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Microplastics and microbiota: Unraveling the hidden environmental challenge

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Abstract

This editorial explores the intricate relationship between microplastics and gut microbiota, emphasizing the complexity and environmental health implications. The gut microbiota, a crucial component of gastrointestinal health, is examined in the context of potential microbial degradation of microplastics. Furthermore, dysbiosis induced by microplastics emerges as a consensus, disrupting the balance of gut microbiota and decreasing diversity. The mechanisms triggering dysbiosis, including physical interactions and chemical composition, are under investigation. Ongoing research addresses the consequences of microplastics on immune function, nutrient metabolism, and overall host health. The bidirectional relationship between microplastics and gut microbiota has significant implications for environmental and human health. Despite uncertainties, microplastics negatively impact gut microbiota and health. Further research is essential to unravel the complex interactions and assess the long-term consequences of microplastics on both environmental and human well-being.

Key Words: Microplastics; Microbiota; Gut; Dysbiosis

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Core Tip: The intricate relationship between microplastics and gut microbiota, as outlined in this article, emphasizes the growing concern for environmental health. Although the potential microbial degradation of certain microplastics is recognized, the dysbiosis induced by these particles is widely acknowledged as a threat, impacting the balance and diversity of gut microbiota. Ongoing research aims to unravel these complex, bidirectional interactions, highlighting the need for a comprehensive understanding of their implications for both environmental ecosystems and human health.

INTRODUCTION

This editorial comments on an article published in a recent issue of *World Journal of Gastroenterology*, entitled "The Invisible Threat: Understanding Microplastics and Nanoplastics in Our Environment"[1]. We delve deeper into the connection between gut microbiota and plastic microparticles.

The interaction between microplastics and microbiota is a subject of growing concern, especially in the context of environmental and human health. Overall, the interaction between microplastics and microbiota is a complex issue that requires further research, particularly to understand the long-term health effects in both animals and humans. The growing body of evidence suggests that microplastics could be a significant environmental health concern, impacting not just ecosystems but also the health of individual organisms by altering their gut microbiota.

MICROPLASTICS

Microplastics can at least be categorized according to their size, origin, or chemical composition.

Classification by size

Microplastics are tiny particles of plastic that measure less than 5 mm in length. Nanoplastics are particles smaller than 1 micrometer in size[2].

Two main categories based on their source

Microplastics can be classified according to their source: Primary microplastics and secondary microplastics.

Primary microplastics encompass various types of tiny plastic particles that directly contribute to environmental pollution. Microbeads, deliberately added to personal care items such as scrubs and toothpaste, have faced bans in several regions due to their detrimental impact. Nurdles, small plastic pellets used in plastic production, are released into the environment through accidental spills during transport. Microfibers from synthetic textiles during washing, become a notable source of microplastic pollution in water. Additionally, microplastics are present in cosmetics and personal care products, including glitter and other small plastic particles used for aesthetic purposes, contributing to the broader issue of microplastic contamination[3].

Secondary microplastics result from the breakdown of larger plastic items through environmental processes such as sunlight exposure, wind, and wave action. Over time, exposure to environmental factors such as sunlight, heat, and mechanical forces can lead to the breakdown of larger plastic items into smaller particles, eventually forming microplastics. The deterioration of vehicle tires represents a noteworthy contributor, as minute particles released during this process contribute to the presence of microplastics in both terrestrial and aquatic ecosystems[4]. Additionally, the degradation of paints, coatings, and finishes on various surfaces releases small plastic particles into the environment, further contributing to the issue of secondary microplastics[5].

Chemical structure of microplastics

Microplastics consist of various synthetic polymers, each characterized by long chains of molecules formed from repeating subunits. The chemical composition of microplastics varies according to the specific polymer used in their production. Noteworthy polymers found in microplastics encompass Polyethylene (PE), prevalent in packaging materials, bottles, and various plastic products; Polypropylene, utilized in packaging, textiles, and plastic containers; PE terephthalate, commonly employed in beverage bottles, food containers, and synthetic fibers; Polyvinyl chloride, used in construction materials, pipes, and certain types of packaging; Polystyrene, commonly present in foam packaging, disposable utensils, and insulation materials; Polyurethane, employed in foams, coatings, adhesives, and flexible plastics; Nylon, found in textiles, fishing nets, and certain plastic components; and Acrylic, used in transparent plastics, lenses, and signage[6]. These polymers are not easily biodegradable, contributing to the persistence of microplastics in the environment.

It's important to note that the chemical composition of microplastics can also be influenced by additives and colorants used in the manufacturing process.

THE GUT MICROBIOTA

The gut microbiota is a complex and dynamic ecosystem, primarily composed of bacteria, along with archaea, viruses, fungi, and protozoa, residing in the gastrointestinal tract. This diverse microbial community is predominantly composed of bacteria from the Firmicutes and Bacteroidetes phyla, with significant contributions from Actinobacteria, Proteobacteria, and Verrucomicrobia. The specific composition varies widely among individuals due to factors such as diet, health status, age, and genetic background. Within these microbial groups, genera such as Lactobacillus, Bifidobacterium, Escherichia, Clostridium, and Faecalibacterium play crucial roles in maintaining gut health [7]. They contribute to nutrient absorption, synthesis of vitamins, protection against pathogens, and modulation of the immune system. The balance and diversity of the gut microbiota are essential for overall health, with imbalances linked to a range of diseases, including obesity, inflammatory bowel disease, diabetes, and allergies.

INTERACTION MICROBIOTA/MICROPLASTICS

The relationship between microbiota and microplastics can exhibit various forms of interaction. The microbiota, with its diverse ensemble of microorganisms, may possess the ability to degrade certain microplastics, a mechanism beyond the capability of eukaryotic cells. Conversely, the gut microbiota, a complex and diverse community of microorganisms, holds the potential to contribute to the degradation of microplastics; nonetheless, this aspect is not yet fully comprehended.

DEGRADATION OF PLASTICS BY THE MICROBIOTA

Some microorganisms have been found to possess enzymes capable of breaking down certain types of plastics. These microorganisms, often bacteria or fungi, can metabolize or degrade plastic polymers to some extent under specific conditions.

Exploring the human digestion of microplastics (MPs) and their influence on colonic microbiota involves a range of methodologies, incorporating both in vitro and in vivo approaches. While investigations using animals and human trials are considered the standard due to their physiological relevance, they face limitations such as ethical concerns, high expenses, and the intricate nature of the multistage processes in human digestion. Consequently, there is a legitimate need for in vitro models that faithfully replicate the physiological conditions of human digestion.

Static models play a crucial role in identifying endpoints or kinetics of particular digestion phases, such as the biotransformation occurring in the stomach and small intestine. In contrast, dynamic models, despite their increased complexity, offer a more accurate representation of the physiological reality within the gastrointestinal tract (7). Among these dynamic simulators, the simgi® system for instance, has been employed to investigate the effects of various foods, for example (8).

Numerous articles have discussed the existence of enzymes within the gut microbiota capable of breaking down microplastics. However, these studies have not provided specific numbers regarding the percentage of microplastics degraded by the microbiota, nor have they clarified whether the degradation process is complete. Additionally, there is a lack of information on the actual impact of the microbiota on eliminating microplastics from the human environment. The diverse structure of microplastics also suggests that the microbiota may not be totally capable of degrading all types of microplastics. The work by Nugrahapraja et al. (2022) serves as an illustrative case of this issue. While the authors delineated enzymatic activities capable of degrading plastics within the human gut microbiota, their conclusion highlighted the challenge in quantifying the actual impact of the microbiota on the elimination of microplastics [8].

The degradation of microplastics by gut microbiota, if possible, would depend on several factors. These include the type of plastic, the size and shape of the microplastics, the specific microbial species present, and the environmental conditions within the gut (such as pH, temperature, and oxygen levels) [9].

If gut microbiota can degrade microplastics, it could have significant implications for reducing the environmental burden of plastic pollution and its impacts on health. However, the potential byproducts or consequences of such microbial degradation in the gut environment are not yet clear and would need to be thoroughly studied.

In summary, while there is potential for certain microorganisms to degrade plastics, the extent to which gut microbiota can break down microplastics is still an open question in scientific research. More studies are needed to understand this interaction and its implications for environmental and human health. Regardless, it is evident that the microbiota within the human gut lacks the capability to break down all the microplastics present in the food ingested by an individual.

DYSBIOSIS INDUCED BY MICROPLASTICS.

If there is a consensus regarding the interrelationships between microplastics and the intestinal microbiota, it is indeed that of dysbiosis. The vast majority of publications related to the connections between microplastics, and the microbiota conclude that microplastics present in the intestine induce, in humans as well as in other species, particularly in fish [10], a modification of the microbiota composition, notably resulting in a decrease in its diversity. Numerous bibliographic references on this topic exist, and some reviews are available on this subject [11, 12].

Dysbiosis induced by microplastics represents a disruption in the delicate balance of the gut microbiota, a complex community of microorganisms residing in the gastrointestinal tract. Microplastics, being foreign entities, can interact with the gut environment in various ways, potentially triggering alterations in microbial composition, diversity, and function.

The precise mechanisms by which microplastics trigger dysbiosis are still under investigation, with several factors currently under consideration. First, the physical presence of microplastics may lead to direct interactions with gut microorganisms, influencing their growth, survival, and metabolic activities. Second, the chemical composition of microplastics and any associated additives might have direct or indirect effects on the microbiota. Moreover, microplastics may serve as carriers for other pollutants or pathogens, further complicating their impact on gut microbial communities. The consequences of dysbiosis extend beyond the gut, potentially affecting immune function, nutrient metabolism, and overall host health. Long-term exposure to microplastics and their influence on gut dysbiosis continue to be critical areas of research, with significant implications for both environmental and human health as contamination levels rise.

CONCLUSION

Overall, microplastics have no positive effect on gut microbiota and human health. The interactions between microplastics and the gut microbiota are complex, given the diverse sources, sizes, shapes, and chemical structures of microplastics. The relationships between plastics and the microbiota operate bidirectionally. While microbiota can, in certain conditions, be able to degrade and eliminate some microplastics, simultaneously, microplastics can alter the function of the microbiota, inducing dysbiosis, and subsequently may have health effects.

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