Unravelling the Impact of Microplastic on Aquatic Biota

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Abstract:
This comprehensive exploration delves into the pervasive presence and ecological implications of microplastics, unravelling a global tapestry of contamination in aquatic environments. From oceans to sediments, the study examines the diverse impact and distribution patterns of these microscopic pollutants. With a focus on oceans, seas, and freshwater ecosystems, we navigate the complex journey of microplastics, shedding light on their extensive reach and persistent environmental concerns. The research sheds light on the intricate threads of contamination, revealing the sources and distribution across diverse regions, from Asia and Europe to Africa, North America, Antarctica, the Atlantic Ocean, and the Arctic Ocean. As we sift through the waves, this study underscores the need for a deeper understanding of the complexity surrounding microplastic pollution to guide effective mitigation strategies and safeguard aquatic ecosystems.

Keywords: Microplastic; Aquatic biota

1. Introduction

Microplastics (MPs), pervasive and accumulating within ecosystems (4), attract substantial public attention and concern (9). The enduring and escalating production, usage, and disposal of plastic materials in modern society contribute to the omnipresence and persistence of MPs in diverse environments (4-8). MPs have been observed in various compartments of aquatic environments, including the pelagic zone and sedimentary habitats (9). For instance, the estimated total particle count of pelagic MPs around Japan's East Asian seas was 1720,000 pieces km-2 (15). Nova Scotia's Eastern Shore sediments exhibited a microplastic abundance of 200–800 fibers kg−1 (14). A comprehensive review highlighted the global distribution of MPs in oceans and continents, encompassing Asia, Europe, Africa, North America, Antarctica, the Atlantic Ocean, and the Arctic Ocean (8). In Hong Kong's water control zones, the mean abundance of MPs was 5595 items/m2 (15). The concentration of MPs in the Ross Sea's seawater (Antarctica) ranged from 0.0032 to 1.18 particles per m3 (7). Marine habitats are considered potential sinks for MPs (14). In the marine environment, sources of MPs include land-based input, marine aquaculture, fishing, and shipping (10). For freshwater pollution, sources of MPs typically include industrial raw materials, wastewater discharge, urban centres, and road runoff (2-5). The severe situation of plastic pollution in the aquatic environment is compounded by the potential toxicity (9), widespread existence (11), and various sources (15) of MPs. Generally, MPs are defined as plastic debris smaller than 5 mm in diameter (7-9). The sources of MPs can be classified into two types: 1) primary MPs, manufactured in microscopic size, and 2) secondary MPs, fragmented from larger debris through UV radiation, mechanical abrasion, and biological degradation (7). MPs, being complex pollutants, undergo diverse weathering processes when released into the environment (11). As the sizes of MPs decrease, the chemical properties of plastics, such as polybutyrate adipate-co-terephthalate (PBAT) and low-density polyethylene, can persist.

While certain properties of microplastics (MPs), as indicated by (9), remain unaltered, various factors, both biotic and abiotic, have the capability to modify characteristics like density, shape, size, type, sorption, leaching, and biofilm in their interactions with the surrounding environment (2,3). The collective influence of these altered properties determines the likelihood of MPs uptake by aquatic animals and subsequent impacts.

2. The Interplay of Microplastics with Gut Microbiota

In the context of microplastic (MP) exposure, ingestion emerges as the predominant pathway for these particles to infiltrate aquatic organisms, notably within the digestive tract, specifically the intestine. This interaction may influence physiological processes at this site, impacting the intestine—a crucial organ for digestion, nutrient uptake, metabolism, and immune defence in aquatic organisms like fish. The intestine, recognized for its vulnerability to MP-induced damage, serves as an entry point for pathogens and a conduit to inner body environments, including lymph nodes, liver, and spleen. The Intestine, housing the largest number of immune cells in the body, assumes a pivotal role in the overall immune system. Villi, distinctive structures of the intestine, enhance surface area for nutrient absorption, playing a crucial role in maximizing nutrient uptake and transport. The mucosa, constituting the innermost layer of the gut, serves as the primary interface where intestinal microbiota and environmental antigens interact with the host.

The realization that gut contents influence the entire body underscores the significance of the gastrointestinal tract, acting as a habitat for beneficial and potentially pathogenic microorganisms and xenobiotics. Epithelial cells form histological boundaries between the host's body and external substances, facilitating digestion, absorption, and the host immune response. The gut microbiota, a complex and dynamic system, intimately interacts with host physiological functions such as metabolism and immune responses, responding to environmental changes induced by factors like environmental chemicals. Indigenous microbial communities within the gut contribute significantly to host development, with a focal point on the gut due to its crucial functions in metabolic processing, energy production, food digestion, and immune regulation. Recognizing the vital contributions of a healthy gut microbiota to host well-being emphasizes its pivotal role in metabolic processes, immune homeostasis, and overall health. The intricate interplay between microplastics and gut microbiota sheds light on the potential implications for the health and resilience of aquatic organisms facing these environmental challenges.

3. Influence of Gut Microbiota on Intestinal Health

The presence of gut microbiota plays a pivotal role in shaping the intestinal health of aquatic animals. It holds substantial influence over the host's physiology, impacting crucial processes such as the metabolism of over 30 environmental contaminants, involving the active participation of gut microbes (1-6). Moreover, the presence of intestinal microbiota contributes to the localization of B cells and T cells within the mucosal immune system, specifically in the intestinal lamina propria. This presence is also essential for the synthesis of immunoglobulin A in the intestinal mucosa (6,10). Additionally, the vital role of gut microbiota in the overall health of the host stems from its metabolic capabilities and extensive genomic content (1,7). A noteworthy example is found in human intestinal bacteria belonging to the Bacteroidetes phylum, which expresses carbohydrate-active enzymes necessary for the digestion of most dietary polysaccharides (3). Furthermore, gut microbiota serves as a linchpin in the de novo synthesis of essential vitamins that the host organism is unable to produce independently (13). The intricate interplay between gut microbiota and host health underscores the indispensability of these microbial communities for the well-being and physiological balance of aquatic organisms.

4. Sensing the Features of Gut Microbial Communities

4.1. Detection of Gut Microbial Features:

The composition of gut microbial communities, the metabolites produced by these communities, and distinctive microbial molecules serve as key signals in host-microbiota interactions. These signals play a crucial role in various functions of the intestine, responding to different types of bacteria (both commensal and pathogenic) and other environmental stimuli.

4.2. Host Responses and Microbial Sensing

Host responses to gut microbiota exhibit bacterial species specificity, implying that specific bacterial species modulate certain host functions. Epithelial cells in the gut play a role in sensing characteristic microbial molecules, influencing activation status and immune regulatory functions. Additionally, microbial metabolites contribute to microbe-to-host metabolic signalling.

4.3. Environmental Impact on Gut Microbiome

Environmental contaminants can impact the gut microbiome of aquatic species, affecting proteins targeted for chemical perturbation. These contaminants can directly interact with the microbiome, highlighting the intricate relationship between environmental factors and microbial communities.

5. Profound Impacts of Gut Microbial Community Dysbiosis

5.1. Understanding Dysbiosis:

Dysbiosis, characterized by an imbalance in microbial communities, manifests as changes in microbial composition, abundance, and diversity. Species composition, diversity, and evenness are crucial factors influencing the mechanistic basis of microbiota-host interactions.

5.2. Dynamic Nature of Microbial Communities:

Microbial communities in the gut constantly undergo changes in response to environmental conditions. Stability in composition enables proper intestinal microbiota functioning, while deviations from normal structure or function, known as dysbiosis, can lead to etiopathology consequences.

5.3. Factors Influencing Dysbiosis:

Various factors, including intrinsic ones like the host's genetic makeup and extrinsic factors such as diet, antibiotics, environmental toxins, and acute enteric pathogens, can disturb host-microbiota homeostasis, decrease microbial diversity, and introduce dysbiosis. Infection by foreign microbes also stands as a potential cause of dysbiosis.

6. Gut Health in Aquatic Animals:

Gut health in aquatic animals, with their dynamic interaction with the surrounding environment, is more fluidic than that of terrestrial vertebrates. The gut microbial communities in aquatic animals are greatly sensitive to dietary changes and influenced by the ambient environment, presenting a dynamic and responsive system.

6.1. Impact of MPs on Gut Microbiota:

Ingestion of microplastics (MPs) into organisms introduces chemical components and foreign microbes from MP biofilm to the gut microbiota. This interaction mediates impacts on the host organism, and studies on MPs and gut microbiota have been conducted under both laboratory and natural conditions. This comprehensive review explores alterations in the dynamics of intestinal microbial communities, encompassing structural and functional changes. These changes are potential mechanisms explaining the impacts on aquatic organisms induced by MPs.

6.2.Ingestion of Microplastics (MPs)

6.2.1. Impact of Size, Shapes, and Colors of MPs on Ingestion

Aquatic organisms, ranging from amphipods to barnacles, exhibit the ingestion of microplastics (MPs) within a short timeframe when exposed to environments containing these particles (4). This holds true for detritivores, deposit feeders, and filter feeders alike. The ingestion of MPs is not restricted to specific trophic levels, encompassing a range from zooplankton to mammals (11-14). In the case of zooplankton, fibers constitute the dominant type of ingested MPs, with the size of the prey closely matching that of the MPs (8). Shrimps, particularly attracted to small-sized blue fibers, showcase a preference for these materials in their ingested content. Fish from specific regions demonstrate selectivity in the types of ingested MPs, with only white and opaque spherules identified in their digestive tracts (2-5). The color, size, and shape of MPs play a crucial role in their ingestion, with certain characteristics potentially leading to mistaken identity as prey. For example, planktivorous fish, visual predators, exhibit a preference for blue polyethylene fragments similar in size and color to their copepod prey (7). Smaller particles have a higher likelihood of entering organisms through ingestion or even cellular endocytosis compared to larger particles (2).

6.2.2. Impact of MPs Densities on Ingestion

Plastic polymers with varying densities are distributed across different compartments of the aquatic environment, including the water surface, water column, and sediment (6,7). The density of plastic polymers theoretically influences the likelihood of encounters by different organisms in various habitats. Floating MPs with lower densities may be more prone to ingestion by pelagic organisms like phytoplankton and small crustaceans (e.g., zooplankton), while denser MPs may be ingested by benthic organisms such as amphipods, polychaete worms, tubifex worms, mollusks, and echinoderms (1,8). However, the influence of polymer density on distribution might not be the sole determining factor, as contradictory occurrences of MPs in different parts of the aquatic environment have been reported. similar types of polymers were found in both the water column and sediments, while certain studies reported the absence of plastic debris in sampled sediment (13).

6.2.3. Impact of MPs Biofilms on Gut Microbiota in Aquatic Organisms

The potential influence of biofilms formed on microplastics (MPs) on gut microbiota hinges on the dynamic processes involved in biofilm formation, development, and interactions from water to the gut. Given the evolving nature of biofilms, exploring the impacts on gut microbiota becomes a relevant discussion. Within the MPs biofilm, the specific environmental microorganisms and gut microbial colonizers enriched by MPs may exert influences on the gut microbial community.

The formation of MPs biofilm, resulting from interactions between microorganisms and MPs, facilitates the introduction of environmental microorganisms to the gut. These interactions take place in aquatic habitats. During transportation across different environmental compartments, microbial biofilms can develop on MPs, created by various microorganisms, primarily bacteria inhabiting the surface of MPs (12-14). MPs act as a unique and selective microbial habitat and a novel vector for transporting bacterial assemblages due to their rapid migration, hydrophobicity, inert surfaces, and distinct composition compared to surrounding water and other natural substrates (14). The microbial composition on MPs commonly includes various classes of microorganisms, with bacteria being the most prevalent, mirroring similarities found in the gut (7-9). The early surface colonization process of bacteria on MPs follows sequential steps, with Rhodobacterales forming the primary bacterial group on the surface (8). The selective enrichment of organisms on MPs occurs due to differences between MPs and their ambient environment, leading to a restricted number of organisms colonizing MPs (7). Additionally, the composition, structure, and functions of plastic-associated microbial communities can be influenced by the type of plastic, degradation degree, and biofilm formation (13-14). Conversely, biofilms also impact MP toxicity, such as the vector effects of MPs' hydrophobic organic compounds (HOC) (11).

Ethical approval: Not applicable.

Consent to publication: All authors are agreeing for publication.

Consent to participate: All authors are participated in this research work.

Author's contribution: JP conceived the idea; JP wrote the whole manuscript. The complete manuscript was revised and edited by JP and TB.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing Interests: The author declare that they have no competing financial interest or personal relationship that could have appear to influence the work reported in this paper.

Availability of data and materials: The data and materials that support he findings of the study are available from the corresponding author upon request

Acknowledgment: Author would like to thanks Tansukh Barupal Assistant professor, SBK Govt. P.G. College Jaisalmer, Rajasthan.

References

1. Anderson JC, Park BJ, Palace VP (2016) Microplastics in aquatic environments: implications for Canadian ecosystems. Environ Pollut 218:269–280. https://doi.org/10. 1016/j.envpol.2016.06.074
2. Andrady AL (2011) Microplastics in the marine environment. Mar Pollut Bull 62:1596–1605. https://doi.org/10.1016/j. marpolbul.2011.05.030
3. Bakir A, O'Connor IA, Rowland SJ et al (2016) Relative importance of microplastics as a pathway for the transfer of hydrophobic organic chemicals to marine life. Environ Pollut 219:56–65. https://doi.org/10.1016/j.envpol.2016. 09.046
4. Barboza LGA, Gimenez BCG (2015) Microplastics in the marine environment: current trends and future perspectives. Mar Pollut Bull 97:5–12. https://doi.org/10.1016/j. marpolbul.2015.06.008
5. Barboza LGA, Vethaak AD, Lavorante BRBO et al (2018) Marine microplastic debris: an emerging issue for food security, food safety and human health. Mar Pollut Bull 133:336–348. https://doi.org/10.1016/j.marpolbul.2018. 05.047
6. Barletta M, Lima ARA, Costa MF (2019) Distribution, sources and consequences of nutrients, persistent organic pollutants, metals and microplastics in South American estuaries. Sci Total Environ 651:1199–1218. https://doi.org/10. 1016/j.scitotenv.2018.09.276
7. Shim WJ, Song YK, Hong SH, Jang M (2016) Identification and quantification of microplastics using Nile Red staining. Mar Pollut Bull 113:469–476. https://doi.org/10.1016/j. marpolbul.2016.10.049
8. Vianello A, Boldrin A, Guerriero P et al (2013) Microplastic particles in sediments of Lagoon of Venice, Italy: first observations on occurrence, spatial patterns and identification. Estuar Coast Shelf Sci 130:54–61. https://doi.org/ 10.1016/j.ecss.2013.03.022
9. Wang W, Wang J (2018) Investigation of microplastics in aquatic environments: an overview of the methods used, from field sampling to laboratory analysis. Trends Anal Chem 108:195–202. https://doi.org/10.1016/j.trac.2018. 08.026
10. Li X, Chen L, Mei Q et al (2018b) Microplastics in sewage sludge from the wastewater treatment plants in China. Water Res 142:75–85. https://doi.org/10.1016/j.watres. 2018.05.034
11. Maes T, Jessop R, Wellner N et al (2017) A rapid-screening approach to detect and quantify microplastics based on fluorescent tagging with Nile Red. Sci Rep 7:1–10. https:// doi.org/10.1038/srep44501
12. Hidalgo-Ruz V, Gutow L, Thompson RC, Thiel M (2012) Microplastics in the marine environment: a review of the methods used for identification and quantification. Environ Sci Technol 46:3060–3075. https://doi.org/10.1021/ es2031505
13. Wright SL, Thompson RC, Galloway TS (2013) The physical impacts of microplastics on marine organisms: a review. Environ Pollut 178:483–492. https://doi.org/10.1016/j. envpol.2013.02.031
14. Xiong X, Zhang K, Chen X et al (2018) Sources and distribution of microplastics in China's largest inland lake—Qinghai Lake. Environ Pollut 235:899–906. https://doi.org/10. 1016/j.envpol.2017.12.081

15. Ziajahromi S, Neale PA, Leusch FDL (2016) Wastewater treatment plant effluent as a source of microplastics: review of the fate, chemical interactions and potential risks to aquatic organisms. Water Sci Technol 74:2253–2269.
16. Ziajahromi S, Neale PA, Rintoul L, Leusch FDL (2017) Wastewater treatment plants as a pathway for microplastics: development of a new approach to sample wastewaterbased microplastics. Water Res 112:93–99. https://doi.org/ 10.1016/j.watres.2017.01.042