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ARTICLE REVIEW: LEVELS OF MICROPLASTIC EXPOSURE IN MOLLUSKS FROM INDONESIAN WATERS IN RELATION TO SALINITY DIFFERENCES

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Abstract

Microplastic pollution in Indonesian waters has emerged as an environmental issue that requires serious attention. This pollution affects marine ecosystems and the organisms inhabiting them, particularly mollusks. This study utilizes mollusks as bioindicators of aquatic pollution to assess the extent of microplastic exposure. The methodology of this study involves a literature review using Google Scholar and the analysis of samples collected from multiple aquatic sites across Indonesia, selected based on varying salinity levels. The findings of the study reveal that multiple mollusk species are contaminated with microplastics, exhibiting variations in the abundance and polymer composition of the particles. The primary factors contributing to the high accumulation of microplastics are human activities, such as plastic waste disposal and the degradation of plastics in aquatic environments. This study confirms that microplastics can enter the food chain and potentially pose negative impacts on human health. Therefore, more effective plastic waste management strategies are needed to reduce microplastic pollution in Indonesian waters.

Keywords: Microplastic, Mollusk, Salinity, Waters, Pollution

INTRODUCTION

The environment, as a natural resource, is an asset that can contribute to societal well-being. Environmental pollution is a growing global issue, driven by increasing population and human industrial activities. It is a shared problem that demands urgent attention, as it directly affects our safety, health, and the sustainability of life. Various forms of pollution, including air, soil, and water contamination, have had detrimental effects on ecosystems and human health (Sompotan and Sinaga, 2022). Water pollution represents one of the most alarming forms of environmental degradation, largely resulting from the inadequate management of domestic, industrial, and agricultural waste (Sianturi *et al*., 2024).

Water is one of the most essential needs for living organisms; therefore, its quality must be maintained. Indonesia is known as a maritime country, with approximately 70% of its territory consisting of ocean and the remaining 30% comprising land (Farhan *et al*., 2023). Water pollution encompasses various types of contaminants, one of which is plastic waste. Plastic is a material that is resistant to natural degradation, leading to the accumulation of plastic debris in aquatic environments, which poses a serious environmental concern. According to Jambeck *et al*. (2015), plastic waste in aquatic environments is projected to increase significantly in the future if not managed appropriately, with anthropogenic activities being the main contributing factor. Over time, plastics undergo degradation processes, resulting in the formation of small particles known as microplastics (Thumury and Ritonga, 2020).

Microplastics are defined as plastic particles less than 5 mm in diameter, typically weighing between 0.1 and 8.8 mg. These particles originate from a variety of sources, including the degradation of larger plastic debris, cosmetic products, and both industrial and domestic waste (Azizah *et al.*, 2020). Microplastics can be categorized into several types based on their morphological characteristics, such as fragments, filaments, films, foams, pellets, and granules (Zhang *et al*., 2017). Fragments, fibers, and films are common types of microplastics found in aquatic environments (Layn *et al*., 2020).

Common types of microplastic polymers found in the environment include Polystyrene (PS), Polypropylene (PP), Polyethylene (PE), Polyethylene terephthalate (PET), Polyvinyl Chloride (PVC), Polyamide or nylon (PA), Acrylonitrile Butadiene Styrene (ABS), Polymethyl Methacrylate (PMMA), and Polycarbonate (PC) (Koelmans *et al*., 2018). Microplastics have been found to contaminate various aquatic ecosystems worldwide, including in Indonesia, and are present even in saline water environments. According to Utami *et al*. (2022), high salinity levels can facilitate the degradation of plastic into microplastics, as the ions present in salt can influence the coagulation and aggregation of polymers.

Indonesia, as one of the largest producers of plastic waste in the world, faces significant challenges in controlling microplastic pollution in its waters. Microplastic contamination in Indonesia has been reported in freshwater, brackish, and marine environments. According to Hotimah *et al*. (2024), plastic production in Indonesia reached approximately 16.5 million tons in 2020, while the country generated 19 million tons of waste in 2022, the majority of which originated from food packaging. The lack of effective waste management, coupled with the high consumption of single-use plastics, has exacerbated this issue. This condition poses a serious threat to the integrity of aquatic ecosystems.

Indonesian waters represent one of the largest marine ecosystems in the world and are characterized by high biodiversity. The diversity of aquatic organisms found in coastal areas plays a crucial role in maintaining environmental stability and supporting the socio-economic livelihoods of coastal communities (Palmer, 2017). Among these aquatic organisms, mollusks constitute an important community with ecological and economic significance (Uneputty *et al*., 2024). Mollusks, such as clams and snails, play a vital role in marine ecosystems and also serve as a food source for humans. However, the increasing presence of microplastic pollution poses a serious threat to the survival of mollusks and the health of humans who consume them.

Microplastic particles can easily enter the bodies of bivalves due to their filter-feeding nature, wherein they collect food by filtering seawater (Rahmaan *et al*., 2021). The accumulation of microplastics in mollusks not only affects their physiology and growth but also poses a risk of entering the human food chain, presenting potential health hazards that are not yet fully understood. According to Juddin and Tamimi (2024), there is scientific evidence indicating that endocrine metabolic disruption may occur as a result of ingesting chemicals contained within microplastics-either through filter-feeding mechanisms in organisms such as bivalves and baleen whales, or through unusual trophic transfer effects in apex predators such as swordfish.

Based on the aforementioned issues, research on the presence of microplastics in mollusks within Indonesian waters is essential to understand their impacts and to formulate appropriate mitigation strategies. This study aims to assess the extent to which microplastics have contaminated mollusks across aquatic environments with varying salinity levels in Indonesia, examine their effects on ecosystems, and explore the implications for human health. The findings of this research are expected to provide valuable insights for policymakers, academics, and the public in addressing microplastic pollution and supporting the sustainability of Indonesia’s marine ecosystems.

METHODS

This research was conducted through a literature review using Google Scholar, employing the keyword "microplastic exposure in mollusks in Indonesian waters. The search results yielded several articles related to microplastic exposure in mollusks in Indonesian waters, with a focus on variations in salinity. The level of microplastic contamination in mussels is determined based on the microplastic content found within their organs. These articles were subsequently used as secondary data.

RESULTS AND DISCUSSION

Based on a review of several literature sources, three aquatic environments were identified as having recorded microplastic exposure in mollusks that is freshwater, brackish water, and marine (saltwater) areas. The secondary data obtained are presented in the following table.

Table 1. Data on microplastic content observed in mollusks from various freshwater areas contaminated with microplastics

Waters Name	Type of Mollusks	Organs Being Observed	Pollution Conditions	Type of Microplastic		References
				Form	Chemical Material	
Brantas River	Freshwater Mussels (*Anodonta Woodiana*)	Digestive Tract	Heavily Polluted	Fiber, fragment and film	-	Wijayanti *et al*., 2021
Pening Swamp	Freshwater Mussels (*Anodonta Woodiana*)	Digestive Tract	Heavily Polluted	Fiber, fragment, film and monofilament	PVC (*polyvinylidene chloride*), PS (*polystiren*), PET and PA (*polyamide*)	Puspita *et al*., 2022
Kwanyar River	Blood Cockle (*Anadara granosa)*	Mussel Body	Moderately Polluted	Fiber, fragment and film	*Poly(Ethylene Terephthalate)* (PET) and *Polypropylene* (PP)	Listiani *et al*., 2021
Teluk Ambon Cultivation Area	Blood Cockle (*Anadara granosa*)	Stomach and Digestive Tract	Moderately Polluted	Fiber, fragment, film, and pellet	-	Sahetapy *et al*., 2023
Siak River	Macrozoobenthos	-	Heavily Polluted	Fiber, fragment and film	-	Ismi *et al*., 2019

Jada Bahrin River	Bivalvia	Mussel Tissue	Moderately Polluted	Fragment, fiber and film	*Nonylphenol, bisphenol* A, *phthalates, Polybrominated diphenyl ether* (PBDE), *Polycyclic aromatic hydrocarbon* (PAH), *Polychlorinated Biphenyls* (PCB) and *Dichlorodiphenyl trichloroethane* (DDT)	Pratiwi *et al*., 2023
Dudat River	Asian Freshwater Mussel (*Pilsbryoconcha exilis*)	-	Moderately Polluted	Fragment, fiber and film	-	Pernanda *et al.*, 2024
Musi River	Bivalvia	Mussel Body	Heavily Polluted	Fragment, fiber and film	Polimer polietilen and polipropil-ene	Umayah *et al.*, 2024
Bedagung River	*Pomacea* sp. and *Sulcospira* sp.	Digestive Tract	Moderately Polluted	Fiber, granul, fragment, foam	Microbeads	Ariyunita *et al.,* 2022

Table 2. Data on microplastic content observed in mollusks from various brackish water areas contaminated with microplastics

Waters Name	Type of Mollusks	Organs Being Observed	Pollution Conditions	Type of Microplastic		References
				Form	**Chemical Material**	
Labuhan Deli Mangrove	Blood Cockle (*Anadara granosa*)	Digestive Tract	Heavily Polluted	Fiber, fragment and film	-	Silalahi and Sudibyo, 2024

Ecosystem						
TPI of Tambak Lorok, Semarang	Blood Cockle (*Anadara granosa*)	Mussel Body	Heavily Polluted	Fiber, film, fragment and pellet.	_	Arifin *et al*., 2023
Kuala Langsa Mangrove Ecosystem	Blood Cockle (*Tegillarca granosa*, Mangrove clam (*Geloina erosa*) and Kepah clam (*Polymesoda erosa*).	Digestive Tract	Heavily Polluted	Fragment, Line and film.	-	Junaidi *et al*., 2024
Fish Auction Center (TPI)	Blood cockle and Green mussel	Ciliary Tract	Lightly polluted	Fiber, fragment and pellet	-	Sekarwardhani *et al.*, 2022
TPI of Bungo, Demak and TPI of Kedungmalang, Jepara.	Blood cockle (*Anadara granosa* Linn)	Mussel Shell	Lightly polluted	-	*Polyglutaryl: alt4,4'-azobisbenzoyl hydrazide, Ethylidenenorbornene, Chloromethyl-silasane, and Poly(4,4'-azobisbenzoyl:alt2,4-dimethylpyrrolehidrazide*	Pungut *et al*., 2021
Kwanyar Bangkalan Madura Mangrove Ecosystem	Blood cockle (*Anadara granosa)*	Mussel Body	Moderately Polluted	Fiber, fragment and film	*Poly(Ethylene Terephthalate)* (PET) and *Polypropylene* (PP)	Listiani *et al*., 2021

Table 3. Data on microplastic content observed in mollusks from various marine (saltwater) areas contaminated with microplastics

Waters Name	Type of Mollusks	Organs Being Observed	Pollution Conditions	Type of Microplastic		References
				Form	Chemical Material	
Maccini Baji Sea	Green Mussel (*Perna viridis*)	Mussel Tissue	Heavily Polluted	Fiber and fragment	-	Ramli *et al.*, 2021
Tanjung Tiram Sea	Blood cockle (*Anadara granosa*)	Stomach and Digestive Tract	Moderately Polluted	Fiber and fragment	-	Tuhumury and Ritonga, 2020
Mandalle Sea	Green Mussel (*Perna viridis*)	Mussel Tissue	Moderately Polluted	Fiber	-	Yaqin *et al.*, 2022
Makassar Strait, Flores Sea and Bone Bay	Simping Clam (*Amusium pleuronectes*)	Mussel Gills	Heavily Polluted	Fiber, fragment, and granule.	-	Hafid *et al.*, 2024
Waters of Banyuurip, Gresik	Blood cockle (*Tegilarca granosa*) and Asian hard clam (*Meretrix meretrix*)	Shell and Mussel Tissue	Heavily Polluted	Fiber, film and fragment	-	Yona *et al.*, 2021
Bangka Barat Sea	Blood cockle (*Anadara granosa* L), Mangrove Clam (*Geloina* sp) and Asian hard clam (*Meretrix meretrix*)	Mussel Tissue	Lightly polluted	Fiber, fragment, granule, film and foam.	-	Pratiwi *et al.*, 2023
The coast of	Hairy Ark Clam	Mussel Tissue	Heavily Polluted	Fragment and fiber	-	Asdar *et al.*, 2024

Garassikang Village						
The Coastal Settlement of Kwanyar Bangkalan Madura	Blood cockle (*Anadara granosa)*	Mussel Body	Moderately Polluted	Fiber, fragment and film	*Poly(Ethylene Terephthalate)* (PET) and *Polypropylene* (PP)	Listiani *et al*., 2021
Lae-Lae Island, Makassar	Green Mussel (*Perna viridis*)	Mussel Tissue	Lightly polluted	Fiber	-	Fachruddin *et al*., 2020

Based on the identification results, microplastic contamination in mollusks in Indonesian waters occurs across various environments with differing salinity levels, including freshwater, brackish water, and marine (saltwater) areas. Each type of aquatic environment exhibits varying levels of contamination and different types of microplastics. Based on Table 1, various forms of microplastics were found in mollusks from different freshwater areas, including fibers, fragments, films, and monofilaments. Several chemical compounds identified in microplastics from freshwater environments include polyvinylidene chloride (PVC), polystyrene (PS), polyamide (PA), and polyethylene terephthalate (PET). The affected mollusks include freshwater mussels (Anodonta woodiana), blood cockles (Anadara granosa), Pilsbryononcha exilis, and other macrozoobenthos. Microplastic contamination in freshwater areas is predominantly found in rivers, swamps, and residential zones, indicating that the primary sources of pollution are industrial and domestic waste. According to Schwarz *et al*. (2019), microplastics found in freshwater bodies such as rivers originate from urban pollution, shipping activities, wastewater treatment plants, textiles, discharges from personal care products, and consumer product packaging.

The results of microplastic identification in brackish water areas, as presented in Table 2, indicate a significant level of contamination, with relatively severe pollution conditions. The types of microplastics found include fibers, fragments, films, and pellets. Several chemical compounds, such as polyglutaroyl, ethylidenenorbornene, and poly(4,4'-azobisbenzoyl), were detected in the bodies of mollusks such as blood cockles (Anadara granosa), Geloina erosa, and Polymesoda erosa. Mangrove ecosystems and fish landing sites (TPI) are among the most affected areas, suggesting a strong correlation between human activities, particularly in fisheries, and microplastic pollution in these environments. According to Hu *et al*. (2023), microplastics can enter mangrove ecosystems through riverine or marine water flows. Plastic waste in rivers that is not properly managed may be transported to the ocean, where it degrades into microplastics and subsequently enters mangrove ecosystems via water currents. These microplastics can then accumulate within mangrove roots or settle on the surface of mangrove sediments. Zamprogno *et a*l. (2021) stated that one of the factors contributing to the vulnerability of mangrove ecosystems to microplastic pollution is the continuous flow of seawater driven by tidal movements. This flow has the potential to accumulate microplastics within the mangrove ecosystem.

Marine (saltwater) areas have been found to be significantly contaminated with microplastics, with identified types including fibers, fragments, films, foams, and granules. The results of microplastic content identification in mollusks from saltwater areas are presented in Table 3. Affected mollusk species include the green mussel

(*Perna viridis*), blood cockle (*Anadara granosa*), scallop (*Amusium pleuronectes*), and the Asiatic hard clam (*Meretrix meretrix*). Microplastics were frequently detected in various mollusk organs, such as the flesh, stomach, gills, and shells. Mollusks are exposed to microplastics through their contaminated habitats. As filter-feeding marine organisms, mollusks filter seawater to obtain their food, primarily consisting of plankton and organic particles. However, during this process, they may inadvertently ingest microplastic particles present in the water. Once ingested, microplastics can accumulate in the digestive tract and tissue of the mollusks.

Based on the identification presented in Tables 1, 2, and 3, the level of microplastic contamination in mollusks ranges from moderate to high in freshwater environments, and from low to high in both brackish and marine waters. According to Sidabutar *et al*. (2019), low salinity levels are influenced by terrestrial inputs, such as the mixing of freshwater from river flows. One of the factors affecting water distribution is the volume of freshwater entering marine environments. In shallower waters, freshwater intrusion can extend to the bottom layers, resulting in lower salinity levels. Research by Cahayani *et al*. (2024) indicates that salinity values are inversely correlated with microplastic abundance. This means that microplastic abundance tends to increase in areas with low salinity, while in areas with higher salinity, the abundance of microplastics tends to decrease.

Microplastics are plastic polymer particles measuring less than 5 mm in size. Based on their shape, microplastics are classified into five types: fibers, filaments, fragments, foams, and granules. According to Laksono (2021), fiber-shaped microplastics are typically polyamide (nylon) polymers derived from fishing nets or laundry waste. Due to their relatively low density, fibers are commonly found floating on the surface of aquatic environments. Labibah and Triajie (2020) stated that fragment- and filament-shaped microplastics are generally composed of polyethylene (PE) and polypropylene (PP), originating from human activities such as the disposal of plastic bottles, which undergo degradation. These types of microplastics have varying and generally higher densities, allowing them to either float or sink in the water column. Fragments, in particular, can contaminate both free-swimming marine organisms and benthic species living on the seabed. According to Hidalgo *et al*. (2012), foam-type microplastics originate from the fragmentation of styrofoam, which is commonly used in floatation devices, food containers, and beverage packaging. The final type, granules, consists of microplastics that serve as raw materials in plastic manufacturing and are typically found in pre-production pellet form.

In terms of their polymer composition, the most commonly used types of microplastics are polyethylene terephthalate (PET) and polypropylene (PP), largely due to the widespread use of products made from these materials in daily life. According to Nistico (2020), PET is utilized in the production of beverage containers and bottles—such as those for water, carbonated soft drinks, and juices—as well as in sheet or film form for the food industry. Singh *et al*. (2020) describe PET as a semi-crystalline, transparent thermoplastic characterized by high rigidity, excellent mechanical strength, and good chemical resistance. Due to these favorable mechanical and chemical properties, PET is widely used in the manufacture of soft drink bottles, water bottles, synthetic fibers, video and audio cassettes, photographic film, and food packaging. This is further supported by Liu *et al*. (2020), who state that while PET is highly useful and contributes significantly to everyday life, its waste poses a serious environmental concern, as PET products may take approximately 300 to 450 years to decompose naturally. Meanwhile, PP (polypropylene) microplastics, according to Labibah and Triajie (2020), originate from community activities, particularly the disposal of plastic bottles, which undergo degradation over time, contributing to microplastic pollution in the environment.

The distribution of microplastic particles within estuarine sediments is influenced by oceanographic factors such as currents and tidal movements, which facilitate the transport of microplastics. According to Rachmat *et al*. (2019), water currents significantly affect the dispersion of debris in aquatic environments, thereby influencing the abundance of microplastics in both the water column and sediments. Microplastics present in the water are carried by currents, allowing them to mix and eventually settle in sediments. As noted by Almahdahulhizah (2019), microplastics can accumulate in high concentrations in both water and sediment. One of the key factors enabling the long-distance transport of debris in aquatic systems is water currents. Wind-driven forces generate the movement of ocean water masses, which can displace debris from one location to another (NOAA, 2015).

Efforts to address and mitigate the issue of microplastics are an integral part of the global initiative to protect the environment and human health from the adverse impacts of plastic waste. This challenge requires a comprehensive approach involving various stakeholders, including governments, industries, civil society, and the scientific community. One of the primary strategies in tackling microplastic pollution is reducing the production and consumption of single-use plastics. This can be achieved through the implementation of plastic reduction policies, such as bans or restrictions on single-use plastic bags, limitations on microplastics in consumer products, and public education on the importance of adopting environmentally friendly alternatives. These measures aim to decrease the amount of plastic entering the environment and, ultimately, reduce the accumulation of microplastics (Amanu *et al*., 2024).

CONCLUSION

The findings of the study indicate that microplastics have contaminated various mollusk species in Indonesian waters, with the primary sources stemming from human activities, such as domestic and industrial waste. The high accumulation of microplastics in mollusks suggests that these organisms can serve as effective bioindicators of aquatic pollution. Moreover, the microplastics accumulated in mollusk tissues have the potential to enter the food chain, posing risks to human health. Therefore, mitigation efforts are essential, including improved plastic waste management and public education on the dangers of microplastics. These measures can contribute to reducing microplastic pollution and safeguarding Indonesia's aquatic ecosystems.

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