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The Role of Environmental Law in Resolving the Effects of Microplastic Contamination on Food Security

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Abstract

There is a growing concern regarding the prevalence of microplastics in the environment and food chain due to the fact that these particles may compromise the quality of food as well as the general population's health. This study examines the role that environmental law plays in finding solutions for the microplastics' effects on food security from production to consumption. In order to appreciate how microplastics permeate the environment and the food chain, the study first investigates the various forms, sources, and entry points for these materials. It is also investigated how various enterprises and activities affect the amount of microplastics in the food supply.

The investigation examines the potential health risks and nutritional effects of consuming food tainted with minute plastic particles, which eventually accumulate in living organisms. The financial effects of microplastic contamination on the food supply chain are also discussed, with an emphasis on potential costs and losses for the food industry and consumers.

Legal provisions at both international level and international level are examined and discussed as well as strategies for reducing microplastics' impact on food security, and best management practises. In order to address the problem of microplastics in the food chain, it also touches on the significance of stakeholder engagement and public awareness. In order to address microplastic contamination in the food chain, the article summarises the research findings and makes recommendations for legislative measures.

Keywords: *Environmental Law, Microplastics; Food security & Food chain; Pollution; Plastic waste' Environment & Health risks; Mitigation strategies.*

1. Introduction

Recent years have seen a rise in the urgency of the issue of the effects of microplastics on the environment and human health. The term "microplastics" refers to tiny plastic particles that are less than 5 mm in size and have been found in a variety of habitats, including freshwater, marine environments, and even our air. They can build up in food

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chains and come from a variety of sources, such as synthetic textiles, industrial processes, and cosmetic goods. There is a need to look into microplastics' possible effects on food security and public health given that if they can linger for a very long period may negatively affect the environment.

Food stability means having enough healthy food available to live a healthy life. It is an important facet of human welfare, and any threat to it may have severe consequences, particularly for weaker populations. The extensive use of microplastics in the food chain raises concerns about their impact on food safety. Microplastics can enter the food chain through human and animal intake, soil and water contamination, and marine life ingestion.

This study examines the food chain to determine how microplastics affect food security. This study examined microplastic sources, how they enter the food chain, and their consequences on food production. The study will focus on vulnerable people, examine microplastics' effects on human health and the environment, identify information gaps, and suggest further research.

2. Presence and Abundance of Microplastics in Different Stages of the Food Chain:

The possible effects of microplastics on the environment and public health have made them a major worry in recent years. Consuming tainted food is one of the primary ways that humans are exposed to microplastics. As evidence of their pervasive presence in the food chain, microplastics have been discovered in a number of food products, including seafood, honey, and bottled water (Guzzetti et al. 2020).

These studies show how pervasive microplastics are throughout the food chain and emphasise the need for additional study to comprehend their prevalence and distribution. Due to their small size, variety of shapes and compositions, and presence in dietary and environmental samples, microplastics can be difficult to detect and quantify(Guzzetti et al. 2020).

i. Temporal patterns of microplastic abundance in different stages of the food chain

a. In the United Kingdom a study had examined sediment and water samples from two estuaries and discovered that microplastics were present in all samples, however they were more prevalent in the estuary that was closer to populated areas (Horton et al. 2017). A different study examined fish from several parts of Indonesia and discovered that microplastics were present in all samples, with the gastrointestinal tract having the highest concentration (Neumann et al. 2021).

b. The geographical and temporal diversity in microplastic abundance at various points in the food chain is shown by this research. Numerous elements, such as closeness to urbanised areas, manufacturing and processing techniques, and meteorological conditions, might be blamed for the fluctuation (Guzzetti et al. 2020).

ii. Comparison of microplastic abundance in different food products and regions

a. Microplastics were found in all samples of the study that looked at their prevalence in different seafood products from throughout the world, with bivalves having the highest concentration (Van Cauwenberghe and Janssen 2014). A study that examined the prevalence of microplastics in bottled and tap water from various parts of the world discovered that microplastics were detected in all samples, with bottled water having the highest concentration.

b. A study had examined the prevalence of microplastics in honey from various parts of the world discovered that microplastics were detected in all samples, with honey from metropolitan areas having the highest concentration (Gallardo et al. 2021). The prevalence of microplastics in salt from various parts of the world are also a proven fact discovered, with sea salt having the highest concentration (Yang et al. 2015).

c. These studies show that microplastics are found globally in various food products and geographical areas. Numerous elements, including production and processing techniques, proximity to urbanised areas, and meteorological conditions, might be blamed for the variation in microplastic abundance.

iii. Factors influencing microplastic abundance in the food chain

a. Consumption of tainted food is one of the ways that microplastics get into the human food supply. Numerous elements, such as the sources and pathways of microplastic contamination, the characteristics of the food product, and the environmental conditions, have an impact on the abundance of microplastics at various points in the food chain.

b. There are many ways that microplastics can contaminate the environment, including wastewater discharge, air deposition, and agricultural runoff. Eerkes-Medrano et al. (2015) assert that wastewater treatment facilities are a significant source of microplastic pollution in the environment. Similar findings and the conclusion that air deposition was a substantial source of microplastic contamination were reported by Mintenig et al. (2014).

c. There could be different levels of microplastics present, depending on the product's nature. A study by Van Cauwenberghe et al. (2015), bivalves like mussels and oysters had a greater concentration of microplastics than fish. Another study by Gündodu and Içek (2018) discovered that salt samples had a higher abundance of microplastic than other food products.

d. The amount of microplastics present in the food chain can also be influenced by environmental variables such as water temperature, salinity, and pH.In reported study bivalves were found to contain more microplastic when the water was warmer (Prata et al., 2019).

e. The kind of polymer, particle size, and exposure duration are other variables that can affect the quantity of microplastic in the food chain. Study revealed that fish were more abundant with microplastics composed of polyethylene terephthalate (PET) than fish were with microplastics made of other polymers (Karlsson et al., 2017).

iv. Pathways of Microplastic Contamination in the Food Chain:

a. The fragmentation of plastic debris that can happen during the creation, use, and disposal of plastic products is one large potential source of microplastics in the food chain (Ziajahromi et al., 2018). Plastics can also be dumped directly into streams and seas, sewage systems, and stormwater runoff, where they can degrade into tiny particles that marine life can consume (Rochman et al., 2015).

b. Microplastics can enter the food chain through agricultural practises such as the usage of plastic mulch and irrigation systems in addition to plastic trash (Huang et al., 2021). The possible route for the contamination of crops and other vegetation with microplastics is atmospheric deposition (Galloway et al., 2017).

c. The use and manufacture of plastic packaging materials also contribute to the contamination of the food chain with microplastics. Plastic bags, bottles, and containers used for food packaging can release microplastic particles that can contaminate food products (Koelmans et al., 2019; Zhang et al., 2021).

d. Microplastic contamination can also result through the production and transportation of food products, as machinery and equipment can release plastic particles into the food stream (Hidalgo-Ruz and Gutow, 2018). Microplastic contamination of the food chain can also be caused by human activities such as littering and beachgoing (Jabeen et al., 2017).

e. Food chain sources and types of microplastics:

Microplastics, which can be found in both terrestrial and aquatic ecosystems and are available in a wide range of sizes and shapes, are persistent environmental contaminants. The environment and food chain are home to a wide range of sources and forms of microplastics. It is crucial to comprehend the sources and varieties of microplastics in order to lessen their negative effects on the ecosystem and general health.

The primary sources of microplastics include sewage treatment plants, home garbage, industrial activity, and agricultural runoff. Industry sectors like textile, personal care, and packaging contribute to the release of microplastics into the environment through the production and disposal of their products. Domestic waste and sewage treatment facilities also contribute to the environmental release of microplastics through the discharge of wastewater into aquatic systems. Microplastics are also found in substantial amounts in agricultural runoff, which enters the soil and waterways via the use of plastic mulch films and other plastic goods.

Several kinds of microplastics come in a variety of shapes and sizes, and their chemical makeup might change depending on where they come from and what they are used for. Depending on their size and structure, microplastics can be divided into fibres and fragments being the two primary forms.

3. Health Risks Associated with the Ingestion of Microplastics-contaminated Food:

Food contaminated with microplastics may be harmful to both people and wildlife when consumed. Microplastics' toxicological impacts on both people and wildlife According to studies (Wagner et al., 2014; Teuten et al., 2009), microplastics can harm living things by causing oxidative stress, inflammation, and DNA damage. In addition, microplastics can build up in tissues and organs, which could have an impact on long-term health (Lusher et al., 2013).

Microplastics can enter living beings through a number of different pathways, including inhalation, skin contact, and ingestion (Rochman et al. 2015). After ingesting microplastics, they can accumulate in tissues and organs, which may be harmful to health (Wright et al., 2013).

Microplastics might decrease nutrient intake and energy levels by preventing living things from receiving nutrients (Galloway et al., 2017). Furthermore, the noxious compounds and substances found in microplastics may lower the nutritional value of food (Horton et al., 2017).

Recent epidemiological research on the connection between exposure to microplastics and harmful human health consequences, like inflammation and autoimmune illnesses, suggests that these effects may be due to microplastic exposure (Hartmann et al., 2019). Similar reproductive and developmental problems have been observed in wildlife exposed to microplastics (McCauley et al., 2019).

4. Impacts of Toxicology and Ecotoxicology on the health

Toxicology evaluates the potential adverse health effects of microplastics on consumers, such as endocrine disruption, immune suppression, and carcinogenicity. According to Kumar et al. (2018), the endocrine system disruption caused by microplastics has been related to hormonal imbalances, developmental problems, and reproductive problems in both humans and animals. A person's immune system may be suppressed by prolonged exposure to microplastics, leaving them more susceptible to infections and diseases (Della Torre et al. 2014). Microplastics have also been connected to DNA deterioration and other negative consequences that, over time, may result in cancer (Wang et al. 2017).

There are numerous ways in which microplastics may endanger the life and general health of species that are not their intended targets. Ingesting microplastics can cause physical blockages, internal damage, and nutritional deficits in fish and other aquatic creatures (Browne et al. 2008). (Teuten et al. 2007) claim that microplastics can accumulate in the tissues of marine animals and have a long-term effect on behavior, reproduction, and growth.

Wildlife such as birds and small animals may consume microplastics in terrestrial ecosystems, which may have consequences comparable to those seen in aquatic organisms. Through modifying soil characteristics and nutrient cycling, microplastics can have indirect effects on terrestrial ecosystems (Huerta Lwanga et al. 2016).

By performing laboratory and field investigations, reviewing data from ecological monitoring programmes, and creating models to foretell the fate and movement of microplastics in the environment, ecotoxicologists assess the effects of microplastics on non-target animals. They evaluate a number of variables, including the concentration, size, and shape of microplastics, the route of exposure, and the sensitivity of the exposed organism.

5. Chemistry and analytical methods to quantify microplastics in different matrices

Analytical chemistry methods are required to locate, quantify, and describe microplastics in various environmental samples. To mention a few, chemists create and improve analytical procedures based on a variety of approaches, including Fourier Transform Infrared Spectroscopy, Raman spectroscopy, Scanning Electron Microscopy, and Transmission Electron Microscopy. These techniques aid in separating microplastics from other particles and differentiating between different kinds of microplastics according to their physical and chemical characteristics.

In order to separate microplastics from complex environmental samples including sediments, soils, and biological tissues, chemists also create extraction and purification techniques. These procedures extract and concentrate microplastics from the target matrix using a variety of sample preparation processes, such as digestion, filtering, and centrifugation.

Chemists can detect and quantify microplastics once they have been extracted using a variety of analytical procedures, including counting the particles or analysing their size, shape, and chemical makeup. These investigations offer vital information for determining the sources and pathways of microplastic pollution as well as the degree and volume of microplastic contamination in various ecosystems.

6. Engineering and testing technologies to remove microplastics in different settings

In order to remove or filter out microplastics from various environmental matrices, including wastewater, soil, and water bodies, engineers build and optimise treatment procedures and systems. They develop and test cutting-edge treatment techniques to filter out microplastics from wastewater before releasing it into the environment, such as membrane filtration, ozonation, and adsorption. In order to stop microplastics from building up in the soil and potentially being absorbed by crops, they also use designed systems to trap them in agricultural areas, such as sedimentation ponds, filtration trenches, and soils altered with biochar.

In aquaculture facilities, where microplastics can build up in fish and other aquatic species, engineers also design and test solutions to remove microplastics. They create and test cutting-edge filtration methods to remove microplastics from the water used in aquaculture systems, lowering the risk of microplastic contamination of fish and other aquatic species.

Engineers also work on developing monitoring and assessment tools to track and measure the levels of microplastics in various environmental matrices, which aids in determining the sources and pathways of microplastic pollution and assessing the efficacy of developed treatment technologies.

7. Economic implications of Microplastic Contamination in the Food Chain:

Economic ramifications of microplastic contamination in the food supply chain have an impact on a variety of stakeholders, including producers, consumers, and regulators. Producers are impacted by microplastic contamination because they may have to pay higher production costs and adhere to stricter food safety rules. According to Hartmann et al. (2019), the European Union has established restrictions for the amount of microplastics that can be found in food, which may force businesses to adopt new production techniques and testing procedures. The price of food may rise as a result of these regulations' implementation costs being passed on to consumers.

Secondly, product recalls brought on by microplastic contamination can cost manufacturers money and hurt their reputations which can be evidenced from the fact when Nestle Company voluntarily recalled their Hot Pockets products in 2021 because they contained glass and plastic shards that could harm or ill-treat consumers (Food Safety News, 2021).

Thirdly, customers may modify their eating habits in response to worries about microplastic contamination. A poll of Chinese customers indicated that more than 90% of respondents were concerned about the presence of microplastics in seafood and more than 80% would pay more for seafood devoid of these particles (Liu et al., 2020). This change in consumer behaviour may have an impact on supply chains, market demand, and production prices.

Fourthly, regulating and keeping track of microplastic contamination in the food chain may cost policymakers money. Such policies demand resources to implement and enforce, which could raise the price of public services.

Fifthly, the financial effects of microplastic contamination in the food supply chain might not just be felt in the food industry but also in other sectors like tourism and recreation. The quality of recreational beaches might be impacted by microplastic contamination in coastal waters, which would result in lower tourism receipts (Depledge&Galgani, 2019).

8. Legal Provisions

i. International Conventions and Agreements:

a. The Stockholm Convention on Persistent Organic Pollutants:

The Stockholm Convention on Persistent Organic Pollutants is crucial for tackling the serious problem of microplastic contamination that may include harmful substances. This international agreement, which was approved in 2001, focuses on a number of dangerous compounds that are known to be associated with microplastics.

The Stockholm Convention has a crucial role to play in decreasing these dangerous substances. The Convention indirectly reduces the presence of hazardous components in the cycle of microplastic contamination by controlling and gradually phaseing out their production and usage. The potential toxicity of microplastics in aquatic habitats and the food chain is lessened as a result.

The Convention also supports worldwide efforts to prevent microplastic pollution at its source by fostering international collaboration and knowledge exchange among nations to monitor and control harmful substances. The Stockholm Convention encourages collaboration between nations in controlling and monitoring dangerous substances, particularly those that might be connected to microplastic contamination. This cooperative strategy enables nations to put controls and mitigation measures in place to reduce the release of these pollutants into the environment, especially the oceans and other water bodies where microplastics are common.

Additionally, the Convention's emphasis on responsible chemical and waste management is consistent with the bigger objectives of reducing plastic pollution. The Convention inadvertently supports initiatives to reduce the hazards to the environment and human health posed by microplastics by lessening the presence of hazardous substances in the environment.

b. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal:

The Basel Convention governs international trade and waste management in relation to the transboundary movement of hazardous wastes, especially plastic trash. It creates a framework for nations to regulate and keep track of the import and export of hazardous wastes, ensuring that these substances don't endanger human health or the environment. The Convention mandates that before sending garbage across borders, generators of hazardous waste must notify and gain approval from receiving nations. By using this method, hazardous trash is not dumped in less developed countries and appropriate waste management is encouraged. The Basel Convention is crucial in limiting the flow of plastic garbage globally and reducing its detrimental effects on the environment and human health.

c. United Nations Convention on the Law of the Sea:

In order to preserve the marine environment, the United Nations Convention on the Law of the Sea establishes a thorough legal framework. This convention includes several clauses that address legal environmental protection to maritime pollution. States are required under UNCLOS to stop, limit, and manage pollution from a variety of sources, including land-based operations, shipping, and seabed mining. This method is appropriate to solve the problem of microplastic pollution as it focuses on the preservation and protection of the marine ecosystem as well.

The provisions of UNCLOS that deal with marine debris and the avoidance of vessel pollution are relevant to addressing microplastic pollution. These rules apply to microplastics since they are a common type of marine waste. States are expected to take action to prevent and decrease plastic marine pollution, particularly microplastics, which can harm marine life and ecosystems.

As microplastics are consumed by marine species, they have the potential to enter the food chain, which is why UNCLOS emphasizes the need to conserve living marine resources. In turn, this helps reduce the hazards related to seafood contamination with microplastics and its possible negative effects on human health by encouraging states to work together to protect the maritime environment.

ii. Law of the European Union:

a. The REACH Regulation (Registration, Evaluation, Authorization, and Restriction of Chemicals) is applicable to microplastics because it addresses the chemicals and additives used in their production and formulation. Any chemical substance, including those used in microplastics, must be registered, evaluated for safety, and given authorization prior to being put on the market under REACH. Data on chemical safety, including potential negative effects on the environment and human health, must be provided by producers and importers. Specific chemicals or additives that are deemed to cause dangers can be limited or even outright banned by authorities. REACH is thus an essential tool for managing and regulating the chemicals linked to microplastics, ensuring their safe use and reducing their negative impacts on the environment and human health.

b. Single-Use Plastics Directive:

The European Union intends to address microplastic contamination by lowering the usage and manufacture of single-use plastics dramatically. The production and sale of some single-use plastic goods, like as straws, cutlery, and cotton buds, are restricted by the Single-Use Plastics Directive, which it has put into effect. Furthermore, it encourages "extended producer responsibility," where manufacturers are financially liable for the collection and handling of plastic garbage. By reducing the frequency of throwaway plastics, the EU hopes to reduce the principal source of microplastic pollution, reducing its entry into the environment and food chain, and eventually protecting ecosystems and human health.

iii. International Environmental Treaties:

Through a number of objectives, such as the preservation of ecosystems, the sustainable use of biodiversity, and the just and equitable distribution of benefits from genetic resources, the Convention on Biological Diversity (CBD) aims to protect biodiversity. These objectives are directly related to the consequences of microplastic contamination on ecosystems and species. Sustainable biodiversity usage helps to decrease the detrimental effects of microplastics by fostering responsible consumption and production behaviors.

iv. Corporate accountability and responsibility:

Corporate social responsibility legal frameworks seek to make industries accountable for microplastic pollution. Existing legislation may include environmental rules and product liability, in which corporations making or utilizing microplastics may be held accountable for environmental damage. Future legal initiatives to promote CSR could include tougher pollution control legislation, extended producer responsibility programs requiring producers to handle microplastic waste, and fines for noncompliance. Furthermore, civil and class-action lawsuits may rise, putting pressure on businesses to adopt more environmentally friendly methods. Prospective legislation should promote pollution avoidance, waste reduction, and sustainable manufacturing while penalizing companies that fail to follow responsible practices.

9. Mitigation Strategies to Reduce the Impact of Microplastics on Food Security:

Effective mitigation measures must take into account a number of variables, including minimising the sources and pathways of microplastic pollution, avoiding human exposure, and promoting sustainable production and consumption practises.

Improvements in waste management procedures are one mitigation technique. The amount of microplastics entering the environment and food chain can be considerably decreased by properly disposing of and reusing plastic debris. High-density polyethylene and polyethylene terephthalate are two plastics that can be protected from becoming microplastics by recycling programmes (Muoz-Palazón et al., 2020). Utilising cutting-edge technologies like pyrolysis and gasification can assist in turning plastic trash into valuable products, decreasing the quantity of plastic waste in landfills (Liu et al., 2021).

Alternative product designs and packaging materials can also limit the release of microplastics. Using packaging materials that are biodegradable and compostable in place of conventional plastics can lower the risk of microplastic contamination (Dorey et al., 2021).

Using agricultural best management practises, such as avoiding plastic mulch and reducing the use of plastic in irrigation, can lessen the contamination of food production with microplastics (Hansen et al., 2020). Using sustainable farming techniques like conservation tillage and cover crops can enhance soil health and lessen the need for synthetic fertilisers, which have the potential to discharge microplastics into the environment (Wang et al., 2021).

10. Stakeholder Engagement and Public Awareness:

To solve the problem of microplastic contamination in the food chain, it is necessary to involve stakeholder and public awareness. The effect of microplastics on food security can be lessened by stakeholders, including legislators, business executives, as well as consumers. Effective communication and policy suggestions can encourage discussion among stakeholders.

In a study published in 2018, (Pivokonsky et al. 2018) put the light on the significance of including stakeholders in treating microplastic pollution. To fully address the issue, the study focused on the necessity for cooperation among politicians, business, and civil society. Consumer awareness of microplastic pollution in seafood was assessed in another study done by Alves et al. (2021). The results revealed that consumers were unaware of any potential health consequences while they were concerned about the issue.

Increasing public knowledge of the problem at hand can be a key goal of effective communication methods. Social media platforms may be helpful for fostering public discourse on microplastic contamination (Prata et al., 2020). Interacting with famous people and influencers on social media may aid in raising awareness of the problem.

Policy ideas may also help stakeholders' discussions concerning microplastic contamination. Wright et al.'s analysis from 2021 claims that a comprehensive, multi-sectoral approach is necessary to address the issue. The study examined legislative tactics for reducing ocean plastic pollution. The study recommended expanding producer accountability and providing financial incentives as legislative measures to reduce plastic waste.

11. Conclusion and Recommendations for Policymakers and Industry Leaders:

A substantial environmental and public health concern has evolved as a result of microplastic contamination in the food chain. The possibility of harmful health effects from ingesting microplastics raises concerns due to their abundance in food goods. According to studies, microplastics can collect in the tissues of living things and produce toxicity, which can have an impact on both human health and the ecological balance of the environment.

A synthesis of research findings on the sources and pathways of microplastic contamination in the food chain, health risks associated with ingesting microplastics, and potential mitigation strategies can have an impact on the development of legislative frameworks and voluntary initiatives to address this issue. Regulations could be made to restrict the use of particular plastic container types or to require the labelling of products that include microplastics. Leaders in the industry can take voluntary initiatives, such as implementing eco-friendly packaging or developing fresh techniques for eliminating microplastic from food and water.

Henceforth, more extensive environmental and public health laws are needed to address the issue of microplastic contamination in the food chain. Policy and research should focus upon microplastic contamination in the food chain and its mitigation. Microplastics in food products have to be regulated and monitored to understand their ecological and health hazards.

Researchers, corporate leaders, and politicians are to cooperate in order to create effective regulatory frameworks and solutions so as to reduce microplastic contamination in the food chain. This could include using best management practices in agriculture, creating cutting-edge technology to remove microplastics from food and water, as well as supporting the use of different packaging materials and product designs in order to reduce the amount of microplastics that get into the environment.

A new idea for cross-sector collaboration can help reduce microplastic pollution and keep food safe. Academia business, , and government cooperation can help research and implement new ways to reduce microplastic inputs to the environment, such as better waste management or packaging materials. Cooperation could potentially lead to new microplastic removal methods for food and water.

Stakeholder involvement and public knowledge are necessary for effective policy development and execution. Policymakers and business leaders should interact with stakeholders to better understand their perspectives on the issue of microplastics in the food chain and to develop effective communication methods to raise public awareness and comprehension of this problem. Increased accountability and openness within the industry can be influenced by public discourse.

12. Limitations of Study

New techniques for their detection, quantification, and analysis in various environmental matrices, including food products, have been developed as a result of advances in the understanding of microplastics from a scientific perspective. To find microplastics in seafood, honey, and other food products, research have employed spectroscopic methods as Raman and Fourier-transform infrared spectroscopy (Catarino et al., 2020; Gündodu et al., 2020). In addition, studies have classified several kinds of microplastics according to their size, shape, and polymer content, offering information about their genesis, movement, and environmental fate (Wang et al., 2020).

However, there are still information gaps and research demand despite the advancements achieved in the scientific understanding of microplastics. The research (Hartmann et al., 2019; Horton et al., 2020) have shown the necessity for more standardised methodologies for microplastic sampling and analysis to provide accurate and comparable data across studies and geographies. The interactions of microplastics with other pollutants, such as pesticides and diseases, in the food chain and their combined impact on human health and the environment also require further research (Hale et al., 2021).

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