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Toxicological Consequences of Microplastics Pollution on Aquatic Li Ving Organisms: A Review

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Abstract

Plastics are used all around the world and so often that their pollution is becoming a concern. The global demand on microplastics has increased because plastics have light weight and low production cost. Microplastics affect the aquatic environment; aquatic organisms and subsequently through food web bioaccumulation human beings. This study review the scientific literature on the current trend of toxicological consequences of micro plastics, sources of micro plastics, their toxicity to different aquatic organisms. Microplastics cause toxicity to humans through accumulation which includes health implications of Microplastic pollution. The most common microplastics found in aquatic environments are Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE), Polyprophylene (PP), Polyvinylchloride (PVC), and Polyehylenetetraacetate (PET.) The effects of Microplastics on aquatic fishes and invertebrates include blockage of the digestive system, weight loss, depletion of energy reserves, disruption of reproduction, change in the ratio and distribution of cholesterol, nutritional shortage, reduction in growth, decline in fertility, abnormal behavior, lesions and internal wounds. Through Bioaccumulation the health effects caused by Microplastics to human beings include oxidative stress, cell damage, inflammation, hepatic lipid disease, skin irritation, breathing issues, cancer risk, cardiovascular illness, reproductive issues, disruption in oxidative stress and immune responses, diabetes, obesity, endocrine disturbance, cancer, cardiovascular, reproductive and developmental problems. Researchers have identified biological remediation and use of bio-plastics as the major methods used for mitigating Microplastic pollution, however the use of bioremediation methods have proven effective and environmentally friendly.

Keywords

INTRODUCTION

Our survival on Earth depends on three fundamental elements which are water, air, and soil they are the three priceless gifts from nature to humanity. The most significant of which is water because it serves as the primary environment for the emergence of life (Postel, 1997). Water pollution is a global issue and will continue to persist as long as mankind lives.

Microplastics (MPs, plastic particles < 5 mm) are steadily becoming a worldwide issue because of their broad spread in the ecosystem and consequences on different life forms. Most marine MPs contamination has been affirmed to start from land-based sources (Yu *et al.*, 2020). Several million tons of plastics have been manufactured within the middle of the last century

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and more than two hundred million tonnes annually (Andrady, 2011). The worldwide plastics creation has expanded from 1.5 million tons during the 1950s to 335'million tons in 2016, with plastics released into practically all parts of the environment (Alimba and Faggio, 2019). Plastic polymers degrade as a result of numerous weathering/aging processes that occur when it is exposed to the environment, these processes include UV exposure, heat aging, biofilm formation, and oxidation (Guo and Wang, 2019). The polymers' physical and chemical characteristics include color, surface morphology, crystallinity, particle size, density, reactivity, surface functionality, and hydrophobicity, are affected by the degradation process (Guo and Wang, 2019). Microplastics cause damage to aquatic organisms, which can aggregate in the human body through natural chain enhancement. Moreover, microplastics are transporters of heavy metals and other organic compounds (Tang *et al.,* 2021). Plastics hardly biodegrade yet through various processes they breakup into microplastics and nanoplastics (Alimba and Faggio, 2019). At present, the most common Microplastics are low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polystyrene (PS), polyethylene tetra acetate (PET), and polyvinyl chloride (PVC). Microplastics are classified into primary and secondary sources (Auta *et al.,* 2017). Primary sources comprise mainly of plastic particles in personal care products and cosmetics. Secondary sources are microplastics formed as a result of the physical, chemical, and biodegradation of large plastics. Surface runoff, wastewater from sewage, effluents from treatment plants, aquaculture and fishery, dumping of household are the processes through which microplastics are exposed to the environment (Talvitie *et al.*, 2016).

Microplastics have been detected in different environments and media such as rivers, oceans, sewages, sediments, and soil (Lechner and Ramler, 2015). Microplastics are mistaken as food by-marine organisms due to their size and resemblance. Many reports have shown that microplastics are consumed by a number of aquatic organisms such as zooplankton, fish and mollusks (Cole *et al.*, 2013), these Microplastics are usually found in many tissues and organ systems like the gut, gills, digestive glands, circulatory system, etc (Von Moos *et al.,* 2012) and transferred to other animals through food chain (from snails to crabs, from zooplankton to fish, etc.) (Setala *et al,* 2014).

Many studies have shown the ability of different vertebrate and invertebrate to ingest microplastics, including mussels and bivalves (Van Cauwenberghe *et al.,* 2015, 2015); crustaceans (Murray and Cowie, 2011; Setala *et al,* 2014); fish (Lusher *et al,* 2013: Neves *et al,* 2015); birds (Zhao *et al,* 2020) as well as marine mammals(Eriksson *et al.,* 2003) . Adverse effects, such as teratogenicity, have also been observed in a variety of organisms after absorption (Nobre *et al,* 2015) and reduced energy reserves (Wright *et al,* 2013). A study conducted on the effects of microplastics to coral reefs showed that microplastic pollution can negatively impact hermatypic corals, the effects include the ability of microplastics to amplify corals' susceptibility to other stressors, further contributing to community shifts in coral reef assemblages (Welder *et al.,* 2016). This review evaluates the current trend of Microplastic pollution, their types, sources, and toxicological effects in living organisms, from scientific literatures and proffers the best environmental friendly mitigation measures.

CONSEQUENCES OF POLLUTION

According to the 2017 Lancet Commission on Pollution and Health, which used data from the 2015 Global Burden of Diseases, Injuries, and Risk Factors Study (GBD), pollution was thought to have caused 9 million or 16% of all deaths worldwide as well as $4.61 trillion in losses in economic output (Landrigan *et al.,* 2018)**.** Worldwide, water pollution contributes to illnesses and deaths, and it is estimated that 14000 people die from it every day (Letchinger, 2000).

Microplastics result of leaching test concluded that the microplastics in the study could generate highly hazardous leachates which can cause cancer and malfunctioning of the endocrine system (Sharma *et al.,* 2020).
Aquatic environment is a place of biodiversity and is responsible for nearly half of primary production. It is a medium for increasing the economic growth of many countries via ecotourism and fishery resources management (Mouat *et al.,* 2010). It is estimated that about 23% of world's population (1.2 billion people) live within 100 km of the coast (Small and Nicholls, 2003), this shows the utmost importance of aquatic environment to living organisms. Despites their enormous significance, mankind have made aquatic environments the final destination of many pollutants through variety of activities (Fazio *et al.,* 2012; Faggio *et al.,* 2018).

Microplastics Pollutant
The term Microplastics was first used in 2004, they are smaller plastic particles Microplastics are tiny plastic particles that are produces as the common plastic degrade naturally, found in almost everything and everywhere. As a result, they have impact on people and wildlife. They have been detected in many marine species, but also in drinking water and in numerous foods, such as salt, honey and marine organisms (Ziani *et al.,* 2023). Microplastics are microscopic plastic particles that are formed either as a result of degradation of plastic particles or are manufactured in industries in such way, **d** epending on whether they are produced to be micron-sized or come from the fragmentation of macro-plastics, microplastics can be classified as primary (like personal care products) or secondary. (Wright *et al.,* 2013; Andrady, 2011; Browne *et al.,* 2008; Gregory, 1996; Zitko and Hanlon, 1991).

Sources of Microplastic
Microplastics can be emitted into the environment as either primary or secondary (Boucher and Friot, 2017; Cole *et al.,* 2011; Wang *et al.,* 2019). Primary microplastics can be found in a wide range of products such as facial cleansers and cosmetics, air blasting media, medicine delivery systems, and virgin plastic manufactured pellet (Auta *et al.,* 2017; Cole *et al.,* 2011). On the other hand the sources of secondary microplastics are many and depend on factors such as sunlight, temperature, characteristics of plastics and so on (Auta *et al.,* 2017; Horton *et al.,* 2017; Wang *et al.,* 2017; Andrady, 2011; Cole *et al.,* 2011). Microplastics source of emission is determined by knowing Microplastics polymer present, chemical composition or particle color, morphology and size (Carr, 2017; Kelly *et al,* 2019; Helm, 2017; Vaughan *et al.,* 2017; Zhang *et al.,* 2017).

Microplastics in Aquatic Ecosystem
In the aquatic environment plastic debris account for about 60-80% of all marine litter and reaching to 90-95% in some areas, accumulation of microplastics by aquatic organisms is rapidly increasing due to this pollution (Liu *et al.,* 2019). Widespread use of plastics makes plastics lead to human exposure through food chain, either through the oral inhalation of nanoplastics containing aerosols, diet, or dermal contact (Wright *et al,* 2013; Liu *et al.,* 2019). Following ingestion of Microplastics, some of the particles can be removed by an organism's digestive system over time, while others bioaccumulate in various tissues of aquatic organisms. Smaller Microplastics are ingested by early-stage organisms of small species, such as copepod oyster larvae, than by bigger species (Novotna *et al.,* 2019; Cole and Galloway, 2015; Cole *et al.,* 2013).). As these plastic pieces are introduced into the aquatic environment some are colonized by a microbial biofilm composed of bacteria, fungi and algae (Hu *et al.,* 2016; Hoellein *et al.,* 2014). Microplastics can accumulated in the digestive tract, gonads, stomach, intestine, viscera, adductor, and mantle tissue (Jeong *et al.,* 2018; Kolandhasamy *et al.,* 2018; Ribeiro *et al.,* 2017; Hu *et al.,* 2016; Von Moos, Burkhardt-Holm and Kohler, 2012).
According to Ding *et al* (2016) many results have shown that accumulation of Microplastics may be due to variation of different factors, such as species, time, particle size, and exposure schemes.

There are still many gaps in our knowledge of uptake, accumulation, and tissue distribution of Microplastics in freshwater fish species. Few laboratory studies have concluded that there is high accumulation of Microplastics in freshwater invertebrates. These invertebrates are the water flea *(Daphnia magna)* (Frydkjaer *et al.,* 2017; Jemec *et al.,* 2016; Ogonowski *et al.,* 2016) amphipods *(Hyalella Azteca* and *Gammarus fossarum)* (Au *et al.,* 2015; Blarer and Burkhardt, 2016), and oligochaetes *{Lumhricus variegates)* (Imhof *et al.,* 2013). However, there is limited information on the bioaccumulation of Microplastics in freshwater fish, especially at tissue level (Lu *et al.,* 2016). In a recent study, red tilapia *(Oreochromis niloticus),* a fish found in fresh water in China, was used as the test organism. The biomagnification and buildup in various tissues (gut, liver, gills and brain) were investigated. Also, a suite of biomarkers at the molecular level in fish tissues was applied to examine the biological effects of Microplastics on *O. niloticus.* Among the applied biomarkers, nervous system enzyme in the brain was used to determine the potential neurotoxicity of Microplastics in the liver which was utilized to assess metabolic disturbances in fish. An antioxidant enzyme in the liver was utilized to assess potential oxidative damage induced. These results showed the ingestion and accumulation of Microplastics in different tissues of freshwater fish, which lead to perturbations in fish biological systems and should be considered in environmental risk assessment (Ding, *et al,* 2018). Microplastics have been found in sea salt, tinned sardines and sprats, and edible marine species' tissues (crustaceans, fish, and mollusks) (Toussaint *et al* 2019). Many studies have suggested that there is a high accumulation of Microplastics by fresh water invertebrate and therefore, through bioaccumulation it is very likely that Microplastics are accumulated by humans through food web.

Toxic Effect of Microplastic

Current studies suggest that microplastics are accumulated by aquatic organisms. Ecotoxicology studies have shown microplastic accumulation in a diverse group of aquatic organisms, including planktonic organisms, invertebrates, and vertebrates (Ribeiro et al., 2019). Numerous studies revealed that aquatic animals, including mammals, seabirds, and invertebrates, might consume microplastics. (Anbumani and Kakkar, 2018) Microplastics can cause inflammation by destroying the filtering mechanisms of marine biota (such as mussels and zooplankton) when they are consumed (Von Moos *et al.,* 2012). Additionally, microplastics can affect how algae feed, reduce fertility, and increase copepod mortality (Cole *et al.,* 2019; Zhang *et al.,* 2017). Microplastics can effectively absorb and concentrate hydrophobic organic pollutants, such as PAHs and organo-chlorine pesticides (OCPs), on their surface due to their hydrophobic surfaces (Zhang *et al.,* 2015). There have been very few studies on the quantity of Microplastics ingested by aquatic organisms and far fewer studies on the potential consequences, or the effects of their presence in organism guts, tissues, and food webs.

Effects of Microplastic on Human Health

Microplastics that have been released into the environment will eventually come into contact with people through a variety of channels, potentially posing health problems (Wang *et al.,* 2021). Microplastics contain organic and inorganic components such as bisphenol A (BPA), tributyltin, Zn, Pb which are directly being released into environments. Pollutants like Poly Aromatic Hydrocarbons (PAHs) absorb on microplastics, thus potentially leading to combined toxicity, therefore, the indirect toxicity induced by microplastics could not be neglected either (Wang *et al.,* 2021). Microplastics are resistant to chemical breakdown in vivo and when they are ingested into the body they pose health concerns as a result of their biological persistence and dose (Wright and Kelly, 2017). Previous research established that microplastics can produce reactive oxygen species, boost glutathione S-transferase activity and activate enzymes involved in antioxidant defense as well as mitogen-activated protein kinase signaling pathways (Alomar *et al.*, 2017; Jeong *et al.,* 2017; Jeong *et al.,* 2016). Additionally, acetylcholinesterase inhibition by microplastics may result in neurotoxicity (Jeong and Choi, 2019).

Based on an examination into simulated human digestion, microplastics may decrease lipid digestion by forming hetero-aggregates of microplastics and oil droplets and by inhibiting the activities of digestive enzymes (Tan *et al.,* 2020) which can pose a threat to human digestive health. Microplastics can also be absorbed into human tissues through endocytosis (on the surface of the gastrointestinal tract and the airways) and paracellular persorption, which can be influenced by the size, surface functionalization, surface charge, generated protein corona, and hydrophobicity of the microplastics (Wright and Kelly, 2017).

In a study of Microplatics detection in human stools it shows that the quantity of Microplastics in stool is large (Schwabl *et al.,* 2019). Microplastics can penetrate cell membranes, the blood-brain barrier, and the placenta and as a result cause oxidative stress, cell damage, inflammation, and impairment of energy allocation (Bouwmeester *et al.,* 2015, Nelms *et al.,* 2018). They can increase cytokinesis production, leading to an inflammatory response in both types of cells, according to research done in the lab using human lung and stomach cancer cells exposed (De-la-Torre, 2020). According to a research conducted Microplastics can move from the gut cavity to the lymphatic and circulatory systems, disrupting intestinal microbiota and introducing hepatic lipid disease (Bouwmeester *et al.,* 2015; Yu *et al.,* 2020). The negative consequences of Microplastics on humans including skin irritation, breathing issues, cancer risk, cardiovascular illness, and reproductive issues (De-la-Torre, 2020, Smith *et al.,* 2018, Yu *et al.,* 2020).

Bioaccumulation of Microplastics damages the tissues which cause physical stress and disruption, oxidative stress, and immune responses (Pirsaheb *et al.,* 2020). Numerous studies have concluded that microplastics enter many human organ systems and acts as both physical and chemical stressors to the human system. This causes several health issues such as diabetes, obesity, endocrine disturbance, cancer, cardiovascular, reproductive and developmental, problems (Alharbi *et al.,* 2018, Ribeiro *et al.,* 2019, Pal *et al.,* 2019). Microplastics act as vectors to other harmful substances such as heavy metals and other organic substances causing the effects to be more adverse. Through bio-accumulation, Microplastics cause many health issues such as breathing problems, endocrine disturbances, cardiovascular and reproductive cancers. Most of the toxicological effects of Microplastics on humans were observed in adults and there is lack of data on the effects on children, pregnant women and lactating mothers, hence there is a need for comprehensive study with both blood and stool samples. There are very limited studies on the potential of developing cancer from prolonged human exposure.

Methods of Controlling Microplastic Pollution

The major methods of controlling microplastics are the substitution of non-plastic materials for plastic ones in products such as personal care products and Microplastic removal from wastewater (Rostami *et al.,* 2021). Bacterial degradation, sunlight-driven photocatalyst, fuels, and biodegradable plastics could be game-changers in future research on Microplastic pollution control (Lamichhane *et al.,* 2023).

GAPS AND FUTURE RESEARCH

Due to the above discussions there are many gaps that have been discovered in the search for the consequences of Microplastics toxicity in living organisms. There is insufficient information on the source of emission of Microplastics. Toxicity mechanisms of microplastics due to ingestion, inhalation or dermal up take by humans or other animals are scarce. As such a comprehensive study should be carried out on the consequences of microplastics toxicity to humans and other organisms. Other Suggestions for future research studied include:

1. Focus on the exact source of Microplastics pollution into the aquatic environment so as to eliminate or reduce their exposure to aquatic organism.
2. Comprehensive research on the microplastics as a vector for other pollutants (e.g., POPs.

PAH's, heavy metals) and investigate the reason why these other pollutants are attracted to microplastics.
3. Investigate the transport mechanisms, accumulation, and metabolism of microplastics within the human body using animal model experiments (e.g., fish, rats).
4. Identify specific microorganisms that are more sensitive to microplastics using rRNA gene sequencing.

RECOMMENDATION
1. Develop modern technologies that will help overcome the issues of aquatic Microplastics Pollution.
2. These modern methods should include biological remediation as it is an environmentally friendly method.
3. Production of bioplastics that can easily breakdown without the release of harmful chemicals.
4. Advanced simple techniques for the detection of microplastics in aquatic environment should be produced.
5. Public enhancements or awareness should be made on the impact of un-proper disposal of Plastics in the environment and the consequences of un-proper disposals.

CONCLUSION
Microplastics are becoming pollutants of concern in aquatic environment as the production of plastics is ten times higher in the last decade. Plastics degrade through chemical, physical and biological process, which leads to the formation of microplastics. Microplastics are ubiquitous with diverse sources and cause a number of consequences to the environment and living organisms. The effect of Microplastics include blockage of the digestive system, weight loss, depletion of energy reserves, disruption of reproduction, change in the ratio and distribution of cholesterol, nutritional shortage, reduction in growth, decline in fertility, cell damage, inflammation, hepatic lipid disease, skin irritation, breathing issues, cancer risk, cardiovascular illness, reproductive issues, disruption in oxidative stress and immune responses, cancer, cardiovascular, reproductive and developmental problems. Control of microplastics can be achieved by substitution of non plastic material with the plastic materials used. Recommendations include development of bioplastics which will be biodegradable and public awareness so as to limit the use of plastics.

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