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The role of microplastics in the spread of antimicrobial resistance in aquatic environments

Thanuja S[1], Abisha Juliet Mary S J[2]
[1]PhD Scholar, Aquatic Animal Health Management, ICAR- Central Institute of Fisheries Education, Mumbai
[2]Assistant Professor, Department of Fish Pathology and Health Management, TNJFU- Dr. MGR Fisheries College and Research Institute, Thalainayeru.
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Abstract

Microplastics, plastic particles smaller than 5 millimeters, originate from various sources, including industrial activities and consumer products like cosmetics. These particles are categorized into primary microplastics, which are manufactured at small sizes, and secondary microplastics, which result from the breakdown of larger plastics. In aquatic environments, microplastics serve as habitats for bacterial colonization, forming biofilms that enhance microbial growth and facilitate the spread of antimicrobial resistance (AMR) genes. The presence of pollutants and antibiotics in these environments increases selective pressure on bacteria, promoting the proliferation and transfer of resistance traits. Environmental factors such as temperature, salinity, and nutrient availability further influence the stability of these biofilms and the mechanisms of gene transfer, making microplastics vectors for spreading resistant strains across aquatic systems. This ecological disruption poses significant risks to human health, primarily through the consumption of contaminated seafood and environmental exposure to resistant pathogens. Addressing this issue requires targeted mitigation strategies, including improved waste management, public awareness, and comprehensive monitoring of microplastics and AMR dynamics, to safeguard aquatic ecosystems and human health.

Introduction

The proliferation of human-made litter, particularly plastic, in both aquatic and terrestrial ecosystems has surged dramatically. With plastic constituting 60–80% of this litter, the large-scale production of plastics, which began in the 1950s, now exceeds 280 million tons annually. Each year, millions of metric tons of improperly managed plastic waste enter the oceans, contributing to widespread pollution. Antimicrobial resistance (AMR) represents a significant challenge to public health, complicating the treatment of infections caused by bacteria, parasites, viruses, and fungi. AMR occurs when microorganisms evolve and become unresponsive to medications, leading to persistent infections and increased transmission risks. The spread of AMR is exacerbated by microplastics in aquatic environments, which facilitate the persistence and transfer of antibiotic-resistant bacteria and their genes, thereby promoting the spread of resistance through food webs.

Sources and Types of Microplastics

Microplastics are defined as plastic particles smaller than 5 millimeters, originating from primary sources, such as cosmetics and medical products, and secondary sources, resulting from the degradation of larger plastics. Primary microplastics are commonly introduced into aquatic environments through sewage discharge or the release of plastic resin powders, while secondary microplastics are produced through the fragmentation of existing plastic debris. The environmental persistence of microplastics is of particular concern due to their ability to adsorb a variety of substances, including heavy metals and persistent organic pollutants (POPs). These adsorbed pollutants can be transferred to aquatic organisms, leading to bioaccumulation and biomagnification within the food chain. They as Habitats for Bacteria Microplastics have been detected in various marine environments and serve as unique habitats for microbial life, forming biofilms known as "plastispheres." These plastispheres support diverse microbial communities that can alter the physical properties of the plastic debris and potentially amplify its toxicological effects.

Accumulation of AMR Genes

The widespread presence of microplastics in the world's oceans, combined with the excessive use of antibiotics, has led to the accumulation of antimicrobial resistance (AMR) genes in these environments. Microplastics provide a surface for the adhesion of antimicrobial-resistant bacteria, facilitating the development and spread of polymicrobial biofilms. These biofilms, in turn, promote the transfer of resistance genes, increasing the prevalence of antibiotic-resistant bacteria in aquatic systems. Influence of Environmental Factors in AMR Spread The spread of AMR in aquatic environments is influenced by various environmental factors, including the presence of antibiotics, heavy metals, and microplastics. These factors create selective pressures that drive the proliferation of resistant bacteria and the transfer of resistance genes through mechanisms such as horizontal gene transfer (HGT).

Spreading Mechanism in Aquatic Systems

Microplastics serve as vehicles for the transfer of antibiotic resistance genes (ARGs) through the formation of biofilms on their surfaces. These biofilms facilitate horizontal gene transfer, increasing the likelihood of transferring resistance genes to opportunistic pathogenic bacteria.

Impact on Ecosystems and Human Health

The ecological and health impacts of microplastic-associated AMR are significant. Microplastics act as vectors for ARGs, altering microbial community structures and promoting the survival of resistant bacteria. This can lead to declines in biodiversity, destabilization of food webs, and increased risks of human exposure to antibiotic-resistant pathogens through contaminated seafood.

Mitigation Strategies

Mitigating the spread of AMR associated with microplastics requires a multi-faceted approach, including the reduction of plastic pollution, improved waste management practices, and the development of policies aimed at limiting the use of antibiotics in agriculture, aquaculture, and other industries. Comprehensive monitoring and public awareness campaigns are also essential to address this growing environmental and public health threat.

Conclusion

The interaction between microplastics and AMR in aquatic environments presents a complex challenge with far-reaching implications for ecosystem and human health. Effective strategies to mitigate these risks must address the sources and pathways of microplastic pollution, as well as the factors driving the spread of antimicrobial resistance. By taking a proactive approach, we can protect aquatic ecosystems and human health from the adverse effects of microplastic-associated AMR.