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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2019; 8(2): 555-561

www.thepharmajournal.com
Received: 12-12-2018
Accepted: 15-01-2019

Priyanka
Department of Veterinary Public Health & Epidemiology,
College of Veterinary Sciences,
LUVAS. Hisar, Haryana, India

Sneh Lata Chauhan
Department of Veterinary Public Health & Epidemiology,
College of Veterinary Sciences,
LUVAS. Hisar, Haryana, India

Correspondence
Sneh Lata Chauhan
Department of Veterinary Public Health & Epidemiology,
College of Veterinary Sciences,
LUVAS. Hisar, Haryana, India

Microplastic pollution: A macro problem

Priyanka and Sneh Lata Chauhan

Abstract
Microplastics are the particles of size <5 mm, which originate from successive degradation of larger plastic debris or are manufactured as small granules and used in many applications. These are the emerging pollutants of increasing environmental concern. These tiny particles easily pass through water filtration systems and end up in the environment the plastic might disintegrate into pieces too small to be caught in. The plastic sinking in sediment could be eaten by plankton or fish from where it enters the food chain and finally it climbs to the top of the pyramid into human body. An important source of microplastic appears to be through sewage contaminated by microfibers from washing clothes. This review outlines the current studies on the effects of plastic pollution in the marine environment and the possible deleterious effects of their presence in the marine food web.

Keywords: Microplastics, microfibers, food web, pollution

1. Introduction
Plastics are synthetic polymers which also contain other chemicals to enhance performance (Costa *et al*. 2016) [13], commonly derived from petrochemical sources and have wide ranges of molecular mass and plasticity. Till now 8.3 BILLION Metric Tons of plastic has been produced since plastic was introduced in the 1950s. Now a days, wide range of products are made up of plastics because of their ease of manufacture, inertness (chemical, temperature and light resistance as well), low cost, high strength/weight ratio and resistance to water (Andrady and Neal 2009; Cauwenberghe *et al*. 2015) [1, 49]. The durability of plastic makes it highly resistant to degradation and therefore, disposing of plastic waste is a big challenge for us (Sivan 2011). Plastic makes up about 10% of all of the waste we generate. Recycling is one of the solutions but unfortunately majority of the plastic debris ends up in landfill which takes a long duration for its breakdown and decomposition (Cole *et al*. 2011) [12]. Microplastics now a ubiquitous pollutant in the oceans, pose a serious potential threat to marine ecology and has justifiably encouraged focused biological and ecological research attention. But the generation, fate, fragmentation and their potency to absorb or release persistent organic pollutants (POPs) are determined by the characteristics of the polymers from which they are made up of. The problem of plastic pollution and its enduring impact was dramatically brought to light with Charles Moore's discovery of the Great Pacific Garbage Patch in 1997 (Parke *et al*, 2018). it is Found in all forms of marine life; in table salt, honey, sugar, and beer; in organic fertilizers; in the dust in our homes; and most alarmingly, in bottled and tap water samples.

2. Microplastics
Microplastics are semi-synthetic plastic polymers particles with a size lower than 5 mm (Browne *et al*. 2015) [7]. Microplastics are commonly used as scrubbers in cosmetics, hand cleansers and are used in air-blasting (Thompson *et al*. 2004; Ryan *et al*. 2009) [14, 12]. The evidence of microplastics fragments in the environment was firstly reported in 1970s (Carpenter and Smith 1972) [11]. After that many scientific organizations around the globe have discovered that microplastics are pervasive within the marine habitat and harming the marine biota (Sutherland *et al*. 2010). There are two types of microplastics found in the environment viz. primary and secondary microplastics.

2.1 Primary microplastics
Primary microplastics are defined as microscopic plastic on the basis of size of fragments. Based on chemical composition, these primary microplastics are produced by the unintentional release of intermediate plastic feedstock (i.e. pellets, nurdles or mermaid tears) and occur as by-products of processes such as particulate emissions from industrial production,

maintenance of plastic or plastic-based materials, release of dust and fibres, and deterioration of plastic products (GESAMP 2015) [18]. The plastic pellets are raw material for manufacturing of plastic products (pellets to made plastic bags) and microbeads in human health care commodities (Magnusson *et al*. 2016) [24]. The plastic pellets comprises of polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyolefin particles, are lipophilic in nature, i.e. they readily adsorb harmful and toxic chemicals from surrounding marine water on its surface. These tiny synthetic primary microplastics are also used as abrasives in various industries like cosmetics, cleaning products, pharmaceuticals and air-blasting media. Several hydrophobic and aromatic compounds such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and dichlorodipheny ltrichloroethane (DDT) have been detected to bond on the surface of pellets collected from marine environment (Cauwenberghe *et al*. 2015) [6].

2.2 Secondary microplastics
Secondary microplastics are defined as fragments of bigger plastic items that suffer fragmentation found both in marine as well as terrestrial habitat (Thompson *et al*. 2004; Ryan *et al*. 2009) [47, 40]. Weathering also causes the breakdown of larger plastic into tiny fragments (Arthur *et al*. 2009) [2]. Another important process is photodegradation caused by ultraviolet radiation from sunlight which results in chemical bond cleavage of polymer matrix by the oxidation process (Barnes *et al*. 2009) [3].

2.3 Nanoplastics
Nanoplastics are minute plastic fragments with size < 100 nm in at least two of its dimensions. The fragmentation or weathering of larger plastic trash gives rise to micro and nanoplastics. The nanoplastics are produced during fragmentation of synthetic fibers during the washing of clothes and during the deterioration of the plastic items such as expanded polystyrene with an accelerated mechanical abrasion system (Costa *et al*. 2016) [13]. The reduced size and high surface area-tovolume ratio of these nanoplastics make them vulnerable to ingestion by different marine organisms such as corals, phytoplanktons and zooplanktons which are the prime consumers of the food chain and also allow persistent organic pollutants (POPs) to adsorb on their surface which increases their potential hazardous effects.

3. The Plastic cycle
The formation of microplastic is due to the effects of weathering, wave action and abrasion of the larger plastic against harder materials as the plastic makes its way to the oceans. The other forms of degradation include UV radiation acting upon the plastics and breaking them down over longer periods of time. Plastic in the marine environment undergoes mainly three kinds of processes which are physical, chemical and biological. In physical degradation, the plastic is disintegrated into smaller particles sizes due to the action of UV rays which further undergo biofouling, sinking and sedimentation. During the chemical phase floating microplastic encounters the persistent organic pollutants present inside the marine water which leads to concentration and adsorption of harmful chemical over the plastic particles. These harmful chemicals get leached out from the plastic and equilibrate in water. Also the chemical coated plastic is ingested by marine organisms. These harmful chemicals undergo bioaccumulation inside the marine organisms and transferred to higher order consumers via food chain.

4. Microplastic everywhere
Recent studies showed that microplastics (fragments, fibers and pellets) are present in seas all over the world, although only microfibers (not microbeads) where found in deep-sea organisms. Microplastic contamination has been found in tap water in countries in whole of the world. The US had the highest contamination rate in the world at 94% with plastic fibres found in tap water sampled at sites including Congress buildings, the US Environmental Protection Agency’s headquarters and Trump Tower in New York. Lebanon and India had the next highest rates of microplastic in tap water (Schymanski *et al*, 2018). There are evidences for the presence of microplastic in bottled water as well. According to the Enviro News World news article, 93 % of bottled water from different brands was found to be tainted with microplastics which indicate that bottled water is not a solution over tap water. A study published in 2017 states the presence of microplastic in the salt also. Seventy different salt brands were tested for the presence of microplastics and all were found to be contaminated with it. This lead to the hypothesis that sea salt might contain microplastics in it, because it is directly produced from seawater pointing out the importance of monitoring the presence of such contaminants in sea salts.

5. Microfiber pollution
Microfiber is another important source of secondary microplastic pollution occurs from the breakdown of synthetic fibers and discharge into the environment through waste water from washing machines (Prata *et al*, 2018) [37]. The problem of microfibers is mainly generated from older clothes undergoing multiple washings, due to which these are released in drain water leading to their discharge in waste water treatment plants, river and ultimately oceans. In oceans, these microfibers encounter marine life and at last come back to us in our plate as food which is matter of concern. Microfibers are globally prevalent in terrestrial, aquatic and atmospheric ecosystems. Higher density of synthetic fibers results in sinking and settling in shoreline and deep sea sediments. Due to the release of fibers, marine systems are an especially substantial receptor. It's increasingly common to apply sewage sludge to agricultural fields so that more fibers are being found on land. The higher shedding in old jackets and clothes is most likely due to the weakening of fibers as a result of wear. Synthetic textiles, such as fleece jackets spread tiny plastic fibers into wastewater after washing. A single fleece jacket sheds as many as 250,000 synthetic fibers (Heartline *et al*., 2016) Researchers have found high numbers of fibers inside fish and shellfish sold at markets. Microfibers act as sponges, carrying invasive bacteria that can be harmful to humans.

6. Interaction of microplastic with marine organisms
The most common way that microplastics will interact with marine biota is through ingestion of tiny particles of plastic present in the water. Primary and low-trophic level organisms are particularly susceptible for ingestion of microplastic particles. The potential for microplastics to cause harm in marine organisms is initially likely to be governed by the susceptibility of species to ingest and/or interact with them. Selectivity is evident in particle ingestion of natural

substances in a range of species and it is therefore likely that such selectivity will extend to microplastics (Wright *et al*., 2013) [52].

Marine algae e.g. Scenedesmus adsorbs nanoplastics, especially when these are positively charged. Grazing microzooplankton e.g. the marine ciliate Strombidium sulcatum have size-based selectivity which indicates the potential to ingest microplastics of appropriate size. On the other hand, for benthic deposit feeders e.g. the polychaete Arenicola marina and the Holothuria floridana, the sea bed is a sink for high-density microplastics and size-based, deposit-feeding strategies are found to be adopted by A. marina which indicate its potential to ingest microplastics of appropriate size (Thompson *et al*. 2004). H. Floridana selectively ingests plastic particles, showing a preference for fibrous shapes (Graham and Thompson, 2009). Benthic scavengers e.g. the crustacean Nephrops norvegicus Fibrous microplastics have been found to accumulate in marine sediments, their gut content analysis has shown that the plastic microfibers are being ingested in the environment and it is found that ingestion is passive via food it scavenges or sediment s (Murray and Cowie, 2011). Mesozooplankton e.g. echinoderm larvae, calanoid copepods, chaetognaths encounter the low density microplastics present on the sea surface with greatest abundances in gyres and industrial harbours and these also show size-based selectivity which indicates potential to ingest microplastics of appropriate size. The benthic suspension feeders e.g. the bivalve Mytilus edulis are susceptible to sinking microplastics and have been found to ingest microplastics despite low qualitative value (Browne *et al*., 2008) [7].

7. Physical impact of microplastics on marine organisms

The species that is most affected by plastic pollution is the marine population. Generally, the physical threat of plastics arises when organisms become tangled in, or mistakenly eat the plastic as food. Plastic rings, nets, bags, string, 6-pack soda rings, bottles. These are all items in which animals can become stuck. They may suffocate; drown, etc. if they are caught in it. Another problem arises when animals eat the plastic because they think it is food. Many plastics (especially the transparent pieces) may look like plankton to fish. Larger pieces may look like fish or invertebrates to diving seabirds. Turtles will mistake thin plastic bags for jellyfish (their main food choice). Once inside their stomach or digestive tract, the plastic cannot be digested, and will likely stay inside the organism for the rest of its life. It may cause them to feel satiated, or may clog their digestion, so that they do not or cannot continue to eat and miss out of vital nutrients because of which animal starve to death.

7.1 Benthic organism

Around 70 % of marine litter is estimated to be accumulated on the seafloor. Litter accumulation can prevent gas exchange between overlying water and the pore waters of sediments leading to reduced oxygen in sediments (Mout *et al*., 2010). An additional impact on the functioning of ecosystem is by smothering of benthic organisms and changes to the composition of biota on the seafloor (Derriak, 2002). Marine litter can also cause physical damage to the benthic habitats through abrasion, scouring, breaking and smothering (Sheavly and Register 2007). Benthic organisms are also at risk from entanglement by and of ingestion marine litter (Derraik 2002).

7.2 Fish

The presence of microplastic was reported in about approximately 30% of the individual fish species (Possatto *et al*. 2011; Lusher *et al*. 2013). The bottom-feeding fish (Gerreidae) from a tropical estuary in northeast Brazil were reported to be contaminated with microplastics and most of their stomach was affected (Ramos *et al*. 2012). The primary route of exposure of microplastics is the direct ingestion as food or ingestion by mistake for prey items. The accumulation of microplastics (< 5 mm) in the gut of fish results starvation and malnourishment of fish and ultimately leading to death (Boerger *et al*. 2010). Apart from fish, ingestion of different type of microplastics was studied in Norway lobster, where 83% of the lobsters were found to be infected with microfibers (Murray and Cowie, 2011).

7.3 Seabird

Sea birds like albatross, shearwaters, petrels and northern fulmar fed at the sea surface and the ingested microplastic gets accumulated in their stomach. By the process of regurgitation seabirds are able to remove microplastics from their digestive tracts and same has been reported for Larus glaucescens (Lindborg *et al*. 2012). Kuhn and van Franeker (2012), reported that in comparison to adult northern fulmars (Fulmarus glacialis) younger one get exposed with more microplastic during the feeding process which ultimately got accumulated in their intestines. Plastic ingestion affects negatively the feeding habits of the seabirds leading to the starvation and loss of fitness (Tanaka *et al*. 2013).

7.4 Large marine animals (marine mammals and turtles)

The hazardous effects of microplastic litter have been reported for many large marine organisms such as sea turtles, whales, harbour seals and polar bears (Derraik 2002). In Brazil, approximately 60.5% of the sea turtles were found to be infected by microplastics accumulation in their digestive track (Nerland *et al*. 2014). Another marine mammal, Baleen whales were highly prone to microplastic contamination as this class of marine organisms was involved in filtering organisms that filter seawater and that facilitate the entry of microplastics in their system (Fossi *et al*. 2012). Because of high fat and lipid content, whales are also highly potential to ingest and accumulate microplastics in stomach and intestine. Recently there are numerous reports of death of stranded whales having a lot of microplastics litter in their gut (Sharma and Chatterjee. 2017). The ingestion of microplastics was recorded in the stomach and intestine of harbour seals (Phoca vitulina) (Bravo Rebolledo *et al*. 2013). Microplastic particles with a diameter of 1 mm were recorded in the Hooker's sea lions and scat of fur seals (Goldsworthy *et al*. 1997; McMahon *et al*. 1999). It is predicted that polar bears are also susceptible to microplastics ingestion but yet no reports have been published.

8. Trophic Transfer of microplastics to the food chain

Once the microplastic has entered the marine environment, it can be passed from species to species by simply being mistaken for prey. The risk of ingestion of plastics by marine animals is strongly influenced by the style of feeding of each particular animal. (Frias 2014). Microplastics are ingested by an array of marine biota because of their microsize as well as their presence in both pelagic and benthic ecosystems (Betts 2008; Thompson *et al*. 2009). Not only the problems with pollutant transference in food chain is an issue of concern but the capacity to absorb pollutants from water and pass to other trophic level by biomagnifications is also a serious threat. Microplastics are composed of toxic additives and monomers which have reasonably large area to volume ratio and thus are effective in absorbing hydrophobic pollutants from the water bodies (Mato *et al*. 2001; Thompson *et al*. 2007) [23, 40]. Very low concentrations of persistent organic pollutants (POPs) which are found in marine habitat are taken up by microplastics through the process of partitioning. The hydrophobicity factor of POPs is responsible for their enhanced absorption in microplastic litter and upon ingestion by marine biota; these hazardous contaminants (POPs) are transferred along the marine food chain. Not only phytoplankton and corals consume microplastics and microbeads and absorbing their toxins, but also a wide range of marine animals getting affected. Once an organism is contaminated with toxins, these toxins can move up the food chain, when a predator eats the contaminated prey. Generally, as one moves to higher trophic levels (secondary consumers and top predators) the concentrations of contaminants increase exponentially. This is because with each increase in trophic level, the amount of energy that the predator gets from each prey is lower than the lower trophic level. Therefore, predators higher on the food chain must eat larger amounts of prey (each potentially containing contaminants from all the previous trophic levels). In this way the toxins accumulate in the top predators (in marine ecosystems, these are the mammals like sharks and seals, and birds). Phycotoxins are mostly passed within the toxic alga and transferred to the plankton or benthos (bivalves or crustaceans) by their feeding. For example, diarrethic and paralytic shellfish poisonings (DSP and PSP) are caused by algal toxins produced by the exposure of microplastics that efficiently accumulate in shellfish and can transfer in food web and indirectly cause hazardous symptoms in humans (Teegarden and Cembella 1996; Mons *et al*. 1998; Campbell *et al*. 2005) [10, 31, 10]. The algal toxins can accumulate in marine food webs and can pass from one trophic level to the next trophic level.

9. Harmful effect on human health

Microplastics are a pollutant of environmental concern. Their presence in food meant for human consumption and in air samples has been reported. Humans are exposed as these particles are found in our seafood and water supply, in the air we breathe and the routine use articles humans are either get direct exposure to microplastics through ingestion and inhalation of contaminated microplastic particles or secondary exposure by ingesting fish, birds or other organisms with accumulated contaminants within their tissue from previously egested microplastics (Ziccardi *et al*., 2016) [53]. The general human population may be exposed to microplastics through different sources like from primary microplastics in cosmetics, toothpastes, scrubs and hand washes. Apart from toxic effects of microplastics, hazardous substances such as phthalates or PCBs within the microplastics or other pollutant adsorbed to the surface of microplastics may contribute to the dietary intake of humans (Lassen *et al*. 2015) [24]. The regular increase of microplastics in seafood also has consequences for the health of human consumers. Microplastics have been shown to be ingested by several commercial sea species such as mussel, oyster, crab, sea cucumber and fish and transferred along the food web. Unfortunately, no concrete data are available about the chemical composition, particle size, shape or concentration of microplastics particles in the food (BfR 2015) [5]. Although microplastics and human health is an emerging field, complementary existing fields indicate potential particle, chemical and microbial hazards. After inhalation or ingestion, microplastics may accumulate and exert localized particle toxicity by inducing or enhancing an immune response. Chemical toxicity could occur due to the localized leaching of component monomers, endogenous additives and adsorbed environmental pollutants. Chronic exposure is anticipated to be of greater concern due to the accumulative effect that could occur. The health hazards resulting from the repeated use of face washes, hand cleansers, toothpastes and dental care products containing PE microplastic particles has been evaluated by the German Federal Institute for Risk Assessment (BfR 2015) [5]. They concluded that microplastic particles used in face pack peelings and shower products are larger than 1 μm and prolonged use of these products lead to absorption of PE and PP particles in the tissues which ultimately result in skin damage. Microplastics and microbeads particles from toothpaste can unconsciously be swallowed and are absorbed through the gastrointestinal tract (Lassen *et al*. 2015) [24]. The harmful effects of microplastics in humans mainly results from the bioaccumulation and biomagnification. Translocation of plastic particles of size < 150 μm occurs from the gut cavity to circulatory system causing serious hazards to health (Hussain *et al*., 2001). Plastic particles may be retained in the tissues (von Moos *et al*., 2012) [51] and the circulatory system (Browne *et al*., 2008) [7], or lodged in the digestive tract (vertebrates e.g. (Denuncio *et al*., 2011; Lazar and Gracan, 2011) [14]; invertebrates (Murray and Cowie, 2011) [21]. Microplastics also pick up harmful bacteria,so that means by ingesting the plastics, we may ingest the harmful bacteria also which is a matter of concern. Although there is very little information of the effects of pathogens on microplastic, studies into the possibility that pathogenic organisms such as *Vibrio* bacteria specifically *V. harvegi* an aggressive marine pathogen and *V. cholera* a human pathogen are using microplastics as transport vector and can survive for quite some time without a host. These pathogens are regularly associated with mortality in fish, mussels and oysters farmed and wild. (Schikorski, 2013) [41]. The accumulation of microplastics inside the body can be a problem in same way like silicosis or byssinosis. Along with it, the inhaled or ingested microplastics may accumulate and exert localized particle toxicity by inducing or enhancing an immune response. Very fine plastic particles are found to cross cell membranes, the blood-brain barrier and the placenta which leads to oxidative stress, cell damage, inflammation (Vethaak and Leslie, 2016) [50]. The alternate ingestion of microparticles can cause alteration in chromosomes which lead to many abnormalities such as infertility, obesity and cancer (GESAMP 2015) [18]. In case of women, estrogenic mimicking chemicals can also cause breast cancer. It is evident that humans are exposed to microplastics through their diet and the high ratio of microplastic pollutants in seafood creates a major risk to food safety (Van Cauwenberghe and Janssen 2014). Long-term impact of MPs on human health remains largely unknown since most studies to date have been limited to marine life. Therefore, a detailed analysis and assessment of the potential health risk of microplastics coming from a range of foods across the total diet should be carried out to find out the causative risk of contaminated marine food on human health.

10. Conclusion

Plastic pollution in general the world over is now of great concern as it presents a threat not only to the marine environment but the global ecosystem which is an issue of concern. The aim of this review is to discuss the presence of a genuine threat to the well being of the marine ecosystem and all those that depend on the condition and wellbeing of it. The effects of microplastic pollution can be summarized into three main areas: ecological, social and economic. The ecological effects are the physical threats to marine organisms. The social effects are pertained to the debris degrades the marine environment which makes it less appealing for tourists. It may also limit recreational use of an area. Natural environments provide ecological services, more simply stated, they are valuable simply because they are there, they are a single part of a much larger system. Degrading the environment decreases their value for us and for our children and future generations. There is a pressing need to take severe measures to address the problem at local, national and international levels. Developing countries are main contributors of plastic pollution in the marine atmosphere. Most of developing countries have not formulated rules and regulations to control microplastic pollution. Therefore, it is recommended that local governments should introduce strong legislative rules and should encourage research to monitor the long-term effects of plastic debris in the environment. There should be formulation of new scientific data on microplastics pollution for conservation management, for normative guidelines and strengthen the basis for educational campaigns.

The public awareness regarding microplastic pollution is very significant because this will govern their behaviour towards plastic consumption and most importantly the negative effects of the plastic pollution are still unrecognizable by the general population. Different campaigns and programmes should be adopted which may play an important role in public awareness against the long-term and chronic effects of plastics pollution. Several socially active international organizations should start certain campaigns on a global scale to minimize microplastics pollution.

Finally, plastics manufacturing industries should take accountability of this and take care of their end-of-life products. Government should set ‘zero tolerance’ for this issue and compel the industries to use biodegradable materials such as starch in place of nondegradable material. This biodegradable material will then be decomposed by microorganisms (bacteria/fungi) and ultimately reducing the lifetime of these plastics in the surroundings. In industries, the process of recycling or upgrading of plastic litter should be promoted. Recently, the tertiary recycling of plastic has emerged as one of the advance techniques where plastic materials are converted into smaller fragments which can be further used as feedstock for the manufacture of new petrochemicals. In conclusion there is sufficient evidence that there is need for concern for the presence of marine plastic pollution. The possible effects of this pollution not only present a threat to the plant and animal life of the marine ecosystem, but to all those that are dependent on it including humans.

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