International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 348-353 www.ijaem.net ISSN: 2395-5252

Microplastic: A Major Emerging Water Pollutant and Its Impact on Freshwater Fishes

[1]Sadguru Prakash and [2]Alok Shukla
[1]Department of Zoology and [2]Physics, M.L.K.P.G. College, Balrampur, U.P.

Submitted: 15-04-2021 Revised: 28-04-2021 Accepted: 30-04-2021

ABSTRACT: Plastic production is increasing tremendously throughout the world without proper management. These plastics degraded into plastic debris of size <5mm termed as microplastics (MPs) and are hazardous to aquatic life. Fishes may ingest microplastics either directly or by the prey containing these particles. MPs were found between the stomach, gut, and intestine of the fishes.These MPs accumulated in the fish body which causes serious health issues leading to mortality of the fishes. MPscan cause variousecotoxicologicaleffects on fishes like behaviouralchange, cytotoxicity, neurotoxicityeffects,and liver stress etc.

KEYWORDS: Microplastics, sources, accumulation, freshwater

I. INTRODUCTION:

The word plastic originally referred to any substance that was easily moulded and shaped (from the Greek adjective plastikos). Plastics were originally developed well before the twentieth century using natural materials such as the insect secretion shellac, latex from tree sap, rubber and celluloids (Meikle, 1995). However today when referring to plastics, we tend to mean synthetic long chain organic polymers derived from the polymerization of monomers extracted from petroleum other products, including polyvinylchloride(PVC), nylon, polyethylene (PE), polystyrene (PS), and poly-propylene (PP) (Vert et al., 2012). Common plastic polymers include PP, PE, low-density polyethylene (LDPE), and polyacrylates (Frias et al., 2014). They are lightweight, inexpensive, and durable materials, which can easily be sculptured into a variety of products that retrieve use in an extensive application. Plastics have attained a crucial status in modern life and are now ubiquitous (Halden, 2010).

With global populations projected to rise to 9.2 billion in 2050 and as developing nations become wealthier, demand for plastics will undoubtedly increase (Bongaarts, 2009). Annual plastic production increased from 1.5 million tons in the 1950s to 360 million tons in 2018 (Plastics Europe, 2019). These usage patterns suggest that plastic production and quantities of plastics (including microplastics) in aquatic environments will likely continue to increase over time(Andrady, 2011).

This high production of plastic associated with their durability, unsustainable use, poor waste management and improper plastic disposal, plastic waste has dramatically accumulated in the natural habitats (Derraik 2002; Thompson, et al. 2009). Plastic compounds take up years to degrade into smaller fragments. Larger plastic debris slowly degrades into small fragments with various sizes ranging from meter to micrometer due to changing environmental conditions. This fragmented plastic with size smaller than 5 mm are termed as microplastics. They are highly persistent in the aquatic ecosystem. These are not easily seen by the naked eye but are found in many areas, including lakes, rivers, oceans, sea ice, remote islands, Antarctic's, sediments and soil, as well as in the digestive systems, respiratory structures, and tissues of wildlife, including birds, mammals, reptiles, fish and shellfish (Depledge et al., 2013).

Microplastics have been found in aquatic environments and their long term exposure produces adverse impact on aquatic animals and ecosystems. In addition, MPs contain a variety of organic plastic additives (OPAs) and have also been shown to adsorb persistent organic pollutants (POPs) from the surrounding seawater, potentially affecting all organisms throughout the aquatic food web (Pinheiro et al., 2017).Bioavailability of MPs increases with decreasing their size, making them easily available to lower trophic organisms (Wright et al., 2013) and also to human food chain.

Fish are an important biological element of the freshwater ecosystems with significant economic and nutritional value worldwide. About 94% of all freshwater fisheries occur in developing countries, providing food and a livelihood for millions of the world's poorest people, and contributing to the overall economic wellbeing by means of exportation, tourism, and recreation. Moreover, they generate many ecosystem-services such as: (1) regulating food web dynamics and nutrient balances; (2) regulating carbon flux; (3) regulating sediment processes and (4) are links between ecosystems (Holmlund and Hammer, 1999). Thus, it becomes vital to protect and preserve the freshwater food fishes from microplastics.

Despite the few studies have assessed the presence, fate, and effects of microplastics in freshwater environments to date, it is fact that 7% of the world's renewable freshwater is contained with microplastic (Julie et al., 2016). Only 4% reports on microplastics are associated with freshwater ecosystem (Lambert and Wagner, 2018). These studies have revealed that the presence of microplastic in freshwater is as alarming as that of marine ecosystem (Peng et al., 2017). The impacts of MPs pollution on aquatic ecosystems and their functioning remain poorly quantified and there is a paucity of information on the impacts of microplastics in freshwater ecosystems and aquatic organism. Therefore, the present review seeks to investigate the occurrence of these contaminants in freshwater fish around the world and what are the possible impacts to these on aquatic animals and human beings since we have a tight relation to this resource.

Sources of microplastics into the environment:

Plastics have been found virtually in all environments ranging from the arctic to deserts to household dust. They are mainly introduced into the environment through ineffective waste management practices. It can be dispersed in the environment through air and water. They can be carried into streams, rivers, wetlands and oceans (aquatic ecosystems) by wind as well as flowing water such as rain, snow melt that makes its way to streams, or via municipal or industrial waste water discharges.

Under environmental influences such as ultraviolet light and physical abrasion the larger plastic particles degrades into macroplastics (> 25 mm) which degraded into mesoplastics (5-25 mm) and then into microplastics (>5mm) in diameter (Wagner et al., 2014). The term nanoplastics are also used for small microplastic particles ranging in size from 0.2-2mm. However not all MPs (secondary MPs) are the result of degradation of larger particles. Many primary MPs are released into the environment in the form of microbeads, resin pellets or personal care products (PCPs) (Wagner et al., 2014), particularly from domestic wastewater. Thus microplastics are small plastic particles released directly from the use of cosmetic products, or indirectly through the degradation of large plastic items under environmental conditions.

Microplastics found in the environment are a very heterogeneous group of particles differing in size, shape, chemical composition and specific density that originate from a variety of different sources. Based on origin, they are also categorized into primary and secondary microplastics depending on whether the particles were originally manufactured to be that size (primary) or whether they have resulted from the breakdown of macroplastics (secondary). Thus primary microplastics are small sized plastic particles produced and released directly into the environment where as secondary microplastics are the fragmentation of larger plastic materials degradation under environmental conditions.

Primary microplastics are manufactured deliberately such as pellets and microbeads. It was estimated that the main contributors of primary microplastic emission to surface water are cleaning agents, paints, coatings and cosmetic products (Naqash et al., 2020). Microplastic particles are released directly into the environment directly from the use of specific personal care or cosmetic productssuch as hand cleaners, facial cleaners and toothpaste (Lassen et al., 2015). Skin cleaners contain microparticles like polyolefin particles (74–420 µm in size) in the form of polyethylene (PE), polypropylene (PP) and polystyrene (PS). Gouin et al. (2015) estimated that in 2012, approx. 6 % of the liquid skin cleaning products contained microplastics. They also accounted that 93% of the microplastics used in skin cleaning products in the form of polypropylene (PP).

Microplastics are also used in medical applications, e.g. in dentist tooth polish, and as carriers to deliver active pharmaceutical agents (Sundt, 2014; Lassen et al., 2015). After use, microplastics from personal care products and such medical products can reach the environment via wastewater.

Microplastics are also used in industrial abrasivesi.e. for air-blasting to remove paint from metal surfaces and for cleaning the engines and machines (Sundt, 2014; Essel, 2015). Industrial abrasives contain e.g. acrylic, PS, melamine, polyester (PES) and poly allyl diglycol carbonate microplastics (Eriksen et al., 2013).

Raw materials used for the fabrication of plastic products (pre-production plastics), namely plastic resin pellets or flakes and plastic powder or fluff, are another important source of primary microplastics. They can reach the environment after accidental loss during transport or with run-off from processing facilities, i.e. often as a result of improper handling (Duis and Coors, 2016).

Secondary microplastics are introduced by the disintegration or decomposition of larger plastic material fragment (macroplastics) after entering into the environment by intense weathering, exposure to ultraviolet radiation, mechanical forces, thermal degradation, photolysis, thermo-oxidation and bio-degradation processes (Zhao et al., 2015). Secondary MPs arising by washing clothes are generally polyester, acrylic,and polyamide which can be more than 100 fibers per litre of effluent (Habib et al., 1998; Browne et al., 2011).

The gradual reduction in size facilitates the transfer of plastic to longer distance. By this, plastic can be considered as a major emerging pollutant globally. These particles can transport other harmful chemicals used as additives in their fabrication or accumulate on them due to strong adsorption capacity of microplastic(Naqash et al., 2020).Moreover, the adsorption capability of microplastic increases with a reduction in size (Wagner et al., 2014).

Use of low-density polyethylene (LDPE) films in large volumes to protect agricultural crops, suppress weeds, increase temperature and retain irrigation water in the soil and also the use of synthetic polymer particles, such as expanded PS flakes and polyurethane (PU) foam in horticulture to improve soil quality and as composting additive are the anthropogenic source of microplastics in the environment (Stöven et al., 2015).

Moreover, synthetic textiles are also an important source of microplastics. Synthetic textile fibres are released to water from waste water of domestic washing machines and in air and dust, either during normal use or during tumble drying . In addition, synthetic fibres are released into environment from hygiene products, e.g. if improperly disposed into wastewater (Duis and Coors, 2016).

The other sources of microplastics are abrasion from car tyros, ship paints and other protective paints contain synthetic polymers, e.g. alkyds, poly(acrylate/styrene), PU and epoxy resins. Microplastics may be released as a consequence of abrasion from household plastics materials, by spills during application of the paint, by abrasion during use of the painted product and during paint removal (Sundt et al., 2014).

Impacts of Microplastics in Freshwater Fish:

There are numerous ways through which MPs and associated contaminants get incorporated into the aquatic biota. This includes filter feeding, suspension feeding, inhalation at air-water surface and consumption of prey exposed to MPs or through direct ingestion. Ingestion is believed to be a main MPs exposure route for several aquatic animals. Aquatic animals including plankton passively ingest MPs due to their inability to differentiate MPs and food.

The effects of MPs contamination on fish health are not yet fully understood.Fishes may ingest microplastics either directly or by the prey containing these particles (Desforges et al., 2014). Pinheiro et al., (2017) concluded that, 34 species of fresh water fishes were found sensitive throughout the world. Raven et al., (2020) observed microplastic in all the 49 fish species inhabiting in two freshwater reservoirs of Bloomington city of Illinosis and reported that microplastics were more concentrated in the guts rather than gills. Although these numbers are very low, it may be due to paucity of research on the accumulation and impact of MPs in freshwater fishes. Due to strong adsorption capacity of microplastic provide surface area for various bio-organic or inorganic toxic substances; the ingestion of these adsorbed toxin containing MPs could be a serious health issue for the fishes.

The minute size, buoyancy and attractive color of MPs particles make them ideal candidates as food for fish (Sanjayet al., 2020). Within aquatic ecosystems, microplastics can have quite harmful effect on local fish fauna which are contaminated through the ingestion of MPs. The ingestion of MPs by fishes can get accumulated in their digestive tract which can cause starvation because of the false sensation of satiation or even perforation of the gastrointestinal tract. These MPs have negative physical and physiological effects on fishes (Lonnstedt and Eklov, 2016).

The negative physical effect includes the clogging and inflammation the digestive system and laceration of gastrointestinal tissues which prevent disturb the mechanism of absorption of nutrients (Lusher et al., 2013). The physiological interference can also be observed when MPs directly interfere with the immune system of fish through the stimulation of degranulation and through behavioural change, reducing the ability of a predator to perceive (Greven et al., 2016; Lonnsted and Eklov, 2016). Internal and digestive enzyme system may get damaged even the reproduction can because of MPs digestion (Talvite et al., 2015; Wright et al., 2013). Tiny particles of low-density polyethylene (LDPE) were exposed to environmental bay condition for consecutive three months and then fed to fishes. Soon after two months, the tissues of fish had a greater concentration of PBTs and showed signs of liver stress, glycogen depletion, fatty vacuolation and cell necrosis (Rochman et al., 2013).

Jabeen et al. (2017) studied on the relationship between plastic pollution and the feeding traits as well as habitats of freshwater fishes and observed that fish inhabiting freshwater waterbodies of urban areas under the higher risk of MPs exposure. MPs were ingested more frequently in these fishes (Silva-Cavalcanti et al., 2017). Similar observation also found by some workers who reported that fishes collected from river near urbanized areas showed a significantly higher proportion of ingestion of plastic debris in relation to fish caught in less urbanized areas (Phillips and Bonner, 2015; Peters and Bratton, 2017). Sanchez et al., (2014)did not observed MPs in edible freshwater fishes collected from upstream areas, while those collected from urban rivers had MPs in their gut and supporting the hypothesis that wastewater treatment plants, in urbanized areas, are one of the sources of MPs in inland surface waters. Raza and Khan, (2018) concluded that in fishes, MPs causes the reduction in the feeding activity, oxidative stress, genotoxicity, neurotoxicity, retardation in growth, reduction in reproductive fitness and ultimately death.

Thusit can be concluded that microplastics are consumed by fishes via a variety of methods and causeadverse effects leading to mortality, neurotoxicity, cytotoxicity, liver stress, behavioural changes, oxidative stress, genotoxicity etc (Luis et al., 2018). Plastic abundance was found between the stomach, gut, and intestine of the fishes.

II. CONCLUSION:

The non-recycled plastic is being disposed off in dump yards, a major proportion of it is thrown as debris in the water bodies. Due to a variety of physical, chemical and biological factors, these non-recycled plastics in the water bodies, breaks down to form microplastics (MPs). MPs from personal care products are one of the potential sources of direct addition to freshwater streams. These microplastics (MPs) become hazardous to aquatic life. They are a potential source of toxins as they offer a large surface area to various chemicals present in the water body, when these MPs are ingested by fishes it causes serious health issues likereduction in the feeding activity, oxidative stress, genotoxicity, neurotoxicity, retardation in growth, reduction in reproductive fitness and ultimately death.

Thus on the basis of present review it can be concluded that:

1. More attention is needed towards freshwater MPs studies.
2. There should be a ban on the production of personal care products and cleaning agents containing MPs, as they are common primary sources of microplastic in fresh waterbodies. .
3. Accumulation and biomagnifications of MPs through food chains and webs need to be evaluated comprehensively.

REFERENCES

[1]. Andrady, A.L.(2011). Microplastics in the marine environment. Mar. Pollut. Bull. 6:1596-1605.

[2]. Bongaarts, J., (2009). Human population growth and the demographic transition. Philos. Trans. R. Soc. B Biol. Sci. 364: 2985–2990.

[3]. Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway. T. et al. (2011) Accumulation of microplastic on shorelines worldwide: sources and sinks. Environ Sci Technol . 45:9175–9179.

[4]. Desforges, J.P.W., Galbraith, M., Dangerfield, N. and Ross, P.S. (2014). Widespread distribution of microplastics in subsurface seawater in the NE Pacific Ocean. Mar. Pollut. Bull.79: 94–99.

[5]. Depledge, M.H., Galgani. F., Panti, C., Caliani, I., Casini, S., et al. (2013) Plastic litter in the sea.Marine Environmental Research 92: 279-281

[6]. Derraik, J. E. G.B., (2002). The pollution of the marine environment by plastic debris: a review. Mar. Pollut. Bull. 44: 842–852.

[7]. Duis, K. and Cooris, A. (2016). Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. Environ Sci Eur. 28:2-25. DOI 10.1186/s12302-015-0069-y

[8]. Essel, R., Engel, R. and Carus, M. (2015). Sources of microplastics relevant to marine protection in Germany. Texte 64/2015. Dessau-Roßlau: German Federal Environment Agency

[9]. Eriksen, M., Mason, S., Wilson, S., Box, C., Zellers, A., Edwards, W. et al (2013). Microplastic pollution in the surface waters of the Laurentian Great Lakes. Mar Pollut Bull. 77:177–182.

[10]. Frias, J.P., Otero, V. and Sobral, P. (2014). Evidence of microplastics in samples ofzooplankton from Portuguese coastal waters. Mar. Environ. Res. 95: 89-95

[11]. Gouin, T., Avalos, J., Brunning, I., Brzuska, K., de Graaf, J., Kaumanns, J. et al (2015) Use of micro-plastic beads in cosmetic products in Europe and their estimated emissions to the North Sea environment. SOFW-J. 141:40–46
[12]. Greven, A.C., Merk, T., Karagoz, F., Mohr, K., Klapper, M., et al. (2016). Polycarbonate and Polystyrene Nanoplastic Particles Act as Stressors to the Innate Immune System of Fathead Minnow (Pimephales Promelas). Environ Toxicol Chem. 35(12): 3093-3100.
[13]. Habib, D., Locke, D.C. and Cannone, L.J. (1998). Synthetic fibers as indicators of municipal sewage sludge,sludge products, and sewage treatment plant effluents. Water Air Soil Pollut. 103:1–8.
[14]. Halden, R.U. (2010). Plastics and health risks. Annual Review of Public Health. 31: 179-194.
[15]. Holmlund, C.M. and Hammer, M. (1999). Ecosystem services generated by fish populations. Ecological Economics. 29(2): 253-268.
[16]. Jabeen, K., Su, L., Li, J.N., Yang, D.Q., Tong, C.F., et al. (2017). Microplastics and mesoplastics in fish from coastal and fresh waters of China. Environ Pollut. 221: 141-149.
[17]. Julie C. Andersona, Bradley, J., Parkb, Vince P. Palace (2016). Microplastics in aquatic environments: Implications for Canadian ecosystems. Environmental Pollution. 218:269-280.
[18]. Lambert, S. and Wagner, M. (2018). Microplastics are contaminants of emerging concern in freshwater environments: an overview. Freshw Microplastics. https://doi.org/10.1007/978-3-319-61615-5_1.
[19]. Lassen, C., Foss Hansen, S., Magnusson, K., Norén, F., Bloch Hartmann, N.I., Rehne Jensen, P., Gissel Nielsen, T. and Brinch, A. (2015). Microplastics occurrence, effects and sources of releases to the environment in Denmark. Environmental project No. 1793. Copenhagen: Environment Protection Agency, Ministry of Environment and Food of Denmark
[20]. Lonnstedt, O.M. and Eklov, P. (2016). Environmentally relevant concentrations of microplastic particles influence larval fish ecology. Science. 352(6290): 1213-1216
[21]. Luís Carlos de Sá, Miguel, O., Francisca, R., Thiago, L., Rocha, M. N. F. (2018). Studies of the effects of microplastics on aquatic organisms: What do we know and where should we focus our efforts in the future?, Science of The Total Environment. 645:1029-1039. https://doi.org/10.1016/j.scitotenv.2018.07.207.
[22]. Lusher, A.L., McHugh, M. and Thompson, R.C. (2013). Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Marine Pollution Bulletin. 67(1-2): 94-99.
[23]. Meikle, J. L.(1995). American plastic: a cultural history. Rutgers University Press.
[24]. Naqash, N., Prakash, S., Kapoor, D. and Singh, R. (2020). Interaction of freshwater microplastics with biota and heavy metals: a review. Environmental Chemistry Letters. 8: 1813-1824. https://doi.org/10.1007/s10311-020-01044-3
[25]. Peters, C.A. and Bratton, S.P. (2016). Urbanization is a major influence on microplastic ingestion by sunfish in the Brazos River Basin, Central Texas, USA. Environ Pollut. 210: 380-387.
[26]. Peng,J., Wang,J. and Cai.,L (2017). Current understanding of microplastics in the environment: Occurrence, fat, risk, and what we should do. Integr Environ Assess Manag. 13(3):476-482.https://doi.org./10.1002/ieam.1912
[27]. Phillips, M.B. and Bonner, T.H. (2015). Occurrence and amount of microplastic ingested by fishes in watersheds of the Gulf of Mexico. Marine Pollution Bulletin. 100(1): 264-269.
[28]. Pinheiro, C., Oliveira, U., Vieira, M. (2017) Occurrence and Impacts of Microplastics in Freshwater Fish. J Aquac Mar Biol. 5(6): 00138. DOI: 10.15406/jamb.2017.05.00138
[29]. Plastics Europe (2019). Plastics – the facts 2019. In:Plastics Europe.
[30]. Raven, H., Catherine, M., Reilly, O. and William, L. P. (2020). Microplastic prevalence in two fish species in two U.S. reservoirs. Limnology and Oceanography Letters. 5: 147–153. doi: 10.1002/lol2.10140
[31]. Raza, A. and Khan, M.F. Z.(2018). Microplastics in freshwater systems: a review on its accumulation and effects on fishes. International Journal of Research and Analytical Reviews. 5(4): 128-140.
[32]. Rochman, C.M., Hoh, E., Kurobe, T. and Teh, S.J. (2013). Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Sci. Rep. 3, 3263 http://dx.doi.org/10.1038/srep03263

[33]. Sanchez, W., Bender, C. and Porcher, J.M. (2014). Wild gudgeons (Gobio gobio) from French rivers are contaminated by microplastics: Preliminary study and first evidence. Environ Res. 128: 98-100.
[34]. Sanjay, K., Mridula, R., Rajesh, K., Suyani, N. and Ahamed, R. A. (2020). Impact of Microplastics on Aquatic Organisms and Human Health: A Review. Int J Environ Sci Nat Res. 26(2): 59-64. DOI:10.19080/IJESNR.2020.26.556185
[35]. Silva-Cavalcanti, J.S., Silva, J.D., França, E.J., Araújo, M.C. and Gusmão, F. (2017). Microplastics ingestion by a common tropical freshwater fishing resource. Environ Pollut. 221: 218-226.
[36]. Sundt, P., Schulze, P.E. and Syversen, F. (2014). Sources of microplastic pollution to the marine environment. Report no M-321/2015. Asker: Mepex Consult.
[37]. Stöven, K., Jacobs, F. and Schnug, E. (2015). Mikroplastik: ein selbstverschul-detes Umweltproblem im Plastikzeitalter. J Kulturpflanzen. 67:241–250.
[38]. Talvitie, J., Heinonen, M., Pääkkönen, J.P., Vathera, E., Setalälä, O. and Vahala, R. (2015). Do wastewater treatment plants act as a potential point source of microplastics? Preliminary study in the coastal Gulf of Finland, Baltic Sea. Water Science & Technology. 72: 1495-1504.
[39]. Thompson, R.C., Moore, C.J., Vom Saal, F.S., Swan, S.H., (2009). Plastics, the environment and human health: current consensus and future trends. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 364: 2153–66
[40]. Vert, M., Doi, Y., Hellwich, K.-H., Hess, M., Hodge, P., Kubisa, P., Rinaudo, M and Schue, F. (2012). Terminology for biorelated polymers and applications (IUPACRecommendations 2012). Pure Appl. Chem. 84: 377- 410.
[41]. Wagner, M., Scherer, C., Alvarez-Muñoz, D., Brennholt, N., Bourrain, X., Buchinger, S., Fries, E., Grosbois, C., Klasmeier, J., Marti, T., Rodriguez-Mozaz, S., Urbatzka, R., Vethaak, A., Winther-Nielsen, M., Reifferscheid, G., (2014). Microplastics in freshwater ecosystems: what we know and what we need to know. Environ. Sci. Eur. 26, 12.
[42]. Wright, S.L., Thompson, R.C. and Galloway, T.S. (2013). The physical impacts of microplastics on marine organisms: A review. Environmental Pollution. 178: 483-492.
[43]. Zhao, S., Zhu, L. and Li, D., (2015). Microplastic in three urban estuaries, China. Environ.Pollut. 206: 597–604.