. If they are not discarded in the efficient way possible, they end up blemishing the environment. Primary microplastics also possess diverse industrial implementations like for gas and oil analysis they are required as drilling fluids, for cleaning metal surfaces to eliminate the paint, rinsing of engines etc. [21–23]. Microplastics like polystyrene, acrylic, polyester are used in industries [24].

2.2 Secondary microplastics

Repudiated plastic bags or fishing nets, household items and discarded plastics undergo weathering and photo degradation process and get transfigured into smaller plastic particles, thus constituting secondary microplastics. Abrasion of plastics is manifested by UV light at soil surface and by ocean waves. Secondary microplastics are also fabricated by washing machines [24, 25]. It also includes fragments of textile fiber originated from synthetic fibers, and released during the laundering process [26]. The root sources of secondary microplastics are discarded plastic debris from household items and industrial products. Secondary microplastics are considered to be the most dominating microplastics [27, 28]. Their copiousness in water bodies increases with elevating discharge of plastic debris and its continuous transformation into secondary microplastics. Textile industry products, tires, decorative paints all contribute to the genesis of secondary microplastics [20].

3. Sources of microplastics

3.1 Personal care products

According to Leslie [29] plastic microbeads are utilized as additives in countless cosmetics and personal care products. They act as sorbent as well as exfoliators. Plastic microbeads are incorporated in several cosmetic products such as 350,000 plastic particles were observed in a facial scrub tube in USA [20]. A study from USA also evaluated the presence of 1700-6400 particles of plastic per g in toothpaste [1]. According to Strand [30] toothpaste contains 0.1-0.4% microbeads in accordance with weight, facial scrubs contain around 1.6-3.0%. Facial scrub possesses 0.9-4.2%, exfoliating scrub contains 10.6% and shower gel around 0.5-3.0%. One of the plastic types that are frequently perceived in microplastics is polyethylene (PE). In European country PE plastic microbeads were considered most dominating, with around 4073 tons usage.

3.2 Blasting abrasives and cleaning products

For cleansing surfaces primary microplastics are used as abrasive. Plastic such as polyester, polycarbonate, polyamide is used in blast media. Main purpose of blasting abrasives is in cleansing of rims, removal of paints and cleansing of ships. These abrasives are also used in marine industries for cleaning the tanks. Blasting is done in different cabins, closed or semi-closed. Area must be encrusted properly. Emission rate are quite high if done in open premises. Turbines blades are cleansed by this process; this leads to release of primary microplastics in aquatic environment. Microplastics are even used in maintenance and cleaning products as abrasive material. To remove grease, paints, oil from hands primary microplastics are used [20].

3.3 Synthetic textile and tyres

Browne et al. [25] assorted that process of laundries in household and industries leads to mass production of primary microplastics via scraping and dispersion of fibers, which was then emitted out in sewage water and culminates in the ocean [31]. Tyres contain profuse mixture of several synthetic polymers in addition with natural rubber. Tyres get deteriorated when used and tyre dust that contains synthetic rubber circulated by wind or swiped away by rain. Large segments of such particles were reported to congregate in the sea [19, 23].

3.4 Paint and wood preservatives

Primary microplastics are appended to paint and preservative. This gives matting effect and acts as color amplifier. This improves longevity of wood, provides hardened and abrasion resistance. It is also used to diminish the density of paints [20]. A study done by Poulsen et al. [32] stated that 8-30% of waste generation is triggered by paint spillage and other paint jobs. Approximately 65-97% of waste culminates as solid waste and around 35% ended up in sewer system. 1.0-5.3 t/y is the estimated amount of microplastics release from paints, out of which 0.1-0.5 t/y is the guesstimate amount of primary microplastics in paints that ends up in aquatic environment.

3.5 Synthetic waxes and oil-gas industry

According to Essel et al. [23] synthetic waxes are scrutinized as primary microplastics. They are used in dyeing, food coating, as lubricants and also in processing of plastics. Synthetic waxes are also used to coat papers they are extensively operative in textile processing by providing smoother surface. Polytetrafluroethylene (PTFR) is used for drilling purpose. Drilling fluids composed of microbeads, used in oil-gas industry [19, 32]. This chemical gets directly discharge into the oceans, contributing to microplastics accumulation.

3.6 Plastic pellets manufactures

Pellets are the primary form of many plastics around 2.55 mm in diameter. These pellets are used to generate plastic products. These pellets, spherules contribute to 79.4% of total plastic debris in the water of river Danube [33, 34]. According to Dhodapkar et al. [35], in addition to pellets, plastic dust also gets accumulated during manufacturing process or generated due to relocation and transportation [20]. Pellets contain certain perilous additives like plasticizers and flame retardants that promote the eco toxicity. These additives mixed prior to the production or added during conversion. These pellets are often termed as nibs and nurdles [19].

3.7 Weathering and abrasion

Metropolitan environment often encounters with city dust. Synthetic cooking utensils abrasion, footwear soles abrasion, infrastructure abrasion, blasting abrasives all culminates into city dust. Independently importance of these factors is insignificant but together they are accountable for sizeable losses in the country [20, 31]. For the advancements of roads, road markings are administered. Thermoplastic, paint, polymer tapes are preferred in this process. Weathering by vehicles induces microplastics loss, which is washed off by rain or wind and ultimately outstretched to oceans [20]. Coatings of boats are done by various anticorrosive paints, mostly polyurethane, lacquers and vinyl [36].

3.8 Packaging material and litter

Higher preference is given to packaging materials as a source of microplastics. It contributes to about 62% of all plastic collected. It usually involves secondary microplastics. Plastic bags, soft drink bottles all culminates into it [1]. Packaging materials constitutes major portion of litter. Toys, cutlery, shoes, clothing are other forms of litter [15]. Litter from agricultural plastics is non-biodegradable, although biodegradable plastics are also prevalent nowadays. Addition of preservatives in such plastics make them less biodegradable, and these plastics get perished into smaller fragments, eventually via nearby streams microplastics enters surface water [1].

3.9 Domestic items, food stuffs and toys

According to United Nations Environment Programme (UNEP), 2014 [15], domestic items are considered as the mighty source of pollution in the sea. Items like cups, plastic cutlery, bottles and straws are present in abundance in oceans.

Food stuffs and snacks also contribute to microplastics. Chewing gum contains microplastics fillers. A study done at Dutch coast revealed the presence of 105 particles of microplastics per gram in mussels and for oyster it reaches up to 87 microplastics particles per gram [37]. Party items like balloons, confetti firework wastes, fragments of toys all culminate to waterborne litter. Loom bracelets contain microplastics which can adulterate the environment via surface runoff [38].

3.10 Medical resources

In medical sector, microplastics are profoundly used [23]. Microplastics treat the reverse flow of gastric juices. Aluminum coated compounds tend to possess deleterious effect on human health. They are replaced by microplastics. Nappies, sanitary towels, plasters constitute litter. Capsules used in the edicine field contain plastic. Spectacles, contact lenses are one of the define sources of microplastics [1].

4. Microplastics in marine ecosystems

The pollution of microplastics varies geographically with location because as the consumption of plastic increases, there is increase in production of MP. Marine life is more disturbed by this plastic waste because ocean become a dump yard for running water system either directly via riverine system as river ultimately end up meet up with the ocean or indirectly as waste water treatment plant dispose of their waste directly in the ocean or in river which end up by meeting the marine water body. However, the size of sediment and distribution of MP is influenced by oxidative degradation (either photo- or thermal initiated), friction and biodegradation [39, 40]. The typical shape of microplastics consists of pellets, fibers and fragments but according to literature, majority of microplastics in Oceans are microfibers [41, 42]. Distribution and abundance of microplastics is chiefly determined by environmental [42–44] and anthropogenic factors [45]. Environmental factors include runoff, infiltration, river discharge, wind action, ocean currents, cyclones, river hydrodynamics, wave current, tides and movement/dispersion of animals. On the other hand, anthropogenic activities either they are for industrial or tourism or transport purpose which further led to accumulation of plastic debris in environment. According to literature, these environmental factors play vital role in determining the distribution of microplastics more intensely than anthropogenic activities, however anthropogenic activities are the core source of production of these plastic wastes.

Abundance of microplastics in oceans distribute across various strata of Ocean. In the sediments- water systems, microplastics only sink and accumulate in the sediment when their density exceed seawater ($>1.02\ g/cm^3$); otherwise it tends to float on the sea surface or in the water column [46], hence low density microplastics float on surface layer of ocean water whereas high density microplastics sinks down to benthos layer [5]. Buoyancy of microplastics can depend on befouling in which former biomass accumulation led to increase in microplastics density and later can decrease microplastics density which is responsible for sinking, neutral or floating action of microplastics. But in case of High density microplastics, there distribution depends on other factors also like change in tidal fronts, high flow rates or larger surface area of High density microplastics.

Beaches are a reservoir of highly fragmented plastic debris that transport microplastics back to costal water and finally to open ocean [47]. It is based on observation of Wang et al. [48] that concentration of microplastics is usually higher in upper layer i.e. epipelagic layer than the immediate lower mesopelagic layer this may be due to preferential flow or animal movement. Even, mesoscale ocean dynamics have impact on distribution of plastic debris at sea surface within subtropical gyres [49]. Usually, sea platforms and marine trafficking are responsible for microplastics in far off Ocean, whereas microplastics in near shore originate mostly from waste water, runoffs, rivers etc. [50, 51]. However terrestrial environment also determines the concentration of microplastics as harbor and industries add huge amount of plastic debris either directly or indirectly which add up to the acumen concentration of microplastics in the ocean. The dire situation of disturbance in aquatic ecosystem is becoming huge day by day as these not only affect flora but fauna as well; even coral beds are not far away from disturbance. This plastic debris also includes mesoplastics accumulation. Use and through plastic items are becoming huge threat to the aquatic organisms hence number of reports are increasing in this area of research which indicate the negative impact of microplastics and is alarming accumulation rate in ecosystem which is also eye catching for researchers and environmentalists.

5. Microplastics in freshwater ecosystem

To understand the impact of microplastics pollution in freshwater environment, various aspects are to be analyzed i.e. source, distribution, type and effect of microplastics. Source of freshwater pollution is usually synthetic textile, personal care products, industrial raw material, whereas the main source of microplastics in riverine system are wastewater discharge which may be industrial or household untreated waste water disposal. Microplastics are of serious concern because their accumulation potential increases with decreasing size [52]. It is also noted that, there may be change of composition of MP as they accumulate with waterborne contaminates which includes metals and persistent, bioaccumulative and toxic compounds this is possible due to larger surface-to-volume ratio. Studies by Engler [53] showed relationship between plastic debris and PBTs (e.g. PCBs and DDT) similarly a number of studies exist for polycyclic aromatic hydrocarbons [54–56]. Since the spectrum of contaminants is different between freshwater and marine system. In stagnant riverine system like ponds and lakes water pollution is more severe problems because of the irresponsible behavior of the inhabitants or by various tourism related activities which disturb the ecosystem due to accumulation of degradable or non- degradable waste. They float in the surface water and stay in the water sink into sediments of lake. For stagnant system rate of accumulation of microplastics is higher, since there is no efflux. Therefore, it can be concluded that there is a direct correlation between distance of contamination source and microplastics pollution levels in sediments [57]. Various studies confirmed the presence of microplastics in drinking water system which makes it a serious issue [58]. Research about river system and watersheds can provide the knowledge to the people to understand the alarming situation of microplastics accumulation in freshwater system [59]. Further the flow of river plays significant role in removal of plastic fragments. It is also observed that after precipitation high amount of MP is observed in sediments and running water [60]. Eventually, freshwater system also contributes to the pollutant content of marine ecosystems because ultimately riverine merge with the ocean resulting merger of mineral, sediments, soil content as well as pollutants. Hence the fact that freshwater system act as strong source of microplastics to marine ecosystem cannot be neglected. Although distribution of microplastics in freshwater system is not uniform, it depends on nearby source of waste water disposal.

It is observed that the condemnation in water is observed higher in riverine near industrial area as compared to the residential area. However waste water treatment plants are established by organizations but they remove large plastic waste more efficiently than meso and micro plastic waste, as various technologies are installed to remove large size particle but these are not specified to retain microplastics [61, 62]. Discharge from waste water treatment plant contain may hazardous compounds along with micro –and Nano- plastic particles which enter the food web and cause diverse effect in biotic ecosystem.

6. Fate of microplastics

The threat of microplastics is rapidly increasing, and as the global plastic production projected to reach an accumulative 25 billion tons by 2050, things are going to be worse [63]. Although these plastic materials are key factors for innovation and development of various fields such as healthcare, energy generation, aerospace, automotive industries, construction, electronics, packaging, textile and many others [64]. However, instead of recycling or incineration or utilizing any other way of removing unused or discarded plastic from environment, these plastic wastes enters the environment from year to year and it is accumulated in Marine, freshwater and terrestrial ecosystem worldwide, even from densely populated countries like India and China to cold desert like Antarctica. And this became a matter of concern for scientists across the world. The reliance on plastic for huge number of consumer products, many of them being single-use, results in continuous entry into environment.

No doubt, with due course of time via biotic and abiotic degradation pathway, plastic loose its mechanical integrity but it may take several years to degrade completely. With gradual degradation this immortal plastic emits smaller size particle in environment i.e. macroplastics, mesoplastics and microplastics. Plastic particles <5 mm size are considered Microplastic, although there are efforts to redefine them as <1 mm in size, as recommended by [65]. However minimum size of Microplastics has not yet been specified and it depends on the sampling and processing as well as on the applied method for Microplastics identification.

7. Effect of microplastics on aquatic biota

Microplastics are of special concern because they can be ingested throughout the food web more readily than larger particles. It is to be noted that the impact of microplastics on public health and aquatic ecosystems is not yet fully understood, but there is increasing number of reports which indicate negative impact of microplastics on marine and freshwater biota.

With increased focus on microplastics debris, several groups have studied the influence of microplastics uptake by different organisms. As microplastics invasion appear to occur across all ecosystem from terrestrial to marine environment in different trophic level not only invertebrates but vertebrates also seem to be affected by their presence [66, 67]. Organism ingests these microplastics debris while swallowing their food. And with due course of time bioaccumulation of microplastics results in diverse negative impact on various organism like disruption of organ system, rupturing of digestive system, weakening of immune system, impotency, various respiratory and circulatory problems, even failure of organ and in extreme cases led to death of organism [51, 68, 69]. However, continuous accumulation of these deadly microplastics in various systems of the body is possible through food chain via ingestion as well as by accumulation around gill aperture (or around respiratory apertures) and appendages of body by diverse aquatic organisms [70, 71]. However, situation become direr for the predators and humans which directly or indirectly consume microplastics affected aquatic organisms [72]. As reported by Wright et al. [5], there are various consequences from ingestion of plastics and MPs by various species such as planktons, copepods, zooplanktons, crabs, small fishes, turtles, fish larvae, sea birds and mammals.

7.1 Effect of microplastics on marine ecosystem

Marine microplastics debris is a global threat because of its abundance, persistence and mobility across scale, with subsequent widespread distribution potential, geophysical and biological impact [73]. Across the globe, research on the ingestion of microplastics by biota has predominantly focused on wide range of marine species with different feeding strategies [74–76]. As microplastics have been shown to obstruct feeding appendages and limit food intake, physical injury and oxidative stress, reduced energy allocation in various aquatic organisms and in some cases damages in the alimentary canal were also observed [77]. Alteration in the feeding behavior of some group of crustaceans was also studied such as in copepods which feed on algae, but when these copepods feed on natural assemblage of algae with the addition of polystyrene microbeads they showed a significant decrease in herbivory which further results in decrease in growth rate of organism [5, 78]. However, it is not just growths which microplastics injection can disrupt, but also observable change in physical development of organism. An alternation was observed in life cycle of sea urchin *Paracentrotus lividus* which depicted alterations in shape of pelagic planktotrophic pluteus larva when Microplastics were ingested [79]. Another study of Kaposi et al. [80] by examining short term exposure of Polyethylene on the sea urchin *Tripneustes gratilla*, which was done by using fluorescent labels green PE Microspheres having diameter 10-45 μm, with exposure of time ranged between 15 min to 5 d. There was decrease in injection rate even when phytoplankton food was provided.

While some of the chemicals associates with microplastics, which possess endocrine disruptive activity and are responsible for the hormonal imbalance in organisms [81]. In a study by Sussarellu et al. [82] on Oysters which is a keystone species with high ecological and economic value. When adult oysters were exposed to microplastics polystyrene of diameter about 2 μm during a critical point of their reproductive stage adults were preparing for production of gametes. And after the exposure, there was an alteration in the feeding as well as absorption efficiency of food. Reproductive changes were also observed that there is reduction in the quality of oocytes and sperm swimming speed as well as fecundity. Moreover, these impacts had clear carryover effect on offspring quality and further reduced growth in their larval progeny. Similar effects were observed in planktonic copepods when exposed to micropolystyrene for prolonged period followed by reduced food consumption and resulting in reduced reproductive outputs [83].

However, Corals which occur in both deep sea and Antarctic system are not untouched by the effect of microplastics as some of the corals known to ingest microplastics and demonstrably negatively impact occurs both in terms of energy level, growth and pathogen frequency of reefs [84, 85].

7.2 Effect of microplastics on fresh water ecosystem

It's is not only marine wildlife that can take up microplastics, bioavailability of microplastics for freshwater fauna (for both invertebrates and fishes) has also been observed. Although there are few freshwater studies so far, A study by Rehse et al. [86] shows that immobilization has occurred in freshwater zooplankton (*Daphnia magna)* after ingestion of polyethylene microplastics of about 1 mm, however due to the smaller size of this freshwater zooplankton, it was not able to engulf microplastics of more than 1 mm size. It is also observed that small size microplastics usually possess large surface area to volume ratio which differentiates the property of microplastics from meso and macroplastics.

In freshwater habitat, the different POPs (persistent organic pollutants) that is PCBs (polychlorinated biphenyls), HCBs (hexachlorobenzenes), PBDEs (polybrominated diphenyl ethers) and metals are present in significantly higher concentrations. And the adsorption ratio of POPs to microplastics is different in freshwater as compared to marine ecosystems due to the proximity to the sources and use of these chemicals. As organism in freshwater ecosystem are more exposed to POPs and microplastics due to occurrence of industrial and populous area nearby. Study by Rochman et al. [87] revealed that freshwater fishes experience hepatic stress due to ingestion of polyethylene which ultimately led to bioaccumulation and toxicity in fishes. A significant amount of POPs to microplastics could accumulate in adult zebrafish gills and zebra fish embryos [88]. Another observation in the study of European perch *Perca fluviatilis* by Lönnstedt and Eklöv [89], suggested the effect of microplastics when larva of European perch were exposed to different concentrations of 10,000 or 80,000 particles/meter which resulted in inhibition of hatching and reduced growth rates. There were alterations in the feeding and innate behavior as compared to normal individuals which were not exposed with microplastics.

Microplastics can also act as an artificial substrate for microorganisms. This has raised concern about the potential ecological effect on freshwater habitat, which is utilized for anthropogenic activities as well as by the wildlife organisms. Microplastics form biofilms by providing surface for microorganisms and rafting the colonized organisms over long distances. It has also been shown that biofilms containing potentially pathogenic microorganisms which can develop on plastic in the marine system. Some microorganisms in the biofilm are assumed to be potentially opportunistic (human) pathogens, for example, members of the genus *Vibrio* have been found on the particles and making microplastics vector for pathogens, toxic algae, bacteria and invasive species. Various studies are performed on different rivers for the estimation of assimilation of microplastics by aquatic organisms. A study conducted by McGoran et al. [90], in the river Thames, revealed that up to 75% of sampled European flounder (*Platichthys flesus)* has plastic fibers in their gut compared to 20% of European smelt (*Osmeruseperlanus)* however it is estimated that this huge difference in the concentration is due to the feeding habitats of both the fishes as European flounder are benthic feeders while European smelt are pelagic feeder and these observations also suggested the relative distribution of microplastics in different strata of riverine system [91].

In study of microplastics in freshwater, Au et al. [92], investigated the ingestion and effects of PE (fluorescent blue PE microplastics particles, 10–27 μm) and PP (black polypropylene microplastics fibers from marine rope, 20–75 mm in length) on the growth and mortality of the freshwater amphipod *Hyalella azteca.* The LC50 of PE and PP in *H. azteca* after a 10-d exposure were 4.6 × 104 and 71 microplastics/mL respectively. The effects of chronic exposure to PE and its influence on the reproduction of amphipods were analyzed. Chronic exposure of *H. azteca* to PP fibers, even at a low concentration, significantly decreased growth and reproduction.

7.3 Toxic effects of microplastics shown by trophic transfer

To evaluate the process of trophic transfer and toxicological effects of microplastics at different trophic levels, a number of factors need to be considered that are involved in ingestion, bioaccumulation and biomagnification of microplastics and their associated chemicals.

Resemblance in shape and size of microplastics with many species of planktons and other type of food particles is usually observed. Hence sometimes microplastics are normally ingested by aquatic filter feeders along with some associated contaminants led to bioaccumulation and trophic transfer to higher organisms [93]. The size and shape of plastic particles are the two most important parameters which determine the extent of microplastics retention. This is because smaller particles are more likely to be ingested and particles with angular shapes may be harder to egest. The available body of evidence indicated that trophic transfer of microplastics may occur [94, 95]. Hence, pollutants may be transferred along with microplastics by means of oral ingestion as well as other pathways, which include ventilation or simple microplastics attachment and resuspension into the water column [88, 96].

Setälä et al. [7], observed the trophic transfer of polystyrene microplastics to macrozooplankton occurred after only 3 hrs of exposure to mesozooplaktons that had previously infested PS microplastics. Studies also revealed that uptake of microplastics can be influenced by the surface characteristics of plastic particles. As MP that was neutrally or positively charged had a higher binding affinity for algal cell wall than negatively charged microplastics. And hence they adhere to surface of seaweeds like *Fucus vesiculosus,* resulting in their consumption by grazing gastropods which further eventually led to trophic transfer of microplastics [97]. Microplastics are ingested by organism at lower trophic level and are further transferred to higher trophic level and ultimately results in bioaccumulation in higher organism and causes ill effects which may be life threating for them.

The impact of microplastics on humans is not yet fully understood, however many studies depict that there are many chemicals that are used in plastic production show toxic effect on living organism some of these chemicals are bisphenol A (BPA), polybrominated diphenyl ethers (PBDE), and tetrabromobisphenol (TBBPA). Studies have already detected these chemicals in human tissues and biological fluids [27]. It has also been reported that additives, for example, di(2-ethylhexyl)phthalate (DEHP), can leach from medical supplies made of PVC and accumulate in the blood of hemodialysis patients [98]. Moreover, the presence of microplastics in seafood, for example, bivalves cultured for human consumption has already been shown [28, 99]. It should be further investigated whether beverage or food products act as possible microplastics sources which is can further enter food web and results in bioaccumulation in living organism.

8. Management of microplastics

To get the problem under control, the society has to take initiatives which includes significantly curtailing unnecessary single-use plastic items such as water bottles, plastic shopping bags, straws and utensils, stringent policies should be implemented by the governments ensuring the need to strengthen garbage collection and recycling systems to prevent waste from leaking into the environment to improve recycling rates. New ways to break plastic down into its most basic units, which can be rebuilt into new plastics or other materials should be considered.

9. Conclusion

Production and applications of microplastics resulted to an enhanced incidence of plastics debris and microplastics, in the aquatic environment. Not only one mechanism such as the weathering-related fracturing and surface embrittlement of plastics in beach environments is the root cause of generation of microplastics but industrial waste also constitute the major sources of them. As microplastics are recalcitrant in nature, only small fraction of the microplastics present in aquatic body imposes a serious threat to aquatic life. As microplastics are potentially ingestible by aquatic organisms including micro and nano plankton species, the delivery of toxins across trophic levels via this mechanism is very common. The efficiency of such transfer will depend on the bioavailability of microplastics and the residence time of meso or microplastics in the organisms. Endocytosis of plastic nanoparticles by micro- or nanofauna can also result in adverse toxic endpoints. As aquatic species constitute the very foundation of the aquatic food web, any threat to these can have serious and far-reaching effects in the world oceans. There is an urgent need to quantify the magnitude of these potential outcomes and assess the future impact of increasing microplastics levels on the world's aquatic bodies.

Author details

Sukanya Mehra, Khushboo Sharma, Geetika Sharma, Mandeep Singh and Pooja Chadha*
Cytogenetics Laboratory, Department of Zoology, Guru Nanak Dev University, Amritsar, India

*Address all correspondence to: poojachadha77@yahoo.co.in

References

[1] Verschoor A, de Poorter L, Roex E, Bellert B. Quick scan and prioritization of microplastic sources and emissions. RIVM Letter report. 2014; 5:156

[2] Duis K and Coors A. Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. Environmental Sciences Europe. 2016;28(1):1-25.

[3] Carpenter EJ and Smith KL Jr. Plastics on the Sargasso Sea surface. Science. 1972;175:1240-1241

[4] Carpenter EJ, Anderson SJ, Harvey GR, Miklas HP, Beck BB. Polystyrene spherules in coastal waters. Science.1972;178:749-750.

[5] Wright SL, Thompson RC, Galloway TS. The physical impacts of microplastics on marine organisms: a review. Environmental pollution. 2013;178:483-92.

[6] Thompson RC, Olsen Y, Mitchell RP, Davis A, Rowland SJ, John AW, McGonigle D, Russell AE. Lost at sea: where is all the plastic? Science (Washington). 2004;304:838.

[7] Setälä O, Fleming-Lehtinen V, Lehtiniemi M. Ingestion and transfer of microplastics in the planktonic food web. Environmental pollution. 2014 Feb 1;185:77-83.

[8] Green DS, Boots B, O'Connor NE, Thompson R. Microplastics affect the ecological functioning of an important biogenic habitat. Environmental Science & Technology. 2017;51(1):68-77.

[9] Free CM, Jensen OP, Mason SA, Eriksen M, Williamson NJ, Boldgiv B. High-levels of microplastic pollution in a large, remote, mountain lake. Marine pollution bulletin. 2014;85(1):156-63.

[10] Woodall LC, Sanchez-Vidal A, Canals M, Paterson GL, Coppock R, Sleight V, Calafat A, Rogers AD, Narayanaswamy BE, Thompson RC. The deep sea is a major sink for microplastic debris. Royal Society open science. 2014;1(4):140317.

[11] Teuten E, Rowland S, Galloway T, Thompson R. Potential for plastics to transport hydrophobic contaminants. Environ Sci Technol.2007; 41: 7759-7764.

[12] Mato Y, Isobe T, Takada H, Kanehiro H, Ohtake C, et al. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environ Sci Technol.2001; 35: 318-324.

[13] Rochman C, Browne M, Halpern B, Hentschel B, Hoh E, et al. Classify plastic waste as hazardous. Nature.2013; 494: 169-171.

[14] GESAMP. Sources, fate and effects of microplastics in the marine environment: a global assessment. 2015

[15] Raynaud J. Valuing plastics: The business case for measuring, managing and disclosing plastic use in the consumer goods industry. UNEP. 2014.

[16] Eriksen M, Lebreton LC, Carson HS, Thiel M, Moore CJ, Borerro JC, Galgani F, Ryan PG, Reisser J. Plastic pollution in the world's oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. PloS one. 2014;9(12):1-15.

[17] Prakash V, Dwivedi S, Gautam K, Seth M, Anbumani S. Occurrence and Ecotoxicological Effects of Microplastics on Aquatic and Terrestrial Ecosystems. In Springer, Berlin, Heidelberg; 2020. p. 1-21.

[18] Foley CJ, Feiner ZS, Malinich TD, Höök TO. A meta-analysis of the effects of exposure to microplastics on fish and aquatic invertebrates. Science of the Total Environment. 2018;631-632:550-9.

[19] Sundt P, Schulze PE, Syversen F. Sources of microplastic-pollution to the marine environment. Mepex for the Norwegian Environment Agency. 2014 ;86.

[20] Lassen C, Hansen SF, Magnusson K, Hartmann NB, Jensen PR, Nielsen TG, Brinch A. Microplastics: occurrence, effects and sources of releases to the environment in Denmark.2015;1-208.

[21] Gregory MR. Plastic 'scrubbers' in hand cleansers: a further (and minor) source for marine pollution identified. Marine pollution bulletin. 1996;32(12):867-71.

[22] Derraik JG. The pollution of the marine environment by plastic debris: a review. Marine pollution bulletin. 2002;44(9):842-52.

[23] Essel R, Engel L, Carus M, Ahrens RH. Sources of microplastics relevant to marine protection in Germany. Texte. 2015;64.

[24] Eriksen M, Mason S, Wilson S, Box C, Zellers A, Edwards W, Farley H, Amato S. Microplastic pollution in the surface waters of the Laurentian Great Lakes. Marine pollution bulletin. 2013;77(1-2):177-82.

[25] Browne MA, Crump P, Niven SJ, Teuten E, Tonkin A, Galloway T, Thompson R. Accumulation of microplastic on shorelines woldwide: sources and sinks. Environmental science & technology. 2011;45(21):9175-9.

[26] Fendall LS and Sewell MA. Contributing to marine pollution by washing your face: microplastics in facial cleansers. Marine pollution bulletin. 2009;58(8):1225-8.

[27] Cole M, Lindeque P, Halsband C, Galloway TS. Microplastics as contaminants in the marine environment: a review. Marine pollution bulletin. 2011;62(12):2588-97.

[28] Eerkes-Medrano D, Thompson RC, Aldridge DC. Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. Water research. 2015;75:63-82.

[29] Leslie HA. Plastic in Cosmetics: Are we polluting the environment through our personal care?: Plastic ingredients that contribute to marine microplastic litter. 2015.

[30] Strand J. Contents of polyethylene microplastic in some selected personal care products in Denmark. In International Conference on Plastics in Marine Environments. 2014.

[31] Magnusson K, Eliasson K, Fråne A, Haikonen K, Hultén J, Olshammar M, Stadmark J, Voisin A. Swedish sources and pathways for microplastics to the marine environment. A review of existing data. IVL, C. 2016;183:1-87.

[32] Poulsen PB, Stranddorf HK, Hjuler K, Rasmussen JO. Vurderingafmalingsmiljø belastningianvendelsesfasen [Assessment of the environmental impact of paint in the use phase]. Miljøprojekt nr. Danish Environmental Protection Agency.2002;662.

[33] Fabbri D, Tartari D, Trombini C. Analysis of poly (vinyl chloride) and other polymers in sediments and suspended matter of a coastal lagoon by pyrolysis-gas chromatography-mass spectrometry. Analytica Chimica Acta. 2000;413(1-2):3-11.

[34] Norén F and Naustvoll LJ. Survey of microscopic anthropogenic particles in Skagerrak. Report commissioned by Klima-ogForurensningsdirektoratet. 2010.

[35] Dhodapkar S, Trottier R, Smith B. Measuring Dust and Fines In Polymer Pellets. Chemical Engineering. 2009 :1;116(9):24.

[36] OECD Series on emissions documents. Emission Scenario documents on coating industry (Paints, Lacquers and Varnishes). 2009.

[37] Leslie HA, Van Velzen MJ, Vethaak AD. Microplastic survey of the Dutch environment. Novel data set of microplastics in North Sea sediments, treated wastewater effluents and marine biota, The Netherlands. 2013 ;1-30.

[38] Siegle, L. Are loom bands the next environmental disaster?, in: The Observer. 2014.

[39] Mason SA, Garneau D, Sutton R, Chu Y, Ehmann K, Barnes J, Fink P, Papazissimos D, Rogers DL. Microplastic pollution is widely detected in US municipal wastewater treatment plant effluent. Environmental Pollution. 2016 Nov 1;218:1045-54.

[40] Hidalgo-Ruz V, Gutow L, Thompson RC, Thiel M. Microplastics in the marine environment: a review of the methods used for identification and quantification. Environmental science & technology. 2012 Mar 20;46(6):3060-75.

[41] Mathalon A, Hill P. Microplastic fibers in the intertidal ecosystem surrounding Halifax Harbor, Nova Scotia. Marine pollution bulletin. 2014 Apr 15;81(1):69-79.

[42] Veerasingam S, Saha M, Suneel V, Vethamony P, Rodrigues AC, Bhattacharyya S, Naik BG. Characteristics, seasonal distribution and surface degradation features of microplastic pellets along the Goa coast, India. Chemosphere. 2016 Sep 1;159:496-505.

[43] Dris R, Imhof HK, Löder MG, Gasperi J, Laforsch C, Tassin B. Microplastic contamination in freshwater systems: Methodological challenges, occurrence and sources. In Microplastic Contamination in Aquatic Environments 2018 Jan 1 (pp. 51-93). Elsevier.

[44] Kim IS, Chae DH, Kim SK, Choi S, Woo SB. Factors influencing the spatial variation of microplastics on high-tidal coastal beaches in Korea. Archives of environmental contamination and toxicology. 2015 Oct 1;69(3):299-309.

[45] Shahul Hamid F, Bhatti MS, Anuar N, Anuar N, Mohan P, Periathamby A. Worldwide distribution and abundance of microplastic: how dire is the situation?. Waste Management & Research. 2018 Oct;36(10):873-97.

[46] Van Cauwenberghe L, Devriese L, Galgani F, Robbens J, Janssen CR. Microplastics in sediments: a review of techniques, occurrence and effects. Marine environmental research. 2015 Oct 1;111:5-17.

[47] Fok L, Lam TW, Li HX, Xu XR. A meta-analysis of methodologies adopted by microplastic studies in China. Science of The Total Environment. 2020 May 20;718:135371.

[48] Wang J, Liu X, Li Y, Powell T, Wang X, Wang G, Zhang P. Microplastics as contaminants in the soil environment: A mini-review. Science of The Total Environment. 2019 Nov 15;691:848-57.

[49] Brach L, Deixonne P, Bernard MF, Durand E, Desjean MC, Perez E, van Sebille E, ter Halle A. Anticyclonic eddies increase accumulation of

microplastic in the North Atlantic subtropical gyre. Marine pollution bulletin. 2018 Jan 1;126:191-6.

[50] Lu K, Qiao R, An H, Zhang Y. I nfluence of microplastics on the accumulation and chronic toxic effects of cadmium in zebrafish (*Danio rerio*). Chemosphere. 2018 Jul 1;202:514-20.

[51] Zhang Y, Gao T, Kang S, Sillanpää M. Importance of atmospheric transport for microplastics deposited in remote areas. Environmental Pollution. 2019 Nov 1;254:112953.

[52] Frias JP, Nash R. Microplastics: finding a consensus on the definition. Marine pollution bulletin. 2019 Jan 1;138:145-7.

[53] Engler RE. The complex interaction between marine debris and toxic chemicals in the ocean. Environmental science & technology. 2012 Nov 20;46(22):12302-15.

[54] Antunes J, Frias J, Sobral P. Microplastics on the Portuguese coast. Marine pollution bulletin. 2018 Jun 1; 131:294-302.

[55] Fisner M, Taniguchi S, Moreira F, Bícego MC, Turra A. Polycyclic aromatic hydrocarbons (PAHs) in plastic pellets: Variability in the concentration and composition at different sediment depths in a sandy beach. Marine pollution bulletin. 2013 May 15;70(1-2):219-26.

[56] Fries E, Dekiff JH, Willmeyer J, Nuelle MT, Ebert M, Remy D. Identification of polymer types and additives in marine microplastic particles using pyrolysis-GC/MS and scanning electron microscopy. Environmental Science: Processes & Impacts. 2013;15(10):1949-56.

[57] Qu X, Su L, Li H, Liang M, Shi H. Assessing the relationship between the abundance and properties of microplastics in water and in mussels. Science of the total environment. 2018 Apr 15;621:679-86.

[58] Li J, Green C, Reynolds A, Shi H, Rotchell JM. Microplastics in mussels sampled from coastal waters and supermarkets in the United Kingdom. Environmental pollution. 2018 Oct 1;241:35-44.

[59] Miller ME, Kroon FJ, Motti CA. Recovering microplastics from marine samples: A review of current practices. Marine Pollution Bulletin. 2017 Oct 15;123(1-2):6-18.

[60] Lima AR, Costa MF, Barletta M. Distribution patterns of microplastics within the plankton of a tropical estuary. Environmental Research. 2014 Jul 1;132:146-55.

[61] Mani T, Hauk A, Walter U, Burkhardt-Holm P. Microplastics profile along the Rhine River. Scientific reports. 2015 Dec 8;5(1):1-7.

[62] Prata JC. Microplastics in wastewater: State of the knowledge on sources, fate and solutions. Marine pollution bulletin. 2018 Apr 1;129(1):262-5.

[63] Geyer R, Jambeck JR, Law KL. Production, use, and fate of all plastics ever made. Science advances. 2017 Jul 1;3(7):e1700782.

[64] Ivleva NP, Wiesheu AC, Niessner R. Microplastic in aquatic ecosystems. Angewandte Chemie International Edition. 2017 Feb 6;56(7):1720-39.

[65] Hartmann NB, Hüffer T, Thompson RC, Hassellöv M, Verschoor A, Daugaard AE, Rist S, Karlsson T, Brennholt N, Cole M, Herrling MP. Are we speaking the same language? Recommendations for a definition and categorization framework for plastic debris.2019

[66] Rezania S, Park J, Din MF, Taib SM, Talaiekhozani A, Yadav KK, Kamyab H. Microplastics pollution in different aquatic environments and biota: A review of recent studies. Marine pollution bulletin. 2018 Aug 1;133:191-208.

[67] Wright SL, Ulke J, Font A, Chan KL, Kelly FJ. Atmospheric Microplastic deposition in an urban environment and an evaluation of transport. Environment international. 2020 Mar 1;136:105411.

[68] Triebskorn R, Braunbeck T, Grummt T, Hanslik L, Huppertsberg S, Jekel M, Knepper TP, Krais S, Müller YK, Pittroff M, Ruhl AS. Relevance of nano-and microplastics for freshwater ecosystems: a critical review. TrAC Trends in Analytical Chemistry. 2019 Jan 1;110:375-92.

[69] James E, Turner A. Mobilization of antimony from microplastics added to coastal sediment. Environmental Pollution. 2020 May 1:114696.

[70] Cressey D. The plastic ocean. Nature. 2016 Aug 18;536(7616):263-5.

[71] Abidli S, Toumi H, Lahbib Y, El Menif NT. The first evaluation of microplastics in sediments from the complex lagoon-channel of Bizerte (Northern Tunisia). Water, Air, & Soil Pollution. 2017 Jul 1;228(7):262.

[72] Guilhermino L, Vieira LR, Ribeiro D, Tavares AS, Cardoso V, Alves A, Almeida JM. Uptake and effects of the antimicrobial florfenicol, microplastics and their mixtures on freshwater exotic invasive bivalve *Corbicula fluminea*. Science of the Total Environment. 2018 May 1;622:1131-42.

[73] Zalasiewicz J, Waters CN, do Sul JA, Corcoran PL, Barnosky AD, Cearreta A, Edgeworth M, Gałuszka A, Jeandel C, Leinfelder R, McNeill JR. The geological cycle of plastics and their use as a stratigraphic indicator of the Anthropocene. Anthropocene. 2016 Mar 1;13:4-17.

[74] Silva-Cavalcanti JS, Silva JD, de França EJ, de Araújo MC, Gusmao F. Microplastics ingestion by a common tropical freshwater fishing resource. Environmental Pollution. 2017 Feb 1;221:218-26.

[75] Gasperi J, Wright SL, Dris R, Collard F, Mandin C, Guerrouache M, Langlois V, Kelly FJ, Tassin B. Microplastics in air: are we breathing it in?. Current Opinion in Environmental Science & Health. 2018 Feb 1;1:1-5.

[76] Redondo-Hasselerharm PE, Gort G, Peeters ET, Koelmans AA. Nano-and microplastics affect the composition of freshwater benthic communities in the long term. Science advances. 2020 Jan 1;6(5):eaay4054.

[77] Cole M, Lindeque P, Fileman E, Halsband C, Galloway TS. The impact of polystyrene microplastics on feeding, function and fecundity in the marine copepod *Calanus helgolandicus*. Environmental science & technology. 2015 Jan 20;49(2):1130-7.

[78] Lindeque PK, Cole M, Coppock RL, Lewis CN, Miller RZ, Watts AJ, Wilson-McNeal A, Wright SL, Galloway TS. Are we underestimating microplastic abundance in the marine environment? A comparison of microplastic capture with nets of different mesh-size. Environmental Pollution. 2020 May 3:114721.

[79] Messinetti S, Mercurio S, Parolini M, Sugni M, Pennati R. Effects of polystyrene microplastics on early stages of two marine invertebrates with different feeding strategies. Environmental Pollution. 2018 Jun 1;237:1080-7.

[80] Kaposi KL, Mos B, Kelaher BP, Dworjanyn SA. Ingestion of microplastic has limited impact on a

marine larva. Environmental science & technology. 2014 Feb 4;48(3):1638-45.

[81] Sazakli E, Leotsinidis M. Possible effects of microplastics on human health. Microplastics in Water and Wastewater, Hrissi K. Karapanagioti, Ioannis K. Kalavrouziotis Download citation file: Ris (Zotero) Reference Manager EasyBib Bookends Mendeley Papers EndNote RefWorks BibTex Close Search. 2019.

[82] Sussarellu R, Suquet M, Thomas Y, Lambert C, Fabioux C, Pernet MEJ, et al. Oyster reproduction is affected by exposure to polystyrene microplastics. Proceedings of the National Academy of Sciences of the United States of America. 2016;113(9):2430-5.

[83] Clark JR, Cole M, Lindeque PK, Fileman E, Blackford J, Lewis C, Lenton TM, Galloway TS. Marine microplastic debris: a targeted plan for understanding and quantifying interactions with marine life. Frontiers in Ecology and the Environment. 2016 Aug;14(6):317-24.

[84] Lamb JB, Willis BL, Fiorenza EA, Couch CS, Howard R, Rader DN, True JD, Kelly LA, Ahmad A, Jompa J, Harvell CD. Plastic waste associated with disease on coral reefs. Science. 2018 Jan 26;359(6374):460-2.

[85] Reichert J, Arnold AL, Hoogenboom MO, Schubert P, Wilke T. Impacts of microplastics on growth and health of hermatypic corals are species-specific. Environmental Pollution. 2019 Nov 1;254:113074.

[86] Rehse S, Kloas W, Zarfl C. Short-term exposure with high concentrations of pristine microplastic particles leads to immobilisation of *Daphnia magna*. Chemosphere. 2016 Jun 1;153:91-9.

[87] Rochman CM, Hoh E, Kurobe T, Teh SJ. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Scientific reports. 2013 Nov 21;3:3263.

[88] Batel A, Borchert F, Reinwald H, Erdinger L, Braunbeck T. Microplastic accumulation patterns and transfer of benzo[a]pyrene to adult zebrafish (*Danio rerio*) gills and zebrafish embryos. Environmental Pollution. 2018 Apr 1;235:918-30.

[89] Lönnstedt OM, Eklöv P. Environmentally relevant concentrations of microplastic particles influence larval fish ecology. Science. 2016 Jun 3;352(6290):1213-6.

[90] McGoran AR, Clark PF, Morritt D. Presence of microplastic in the digestive tracts of European flounder, Platichthys flesus, and European smelt, Osmeruseperlanus, from the River Thames. Environmental Pollution. 2017 Jan 1;220:744-51.

[91] Meng Y, Kelly FJ, Wright SL. Advances and challenges of microplastic pollution in freshwater ecosystems: A UK perspective. Environmental Pollution. 2020 Jan 1;256:113445.

[92] Au SY, Lee CM, Weinstein JE, van den Hurk P, Klaine SJ. Trophic transfer of microplastics in aquatic ecosystems: identifying critical research needs. Integrated environmental assessment and management. 2017 May 1;13(3):5059.

[93] Desforges JP, Galbraith M, Ross PS. Ingestion of microplastics by zooplankton in the Northeast Pacific Ocean. Archives of environmental contamination and toxicology. 2015 Oct 1;69(3):320-30.

[94] Nelms SE, Galloway TS, Godley BJ, Jarvis DS, Lindeque PK. Investigating microplastic trophic transfer in marine top predators. Environmental Pollution. 2018 Jul 1;238:999-1007.

[95] Welden NA, Abylkhani B, Howarth LM. The effects of trophic

transfer and environmental factors on microplastic uptake by plaice, Pleuronectes plastessa, and spider crab, *Maja squinado*. Environmental Pollution. 2018 Aug 1;239:351-8.

[96] Gray AD, Weinstein JE. Size-and shape-dependent effects of microplastic particles on adult daggerblade grass shrimp (*Palaemonetes pugio*). Environmental toxicology and chemistry. 2017 Nov;36(11):3074-80.

[97] Nolte TM, Hartmann NB, Kleijn JM, Garnæs J, Van De Meent D, Hendriks AJ, Baun A. The toxicity of plastic nanoparticles to green algae as influenced by surface modification, medium hardness and cellular adsorption. Aquatic toxicology. 2017 Feb 1;183:11-20.

[98] Dong CD, Chen CW, Chen YC, Chen HH, Lee JS, Lin CH. Polystyrene microplastic particles: In vitro pulmonary toxicity assessment. Journal of hazardous materials. 2020 Mar 5;385:121575.

[99] Van Cauwenberghe L, Janssen CR. Microplastics in bivalves cultured for human consumption. Environmental pollution. 2014 Oct 1;193:65-70.