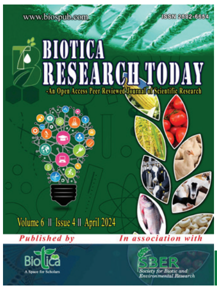

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Microplastic Contamination in Aquaculture: Sources, Effects and Mitigation Strategies

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Abstract

The prevalence of plastics in contemporary society has resulted in unprecedented levels of plastic pollution, raising significant environmental and health concerns. Since the 1950s, global plastic production has surged, leading to widespread accumulation of plastic waste. Microplastics (Mps), particles measuring less than 5 mm in diameter, have emerged as a particularly worrisome aspect of plastic pollution due to their persistence and potential adverse effects. Various sources contribute to the presence of Mps in aquatic environments, including land-based plastic waste, tourism-related littering, shipping activities, fisheries, aquaculture and atmospheric deposition. Mps can adversely impact aquatic organisms, affecting their feeding behavior, reproduction, immune responses and gene expression. Moreover, microplastics pose potential health risks to humans. Several measures can be undertaken to address the issue, including removing plastic microbeads from personal care products, utilizing biodegradable materials, enhancing waste management and recycling practices, upgrading wastewater treatment plants and advancing cleanup and bioremediation technologies.

Keywords: Aquaculture, Microplastics (Mps), Primary source, Secondary source

Introduction

Plastic products have completely changed modern living by providing affordability and convenience due to its advantageous qualities. Global plastic output has increased dramatically since the 1950s and reached about 359 million tons in 2018 alone. But because plastic waste is difficult to handle and doesn't decompose easily, it has become a serious environmental problem. According to estimates, 79% of plastic trash ends up in the environment; just 9% is recycled and 12% is burned (Chen *et al*., 2021). Because plastic is used so extensively in so many different industries, plastic garbage is now present in every environmental area. The plastics industries purposefully produce primary microplastics with a diameter of less than 5 mm for usage as microbeads in industrial processes, healthcare products and household cleaners (Chen *et al*., 2021). Plastic is subject to mechanical, physical and biological pressures in the environment, particularly in the water. Indeed, plastic deteriorates and turns into scrap after being exposed to UV radiation, low temperatures and mechanical wear from sand and waves. Thus, the fragmentation of macroplastics yields secondary microplastics. Because microplastics are so tiny, they can be inadvertently swallowed or breathed by animals, which can lead to an accumulation of particles in their bodies and possible health hazards. Consequently, Mps have garnered significant global attention in recent years, leading to a surge in research in this field.

Characterization of the Source of Microplastic in Aquaculture

Primary Source

Microplastics (Mps) are introduced into the environment through direct discharge into water bodies, either as micro or nanoparticles utilized in textiles, medications, toothpaste and an array of personal care products like facial cleansers and exfoliating scrubs.

Secondary Source

Microplastics originate from the gradual deterioration and fragmentation of larger plastic items. Textiles, tire debris and

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sizable plastic pieces serve as potential origins of secondary microplastics, such as microfibers, which form through degradation and fragmentation induced by environmental weathering processes like wave action and wind abrasion.

Various Sources of Mps in Aquaculture Environments

Mps in aquaculture environments originated from various sources as follows.

- Land-related plastic waste,
- Tourism-related plastic waste dumping,
- Shipping transit,
- Fishing and aquaculture, and
- Atmospheric transport.

1. Land-related Plastic Waste

It stands as one of the primary contributor to microplastic pollution in aquatic ecosystems. Plastics are predominantly manufactured and utilized on land, with rivers serving as conduits for transporting microplastics from terrestrial to marine environments, owing to their freshwater habitats. Furthermore, Mps are prevalent in industrial, agricultural and household wastewater, constituting significant sources of microplastic contamination in aquatic ecosystems.

2. Tourism-related Plastic Waste Dumping

Tourism development has also played a role in dispersing plastic waste into aquatic ecosystems (Zhou *et al*., 2021). Numerous plastic items, including bags, water bottles and food packaging, are transported and discarded by tourists in areas near or within rivers, lakes, coastal regions, beaches and oceans.

3. Shipping Transit

It significantly adds to the microplastic contamination in aquatic settings through the disposal of plastic waste from ships. Considerable quantities of primary microplastics are incorporated into gasoline, diesel and other fuels to enhance their properties. Throughout shipping activities, incomplete combustion of plastic particles releases them into both the atmosphere and water environments. Furthermore, shipping incidents also result in the discharge of plastic products into aquatic ecosystems.

4. Fishing and Aquaculture

The majority of fishing equipment, including nets, lines, buckets and various tools, are constructed from plastic or incorporate plastic components (Zhou *et al*., 2021). Artificial feeds and medicinal items often contain substantial quantities of microplastics, which may be introduced during their manufacturing, transportation, storage and usage phases. Moreover, numerous organisms such as zooplankton, invertebrates, small fish and aquatic plants found in natural habitats contain microplastics, serving either as ingredients in artificial feeds or as direct sources of natural food in aquaculture.

5. Atmospheric Transport

Microplastics have been detected in the atmosphere and can be carried across vast distances through atmospheric transport. Subject to gravitational forces and diverse weather patterns, microplastics in the atmosphere settle on terrestrial landscapes and into aquatic ecosystems. Similar degradation characteristics observed in Mps from atmospheric deposition and those found in lakes suggest that a portion of microplastics in aquatic environments may originate from atmospheric fallout. Research indicates that Mps present in the atmosphere serve as a notable source of microplastic pollution in aquatic environments.

Effects on Fish

Microplastics (Mps) pose a severe hazard to aquatic life, disrupting a variety of biological activities and behaviors. Mps ingestion has been shown to change aquatic animals' eating and swimming behavior, potentially having a cascading effect on the ecology. Additionally, Mps have been discovered to interfere with these species' reproductive activities, potentially leading to population decreases. Specific species, such as *Pomatoschistus microps*, have demonstrated lower predation capacity after swallowing Mps, which may have an impact on their survival and the ecological balance. Once inside the tissues and organs, Mps can elicit a variety of immunological responses in aquatic species. For example, PVC and PET microplastics have been shown to induce oxidative damage to the white blood cells of sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*), endangering their health. Even smaller Mps (less than 80 micrometers) can enter the digestive system of mussels and cause an inflammatory reaction (Chen *et al*., 2021). Furthermore, the presence of Mps can alter gene expression, potentially leading to long-term genetic consequences for aquatic creatures.

Effects on Humans

Aquaculture products are one the major sources of Mps in humans. The Mps-contaminated fish or shellfish if consumed then it leads to bioaccumulation in the human body thereby causing many health-related issues. Moreover, the inhalation of airborne MPs, especially in highly polluted environments, can lead to respiratory problems. Symptoms may include irritation of the respiratory tract, coughing, wheezing and could even exacerbate pre-existing conditions such as asthma (Carbery *et al*., 2018). The impact of Mps extends to cardiovascular health, where exposure to these particles and their associated chemical pollutants may increase the risk of heart disease and stroke. The mechanisms behind this include inflammation, oxidative stress and disruption of normal cardiovascular function. Digestive issues are another concern, as ingestion of Mps through contaminated food and water can cause gastrointestinal irritation, inflammation and discomfort. These particles can also interfere with nutrient absorption and potentially cause blockages in the gastrointestinal tract (Li *et al*., 2023).

Reproductive health is not immune to the effects of Mps either. Exposure to these particles and their associated chemicals can disrupt hormone regulation, lead to fertility issues and cause developmental abnormalities in offspring, among other reproductive disorders (Carbery *et al*., 2018). Lastly, while the link between microplastic exposure and cancer in humans requires further research, some studies suggest that Mps may contain carcinogenic chemicals or contribute to carcinogenesis through chronic inflammation or oxidative stress.

Mitigation Strategies

• *Adaptation of 4Rs Approach*: Reduce, reuse, recycle and recover for efficient plastics use and environmental sustainability.

• *Utilization of Biodegradable Materials*: Commercially available biodegradable or biocompatible plastics, such as polylactide (PLA), polyhydroxyalkanoates (PHA) and others, can replace conventional plastics in a wide range of uses. For example, PHA and PLA microbeads can be created (Wu *et al*., 2017).

• *Improvement of Separation Efficiency at Wastewater Treatment Plants (WWTP)*: Improving preexisting WWTPs to efficiently eliminate microplastics and avoid their release into aquatic environments such as rivers and oceans. Modifying filters in washing machines represents a simple and effective measure to prevent microplastic fibers from entering sewage systems.

• *Technological Developments in Bioremediation and Cleaning*: Since the 1970s, researchers have been looking into microbial biodegradation of petroleum-based plastics, specifically polyethylene (PE), polypropylene (PP) and polystyrene (PS). Several fungi have been reported to degrade polyurethane (PUR) (Wu *et al*., 2017). PE, PP and PS are generally regarded as non-biodegradable without preparation such as heat or UV treatment, allowing them to persist in natural environments for long periods of time. However, research indicates that PE, PS and PET may be biodegradable. Bacterial strains such as *Bacillus* sp. and *Enterobacter asburiae*, capable of degrading PE and *Exiguobacterium*, capable of degrading PS, have been isolated from the digestive tracts of pest insect larvae such as waxworms (*Plodia interpunctella*) and mealworms (*Tenebrio molitor*), respectively. PS foam is completely mineralized within mealworm guts within 12-24 hours (Wu *et al*., 2017).

• *Government Intervention*: Imposition of heavy fines on disposal of Plastic waste in ecologically sensitive areas and a complete ban on single-use plastic are some measures that can be taken by the government. The United States (US) government passed the Microbead Free Waters Act (2015), which limits the sale of personal care items that include plastic microbeads.

Conclusion

Plastics undoubtedly pose risks to human health because of their physical and chemical toxicity and the degraded byproducts of plastics, known as microplastics (Mps), have the potential to harm our bodies. Researchers are increasingly focusing on how Mps affects the human body after consumption of aquatic products. Therefore, it is crucial to comprehend the connection between Mps and aquaculture systems. Such understanding will not only deepen our knowledge of the impact of Mps on ecosystems but also prompt the use of advanced ecological water treatment technologies to minimize the risk of Mps discharge into the surrounding environment.

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