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Microplastic Pollution and Its Implications for Food Safety and Human Health: A Systematic Review

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Abstract

Microplastic pollution has become a rapidly growing global environmental issue, raising serious concerns about food safety and human health. This study aims to analyze the presence of microplastics in aquatic environments, their entry into the food chain, and their implications for human health through a systematic literature review (SLR) approach. Data were obtained from scientific articles published in the last five years and systematically analyzed to identify patterns and key findings. The results of the review indicate that microplastics are widespread in aquatic environments and can accumulate in various aquatic organisms, including seafood consumed by humans. Microplastics not only act as physical particles but also as vectors carrying hazardous substances such as heavy metals and persistent organic compounds. Exposure to microplastics has the potential to cause health issues, such as inflammation, oxidative stress, and gut microbiota disruption, although their long-term effects still require further research. Additionally, public awareness of the risks associated with microplastics remains relatively low. Therefore, integrated efforts through research, education, and policy are needed to mitigate the impact of microplastics on food safety and human health.

1. Introduction

The increase in plastic production globally in recent decades has become one of the most significant environmental problems. Plastics that are difficult to decompose cause an increasing accumulation of waste, especially in the aquatic environment. Over time, plastic waste that enters the ecosystem will undergo a fragmentation process into small particles known as microplastics, which are plastic particles with a size of less than 5 mm (De-la-Torre, 2020). The current existence of microplastics is not only an environmental issue, but also emerging as a new threat to food security and human health (Sana et al., 2020).

Microplastics can come from two main sources, namely primary and secondary microplastics. Primary microplastics are particles that are produced in small sizes, such as those found in cosmetic and industrial products, while secondary microplastics are formed from the degradation of large plastics due to physical, chemical, and biological influences on the environment (Llorca et al., 2020). Their small size and persistent nature cause microplastics to easily spread widely in various environmental compartments, including water, sediment, and living organisms. This makes microplastics a contaminant that is difficult to control and has the potential to enter the food chain.

In aquatic environments, microplastics can be easily ingested by a variety of organisms, especially low-trophic level organisms such as plankton and benthic organisms. These particles can then move through the process of trophic transfer in the food chain until they reach high-level organisms, including human-consumed seafood species (Walkinshaw et al., 2020). Various studies show that fish, shellfish,

and shrimp as important food commodities have been contaminated with microplastics, thus becoming the main route of microplastic exposure for humans (Chen et al., 2020).

The presence of microplastics in seafood raises serious concerns about food safety aspects. Unlike conventional contaminants, microplastics not only act as physical particles, but also as vectors that can carry various harmful substances, such as heavy metals and persistent organic pollutants (POPs). These substances can be adsorbed on the surface of microplastics and increase their potential toxicity when they enter the body of the organism (Unuofin & Igwaran, 2023). Thus, the consumption of seafood contaminated with microplastics has the potential to have a double impact, both in terms of exposure to harmful particles and chemical compounds.

From a human health perspective, the impact of microplastic exposure is still an evolving field of research. Nevertheless, some early studies suggest that microplastics can trigger a variety of biological responses, such as inflammation, oxidative stress, as well as disruptions in the gut microbiota (Li & Liu, 2024). In addition, the very small size of microplastics allows these particles to penetrate biological membranes and potentially accumulate in body tissues. However, scientific evidence on the long-term impact of microplastics on human health is still limited, so further studies are needed to comprehensively understand the risks posed.

On the other hand, the level of public understanding of microplastic pollution and its implications for food safety is still relatively low. Although some people are aware of the issue of plastic pollution in general, a deep understanding of the risks

of microplastics in food is still inadequate (Deng et al., 2020). This is in line with previous research findings that show that public knowledge regarding the impact of microplastics on food safety is still not comprehensive and needs to be improved. This limited understanding has the potential to hinder effective mitigation and policy-making efforts.

Based on this description, microplastic pollution in the aquatic environment and its implications for food safety is an increasingly important issue to be studied. Therefore, this study aims to analyze microplastic pollution in the context of food safety and evaluate its potential impact on human health. Through the latest literature review approach, it is hoped that this research can provide a more comprehensive understanding and support the development of strategies to reduce the risk of microplastic pollution in the future.

2. Literature Review

2.1. Microplastics in the Aquatic Environment

Microplastics are one form of pollutant that is currently of global concern due to their persistent existence and difficulty in degrading in the environment. Microplastics are formed from two main sources, namely primary microplastics produced directly in small sizes, and secondary microplastics derived from the degradation of large plastics due to physical, chemical, and biological processes in the environment (Llorca et al., 2020). The presence of microplastics has been detected in various compartments of the aquatic environment, including water

columns, sediments, and living organisms, indicating a wide and complex degree of distribution.

In aquatic ecosystems, microplastics can enter through various pathways, such as land runoff, domestic waste, industrial activities, and the degradation of plastic waste in the sea. Microplastic particles that are small in size allow them to remain suspended in water or settle in sediment, depending on their physical and chemical characteristics. This causes microplastics to interact with various organisms at different trophic levels (Zhang et al., 2022). In addition, microplastics also have the ability to absorb other pollutants in the environment, thereby increasing their potential ecological impact.

Aquatic organisms, particularly those at low trophic levels such as plankton, are at high risk of consuming microplastics due to the size of particles that resemble natural food sources. This process then continues through the food chain to higher organisms, including fish and other marine life (Walkinshaw et al., 2020). The accumulation of microplastics in the food chain is a major concern because it has the potential to disrupt the balance of ecosystems and increase the risk of exposure to other organisms, including humans.

Thus, the presence of microplastics in the aquatic environment not only has an impact on environmental quality, but also contributes to broader problems, including food safety and human health. Therefore, understanding the source, distribution, and dynamics of microplastics in the aquatic environment is important as a basis for pollution management and mitigation.

2.2. Microplastics in Food Safety and Human Health

The presence of microplastics in the food chain has raised serious concerns about food safety aspects, especially in seafood products that are widely consumed by humans. Various studies show that microplastics have been found in different types of marine organisms that have high economic value, such as fish, shellfish, and shrimp (Chen et al., 2020). This shows that microplastics are not only an environmental issue, but have also entered the human food system.

Microplastics contained in seafood have the potential to have a more complex impact than other contaminants. In addition to being physical particles, microplastics can also act as vectors that carry various harmful substances, such as heavy metals and persistent organic compounds. These substances can be adsorbed on the surface of microplastics and then enter the body of the organism that consumes them, thereby increasing the potential for toxicity (Usman et al., 2020). This condition makes microplastics a new threat in the context of food safety.

In terms of human health, exposure to microplastics through food consumption is still a topic that continues to be researched. Several studies suggest that microplastics can cause a variety of biological effects, such as inflammation, oxidative stress, as well as disturbances in the digestive system and gut microbiota (Li & Liu, 2024). In addition, the very small size of microplastics allows these particles to penetrate biological tissues and potentially accumulate in the human body, although their mechanisms and long-term impacts are still not fully understood.

However, the level of public understanding of the risks of microplastics in food is still relatively low. Studies show that public awareness of plastic pollution has not been followed by a deep understanding of its impact on health (Deng et al., 2020). Therefore, more intensive research and education efforts are needed to increase public understanding and support science-based policy making in overcoming microplastic problems.

3. Methods

This study uses the Systematic Literature Review (SLR) approach to comprehensively examine various scientific findings related to microplastic pollution and its implications for food safety and human health. The SLR method was chosen because it is able to provide a systematic, transparent, and structured synthesis of relevant literature, so as to produce a deeper understanding of the topic being studied. The research process begins with the formulation of research questions that focus on how microplastics pollute the aquatic environment, how microplastics enter the food chain, and how they impact food safety and human health.

The next stage is the process of searching literature which is carried out systematically through scientific databases such as ResearchGate, Elsevier, especially Google Scholar, using keywords such as "microplastics", "food safety", "seafood contamination", "human health", and a combination of these keywords. The inclusion criteria in this study include scientific articles published in the last five years, written in English or Indonesian, and have direct relevance to the topic of microplastics and food safety. Meanwhile, the exclusion criteria include articles that

do not have full access, do not go through a peer-review process, or are not directly related to the focus of the research.

After the search process is carried out, the articles obtained are then selected through several stages, namely selection based on the title, abstract, and full content of the article. This stage aims to ensure that only the truly relevant literature is used in the analysis. Articles that pass the selection are then analyzed in depth to identify important information, such as the source of microplastics, contamination pathways in the food chain, impacts on marine organisms, and potential risks to human health. The data obtained from each article is then classified based on key themes to facilitate the synthesis process.

Furthermore, the process of analysis and synthesis of data was carried out by integrating various findings from the selected literature. This approach allows researchers to compare the results of different studies, identify similarities and differences, and find patterns or trends that emerge in studies related to microplastics and food safety. The results of this synthesis are then used to compile a comprehensive and structured discussion.

Using the SLR method, this study is expected to provide a comprehensive overview of the latest research developments related to microplastics and their implications for food safety. In addition, this approach also makes it possible to identify research gaps that still exist, so that it can be the basis for further research in this area.

4. Results and Discussion

Based on the results of a literature review conducted through a systematic literature review approach, it is known that microplastic pollution has become a significant global issue and has continued to increase in recent years. Microplastics are found extensively in various compartments of the aquatic environment, both in water columns, sediments, and in the bodies of aquatic organisms. This suggests that microplastics have persistent and easily distributed properties, making them difficult to control (Sana et al., 2020). The presence of microplastics in the aquatic environment is influenced by various factors, including the high use of single-use plastics, low recycling rates, and suboptimal waste management.

The process of microplastic formation, both from primary and secondary sources, also contributes to the high number of microplastic particles in the environment. Secondary microplastics derived from the degradation of large plastics are a major contributor to aquatic environmental pollution (Llorca et al., 2020). This degradation process is influenced by environmental factors such as ultraviolet radiation, temperature, and biological activity. Over time, plastic particles will fragment into smaller sizes and disperse more easily, increasing their potential interactions with living organisms.

The wide distribution of microplastics in the aquatic environment causes these particles to easily enter the food chain. Low-trophic level organisms, such as plankton and benthic organisms, are at high risk of consuming microplastics due to the particle size that resembles natural food sources (Walkinshaw et al., 2020). Once ingested, microplastics can move to higher trophic level organisms through the

process of biomagnification, thereby increasing the concentration of microplastics in the food chain. This condition is a serious concern because in the end microplastics can reach humans through seafood consumption.

Various studies show that microplastics have been found in various types of seafood that are commonly consumed, such as fish, shellfish, and shrimp (Chen et al., 2020). These findings indicate that microplastics have entered the human food system and have the potential to pose a threat to food security. In addition, the results of the research in the analyzed article show that microplastics are found in the digestive tract of various marine life for consumption, which strengthens the evidence that microplastic contamination in seafood is a real phenomenon and needs serious attention.

From a food safety perspective, microplastics have unique characteristics compared to other contaminants. Microplastics not only act as physical particles, but also as carriers of harmful substances. The surface of microplastics that are hydrophobic allows these particles to absorb various environmental pollutants, such as heavy metals and persistent organic compounds (Unuofin & Igwaran, 2023). When these contaminated microplastics enter the body, these harmful substances can be released and cause toxic effects. This increases the complexity of the risks posed by microplastics in the context of food safety.

In addition to carrying external pollutants, microplastics can also contain additional chemicals used in their production processes, such as plasticizers and stabilizers. These substances are potentially toxic and can affect the biological systems of exposed organisms. Thus, microplastics can have a dual impact, both as

physical particles and as a source of chemical contaminants. This condition makes microplastics a more complex threat compared to other conventional contaminants (De-la-Torre, 2020).

In terms of human health, exposure to microplastics through food consumption, especially seafood, is a growing concern. Although research on the impact of microplastics on human health is still limited, some studies suggest that microplastics can cause a variety of adverse biological effects. Microplastics are known to trigger inflammation, oxidative stress, and disorders of the digestive system (Li & Liu, 2024). In addition, the very small size of microplastics allows these particles to penetrate biological tissues and potentially accumulate in the body's organs.

Furthermore, microplastics can also affect the balance of the human gut microbiota. Disruptions in the gut microbiota can impact a variety of bodily functions, including the immune system and metabolism. Some studies suggest that exposure to microplastics can lead to changes in the composition of the gut microbiota, potentially leading to long-term health effects (Sana et al., 2020). However, the exact mechanism and long-term impact of microplastic exposure on human health still require further research.

In addition to biological aspects, the level of exposure to microplastics in humans is also influenced by food consumption patterns. High seafood consumption can increase the risk of microplastic exposure, especially if the seafood comes from a polluted environment. This suggests that environmental factors and

consumption behavior play an important role in determining the level of risk of microplastic exposure in humans.

On the other hand, the results of the study also show that the level of public knowledge and awareness of microplastics is still relatively low. Although some people are aware of the existence of plastic pollution, a deep understanding of microplastics and their impact on food safety is still limited (Deng et al., 2020). This is in line with the findings in the article analyzed, which show that most respondents do not yet have a good understanding of the impact of microplastics on human health. This limited understanding can hinder efforts to mitigate and reduce the risk of microplastic pollution.

The lack of public understanding also has an impact on behavior in the use of plastic. The high use of single-use plastics is still one of the main factors contributing to microplastic pollution in the environment. Therefore, increasing public awareness and education is an important step in reducing microplastic pollution. In addition, the results of the study show that efforts to control microplastic pollution require a comprehensive approach and involve various parties. Government policies, effective waste management, and changes in people's behavior are key factors in reducing microplastic pollution. This approach needs to be supported by ongoing scientific research to provide a solid foundation for policymaking.

Despite the extensive research that has been conducted, there is still a considerable knowledge gap regarding microplastics, especially in terms of long-term impacts on human health. Most research still focuses on the environment and

marine organisms, while research on impacts on humans is limited. This shows the need for further multidisciplinary research to comprehensively understand the risks posed by microplastics. The results of this study show that microplastics are a complex and multidimensional issue, which is not only related to environmental pollution, but also has serious implications for food safety and human health. Therefore, an integrated effort between research, policy, and public education is needed to effectively overcome this problem.

5. Conclusion

Microplastic pollution has evolved into a global environmental issue with far-reaching implications for food safety and human health. Based on a review of the literature, microplastics have been shown to be widely distributed in aquatic environments and are capable of entering the food chain through aquatic organisms. The presence of microplastics in various types of seafood indicates that this contamination has reached the human food system and has the potential to become a significant source of exposure. In the context of food safety, microplastics have complex characteristics because they act not only as physical particles but also as carriers of hazardous substances such as heavy metals and toxic chemical compounds. This increases the potential risks to consumers, particularly through the consumption of contaminated seafood. From a health perspective, although scientific evidence is still evolving, microplastics are known to potentially cause biological disturbances such as inflammation, oxidative stress, and disruptions to the digestive system and gut microbiota.

Furthermore, the low level of public understanding regarding the risks of microplastics poses a unique challenge in mitigation efforts. This lack of awareness contributes to high plastic usage and insufficient waste reduction efforts, thereby exacerbating pollution conditions. Therefore, a comprehensive approach is needed through increased research, public education, and more effective waste management policies. Based on the research conducted, microplastics represent a multidimensional threat that requires serious attention from various stakeholders. Collaborative efforts between researchers, the government, and the public are essential to reduce the impacts of microplastic pollution and safeguard food safety and human health in the future.

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