REVIEW ARTICLE

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Microplastics in indonesian fishery products: a literature review of contamination levels and exposure risks

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Abstract

The main problem in this study is the increasing discovery of microplastics in fishery products in Indonesia without an in-depth study of their potential risks to human health. This study aims to identify the content of microplastics in various fishery and marine products in Indonesia and assess the level of danger using the polymer hazard index (PHI). Secondary data were obtained from various international scientific publications that contained information on the type of fishery product, the number of microplastic particles, shape, color, and type of polymer. Each data is analyzed descriptively to find the distribution pattern of microplastics between products, then PHI calculations are carried out based on the composition of the polymer and its hazard score. The estimated annual exposure of microplastics per individual in Indonesia is calculated based on the average national consumption of marine products. The results of the analysis showed that all marine products contain microplastics with varying amounts and types of polymers, where green shellfish have the highest PHI value (1080; category IV) and the greatest risk of harm, while annual microplastic exposure is estimated to be 77.,313 particles per individual per year. In conclusion, the level of microplastic hazards in Indonesian marine products is influenced by the type of polymer and the characteristics of the organism consumed. This study has important implications for marine food safety monitoring and the need for follow-up toxicological studies to assess the impact of microplastics on human health.

KEYWORDS
Microplastic, fish, seaweed, shrimp, salt, mussel

1. INTRODUCTION

Research on microplastic contamination of fishery products in Indonesia is very important because the country is one of the largest seafood producers and consumers in the world, with communities heavily dependent on seafood as the main source of animal protein (Kibria, 2023; Widyastuti et al., 2023). Fishery products are various commodities that come from the aquatic environment and are commonly consumed by humans, which include fish (marine and freshwater fish), bivalve organisms such as shellfish and oysters, crustaceans such as shrimp and crabs, and aquatic derivative products such as seaweed and sea salt. All these commodities were chosen because of their relevance to microplastic intake through water-based food consumption channels (Alberghini et al.,

2023). High fishing activities, coastal urbanization, and plastic waste disposal that has not been optimally managed make Indonesia's waters vulnerable to microplastic pollution (Arifin et al., 2023). The contamination not only threatens the quality and safety of marine food but also has the potential to pose a risk to human health due to exposure to microplastic particles and chemicals adsorbed on its surface (Carbery et al., 2018; Ziani et al., 2023). In addition, this research is crucial to provide a scientific basis in formulating marine environmental management policies, food safety standards, and plastic pollution mitigation strategies nationally (Wu, 2022). By understanding the extent to which fishery products in Indonesia are contaminated with microplastics, prevention and control measures can be designed in a more appropriate and sustainable manner (Alam & Rahman, 2025).

Previous studies have shown that microplastics are widespread in Indonesia's coastal waters and marine life, with concentrations generally higher in coastal areas, river estuaries, and sediments than sea levels; many studies have also found microplastic particles in a variety of fishery commodities—including small fish/anchovies, shellfish, and shrimp—with a predominance of fiber and fragment morphology as well as polymer types such as polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET) (Ali et al., 2021; Cordova et al., 2019). The national review and literature review highlight that most of the studies are located on the island of Java and coastal areas that experience high anthropogenic stress and confirm variations in analytical methods between studies (e.g., differences in threshold size and identification techniques such as FTIR/Raman) that affect the comparability of the data (Iskandar et al., 2024). Recent research also extends the monitoring range to the subsurface layer of the sea surface and reports findings of sub-surface microplastics that enrich the picture of the vertical distribution of particles in the archipelago, while case studies on consumption species such as anchovy (2.2 ± 0.5

particles/ind) report alarming levels of contamination in several locations, which together mark the need for integrated surveillance and harmonization of methodologies to assess health risks and food security (Michishita et al., 2023; Ristea et al., 2025).

Most previous research on microplastics in fishery products in Indonesia is still limited to the identification and reporting stages, without further analysis of their implications for human health. The studies generally only highlighted the types of contaminated fishery products, the number of microplastic particles found, and the variation in polymer types, but did not link these data to public consumption levels, potential daily exposures, or possible toxicological effects that could occur from long-term accumulation (Imamah et al., 2025). In addition, there have not been many studies that have examined the relationship between particle size, bioavailability, and the interaction of microplastics with other harmful chemicals that can increase biological risk (Deswati et al., 2025). Polymer Hazard Index (PHI) is an indicator used to assess the potential hazard of a polymer to human health and the environment based on its chemical composition, especially the presence of monomers, additives, and other harmful substances contained in it. The index was developed as a quantitative approach to help identify the risk levels of different types of polymers commonly used in everyday products. The use of PHI in this study was chosen because of its ability to provide a comprehensive initial overview of the relative hazard level of a polymer material, so that it can be a basis for consideration in risk evaluation, comparison between polymer types, and decision-making related to the selection of safer and more environmentally friendly materials (Siddique et al., 2024). These limitations mean that understanding the extent to which microplastic exposure from seafood can affect human health is still very limited. Therefore, further research is needed that not only

detects the presence of microplastics in fishery products, but also evaluates the route of exposure, absorption mechanisms, and their potential impact on the human physiological system.

This study aims to comprehensively analyze the findings of microplastics in various fishery products in Indonesia based on secondary data from international scientific publications, as well as assess the potential health risks that may arise from the consumption of these products. The novelty of this research lies in its approach that not only compiles and compares quantitative data from previous studies but also integrates it with exposure analysis and risk assessment to humans—a step that is rarely done in the study of microplastics in the Indonesian context. Thus, this research contributes to filling the scientific gap between empirical findings on microplastic contamination and the understanding of its potential impact on human health. The significance of this research lies in providing a strong scientific basis for policymakers, health institutions, and marine resource managers to formulate plastic pollution mitigation strategies, improve marine food safety standards, and encourage public awareness of the importance of plastic waste control for ecosystem sustainability and public health.

2. MATERIALS AND METHODS

2.1 Data collection procedures

This study is a secondary study and a follow-up analysis based on previously published data. Primary data were taken from previous studies on shrimp (Ekalaturrahmah et al., 2025; Musa et al., 2025), fish (Deswati et al., 2025; Imamah et al., 2025; Siregar et al., 2025), mussel (Buwono et al., 2025; Irnidayanti et al., 2025; Soegianto et al., 2025), seaweed (Suryandari & Nugroho, 2025) and salt (Efendy et al., 2025; Putri et al., 2023; Suteja et al., 2025). From the publication, quantitative information was extracted related to the findings of microplastics in fishery products in Indonesia (type of fishery product, the number of microplastic particles found, and the type of microplastic polymer). The secondary data is then used to conduct descriptive analysis, quantitative synthesis, and assessment of potential health risks through exposure models and risk characterization.

2.2 Data analysis

Annual oral exposure is calculated using a common formula:

$$EDI = C\_mp \times IR$$

Where:
EDI = estimated daily intake (particles per kg per person per year).
C_mp = the concentration of microplastics in the product (particles per kg) obtained from the research source.
IR = intake rate (seafood consumption per year (kg/person/year)

Basic assumptions of Indonesia's per capita consumption : Fish and seafood: 46 kg/person/year, salt: 4 kg/person/year and seaweed: 2 kg/person/year (Irnidayanti et al., 2025; Partelow et al., 2023).

2.3 Polymer hazard index (PHI)

The toxicological effects of plastic monomers and their chemical derivatives are primarily linked to the possible risks that microplastics provide to human health and the environment (Lithner et al., 2011). The PHI evaluates the potential hazards posed by various plastic polymer types to the environment and human health (Lithner et al., 2011). The risk associated with microplastics was assessed using the chemical components of various polymer kinds, along with their hazard score and hazard level. The PHI is calculated by the subsequent equation:

$$PHI = \Sigma Pn \times Sn$$

Pn stands for the percentage of polymers found in the sample (weighted average of all studies that met the inclusion criteria), Sn for the polymer hazard score, and PHI for the polymer hazard index. Based on the health hazards connected to polymers and the environment, the PHI value is divided into

four hazard levels (I to IV): hazards category I - PHI < 10; II - PHI 10–100; III - PHI 100–1000; and IV - PHI > 1000 (Soegianto et al., 2025).

3. RESULT AND DISCUSSION

3.1 Microplastic findings in several Indonesian marine products

Results.

Table 1 presents a list of the fishery commodities tested (fish, shellfish, shrimp, seaweed, and salt). The data pattern suggests that microplastic findings are not limited to one group—they are found in small fish or whole-eaten macrofauna such as shellfish/shrimp—with variations in frequency between species. This pattern arises due to different routes of exposure: bivalves filtrators more easily accumulate particles suspended in water, while fish can be exposed through the consumption of plankton or particles in benthic/pelagic habitats. In addition, food size, feeding behavior, and trophic position affect the probability of ingestion. Similar patterns have been reported in many international studies: bivalves and filterer types often show a high prevalence of

microplastics per individual/weight, while fish show species-dependent heterogeneity and sampling location (Li et al., 2023; Tang et al., 2023).

Table 1 shows the quantification of microplastics (e.g. particles/individuals or particles/100 g). The general pattern is large variation between locations and between species; Some samples show low or zero numbers, while other locations show high particle loads. This high variability is explained by local factors (near river mouths, ports, coastal villages with garbage dumps), seasonality, and analytical methods (detection limits, size thresholds—e.g., >300 μm vs >20 μm). Many other studies also reported similar heterogeneity: findings that appear "high" in one study often cannot be directly compared to other studies due to differences in reporting units and blank corrections. The methodological implications are the need for harmonization of reporting units and sensitivity analysis; From a public health perspective, even low numbers become relevant when consumed regularly, so it is important to associate this amount with consumption data (Erni-Cassola et al., 2019).

Table 1. Discovery of microplastics in marine products

Product	Particle	Shape	Color	Polymer	Reference
Milkfish (Chanos chanos)	11.23 particles/ind	Fiber	Black	polyvinyl chloride, polystyrene, polyamide, polymethyl methacrylate, polyethylene terephthalate, polyethylene, and ethylene-vinyl acetate	(Imamah et al., 2025)
Tilapia (O. niloticus)	725 ± 25–1450 ± 100 particles/kg	Fragment	Black	Polyamide, polyethylene, and polyester	(Deswati et al., 2025)
Mullet fish (Mugil cephalus), glassfish (Ambassis nalua), and mudskipper (Periophthalmus sp.)	1.55 - 1.77 particles/ ind	Film	Black	Polypropylene	(Siregar et al., 2025)

Green mussel	8 ± 9.4 particles per individual or 4 ± 2.8 per gram	Fragments, fibers and films	Black	Polystyrene	(Irnidayanti et al., 2025)
Green mussel	16.14 ± 4.39 particles/ind	Fiber and fragment	Black and red	Polyvinyl chloride (PVC), polycarbonate (PC), polystyrene (PS)	(Soegianto et al., 2025)
Green mussel	60-180 particles/ind	Fragment	Black	Polyethylene (PE)	(Buwono et al., 2025)
Blood clams Anadara granosa (Mollusca: Bivalvia)	21.05±10.31 particles/ind	Film	Black	-	(Rahman et al., 2025)
Shrimp	6.75 ± 0.6 particles/g	Fiber and fragment	Black	Polyethylene and polypropylene	(Musa et al., 2025)
Shrimp	80 - 360 particles/kg	Fiber and fragment	Black	Cellophane, polypropylene (PP), and polyethylene (PE)	(Ekalaturrahmah et al., 2025)
Puffer Fish (*Rastrelliger kanagurta*)	3.64 ± 0.35 particles/ind	Fragment	Blue	Polyethylene terephthalate (PET)	(Samitra et al., 2025)
Cottonii Seaweed (Kappaphycopsis cottonii)	40 – 53 particles/ind	Fiber	Black	Polypropylene (PP)	(Suryandari & Nugroho, 2025)
Salt	35-38 particles/g	Fragment	Blue, black, red, and white	Cellophane, polyethylene (PE), and Polyethylene terephthalate (PET)	(Putri et al., 2023)
Salt	173 ± 119 particles/kg	Fragments	Black	chlorobutyl (33%) and ethylene propylene rubber (29%)	(Suteja et al., 2025)
Salt	14 ± 1.63 to 37.33 ± 4.5 particles/kg	Fiber	Black	-	(Efendy et al., 2025)

The high variability of microplastic concentrations in the same commodity in different locations suggests that the distribution of microplastics is strongly influenced by environmental factors and local human activities (Jia et al., 2022). Coastal areas adjacent to river mouths generally receive larger inputs of plastic waste from land, either through river flows, surface runoff, and domestic and industrial activities, so they tend to show higher concentrations of microplastics compared to freshwater waters that are relatively farther away from direct sources of pollutants. In addition, local anthropogenic stress levels—such as settlement density, industrial presence, port activity, tourism, and intensity of fishery activities—contribute to increased input and resuspension of plastic particles in the water and sediment columns, which further increases the chances of exposure to aquatic organisms. On the other hand, differences in sample collection and analysis methods between studies also have the potential to be a source of significant variation, for example related to the size of the mesh used during screening, the variety of sample preparation procedures (including the process of digesting organic matter), and differences in polymer identification techniques and instruments. This combination of ecological and methodological factors needs to be carefully considered when comparing microplastic concentration data between sites and studies, as well as in interpreting the ecological implications and risks to biota and human health (Ding et al., 2022).

3.2 Shape

Table 1 records the shape of the particles found (Figure 1). A common pattern that often appears is the dominance of fibers and fragments, with fiber usually more dominant in biota living in coastal waters. The causes of this pattern include sources of pollution (textile fibers from laundry, fibrous waste from nets and fishing gear, as well as fragments from consumer plastic degradation) and transport mechanisms (fibers are more easily suspended and enter the trophic chain). A comparison of the literature shows global consistency: many studies in coastal regions report fiber as the most common form, while fragments and films often appear near urban centers and the plastics industry. The classification of microplastic forms also depends on the resolution of the observation—particles that are very small or deformed due to digestion procedures can be classified differently (Stock et al., 2020).
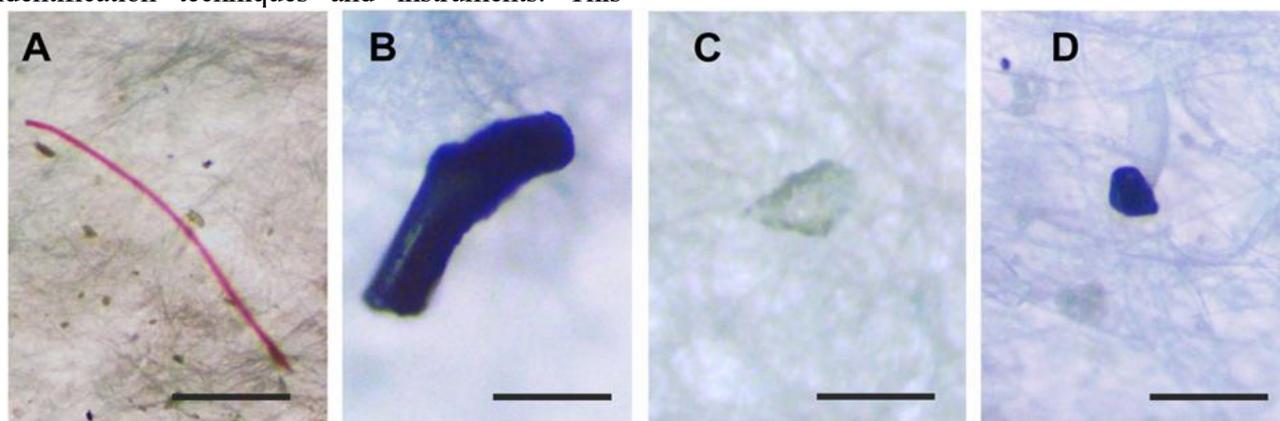

Figure 1. Shape of microplastic, A = fiber, B = fragment, C = film, D = pellet, bar size = 100 µm (Soegianto et al., 2025).

3.3 Color

Table 1 details the color of the microplastic particles (e.g. black, blue, white/transparent, red, etc.). The patterns that are often seen are the predominance of dark (black/gray) and blue colors, because many marine sources (nets, ropes, bottle

pieces/packaging) produce these colored fragments, and textile dyes produce blue/white fibers. Color also affects the likelihood of consumption by organisms—e.g. Feed agents that resemble plankton or natural particles tend to increase insertion into the gastrointestinal tract. Many international studies confirm similar color patterns; For example, blue and black fibers are often reported in fish and shellfish in coastal areas. However, color interpretation should be careful as staining can fade after exposure to the environment and laboratory procedures; Color does not always indicate a specific industrial source without polymer analysis (Zhao et al., 2022).

3.4 Polymer

Several polymers were found in samples of marine products (Table 1). Common patterns typically feature a predominance of lightweight and common polymers such as polyethylene (PE) and polypropylene (PP), sometimes accompanied by PET and PVC; this is consistent with the global distribution of plastic production and use (PE/PP is widely used for bags, packaging, nets). The dominance of certain polymers also reflects local sources (e.g. PET on beverage bottle fragments, PA/nylon on nets). In many international studies, PE and PP are often the main polymers detected in marine life, while PET appears mainly in fragments of packaging. It is important to note that reliable polymer identification depends on the method (FTIR/Raman vs visual inspection only); Studies that rely solely on visuals tend to be over-/mis-classified. Therefore, the polymer patterns in the table should also be seen in the context of the analytical validity of each source study.

3.5 Estimated human microplastic consumption

Estimates of annual microplastic exposure per individual (EDI) in Indonesia based on the consumption of various fishery and marine products are shown in Table 2. In general, the data pattern shows that products with refined forms or finer physical characteristics such as salt and green

shellfish have a much higher content of microplastics than animal products such as fish or shrimp. Green mussel showed the highest number (271,313 MP items/person/year), followed by salt (146,000 MP items/person/year), while fish groups such as tilapia, milkfish, and puffer fish were in the range of 50,000 MP items/person/year. The lowest values were found in shrimp (10,120 MP items/person/year) and seaweed (18,600 MP items/person/year). This pattern suggests that products that have direct contact with seawater in the form of fine granules or filtrators such as shellfish tend to accumulate microplastics higher.

The distribution pattern can be explained ecologically and functionally. Products such as green mussels and blood mussels are filter feeder organisms that filter particles from seawater during the feeding process, so microplastics with micron sizes can be easily trapped in their tissues. Meanwhile, sea salt is sourced directly from the evaporation of seawater without a thorough chemical purification process, so microplastic residues contained in the water column can be left behind in the final product. In contrast, fish and shrimp that have closed digestive systems and more complex metabolic processes tend to have lower microplastic accumulation per unit of body mass.

When compared to previous studies, these results are in line with the findings of Silva et al. (2025) in Europe which showed that sea salt and bivalves are major contributors to microplastic exposure in humans, with a range of 100,000–200,000 particles per year. However, the exposure value in Indonesia appears to be higher for the shellfish category, which is likely due to high levels of coastal pollution and the lack of plastic waste management systems in tropical coastal areas (Herdiansyah et al., 2021). In addition, the characteristics of Indonesia's semi-closed waters (such as Jakarta Bay and the Madura Strait) cause the accumulation of microplastics in sediments and marine life to be greater than in open sea areas (Widiaratih et al., 2025).

Table 2. The estimated total of microplastics consumed by persons in Indonesia.

Product	Microplastics particles/year/person (EDI)	PHI (hazard category)
Milkfish (*Chanos chanos*)	50.025	24.6 (II)
Tilapia (*O. niloticus*)	50.025	15.3 (II)
Mullet fish (*Mugil cephalus*), glassfish (*Ambassis nalua*), and mudskipper (*Periophthalmus sp.*)	50.025	1 (I)
Green mussel	271.313	1080 (IV)
Blood clams Anadara granosa (*Mollusca: Bivalvia*)	49.680	-
Shrimp	10.120	6 (I)
Puffer Fish (*Rastrelliger kanagurta*)	50.025	4 (I)
Cottonii Seaweed (*Kappaphycopsis cottonii*)	18.600	1 (I)
Salt	146.000	78 (II)

3.6 Polymer hazard index (PHI)

The Polymer Hazard Index (PHI) value calculated from various fishery and marine products in Indonesia (Table 2), reflects the level of potential hazards of microplastic polymers to human health and the environment. The PHI values obtained ranged from 1 to 1080, with hazard categories ranging from low (I) to very high (IV). The highest value product was found in green mussels (Perna viridis) with PHI 1080 (category IV), indicating a very high potential hazard. Meanwhile, the lowest PHI values (1, category I) were found in mullets, glassfish, mudskippers, and Kappaphycopsis cottonii seaweeds, indicating a relatively low risk of exposure to harmful polymers.

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If you look at the pattern, sedentary organisms such as green mussels have a much higher accumulation of microplastics than fish or other mobile organisms. This is due to the filter-feeding mechanism, in which shellfish filter large amounts of seawater and suspended particles, including microplastics (Zhao et al., 2024). In contrast, pelagic fish such as puffer fish and tilapia show lower PHI because their diet is more selective and their living space is more dynamic, so exposure to microplastics is more limited (Rist et al., 2018). The PHI value of salt (78, category II) indicates that the process of seawater evaporation in salt production has the potential to concentrate microplastic particles, albeit at a moderate hazard level (Zhang et al., 2020).

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The pattern of PHI value distribution is in line with the results of previous research. Rist et al.

(2018) showed that bivalves are the most sensitive biological indicators of microplastic contamination in coastal areas due to their sedentary nature and high bioaccumulation capabilities. Zhao et al. (2024) found that shellfish from Bohai Bay, China, showed the highest PHI values compared to fish or crustaceans, with the hazard category reaching level IV — comparable to the results of this study in Indonesia. Meanwhile, a study by Falahudin et al. (2020) in Indonesian waters noted that microplastics in marine fish generally come from the polyethylene (PE) and polypropylene (PP) fractions with a moderate hazard level (category II), in accordance with the PHI values in tilapia and milkfish in this study.

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3.7 Exposure Routes of Microplastics to Humans

Although this study focused on microplastic exposure through the consumption of fishery products, it is important to emphasize that this pathway is not the only source of exposure for humans. Studies have shown that microplastics can also enter the body through drinking water, inhaled air (dust and synthetic fibers in indoor environments), table salt, and other food products (Figure 2). Therefore, the estimated exposure obtained from the consumption of fish, shellfish, and other aquatic commodities in this study needs to be interpreted as part of the overall total microplastic exposure, not as the sole or necessarily dominant source of exposure. Taking into account these different routes of exposure, a more comprehensive risk assessment of the impact of microplastics on human health can be carried out in the future (Sun & Wang, 2023).

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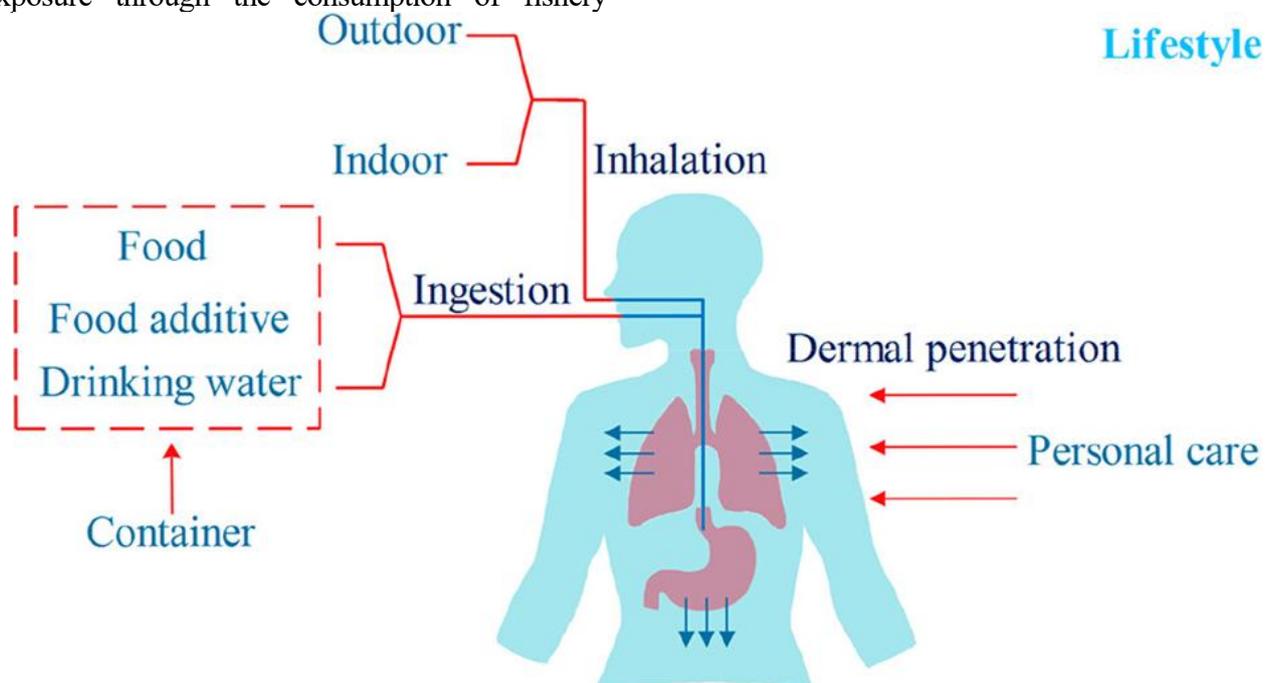

Figure 2. Exposure routes of microplastics to humans (Sun & Wang, 2023).

The route of exposure to microplastics in humans is mainly through consumption (as the main route), inhalation, and skin penetration. Seafood, drinking water (especially packaged), and sea salt are significant sources of consumption, with eating habits and food sources greatly influencing the amount ingested. Through inhalation, microplastic fibers from synthetic textiles and dust, especially in indoor air, can be inhaled and reach the lungs. Meanwhile, skin penetration is more limited due to the skin barrier, but nanoplastics (<100 nm) from personal care products have the potential to be absorbed and carry harmful chemical compounds. Although the absorption rate through the skin is currently considered to be lower, the large surface area of the skin makes it an important route of exposure to be studied further along with the other two routes (Tang et al., 2024).

4. CONCLUSION

This study aims to identify the findings of microplastics in various fishery and marine products in Indonesia and assess their potential hazards through the calculation of the *Polymer Hazard Index* (PHI) based on secondary data from various previous studies. The results of the analysis showed that all the products analyzed contained microplastic particles with variations in the amount and type of different polymers, of which green mussels (Perna viridis) showed the highest PHI value (1080; category IV) and the requires particular attention. Products such as milkfish, tilapia, and other marine fish show a category II PHI value of moderate risk, while seaweed and some types of groundfish are at low risk. Based on the estimated annual consumption of Indonesian fishery products, annual microplastic exposure is estimated to reach average 77,.313 particles per individual per year, with the largest contribution coming from the consumption of green shellfish and sea salt. These findings show that the level of danger of microplastics is greatly influenced by the type of polymer that makes up them as well as the biological characteristics of marine organisms. The results of this study are significant because they provide an initial overview of the potential health risks due to the consumption of marine products contaminated with microplastics in Indonesia, as well as affirming the importance of monitoring pollutant sources in marine ecosystems. For further research, it is recommended to conduct experimental toxicology analysis and direct biomonitoring on humans to assess the real impact of microplastics on the health of marine consumers in Indonesia.

CONFLICT OF INTEREST
The author declares no conflicts of interest.

DATA AVAILABILITY STATEMENT
The review did not report any data.

REFERENCES
Alam, M. J., & Rahman, M. M. (2025). Chapter 19 - Challenges associated with preventive measures and environmentally acceptable techniques to control microplastics. In B. Singh & S. K. Upadhyay (Eds.), *Microplastics* (pp. 441-449). Elsevier.

https://doi.org/https://doi.org/10.1016/B 978-0-443-29804-2.00019-6

Alberghini, L., Truant, A., Santonicola, S., Colavita, G., & Giaccone, V. (2023). Microplastics in Fish and Fishery Products and Risks for Human Health: A Review. *International Journal of Environmental Research and Public Health*, *20*(1). https://doi.org/10.3390/ijerph20010789

Ali, F., Azmi, K. N., & Firdaus, M. R. (2021). Existence of microplastics in Indonesia's surface water: a review. *International Journal of Integrated Engineering*, *13*(3), 100-107. Retrieved from https://publisher.uthm.edu.my/ojs/index. php/ijie/article/view/8906

Arifin, Z., Falahudin, D., Saito, H., Mintarsih, T. H., Hafizt, M., & Suteja, Y. (2023). Indonesian policy and researches toward 70% reduction of marine plastic pollution by 2025. *Marine Policy*, *155*, 105692. https://doi.org/10.1016/j.marpol.2023.10 5692

Buwono, N. R., Soegianto, A., Hartati, R., Vanny, R. M., & Abidah, Z. N. (2025). Microplastics Contamination in the Kalirejo Coastal Area, East Java, Indonesia and their Presence in Green Mussels (Perna viridis). *Bulletin of Environmental Contamination and Toxicology*, *114*(3), 41. https://doi.org/10.1007/s00128-025-04025-w

Carbery, M., O'Connor, W., & Palanisami, T. (2018). Trophic transfer of microplastics and mixed contaminants in the marine food web and implications for human health. *Environment International*, *115*, 400-409. https://doi.org/10.1016/j.envint.2018.03. 007

Cordova, M. R., Purwiyanto, A. I. S., & Suteja, Y. (2019). Abundance and characteristics of microplastics in the northern coastal waters of Surabaya, Indonesia. *Marine Pollution Bulletin*, *142*, 183-188. https://doi.org/10.1016/j.marpolbul.2019 .03.040

Deswati, D., Rizka, A. F., Putra, Z. A., Fitri, W. E., Suparno, S., & Pardi, H. (2025). Preliminary assessment of microplastic contamination in fish species from Lake Maninjau, West Sumatra, Indonesia. *Regional Studies in Marine Science*, *89*, 104346. https://doi.org/10.1016/j.rsma.2025.1043 46

Ding, Y., Zou, X., Chen, H., Yuan, F., Liao, Q., Feng, Z., Fan, Q., Wang, Y., Fu, G., & Yu, W. (2022). Distribution pattern and influencing factors for the microplastics in continental shelf, slope, and deep-sea surface sediments from the South China Sea. *Environmental Pollution*, *309*, 119824. https://doi.org/10.1016/j.envpol.2022.11 9824

Efendy, M., Amir, N., Nuzula, N. I., Syaifullah, M., Efendi, M. Y., & Gozan, M. (2025). Microplastic contamination along the salt production system: insights from water, sediment, and salt samples. *International Journal of Environmental Science and Technology*, *22*(13), 12799-12812. https://doi.org/10.1007/s13762-025-06449-7

Ekalaturrahmah, Y. A. C., Shidqi, M. T., Garfansa, M. P., Sholeh, M. S., Hartati, F. K., Sutanto, A., Iswahyudi, I., & Putri, A. K. (2025). Identification and quantification of microplastics in water, sediment, and shrimp collected from shrimp farming ponds. *Bioresource Technology Reports*, *29*, 102064. https://doi.org/10.1016/j.biteb.2025.102 064

Erni-Cassola, G., Zadjelovic, V., Gibson, M. I., & Christie-Oleza, J. A. (2019). Distribution of plastic polymer types in the marine environment; A meta-analysis. *Journal of Hazardous Materials*, *369*, 691-698. https://doi.org/10.1016/j.jhazmat.2019.02.067

Falahudin, D., Cordova, M. R., Sun, X., Yogaswara, D., Wulandari, I., Hindarti, D., & Arifin, Z. (2020). The first occurrence, spatial distribution and characteristics of microplastic particles in sediments from Banten Bay, Indonesia. *Science of the Total Environment*, *705*, 135304. https://doi.org/10.1016/j.scitotenv.2019.135304

Herdiansyah, H., Saiya, H. G., Afkarina, K. I. I., & Indra, T. L. (2021). Coastal Community Perspective, Waste Density, and Spatial Area toward Sustainable Waste Management (Case Study: Ambon Bay, Indonesia). *Sustainability*, *13*(19), 10947. https://doi.org/10.3390/su131910947

Imamah, S. W., Soegianto, A., Jamlean, S. A., Khairunnisak, K., Hariyanto, S., Payus, C. M., Buwono, N. R., & Hartati, R. (2025). The abundance and characteristics of microplastics in different organs of both wild and farmed milkfish (Chanos chanos) from Madura, Indonesia. *Regional Studies in Marine Science*, *91*, 104505. https://doi.org/10.1016/j.rsma.2025.104505

Irnidayanti, Y., Purwanto, M. D., Soegianto, A., Hartl, M. G. J., Sarma, H., & Narayan, M. (2025). Characterization of microplastics and associated metals in green mussel cultivation: Estimation of potential health risks. *Chemosphere*, *390*, 144719. https://doi.org/10.1016/j.chemosphere.2025.144719

Iskandar, M. R., Park, Y.-G., Surinati, D., Nugroho, D., & Cordova, M. R. (2024). Estimation of bottom microplastic flux in the Indonesian seas. *Marine Pollution Bulletin*, *209*, 117047. https://doi.org/10.1016/j.marpolbul.2024.117047

Jia, Q., Duan, Y., Han, X., Sun, X., Munyaneza, J., Ma, J., & Xiu, G. (2022). Atmospheric deposition of microplastics in the megalopolis (Shanghai) during rainy season: Characteristics, influence factors, and source. *Science of the Total Environment*, *847*, 157609. https://doi.org/10.1016/j.scitotenv.2022.157609

Kibria, G. (2023). Impacts of microplastic on fisheries and seafood security — Global analysis and synthesis. *Science of the Total Environment*, *904*, 166652. https://doi.org/10.1016/j.scitotenv.2023.166652

Li, J., Shan, E., Zhao, J., Teng, J., & Wang, Q. (2023). The factors influencing the vertical transport of microplastics in marine environment: A review. *Science of the Total Environment*, *870*, 161893. https://doi.org/10.1016/j.scitotenv.2023.161893

Lithner, D., Larsson, Å., & Dave, G. (2011). Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. *Science of the Total Environment*, *409*(18), 3309-3324. https://doi.org/10.1016/j.scitotenv.2011.04.038

Michishita, S., Gibble, C., Tubbs, C., Felton, R., Gjeltema, J., Lang, J., & Finkelstein, M. (2023). Microplastic in northern anchovies (Engraulis mordax) and common murres (Uria aalge) from the Monterey Bay, California USA - Insights

into prevalence, composition, and estrogenic activity. *Environmental Pollution*, *316*, 120548. https://doi.org/10.1016/j.envpol.2022.12 0548

Musa, M., Mahmudi, M., Lusiana, E. D., Arsad, S., Martassha, A., Abidah, Z. N., Naba, M. H. A., Alvionita, R. M. V., & Buwono, N. R. (2025). Comparing microplastic contamination in vannamei shrimp aquaculture: the impact of concrete and HDPE pond materials in Probolinggo, East Java, Indonesia. *Aquaculture International*, *33*(5), 369. https://doi.org/10.1007/s10499-025-02050-4

Partelow, S., Nagel, B., Paramita, A. O., & Buhari, N. (2023). Seafood consumption changes and COVID-19 impact index in West Nusa Tenggara, Indonesia. *PLOS ONE*, *18*(1), e0280134. https://doi.org/10.1371/journal.pone.028 0134

Putri, E. B. P., Syafiuddin, A., Aini, S. A., Iswahyudi, I., & Garfansa, M. P. (2023). Identification and quantification of microplastics in sea water and sea salt collected from sea salt ponds. *Desalination and Water Treatment*, *300*(7), 130-135. https://doi.org/10.5004/dwt.2023.29719

Rahman, M. A., Putri, W. E. A., Diansyah, G., Delya, I., & Nugroho, R. Y. (2025). Implication of microplastic presence in sediment and blood clams Anadara granosa (Mollusca: Bivalvia) in the Musi Estuary, Indonesia [Article]. *Biodiversitas*, *26*(4), 1720-1733. https://doi.org/10.13057/biodiv/d260422

Rist, S., Carney Almroth, B., Hartmann, N. B., & Karlsson, T. M. (2018). A critical perspective on early communications concerning human health aspects of microplastics. *Science of the Total Environment*, *626*, 720-726. https://doi.org/10.1016/j.scitotenv.2018. 01.092

Ristea, E., Pârvulescu, O. C., Lavric, V., & Oros, A. (2025). Assessment of Heavy Metal Contamination of Seawater and Sediments Along the Romanian Black Sea Coast: Spatial Distribution and Environmental Implications. *Sustainability*, *17*(6), 2586. https://doi.org/10.3390/su17062586

Samitra, I., Werorilangi, S., & Burhanuddin, A. I. (2025). Microplastic Contamination in Commercially Important Fish from Labuan Bajo Fish Landing Site, Donggala, Central Sulawesi, Indonesia. *Egyptian Journal of Aquatic Biology and Fisheries*, *29*(5), 1323-1345. https://doi.org/10.21608/ejabf.2025.366 970.5730

Siddique, M. A. M., Hossain, I., Sunji, M. M. R., Tahsin, T., Walker, T. R., & Rahman, M. S. (2024). Characterization, source identification and hazard index assessment of ingested microplastics in farmed tilapia Oreochromis niloticus. *Ecological Indicators*, *158*, 111334. https://doi.org/10.1016/j.ecolind.2023.11 1334

Silva, D. C. C., Borba, A., de Sousa, H. C., Marques, J. C., & Gonçalves, A. M. M. (2025). Microplastic pollution in marine bivalves, surface water and sediments from an aquaculture in Portugal and possible intake by humans. *Regional Studies in Marine Science*, *85*, 104146. https://doi.org/10.1016/j.rsma.2025.1041 46

Siregar, L. Y., Muchlisin, Z. A., Pradit, S., Yucharoen, M., & Faradilla, S. B. (2025). Microplastic contamination in fish harvested from the estuarine mangrove forest of Banda Aceh City, Indonesia [Article]. *Archives of Environmental*

Protection, *51*(1), 3-11. https://doi.org/10.24425/aep.2025.153745

Soegianto, A., Putranto, T. W. C., Affandi, M., Imamah, S. W., Jamlean, S. A., Khairunnisak, Mukholladun, W., & Payus, C. M. (2025). Microplastic contamination in green mussels (Perna viridis Linnaeus, 1758) collected from the traditional fish markets along the East Java coast of Indonesia and the associated risk assessment. *Environmental Toxicology and Pharmacology*, *118*, 104762. https://doi.org/10.1016/j.etap.2025.104762

Stock, V., Fahrenson, C., Thuenemann, A., Dönmez, M. H., Voss, L., Böhmert, L., Braeuning, A., Lampen, A., & Sieg, H. (2020). Impact of artificial digestion on the sizes and shapes of microplastic particles. *Food and Chemical Toxicology*, *135*, 111010. https://doi.org/10.1016/j.fct.2019.111010

Sun, A., & Wang, W.-X. (2023). Human Exposure to Microplastics and Its Associated Health Risks. *Environment & Health*, *1*(3), 139-149. https://doi.org/10.1021/envhealth.3c00053

Suryandari, R., & Nugroho, A. P. (2025). Microplastic Contamination on Cottonii Seaweed (Kappaphycopsis cottonii) Cultivated in Bomo Beach, Banyuwangi, East Java, Indonesia. *EnvironmentAsia*, *18*(1). https://doi.nrct.go.th/ListDoi/listDetail?Resolve_DOI=10.14456/ea.2025.2

Suteja, Y., Dirgayusa, I. G. N. P., Purnama, S. G., & Purwiyanto, A. I. S. (2025). From sea to table: Assessing microplastic contamination in local and non-local salt in Bali, Indonesia. *Chemosphere*, *374*, 144192. https://doi.org/10.1016/j.chemosphere.2025.144192

Tang, K. H. D., Li, R., Li, Z., & Wang, D. (2024). Health risk of human exposure to microplastics: a review. *Environmental Chemistry Letters*, *22*(3), 1155-1183. https://doi.org/10.1007/s10311-024-01727-1

Tang, L., Feng, J.-C., Li, C., Liang, J., Zhang, S., & Yang, Z. (2023). Global occurrence, drivers, and environmental risks of microplastics in marine environments. *Journal of Environmental Management*, *329*, 116961. https://doi.org/10.1016/j.jenvman.2022.116961

Widiaratih, R., Sulhana, B. L. A., Putranto, A. B., Maslukah, L., Ismanto, A., Ayuningrum, D., Hadibarata, T., & Satya, E. D. (2025). The correlation between microplastics characteristics and sediment grain size to microplastics accumulation in coral reef sediment in Gede Island, Rembang, Indonesia. *Journal of Ecological Engineering*, *26*(3), 200-212. https://doi.org/10.12911/22998993/199648

Widyastuti, S., Abidin, A. S., Hikmaturrohmi, H., Ilhami, B. T. K., Kurniawan, N. S. H., Jupri, A., Candri, D. A., Frediansyah, A., & Prasedya, E. S. (2023). Microplastic Contamination in Different Marine Species of Bintaro Fish Market, Indonesia. *Sustainability*, *15*(12), 9836. https://doi.org/10.3390/su15129836

Wu, H.-H. (2022). A study on transnational regulatory governance for marine plastic debris: Trends, challenges, and prospect. *Marine Policy*, *136*, 103988. https://doi.org/10.1016/j.marpol.2020.103988

Zhang, Q., Xu, E. G., Li, J., Chen, Q., Ma, L., Zeng, E. Y., & Shi, H. (2020). A Review of Microplastics in Table Salt, Drinking Water, and Air: Direct Human Exposure. *Environmental Science & Technology*, *54*(7), 3740-3751. https://doi.org/10.1021/acs.est.9b04535

Zhao, S., Liu, Y., Sun, C., Wang, X., Hou, C., Teng, J., Zhao, J., Fang, Y., & Wang, Q. (2024). The pollution characteristics and risk assessment of microplastics in mollusks collected from the Bohai Sea. *Science of the Total Environment*, *913*, 169739. https://doi.org/10.1016/j.scitotenv.2023.169739

Zhao, X., Wang, J., Yee Leung, K. M., & Wu, F. (2022). Color: An Important but Overlooked Factor for Plastic Photoaging and Microplastic Formation. *Environmental Science & Technology*, *56*(13), 9161-9163. https://doi.org/10.1021/acs.est.2c02402

Ziani, K., Ioniță-Mîndrican, C.-B., Mititelu, M., Neacșu, S. M., Negrei, C., Moroșan, E., Drăgănescu, D., & Preda, O.-T. (2023). Microplastics: A Real Global Threat for Environment and Food Safety: A State of the Art Review. *Nutrients*, *15*(3), 617. https://doi.org/10.3390/nu15030617