MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 2719-2723

THE EFFECT OF MICROPLASTIC WASTE ON THE SUSTAINABILITY OF THE FOOD CHAIN IN THE ENVIRONMENT AND RECYCLING INTO VARIOUS PRODUCTS

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Abstract. Plastic waste has become an increasingly pressing global issue, with enormous impacts on the environment, human life, and the sustainability of the food chain. Plastics used in various products, from packaging to everyday items, often end up in landfills or, worse, polluting the outdoors. Dumped plastics in the ocean, rivers, or land environments can persist for hundreds of years without naturally decomposing. During this time, plastics can pollute ecosystems and negatively affect living things that depend on the food chain. Microplastics can enter an organism's body through the consumption of food contaminated with plastic. Marine organisms, such as fish, crustaceans, and plankton, are the most vulnerable to microplastic accumulation. Such accumulation not only jeopardizes the sustainability of these species' populations but also threatens the entire ecosystem and the health of humans who consume microplastic-contaminated marine products. Non-governmental organizations play a crucial role in environmental protection, sustainability, and skill development. Therefore, the effect of microplastic waste on the sustainability of the food chain and recycling in the environment is important to study. The public needs to be made aware of the harm that microplastics cause to the ecosystem as well as the direct and indirect effects they have on humans. So, the formulation of the problem What are the effects of harmful microplastic waste on the sustainability of the food chain? How is the recycling of microplastics into products, and what factors affect us as humans, both directly and indirectly? Plastic waste harms the food chain, so the research aims to recycle microplastics into various products. And the research methods used are theoretical and previous tests. Therefore, we conclude that the chemicals in microplastics pose a potential danger to human health.
Keywords: Microplastics; Plastic Waste; Food Chain Sustainability; Recycling Technologies; Marine Ecosystems;

1. Introduction

Plastic waste has become an increasingly pressing global issue, with enormous impacts on the environment and human life. Plastics used in various products, from packaging to everyday items, often end up in landfills or, worse, polluting the outdoors. One of the major problems arising from plastic waste is its impact on the environment and the sustainability of the food chain. Dumped plastics in the ocean, rivers, or land environment can persist for hundreds of years without naturally decomposing. During this period, plastics can contaminate ecosystems and negatively affect living things that depend on the food chain. Microplastics can enter an organism's body through the consumption of food contaminated with plastic.

Marine organisms, such as fish, crustaceans, and plankton, are the most vulnerable to microplastic accumulation. This not only jeopardizes the sustainability of these species' populations but also threatens the entire ecosystem and the health of humans who consume microplastic-contaminated marine products. The role of NGOs in environmental protection and sustainability, human rights, women's empowerment, world peace, fighting poverty, health campaigns, skills and capacity building for childcare, and fighting. The effect of microplastic waste on the sustainability of the food chain and recycling in the environment is a critical and relevant topic today. To socialize this, we must teach the public about microplastics' effects on the ecosystem and humans.

The formulation of the problem is what elements of harmful microplastic waste affect the sustainability of the food chain, and how is the recycling of microplastic into products and what factors affect us as humans, both directly and indirectly? The purpose of the research is to know the elements and factors that are harmful from plastic waste to the sustainability of the food chain and to know the recycling of microplastic into various biodegradable products. The research method was the descriptive research method and literature study.

2. Literature Review

2.1. Definition of microplastics, the influence of elements and composition contained in microplastics

According to [1], microplastics are plastic particles <5 mm in size that come from the degradation of large plastics (secondary microplastics) or are deliberately produced in small sizes such as microbeads (primary microplastics). And the main types of synthetic polymers are Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Polyvinyl chloride (PVC), and Polyethylene terephthalate (PET). Each of these types of polymers consists of long carbon chains with specific functional groups, which determine their physical properties.

The chemical elements that make up microplastics are composed of carbon (C) and hydrogen (H), some plastics also contain other elements, depending on the polymer and additives are oxygen (O), Chlorine (Cl), Nitrogen (N), Sulfur (S) and heavy metals such as cadmium (Cd), lead (Pb), and mercury (Hg) can be found as contaminants or additives [2]. Additives and additional chemical composition are to improve mechanical properties, color, or durability, microplastics often contain plasticizers, UV stabilizers, dyes/pigments and flame retardants. The impact and significance of the chemical composition of microplastics is very important because it determines their interaction with the environment and organisms, where some additive compounds are toxic and can be released into the environment or bioaccumulate in marine organisms.

2.2. Recycling microplastics into biodegradable products.

There are two types of microplastics, namely (1) large particles are plastic particles less than 5 mm in size that come from the degradation of large plastics and (2) small particles are consumer products such as cosmetics or synthetic textiles [1]. Microplastics have been found in various ecosystems, including oceans, soil and air, and can enter the human food chain through water and seafood consumption [3]. The presence of microplastics has a negative impact on the environment and health due to their non-biodegradable nature and ability to absorb and carry harmful pollutants.

The impact of microplastic recycling technology through conventional processing of microplastics is difficult due to their small particle size and mixing with other materials. However, some recent approaches involve the utilization of pyrolysis methods, bioconversion, and chemical technologies to convert microplastics into new base materials [4]. One innovative approach is biodepolymerization, which is the conversion of microplastics into simple compounds that are then used as raw materials for making bioplastics or biodegradable materials.

The role of microorganisms in the decomposition of certain microplastics, such as Ideonella sakaiensis, is able to break down PET plastic into terephthalic acid and ethylene glycol [5]. Other studies have developed consortia of bacteria and enzymes that can decompose other types of microplastics, such as polyethylene and polypropylene. These degradation products can then be used as substrates to produce polyhydroxyalkanoates (PHAs), which are natural biodegradable polymers [6]. And biodegradable products from microplastic microplastics

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are starting to be developed to reduce plastic waste and its ecological impact. Several types of bioplastics such as PHA, PLA (polylactic acid), and PBS (polybutylene succinate) are already used in packaging, agriculture, and medical industries [7]. This innovation provides an economic and ecological solution to the problem of microplastics, while maintaining process efficiency and production costs. So, although the technology is promising, there are still many challenges that need to be overcome, such as conversion efficiency, availability of enzymes or degrading microbes, and limited production scale. Further research is needed to develop microplastic recycling technology into biodegradable materials that are more efficient, cheaper, and environmentally friendly [8].

2.3. Effect of microplastic waste on the sustainability of the food chain

Microplastics can be primary (directly produced small) or secondary (the result of degradation of larger plastics due to environmental exposure) [9] (Andrady, 2011). The main source of microplastics comes from household and industrial waste, as well as the degradation of plastic waste in marine and terrestrial environments. Products such as soap, toothpaste, and synthetic clothing washing processes also contribute to the entry of microplastics into aquatic systems [2]. Microplastics enter the food chain, saying that microplastics enter the food chain through low-level organisms such as plankton, which are then eaten by higher trophic level animals such as fish, seabirds, and marine mammals. This accumulation of microplastics leads to bioaccumulation and biomagnification, where the concentration of harmful substances increases as trophic levels rise [10].

According to [2], it shows that the impact of microplastics on organisms is that they can cause physiological disorders such as tissue damage, decreased reproductive function, hormone disruption, and even death. In addition, microplastics often absorb chemical pollutants such as heavy metals and pesticides that exacerbate the toxic impact when they enter the organism's body [11]. According to [1], Implications for Food chain sustainability states that disturbances in low-level organisms will have a systemic impact on the stability of the food chain. If plankton or small fish populations are disrupted, then top-level predators will lose food sources.

In the long term, this can lead to ecosystem imbalance and potential food chain collapse. According to [12], said that human risk through the consumption of fish and seafood, microplastics can also enter the human body. Although the long-term effects are still being researched, some studies indicate potential health effects such as inflammation, metabolic disorders, and systemic toxic effects.

Recycling microplastics into biodegradable products are microplastics, small pieces of plastic less than 5 millimeters in size, that come from the degradation of larger plastic waste or can also be plastics that are manufactured in small sizes (such as in cosmetics or cleaning products). These microplastics can pollute the environment, especially in the oceans, and enter the bodies of animals and plants. The effect of microplastics on the food chain in microplastics released into the environment, especially in the ocean, can be eaten by various types of marine animals, such as plankton, fish, and other marine animals. When these animals consume microplastics, the harmful chemicals in the plastic can enter their bodies. Larger animals, such as large fish or marine mammals, will then consume them, causing microplastics to enter the food chain. As a result, microplastics can enter the bodies of humans who consume marine products, potentially causing health problems.

Impacts on Ecosystems and Biodiversity. Microplastics can damage natural habitats, such as coral reefs or sediments on the seafloor. Animals exposed to microplastics can experience health problems, ranging from digestive disorders, decreased fertility, to death. To a larger extent, this can disrupt the balance of the ecosystem and lead to population declines of certain species.

3. Research and processing methods

This research was conducted with the steps in figure 1. And the stages as follows:

Figure 1. Research Flow chart

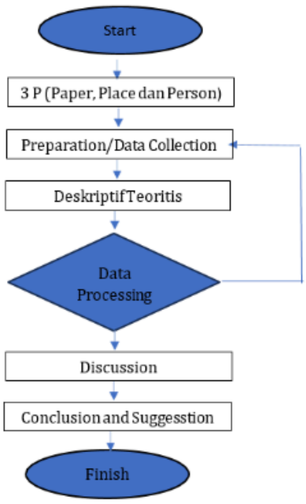

Figure 1. Research Flow chart

Research activities are carried out in three stages, namely before research activities, research activities,, and writing research reports. Before the research activities, the preliminary study is 3 P (paper/earch for references, place/eld survey,, and person/scuss with experts in their fields). So,

when it is complete, research activities continue. The type of research is descriptive research to describe systematically, factually, and accuratelythe facts and properties of certain populations or phenomena. This research does not look for cause-and-effect relationships (such as experimental research) ut rather focuses on the "what is" of the object under study.

The object of research is to prove the effect of hazardous microplastic waste on the sustainability of the food chain, the recycling of microplastic into products, namely the process of making bioplastics involving natural biodegradable materials, such as starch (from corn, cassava, or or potatoes), cellulose, or polylactic acid (PLA), and influencing factors on humans, both directly and indirectly. The research was conducted at the Faculty of Engineering, Krisnadwipayana University,, Jakarta. Data sources were taken from from secondary data. Followed by theoretical description, data processing, and and discussion, and concluded with suggestions.

4. Discussion

4.1. Effect of elements and composition contained in microplastics

The elements and composition contained in microplastics vary greatly depending on the type of plastic they come from [13].

Table 1. Elements and composition of the main elements of microplastics

NO	ELEMENT	COMPOSITION (%)	DESCIPTION
1	C	65-85	-
2	H	8-15	-
3	O	0-15	High in PET
4	Cl	0-30	Only If PVC in Pesent
5	N	0-5	If present Nylon or PU < 1 %
6	S	< 1 %	Rarely dependeng on Additive

Table 2. Elements and composition of microplastics by polymer type

NO	POLYMER TYPE	COMPOSITION (%)	DESCRIPTION/DENSITY
1	PE (Polyethylene)	30-50	0,917-0,965
2	PP (Polypropylene)	20-30	0,9-0,91
3	PS (Polystyrene)	5-10	1,04 – 1,1
4	PET (Poliethylene Terephthalate)	5-15	1,37 – 1,45
5	PVC	2-10	1,16 – 1,58

Table 3. Main elements and composition of plastic resins

NO	POLYMER TYPE	COMPOSITION (%)	DESCRPTION
1	Main Polymer (Plastic Resin)	70-99	-
2	Additive	1-30	-

4.2. Effects of hazardous microplastic waste on food chain sustainability,

The effects of hazardous microplastic waste on ecosystems and food chain sustainability can be very complex. For some of the main impacts that can occur, see table 4.

Table 4. Effects of hazardous microplastic debris on food chain sustainability [

NO	MICROPLASTIC TYPE	TYPES OF ORGANISMS	DESCRIPTION
1	Consumption of Marine Organisms (Microplastics are often ingested)	marine organisms such as plankton, small fish, crustaceans, and even marine mammals	Based on research 88% of organisms contaminated with microplastics vary.
2	Microplastic Dispersal.	Large fish, seabirds and marine mammals (bioaccumulation and biomagnification)	The transfer of microplastics from smaller organisms to larger predators, including percentages, has not been studied, however, research shows that microplastics can spread through the food chain and carry harmful chemicals, which can be detrimental to human health and ecosystems. Bioaccumulationn (marine mammals) or low-level organisms consume microplastics, their larger predators and and Biomagnification (fish, marine animals, or even plants), microplastics can transport harmful chemicals bound to their surfaces, and when organisms (such as fish, marine animals, or even plants) eat those microplastics, those chemicals can accumulate in their body tissues. transport different types of pollutants, such as pesticides, heavy metals, and persistent organic pollutants (PBTs), microplastics come from various sources such as industrial waste, agriculture, and plastic waste disposal. Consumption of seafood contaminated with microplastics may pose a risk to human health, as harmful chemicals accumulated in the tissues of marine animals can enter the human body through seafood consumption. Studies have found microplastics and hazardous chemicals in various types of seafood, such as fish, shellfish and crustaceans. , which is then consumed by humans.
3	Human exposure to microplastics.	Consumption of contaminated fish and seafood, fish, shellfish and other seafood.	It is estimated that up to 90% of shellfish worldwide contain microplastics. Microplastic Contamination in Seafood, the spread of Microplastics in the digestivesystem, reproductive system, and immune system. The main source of microplastics is plastic
			waste, including plastic bags, food packaging, and plastic bottles. Microplastics and the harmful chemicals they contain can pose significant health risks, including immune system disorders, reproductive problems, and even potential cancer. Microplastics can enter the body through a variety of pathways, including food and drink, and cause irritation, inflammation and cell damage.
4	Microplastics on Marine Ecosystems.	Changes in animal behavior.	Microplastics can affect predator and prey behavior, habitat destruction: Microplastic particles can contaminate marine habitats such as coral reefs and the seafloor. While there are no specific percentage figures, it is clear that microplastics are a serious threat to marine habitats and food chains. This pollution can have long-term impacts on marine ecosystems and human health.

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5	Microplastics in soil and freshwater bodies	Soil organisms such as worms and insects that play an important role in the decomposition of organic matter and contaminated microplastics in freshwater can move into the food chain of rivers and lakes.	Consumption by soil organisms (worms and insects can inadvertently consume contaminated microplastics in soil). Transfer to freshwater food chain (When these soil organisms are then preyed upon by freshwater animals (e.g. small fish, insects). Increased concentration (the higher the level of the food chain, the greater the potential for microplastic accumulation). Concentration levels, long-term effects and data limitations need to be considered.
6	Broader environmental effects (Microplastics in the ecosystem).	Species at risk of extinction, plactons and invertebrates	Microplastics in the ocean can disrupt the food chain in ways that could potentially lead to species extinction. Microplastics can be consumed by plankton and invertebrates, which can then cause health problems in these animals and negatively impact the food chain. Species at risk of extinction. Plankton fish, which are the base of the marine food chain, can ingest microplastics that disrupt the photosynthesis process and cause digestive problems, Invertebrates (Invertebrates, such as shellfish and shrimp, can also ingest microplastics, which can cause digestive blockages, organ damage, and reproductive problems) Fish(microplastics can attach to the gills of fish and accumulate in the digestive tract, Other Marine
			Animals (microplastics can also be found in other marine animals, such as whales and seabirds,The spread of microplastics through the food chain is direct ingestion, absorption, transfer to higher levels (when marine animals, such as fish, ingest marine organisms that have ingested microplastics, the impacts occur in digestivedisorders, organ damage, reproductive problems, etc.).

4.3. Recycling microplastics into biodegradable products

The process of making bioplastics involves natural biodegradable materials, such as starch (from corn, cassava, or potatoes), cellulose, or polylactic acid (PLA). There are PET microplastics by bacteria (bacteria can be used to decompose microplastics derived from poly (ethylene terephthalate) or PET, producing biodegradable products and bioplastic decomposition through composting (the mechanism of bioplastic decomposition through the composting process, which involves the interaction of microbes and environmental factors in soil contaminated with microplastics). Then the general steps of making starch-based bioplastics (e.g., from cassava or cornstarch):

Raw materials are starch flour (e.g., cassava starch), water, glycerol (as plasticizer), acetic acid (kitchen vinegar), and optionally natural colorants or other additives. The steps are as follows: (1) Mixing of Ingredients (Mix about 10 grams of starch flour, 100 ml of water, 5 ml of glycerol, and 5 ml of vinegar in a container), (2) Heating (Heat the mixture over low heat or an electric stove while stirring constantly, and the mixture will turn into a thick gel (starch gelatinization) and become clear after a few minutes. (3) Forming (once the mixture is sufficiently thick and homogeneous, pour it onto a mold or flat surface that has been lined with plastic/silicone mat). (4) Drying (allow the bioplastics to dry at room temperature for 24-48 hours or dry in a low-temperature oven (±60°C) for several hours). And (5) Testing & Use (After drying, bioplastics can be tested for strength or used as needed (e.g., for packaging, coatings). So that the resulting product is biodegradable. The process is a biotechnological approach, including microbial and enzymatic degradation, to convert microplastics into environmentally friendly products.

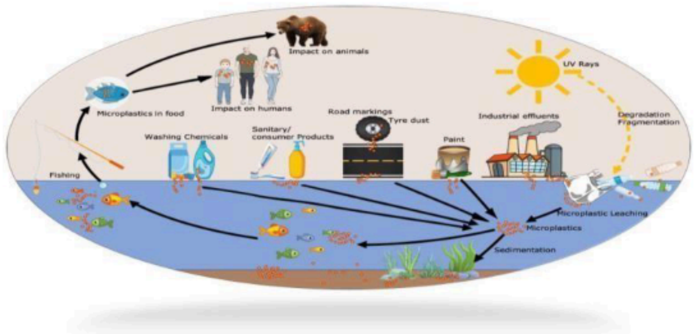

Figure 2: Research results on recycling microplastics into biodegradable products. [15]

5. Conclusion and Suggestion

5.1. The elemental and chemical composition of microplastics varies greatly depending on the type of plastic they come from (such as polyethylene, polypropylene, PVC, etc.) as well as the additives used during the production process. These variations affect the physicochemical properties of microplastics, including durability, ability to absorb pollutants, and potential toxicity. Some elements, such as chlorine, heavy metals (e.g., lead and cadmium), and additives such as phthalates and bisphenol A (BPA), can have negative impacts on the environment and the health of exposed organisms, including humans. Therefore, understanding the constituents and composition of microplastics is important to assess the ecological and health risks they pose. Standardized and accurate analytical laboratory testing (e.g., FTIR, Raman spectroscopy, SEM-EDX) is recommended to detect not only the shape and size of microplastics but also their chemical constituents.

5.2. Recycling microplastics into biodegradable products is an innovative and sustainable approach to reducing environmental pollution from plastic waste. This process addresses the accumulation of hard-to-degrade microplastics and produces eco-friendly products that can return to the natural cycle without harming the ecosystem. With proper technology development, this approach has the potential to be a long-term solution to the global plastic crisis as well as supporting circular economy and environmental protection. And it is suggested that research be conducted across the fields of biotechnology, chemical engineering, and materials engineering, as well as pyrolysis (converting microplastics into fuel or activated carbon).

5.3. Overall, microplastics are harmful to the sustainability of the food chain because they can interfere with the health and survival of organisms at various trophic levels. As microplastics accumulate in organisms and move through the food chain, their impact can be felt all the way to the top of the food chain, including humans. Therefore, plastic waste management and plastic pollution prevention should be prioritized to maintain ecosystem sustainability and human health. And it is recommended to clean up polluted areas and carry out habitat rehabilitation.

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