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Analysis of Microplastic Content in Edible Fish from a Traditional Market X, Bandung City, Indonesia

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ABSTRAK

Polusi mikroplastik di lingkungan perairan merupakan masalah lingkungan yang semakin parah, dengan konsumsi ikan berpotensi menjadi salah satu jalur paparan bagi manusia. Penelitian ini mengkaji kelimpahan, karakteristik, dan jenis polimer mikroplastik pada insang dan saluran pencernaan tuna mackerel (*Euthynnus affinis*) dan mackerel India (*Rastrelliger kanagurta*) yang diperoleh dari Pasar Tradisional X di Kota Bandung, Indonesia. Seluruh 550 partikel yang diduga sebagai mikroplastik dianalisis menggunakan FTIR untuk identifikasi polimer. Uji Mann–Whitney digunakan untuk menilai perbedaan tingkat mikroplastik antar spesies ikan, sedangkan analisis deskriptif menggambarkan bentuk, warna, dan ukuran partikel. Setiap sampel ikan mengandung mikroplastik (100%), dengan total 550 partikel dan rata-rata 15,278 ± 5,629 partikel per ikan. Tidak ditemukan perbedaan yang signifikan dalam jumlah partikel antar spesies ($p > 0,05$). Bentuk serat merupakan yang paling umum (43%), warna transparan mendominasi (40%), dan 70% partikel berukuran kurang dari 500 µm. Polimer utama yang teridentifikasi adalah PE dan PET pada tuna makarel, serta PE, PET, dan PS pada makarel India. Kehadiran mikroplastik dalam jaringan ikan menunjukkan potensi paparan lingkungan pada ikan yang dijual secara komersial. Karena jaringan yang diperiksa adalah insang dan saluran pencernaan, bukan otot yang dapat dimakan, hasil ini tidak secara langsung mencerminkan paparan melalui makanan pada manusia. Penelitian lebih lanjut yang menganalisis jaringan otot yang dapat dimakan dan pola konsumsi diperlukan untuk mengevaluasi potensi risiko kesehatan bagi konsumen.

Kata Kunci: ikan kembung, ikan tuna, mikroplastik

ABSTRACT

Microplastic pollution in aquatic environments is an escalating environmental issue, with fish consumption potentially serving as a route of human exposure. This study examined the abundance, features, and polymer types of microplastics in the gills and digestive tracts of mackerel tuna (*Euthynnus affinis*) and Indian mackerel (*Rastrelliger kanagurta*) from Traditional Market X in Bandung City, Indonesia. All 550 suspected microplastic particles underwent FTIR analysis for polymer identification. The Mann–Whitney test assessed differences in microplastic levels between fish species, while descriptive analysis characterized shape, color, and size. Every fish sample contained microplastics (100%), totaling 550 particles with an average of 15.278 ± 5.629 particles per fish. No significant difference in abundance was observed between species ($p > 0.05$). Fiber was the most common shape (43%), transparent was the predominant color (40%), and 70% of particles were smaller than 500 µm. The main polymers identified were PE and PET in mackerel tuna, and PE, PET, and PS in Indian mackerel. The presence of microplastics in fish tissues indicates potential environmental exposure in fish sold commercially. Since the tissues examined were gills and digestive tracts, not edible muscle, these results do not directly reflect human dietary exposure. Further research analyzing edible muscle tissue and consumption patterns is necessary to evaluate potential health risks for consumers.

Keywords: indian mackerel, mackerel tuna, microplastics

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1. INTRODUCTION

Plastic pollution is one of the global environmental issues that has a serious impact on ecosystems and human health. The ability of plastics to degrade over a very long period of time, namely tens to hundreds of years, creates environmental problems in the form of microplastic accumulation in marine ecosystems. The process of physical abrasion due to wave impact, reinforced by mechanical mechanisms, as well as photochemical degradation triggered by exposure to ultraviolet (UV) light, can cause plastic to fragment into small parts. Plastic fragments less than 5 millimeters in size are classified as microplastics (Yudhantari et al., 2019).

Microplastics carry harmful chemical compounds, including plastic additives and environmental contaminants, that are known to disrupt the endocrine system and trigger carcinogenic effects when they accumulate in aquatic organisms (Wright & Kelly, 2017). This risk affects not only marine life but also potentially jeopardizes human health through the food chain, particularly through the consumption of seafood contaminated with microplastics. Commercial fish such as mackerel, mackerel tuna (*Euthynnus affinis*), and Indian mackerel (*Rastrelliger kanagurta*), which are important components of public consumption, may serve as transmission media for microplastic exposure. Given that both species are commonly sold in traditional and modern markets, the presence of microplastics in these fish could increase the potential for exposure to toxic compounds in the wider community, especially among those who consume fish regularly. Possible health impacts include chromosomal changes, infertility (Chatterjee & Sharma, 2019), pathogen transfer, and chronic inflammation of body tissues (Prata et al., 2020).

This concern is increasingly relevant in Indonesia, where the estimated dietary intake of microplastics is about 15 g per capita per month (Zhao & You, 2024). This dietary exposure is strongly linked to aquatic food sources, particularly seafood, which is an important source of animal protein in the Indonesian diet. Aryani et al. (2024) examined microplastics in fish samples from traditional markets and found that milkfish contained an average of 149.4 microplastic particles per individual, while mackerel tuna contained about 178 particles per individual. The study was conducted at Kranggot Traditional Market in Cilegon, Banten. These findings indicate that fish sold in traditional markets may be contaminated with microplastics, raising concerns about their potential impact on human health.

Fish consumption in Bandung City continues to rise year after year. According to data from the West Java Maritime and Fisheries Service, fish consumption in Bandung in 2022 reached 41.37 kg/capita/year, with mackerel tuna and mackerel the most commonly consumed marine fish, averaging 0.017 per capita per week. Mackerel tuna and Indian mackerel are economically important pelagic fish. Fish are sold and traded at Traditional Market X in Bandung City, Indonesia. The market features a dedicated section for both sea and freshwater catches. Known as a major source of various fish types, Traditional Market X is a key supplier of animal protein (Ria Arifianti, 2019).

As a key supplier of fish to consumers in Bandung City, food safety concerns, especially microplastic contamination, require attention. However, data on microplastic presence in fish meant for human consumption in Bandung are scarce, particularly regarding their abundance, features, and polymer types in market fish. While previous research has identified microplastic contamination in fish from other regional markets, such as Cilegon's Kranggot Traditional Market, similar data on fish sold at the Traditional Market in Bandung are unavailable. This study aimed to evaluate the quantity, features (such as shape, color, and size), and polymer makeup of microplastics found in the gills and digestive tracts of mackerel tuna (*Euthynnus affinis*) and Indian mackerel (*Rastrelliger kanagurta*) sold at Traditional Market X in Bandung City. It also compared microplastic levels between the two species and explored links with fish size, including body length, weight, gill weight, and digestive tract weight.

2. RESEARCH AND METHODS

2.1. Research time

This research was conducted from February to April 2025. Fish samples were collected from Traditional Market X in Bandung City. The samples were then identified at the Integrated Laboratory of the State Islamic University Sunan Gunung Djati Bandung by observing them under a Stereo Microscope, and further FTIR (Fourier-transform Infrared Spectroscopy) tests were conducted at the Chemistry Department Laboratory of the Bandung Institute of Technology.

2.2. Tools and Materials

The core tools and materials used in this research include a stereo microscope, an Optilab camera, Optilab Viewer software, Image Raster software, FTIR spectroscopy, glass beakers, Erlenmeyer flasks, funnels, 0.45 µm filter paper, an oven, a digital balance, and an analytical balance. The materials used include mackerel tuna (*Euthynnus affinis*), mackerel (*Rastrelliger kanagurta*), 10% KOH solution, 30% H_2O_2, and distilled water.

2.3. Sampling

Sampling was carried out through purposive sampling at Traditional Market X, a fish market in Bandung. A total of 36 fish were collected, including 18 mackerel tuna (*Euthynnus affinis*, 34-40 cm) and 18 Indian mackerel (*Rastrelliger kanagurta*, 20-28 cm). Fish were selected based on size criteria for adult, commercially consumed fish (gonad maturity). They were sourced from the appropriate stalls, stored in a cool box, and transported to the lab for analysis of microplastics in their digestive tracts and gills. Samples were collected from six stalls, with six fish sampled in each, totaling 36 fish. The collection occurred over two weeks, with one purchase per week, and samples were sourced from various supply batches instead of just one.

2.4. Microplastics Extraction

Research procedures follow quality-assurance standards to prevent contamination, including cleaning equipment before use, keeping samples covered, and wearing cotton clothing and gloves. Sample testing followed the method of Lusher et al. (2016), beginning with species identification and measurement of fish length and weight. The stages of

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microplastic analysis include: (1) fish dissection according to Suprijanto et al. (2021), which involves removing the digestive tract and gills; (2) tissue deconstruction using a 10% KOH solution at three times the sample weight, incubated for 24 hours at 40°C (Rochman et al., 2015). If the tissue was not fully digested, 5 mL of 30% H_2O_2 was added, and the sample was incubated for another 24 hours at room temperature (Yudhantari et al., 2019); and (3) filtering through 0.45 µm filter paper, followed by drying in an oven at 60°C for 1 hour. The dried samples were then identified according to the guidelines of Kovač Viršek et al. (2016).

2.5. Microplastic Identification

Dried samples are identified using a stereo microscope at 4-13.5X magnification (Yudhantari et al., 2019). Samples are placed on a Petri dish, focused, and visible microplastic particles are documented with Optilab software and analyzed for size using Image Raster. This identification aims to determine the type, shape, color, and size of microplastics in the sample.

2.6. FTIR Test

Identification of microplastic polymer type was carried out using FTIR spectroscopy with the KBr disc method (Campopiano et al., 2015; Olori et al., 2021). Microplastics were finely crushed, mixed with dry KBr powder, and pressed into thin disks. Analysis was performed in transmission mode over the range 4000-400 cm-1 with a resolution of 4 cm-1 and 50 scans. The resulting absorption spectra were compared with spectral libraries to identify polymer types such as PE, PP, and PET (Veerasingam et al., 2024).

2.7. Data Analysis

The microplastic data obtained were analyzed to calculate their abundance based on the formula developed by Crawford & Quinn, (2017).

$$K = \frac{Ni}{N}$$

Description:
K : Microplastic abundance (partikel/indivdu)
Ni : Number of microplastic (particle)
N : Number of fish (individuals)

2.8. Statiscal Analysis

Microplastic data were analyzed descriptively and inferentially using RStudio. Descriptive analysis included counts, shapes, colors, and sizes of microplastics, presented in tables and graphs. For inferential analysis, the Mann-Whitney Test was used to compare microplastic abundance between two fish species, and the Spearman Correlation Test was used to evaluate the relationship between fish morphometric parameters and the number of microplastics found. All analyses considered data distributions and the suitability of non-parametric methods.

3. RESULT AND DISCUSSION

3.1. Microplastic Abundance

This study found microplastic contamination in 100% of mackerel tuna (*Euthynnus affinis*) and Indian mackerel (*Rastrelliger kanagurta*) samples, with an average of 15.00 ± 6.61 particles in mackerel tuna and 15.56 ± 4.63 particles in Indian mackerel (see Table 1). Although the average was slightly higher in Indian mackerel, this difference was not statistically significant ($p = 0.349$) based on the Mann–Whitney U test. The 100% prevalence of microplastics, together with the absence of a significant difference in particle abundance between the two species, may indicate relatively widespread exposure among fish entering the market distribution chain. This pattern suggests that the observed contamination may not be explained solely by interspecific differences in feeding behavior or habitat use. Differences in feeding behavior and ecology may still influence microplastic exposure; however, these factors were not directly examined in the present study.

Fish traders reported that the fish were caught from coastal areas along the north coast of Java, such as Tegal, Pekalongan, and Kendal. However, the researchers did not independently verify these catch locations. As a result, this study should be viewed as preliminary evidence of microplastic contamination in fish sold at Traditional Market X in Bandung City, rather than definitive data on pollution levels in the fishing areas. Previous research has identified microplastic contamination in the coastal waters along Java's north coast, including Tegal, Pekalongan, and Kendal (Cordova et al., 2024). Since the samples were collected from a market and their exact origins were not verified by the researchers, these findings should be regarded as regional context rather than direct proof of microplastic sources in the fish.

Spearman correlation analysis revealed very weak negative links between fish body length and body weight and microplastic abundance per individual ($\rho = -0.084$, $p = 0.628$ and $\rho = -0.046$, $p = 0.790$, respectively). Similarly, gill weight showed a very weak negative correlation ($\rho = -0.15$, $p = 0.37$), while digestive tract weight exhibited a weak positive correlation ($\rho = 0.23$, $p = 0.18$). None of these relationships were statistically significant ($p > 0.05$), suggesting that fish morphometric parameters were not strongly associated with microplastic abundance per individual in this analysis.

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Similar research by Koongolla et al. (2022) and Seetapan & Prommi (2023) also indicated that fish body size does not significantly correlate with microplastic load. This implies that external environmental factors, like fishing areas and water quality, may play a role in microplastic accumulation alongside biological traits, which were not directly examined here. Variations in diet and habitat preferences among species could affect microplastic exposure; however, this study could not determine how much these factors contribute to microplastic levels (Morgana et al., 2018).

3.2. Shape of microplastics

This study identified four main forms of microplastics in fish: fiber, fragment, film, and pellet. Of the four, fiber was the most dominant form in both species, with a higher proportion in mackerel (46.43%) than in mackerel tuna (41.11%) (Figure 1a). Pellets were the least abundant. The dominance of the fiber form has also been reported in previous studies, such as Hastuti et al. (2019), which noted that 89.63% of microplastics ingested by fish were fiber, and Hidayati et al. (2023), which found a proportion of 62%. Similar patterns are observed regionally and globally, with fiber-shaped microplastics being the most common in Asian waters (Cordova et al., 2024; Oza et al., 2024).

Based on their physical characteristics (Figure 1b) and sources, fibers are elongated particles derived from synthetic textile waste, fishing nets, or plastic ropes (Dewi et al., 2015), as well as from clothes washing activities (Rochman et al., 2015; Hiwari et al., 2019). Fragments are small pieces of solid plastic objects such as bottles, gallons, pipes, or jars that experience physical weathering (Dewi et al., 2015). Meanwhile, film generally comes from plastic bags and food packaging and has a lower density than other forms (Hiwari et al., 2019)

Table 1. Microplastic Abundance in Mackerel Tuna and Indian Mackerel

Local Name (Scientific Name)	Number of Samples	Number of Samples with MPs	Body Length (cm)	Body Weight (g)	Gill Weight (g)	Range of MPs per Individual in Gills	Digestive Tract Weight (g)	Range of MPs per Individual in the Digestive Tract	Number of MPs per Individual (mean±SD)
Tuna (Euthynnus affinis)	18	18	37.806±2.214	803±70.580	39.39±7.155	2-16	28.39±4.840	1-19	15.00±6.607
Mackerel (Rastrelliger kanagurta)	18	18	23.706±1.034	170.72±20.894	8.39±2.173	4-18	8.17±2.007	2-11	15.56±4.630

Notes: MPs (Microplastics)

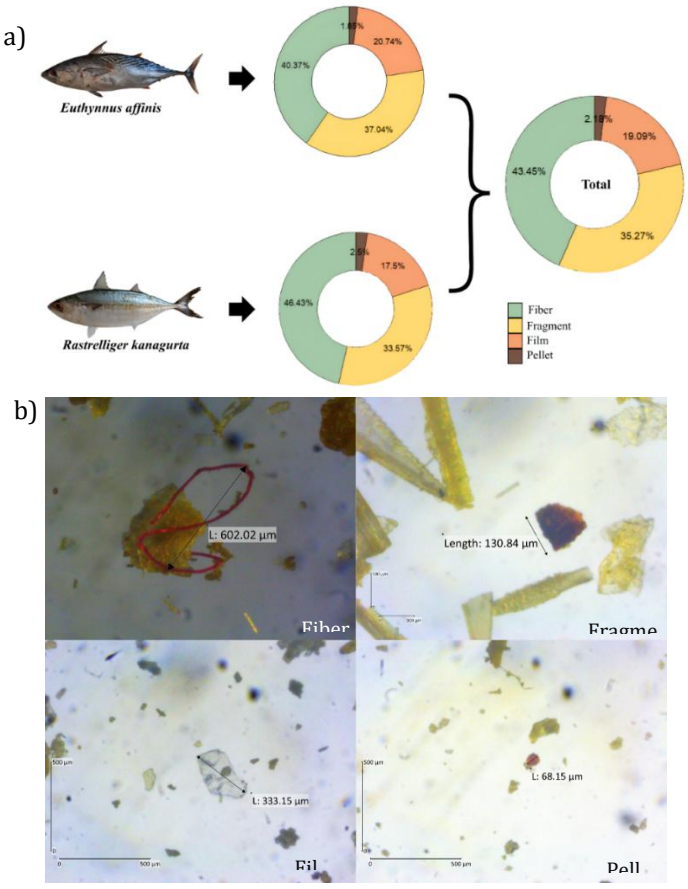


Figure 1. Microplastic Forms in Mackerel Tuna and Indian Mackerel: a) Abundance of Microplastic Forms, b) Microscopic Images of Microplastic Forms

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Fiber dominance is strongly suspected to be linked to high domestic and industrial textile activities that produce synthetic fibers, which are then transported into the aquatic environment and may accumulate in fish bodies (Zhang et al., 2022). The flexible, lightweight, and elongated nature of fibers makes them easily suspended in the water column and more likely to be ingested by fish, either actively or passively. Because they resemble plankton or small invertebrates, fiber particles can be mistaken for prey by pelagic fish that rely on vision for foraging (Mizraji et al., 2017; Ory et al., 2018).

Experiments by Roch et al. (2020) support these findings, showing that fish with a visual feeding orientation tend to ingest more microplastics than those relying on olfactory or taste (chemosensory) systems. Pathways for microplastics to enter fish include active ingestion due to misidentification, passive ingestion during foraging, serta transfer trofik dari mangsa yang telah terkontaminasi (Welden et al., 2018). Thus, fiber shapes that resemble natural food particles, coupled with the visual feeding behavior of pelagic fish, are major factors in the high accumulation of microplastics in these species.

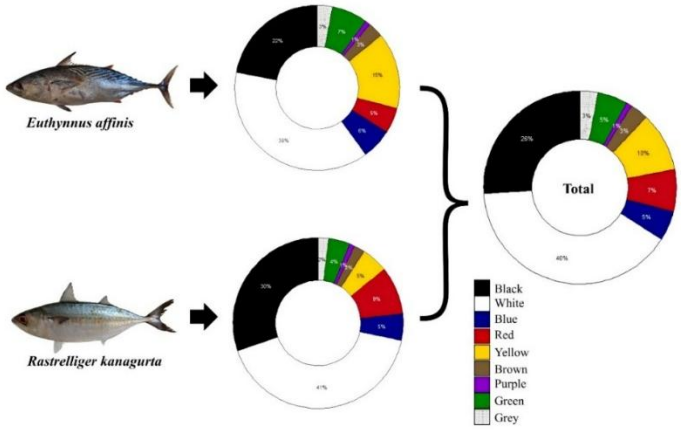
3.3. Microplastics color

The results of this study showed that microplastics in mackerel tuna (*Euthynnus affinis*) and Indian mackerel (*Rastrelliger kanagurta*) were dominated by transparent particles, followed by black particles (Figure 2a). The dominance of transparent particles is most likely due to the physical and chemical degradation of plastics, such as UV exposure, abrasion, and biological weathering, which cause plastics to lose their original color (Song et al., 2017). Transparent particles are also difficult for fish to visually recognize, increasing the risk of accidental ingestion, especially among fish that actively forage in the water column.

Feeding behavior also influences the color type of ingested microplastics. Mackerel tuna, which are opportunistic carnivores, and mackerel, which are filter feeders, have different tendencies to ingest microplastics. Mackerel tuna can ingest particles that resemble prey, while mackerel's filtering system facilitates the entry of small, transparent microplastics with plankton (Pebiloka et al., 2023; Rahma et al., 2024). The black color is likely from recycled plastic or rubber-based materials, such as nets, pipes, and garbage bags.

Transparent microplastics generally originate from single-use plastics such as bottles, food packaging, and clear plastic bags. In aquatic environments, photodegradation and abrasion fragment these plastics into small, translucent particles that resemble zooplankton or fish eggs, increasing the likelihood of active or passive ingestion. In contrast, black-colored particles containing carbon black are more resistant to degradation and persist longer in the environment. Their dark color also makes it difficult for fish to distinguish them from detritus or organic particles, especially in turbid waters (Bessa et al., 2018).

a)



b)

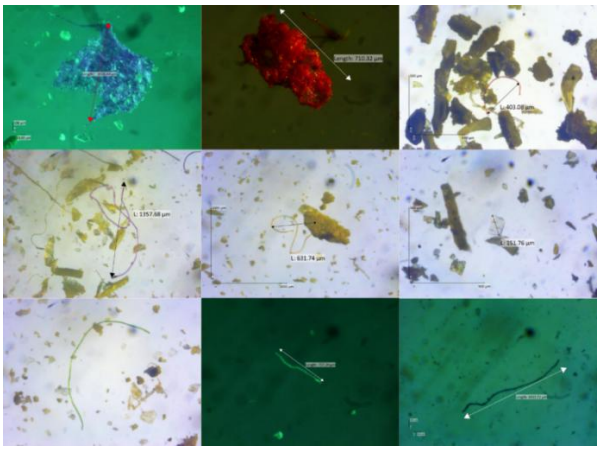


Figure 2. Microplastics Color in Mackerel Tuna and Mackerel: a) Percentage of Microplastic Color, b) Microscopic Color of Microplastic

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Furthermore, the color of microplastics is closely related to fish feeding strategies. Omnivorous and carnivorous species generally have higher levels of microplastic exposure due to lower prey selectivity, including particles that resemble natural food, such as transparent and black-colored microplastics (Oza et al., 2024). This confirms that visual factors, including color, play an important role in the interaction between fish and microplastics in aquatic environments.

3.4. Microplastics Size

The size of microplastics plays an important role in determining the likelihood of ingestion by aquatic organisms. The results showed that the majority of microplastics found in *Euthynnus affinis* and *Rastrelliger kanagurta* were in the <500 µm range. Particles of this size tend to remain suspended in the water column and resemble plankton in size, making them easier to ingest accidentally, especially by pelagic fish that actively forage in the surface-to-subsurface zone (Wright & Kelly, 2017). The results of this study are consistent with the study of Cordova et al. (2024), which reported that more than 51% of microplastics in Indonesian sub-surface waters, including the North Sea of Java, were below 500 µm in size

The majority of microplastics found in both fish species were <500 µm in size, with the highest proportions in mackerel tuna (72.96%) and Indian mackerel (67.14%), and 70% in total (Figure 3a). This indicates that small particles are more likely to enter and accumulate in the fish body. The size distribution of microplastics by organ also showed a similar pattern, with the gills dominated by small particles. At the same time, the digestive tract contained a wider range of sizes including medium to large particles. However, small particles remained the most dominant form in both organs (Figure 3b).

The dominant size distribution of microplastics in the <500 µm range also indicates the potential accumulation of primary microplastics, which are particles that have been produced in micro sizes from the beginning, such as microbeads or fibers from textiles. Meanwhile, particles >500 µm in size tend to be secondary microplastics resulting from the fragmentation of macroplastics that have undergone physical and chemical weathering (Duis & Coors, 2016).

Microplastics <500 µm in size can penetrate deeper into an organism's tissues, increasing the risk of systemic toxicity. These particles can pass through the digestive system and trigger physiological responses such as oxidative stress, inflammation, and impaired nutrient absorption. In addition, these small particles have a high potential to move between trophic levels, from low-level organisms such as zooplankton to fish, and ultimately to humans as the ultimate consumers (Wright & Kelly, 2017).

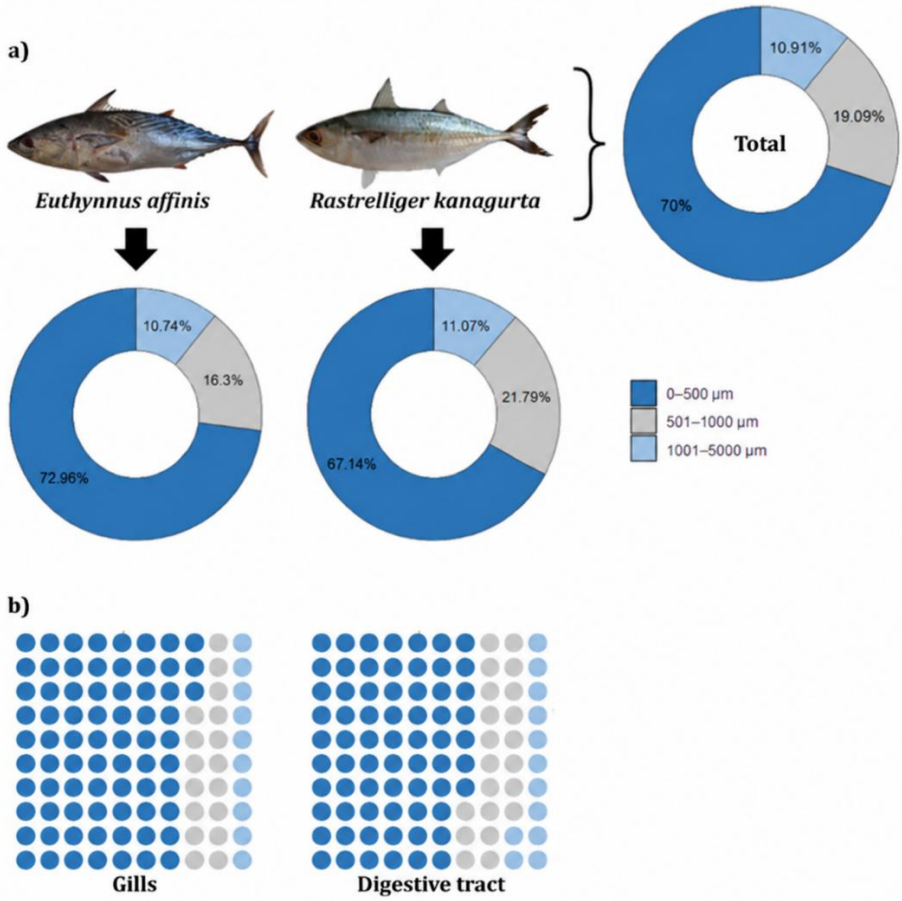


Figure 3. Microplastic Size in Mackerel Tuna and Indian Mackerel, a) By Individual, b) By Organ

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The presence of small microplastics in the marine environment is also attributed to the degradation of plastic by UV exposure, wave abrasion, and microbial activity, which produces micro-sized fiber particles and fragments. In the Java North Sea region, these small particles were found to dominate, and local oceanographic characteristics, including strong currents and short water residence times, cause suspended microplastics to be evenly distributed throughout the water column (Cordova et al., 2024; Iskandar et al., 2021).

3.5. Polymer Type of Microplastics

FTIR spectroscopy analysis showed that the microplastics detected in the gills and digestive tract of mackerel tuna (*Euthynnus affinis*) and Indian mackerel (*Rastrelliger kanagurta*) consisted of three main polymer types, namely polyethylene (PE), polyethylene terephthalate (PET), and polystyrene (PS) (Figure 4). These three types are synthetic polymers commonly used in various plastic products and have physicochemical characteristics that allow for their widespread presence in the aquatic environment.

In mackerel tuna (Figure 4a), PE was indicated by absorption peaks at wavenumbers 1465, 2852.72, and 2922.16 cm^{-1}, corresponding to bending vibrations of -CH_2- groups and the symmetric and asymmetric stretching of aliphatic C-H bonds, respectively (Amelia et al., 2016). In addition, PET was identified by absorption peaks at 3425.58 cm^{-1} (-OH group), 1653 cm^{-1} (C=O stretching), 1035.77 cm^{-1} (C-O stretching), and 871.82 cm^{-1} (aromatic C-H bending), indicating the typical structure of aromatic esters (Alzuhairi et al., 2018). In indian mackerel (Figure 4b), in addition to PE and PET showing similar absorption patterns, PS was also identified by wavenumbers 1601, 1492, 872.44, 758, and 698 cm^{-1}, reflecting the presence of aromatic groups and out-of-plane bending in the PS structure (Smith et al., 2024).

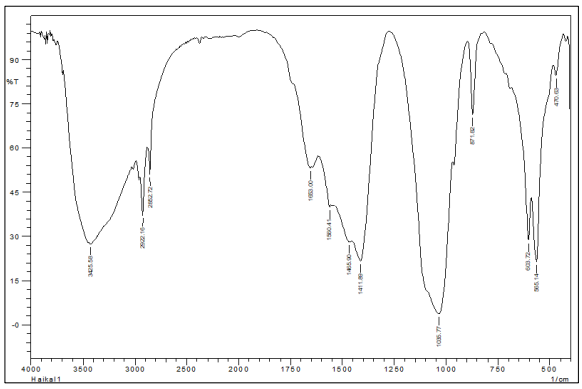
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Polyethylene (PE) is the most widely used polymer. PE is known for its low density and high resistance to biological degradation, so it tends to float on the surface of seawater and persist in the environment for a long time. This polymer is commonly used in the production of plastic bags, food wrappers, and fishing equipment such as nets and ropes (Amelia et al., 2016). PET, which was also identified in the samples, is widely used in the manufacture of beverage bottles and food packaging. PET has a higher density and therefore has the potential to settle to the bottom, especially when bound to other particles. PS is found in the form of small particles from Styrofoam products, food containers, and plastic cutlery, and is known to fragment easily into very small microplastics.

Each polymer type has a distinct toxicological potential. PE is known to disrupt digestive function and inhibit nutrient absorption. PS is reported to have higher genotoxic effects and can trigger physiological stress, such as increased cortisol levels in fish. PET is associated with oxidative stress and metabolic disorders (Jakubowska et al., 2020; Ma et al., 2024).

The presence of these polymers suggests that the primary source of pollution stems from daily human activities, particularly in the household, fishery, and food industry sectors. Poorly managed plastic waste tends to fragment and become microplastics in the water, which can then accumulate in the bodies of fish consumed by humans. The detection of PE, PET, and PS in the analyzed fish tissues indicates microplastic exposure in commercially sold fish. Past studies have shown that micro- and nanoplastics can impact biological processes, such as protein folding and amyloid formation (Windheim et al., 2022).

a)



b)

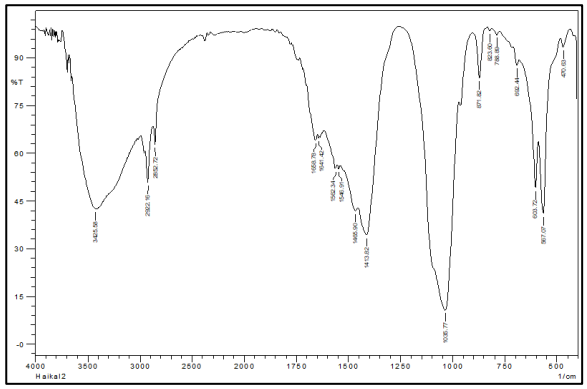


Figure 4. FTIR Spectra of Microplastics, a) Tuna MPs, b) Mackerel MPs

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This study has some limitations to consider when evaluating its implications for food safety. Microplastics were analyzed in the gills and digestive tracts, which are not typically the main edible parts of fish. As a result, the detected microplastic levels mainly indicate fish exposure rather than directly representing human dietary intake. The study did not include analysis of microplastics in muscle tissue nor estimate the amount of microplastic consumed by humans. Future research should examine edible muscle tissue and combine microplastic data with fish consumption rates to better understand potential health risks to consumers. Although precautionary steps such as cleaning equipment, covering samples, and wearing cotton clothing and gloves were taken to reduce contamination, the study did not report procedural blanks or other contamination controls. Thus, background contamination during sample processing cannot be entirely ruled out.

4. CONCLUSIONS

All fish samples from Traditional Market X in Bandung City, Indonesia, contained microplastics (100%). Fibers were the most common shape (43%), with transparent particles being the main color (40%), and particles under 500 µm representing 70% of the size. FTIR analysis identified three polymer types: polyethylene (PE), polyethylene terephthalate (PET), and polystyrene (PS). The Mann–Whitney test revealed no significant difference in microplastic levels between mackerel tuna (*Euthynnus affinis*) and Indian mackerel (*Rastrelliger kanagurta*) ($p > 0.05$). These results offer initial insights into microplastic presence and characteristics in fish sold at the market. Since the fish were sourced from a market and not directly from fishing grounds, the data should not be seen as a direct measure of microplastic pollution in the catch areas' waters. Additionally, because microplastics were analyzed in the gills and digestive tracts rather than the edible muscle tissue, the results indicate exposure in fish but do not directly assess potential human dietary risks. Future research, including sampling directly from fishing grounds, analyzing edible muscle tissue, and evaluating dietary intake, is necessary to better understand environmental sources and possible consumer exposure.

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