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Chapter- 10

The Impact of Microplastics on Fish Poses a Threat to Human Health

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Abstract:

With the growth of human population, the production and usage of plastics are also increasing. Overuse of plastics has adverse effects on the environment. Underwater plastics fragment into microplastics (MPs). This MP is a major cause of concern as a pollutant in aquatic ecosystems. Microplastic contamination is not a newly discovered problem, but it is still a crucial issue to discuss. MP exposure poses a great threat to fish health. MPs contamination can cause organ damage, toxic responses, behavioral changes, and so on. Additionally, MP ingestion by fish directly or indirectly affects human lives. Microplastics enter the human body in large amounts through fish consumption. The accumulation of microplastics within the human body has a wide range of toxicological and negative consequences. The control strategies for microplastic contamination are still in their infancy. More detailed study is needed about the nature and toxic effects of the MPs in order to mitigate their effects.

Introduction:

An aquatic ecosystem is an aquatic environment where living organisms live and interact with one another for shelter and nutrients. This ecosystem covers almost 71% of the Earth's surface and contributes about 50% of global productivity (Hader & Gao, 2023). Aquatic ecosystems also act as CO_2 sinks to mitigate climate change. According to aquatic ecologists, three trophic levels (phytoplankton, zooplankton and fish) represent the whole aquatic ecosystem (*Patra* & Madhu, 2009; Dutta et al., 2014; Meyers, 2019; Biswas et al., 2023). Fish are a major component of marine as well as freshwater habitats. They play a vital role in food chain dynamics, nutrient cycling, and ecosystem services. Fish also provides large-scale employment around the world. India itself contributes 8% of global fish production, becoming the 3rd largest fish-producing country (https://pib.gov.in/index.aspx). Fish also serve as one of the most essential animal protein sources. More than 1.5 billion people consume fish as food (https://www.greenfacts.org). This economically and nutritionally important species is likely to

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be under threat of pollution (Bhattacharya, 2015; Mondal et al., 2022). Several studies have reported in which fish are used as bioindicators of water pollution (Fierro et al., 2017). Heavy metals like cadmium and lead were also determined from fish bodies to evaluate the water pollution rate (Rashed, 2001; Madhu et al., 2022). There are several causes associated with the pollution of aquatic ecosystems. Industrialization, agricultural activities, overuse of pesticides, and sewage-related debris are mainly responsible for water pollution. Over the past several years, the increasing use of plastics has caused a significant environmental problem. Every day, our oceans are polluted by 8 million pieces of plastic, and almost 88% of the sea surface is covered by plastic waste (Condor Ferries, Plastic in the Ocean Statistics, 2020). The World Wildlife Fund (WWF) reported that plastic has become the reason for the deaths of 100,000 marine animals. Recently, microplastics (MPs) have become a topical issue as a prime pollutant in aquatic ecosystems. Enormous anthropogenic activities are one of the primary reasons for microplastic contamination in aquatic ecosystems (Alimba and Faggio, 2019). Naturally, plastics remain under water for centuries. During the time course, plastics undergo changes by UV radiation, biodegradation, or mechanical force of water to form small fragments of microplastics (Wang et al., 2021). These MPs have a severe impact on fish health. Microplastics contamination leads to damage to fish's organs like the intestine, liver, gill, and brain (Roy et al., 2022; Das et al., 2023; Bandyopadhyay et al., 2023). This may also alter metabolic balance, behavior, and reproductive health. Once fish ingest MPs, they may enter the food chain and transfer across the trophic levels of the food web. This results in toxic effects on the environment. MPs ingestion by fish also poses risks to human health, as fish and fishery products are the main path of microplastic contamination in the human diet.

What is microplastic?

In 2004, the term 'Microplastics' was first coined. Initially, microplastics were used to define smaller fragments of plastic particles. However, to date, there is no accurate definition to describe microplastics (Frias & Nash, R. 2019). A commonly used description of microplastics is that they are smaller plastic particles under 5 mm in size. In 2016, EFSA (the European Food Safety Authority) reported that microplastics are heterogeneous mixtures of diverse forms (like spheres, fragments, and fibres) of materials. Therefore, microplastics are a transitory form between macrodebris and nanoparticles (Hale et al., 2020). Microplastics can be categorized into two classes: primary microplastics and secondary microplastics. Primary microplastics are tiny particles, including microbeads, exclusively designed for industrial and domestic uses. Secondary microplastics are derived from the breakdown or degradation of larger plastic items. This fragmentation is caused by atmospheric factors.

Sources of microplastics:

The presence of microplastics in aquatic environments has become an emerging concern globally. Microplastics in aquatic bodies originate from different sources. Around 80–90% of microplastics are released into the water bodies from land-based sources (Duis and Coors 2016). Therefore, a major share of microplastics is released into the ocean through rivers (Lebreton et al. 2017). Furthermore, in 2017, the International Union for Conservation of Nature (IUCN) divided the sources of marine microplastics into seven different categories: 1) synthetic textiles; 2) vehicle tires; 3) road markings; 4) city dust; 5) personal care products and cosmetics; 6) marine coatings; and 7) plastic pellets. IUCN (2017) also states that synthetic textiles are responsible for the release of 35% of primary microplastics into the global marine environment every year. IUCN (2017) also estimates that 28% of the annual total primary microplastics enter the oceans from the abrasion of automotive tires. Personal care products and cosmetics are also prime sources of microplastics entering the marine environment. Microbeads, polyethylene, and polyurethane are used in personal care or cosmetics as additives, viscosity controllers, stabilizers, thickeners, colors, binders for powders, bulking agents, and dispersant agents (Lassen et al. 2015; Scudo 2017). It contributes around 2% of total primary microplastics released into the marine environment (IUCN 2017). Whereas road markings and plastic pellets contribute 7% and 0.3% of primary microplastics in marine environments annually (IUCN 2017). City dust refers to artificial turf, abrasion of objects, building paint, and industrial blasting of abrasives originating from urban areas, sharing 24% of total primary microplastics that are released into marine ecosystems (Sundt, Schulze, and Syversen 2014; IUCN 2017). The paints applied to commercial ships contain polymers that act as binding agents in marine coatings (Tamburri et al., 2022). It makes up 3.7% of total marine primary microplastic pollution.

In addition, secondary microplastics enter the water bodies in macro-size, breaking down into microplastics under water. The major sources of secondary microplastics are mainly terrestrial macro-sized refuse and marine-based refuse (e.g., fishing gear, shipping waste, and losses) (https://www.firstsentier-mufg-sustainability.com/research/microplastics-05-2020.html).

Impact of microplastics on fish health:

MPs pollution is a growing environmental issue posing a great threat to fish health (Garrido Gamarro et al., 2020; Kutralam-Muniasamy et al., 2020; Huang et al., 2021; Aragaw and Mekonnen, 2021). Many studies have been reported about MPs, but a large portion of their consequences is unknown to us (Kutralam-Muniasamy et al., 2020). MPs affect every aquatic life, being fish among the most affected taxa. A large number of fish species suffer adversely due to the toxic effects of MPs (Mizraji et al., 2017; Fonte et al., 2016). The presence of microplastics has been detected in a large scale of edible fishlike mackerel (*Scomber scombrus*), blue whiting (*Micromesistius poutassou*), chub mackerel (*Scomber japonicus*), hake (*Merluccius merluccius*), sprat (*Sprattus sprattus*), etc. (Alberghini et al., 2022). MPs contamination was also observed in many migratory fish, like *Dicentrarchus labrax* (seasonal migratory fish) and *Thunnus thynnus* (migratory commercial fish) (Alberghini et al., 2022). Many studies have described the negative effects of microplastics on fish. Microplastics cause physical harm as they build up in the gastrointestinal tract of fish, causing hazards in their digestive system and feeding mechanism (Lusher et al., 2013; Wright et al., 2013). Ingestion of MPs could also induce clogging of the alimentary appendages, anatomical and functional changes in the digestive tracts, and inflammation leading to dietary and developmental issues in fish (Huang et al., 2022; Borrelle et al., 2017; Peda et al., 2016; Jabeen et al., 2018;). MPs are mainly stored in the gills, gut, and stomach within the fish body (Lu et al., 2018; Güven et al., 2017; Greven et al., 2016). MPs can cause behavioral alterations, such as affecting predatory behavior in fish and reducing the ability to differentiate between microplastics and genuine prey (de Sá et al., 2015). This harmful effect results in malnutrition in fish. Several studies have demonstrated the negative consequences of microplastics on the immune system of fish (Greven et al. 2016). Sometimes MP contamination can induce mortality (Mallik et al., 2021). *Danio rerio* was the most studied fish to show the impact of microplastics on fish health. The visible effects of MPs contamination in *Danio rerio* are damage to reproductive organs, disruption of gene expression and oxidative stress (Mu et al., 2021; Zhao et al., 2021;

Zhang et al., 2022). The second most studied fish is *Oryzias melastigma*, to know how ingestion of MPs causes physiological changes (Xia et al., 2022). The common effects of MPs ingestion in *Oryzias melastigma* are weight reduction, retardation or inhibition of growth, damage to the reproductive system, and liver dysfunction (Wang et al., 2022; Feng et al., 2021; Li et al., 2021; Le Bihanic et al., 2020). Sometimes, microplastics act as carriers for transferring additives, toxic chemicals, and metals from the environment to fish (Du, H., Xie, Y., & Wang, J., 2022). Monomers and additives of MPs disrupt endocrine function in fish (Kumar et al., 2020). In the case of freshwater fish, MP exposure levels are highly variable. It is typically based on the type, size, and shape of MPs. MPs contamination in freshwater fish is also associated with cell damage and altered morphology of physiological structures (Lu et al., 2016; Yu et al., 2020). Microplastics also act as a vector for various pathogens and invasive species (Caruso, 2019).

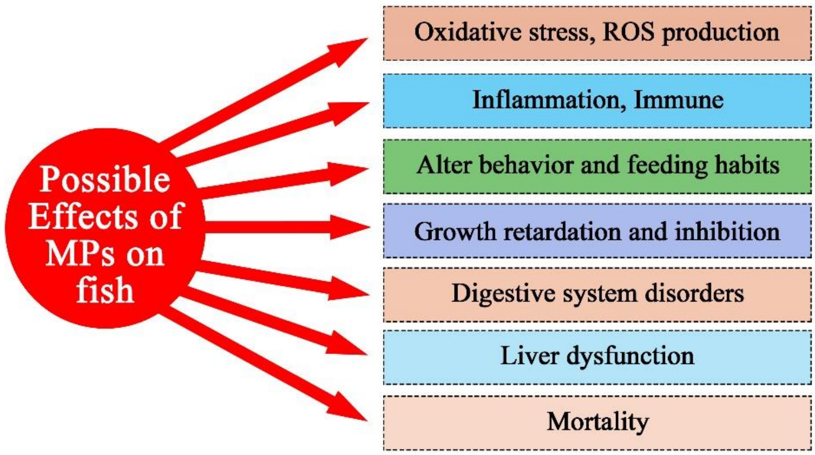

Figure 1. Possible Effects of Microplastics contamination in fish

Microplastics contamination in fish poses risks to human health:

Microplastics contamination in fish is a potential threat to human health, as fish or fishery products are one of the prime sources of contamination in the human diet. Generally, MPs enter the human body through endocytosis or persorption (Bhuyan, 2022). Biomagnification and trophic transfer have been seen in a wide variety of fish. Microplastics are biomagnified and transferred from fish to humans through the food-consumer relationship (Bhuyan, 2022). Recently, there has been a lot of research on microplastics around the world, but that is not enough; more research is required to understand this topic scientifically. *In vitro* tests revealed that MPs can be absorbed by macrophages, leading to cytotoxicity like oxidative damage and inflammation (Geiser et al., 2005; Yacobi et al., 2008). A small amount (0.05–10 mg/L) of MPs produces ROS (reactive oxygen species) at a large level, which results in cytotoxicity in the human brain and epithelial cells (Schirinzi et al., 2017). MPs also have toxicological consequences for human health, such as immune cell impairment and chronic discomfort (Smith et al., 2018). Accumulation of MPs at a high level in the human body can cause inflammatory bowel disease (Yan et al., 2021). MPs can change the human body's metabolism and energy flow. It alters the function of metabolic enzymes, disrupts energy equilibrium, and hampers nutritional intake (Bhuyan, 2022). MPs can also induce autoimmune disorders or immunosuppression (Prata, 2018; Prata et al., 2020). Within the human body, MPs transport from one tissue to another via the circulatory system. MPs build up in the cardiovascular system, leading to blood cell cytotoxicity, respiratory high blood pressure, vascular swelling, and inflammatory reactions (Wright and Kelly, 2017; Campanale et al., 2020). According to Hwang et al. (2019), MPs instigate hemolysis and the production of inflammatory molecules like histamine. MPs may increase the risk of neoplasia when transported to distal tissues (Prata et al., 2020). Persistent exposure to microplastics leads to neurotoxicity. MPs alter serum neurotransmitters and elevate AChE activity in the brain (Deng et al., 2017). In some cases, MPs cause prolonged inflammation and irritation that lead to cancer by damaging DNA (Prata, 2018). MPs also generate free radicals within the human body, causing cytolysis and agglomeration of unfolded protein particles in the endoplasmic reticulum (Chiu et al., 2015). Microplastics also transport a variety of microbes that are harmful to humans (Kirstein et al., 2016). Some chemical additives in MPs, like phthalates bisphenol-A, disrupt endocrine systems (Ludovic H et al., 2017).

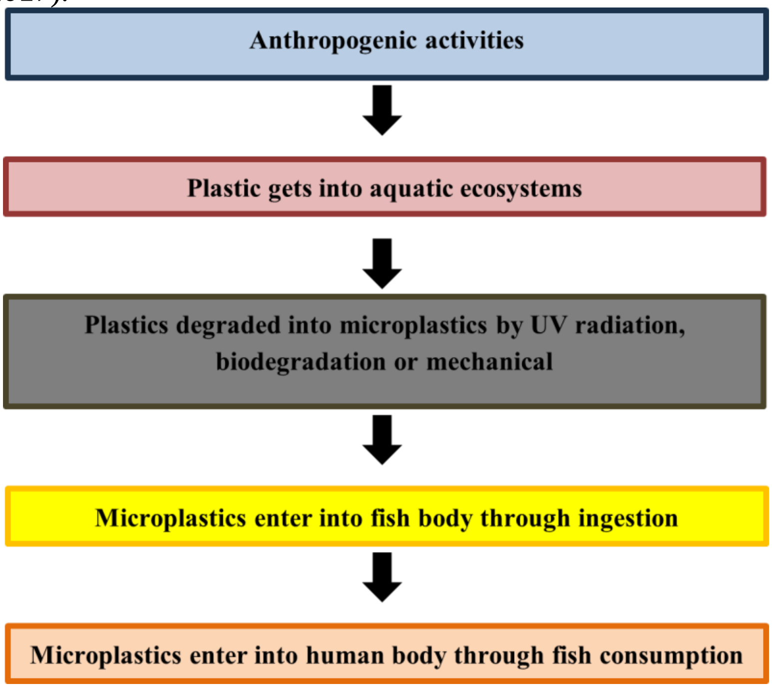

Figure 2. A model showing how microplastics make a path to human body

Discussion:

Both fish and humans are extremely vulnerable to microplastic pollution. Plastic production will continue to increase with the growth of the human population. Nevertheless, the lack of standard protocol and lack of public awareness made it an omnipotent issue. Nowadays, research is mainly focused on microplastics' impact on marine fish or other animals. Studies are required about the impact of microplastics on freshwater fish for a better understanding of this emerging concern. The contamination of microplastics in fish species used for human consumption is a burning issue. Yet, the transmission of microplastics from fish to the human body requires lots of studies to understand. Moreover, a handful of strategies are present to control this global issue. Strategies should focus on remediation technologies and the development of cost-effective ways to clean up microplastics. Research is going on microbial biodegradation and bioremediation of microplastics, which is a potential hope. Thus, there is a need for an immediate action plan and proper waste management to reduce microplastic pollution.

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