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Microplastic contamination in sea catch processing waste from coastal areas: Identification and characterization

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ABSTRACT

The presence of microplastics in marine environments poses a major ecological risk, particularly along densely populated coastal regions like the Sukolilo Baru Kenjeran Coast, Surabaya. The waste from sea catch processing industries represents a significant yet underexplored source of contamination. This research aimed to identify the abundance, characteristics, and polymer composition of microplastics in sea catch waste (shrimp, sea cucumber, ball sea cucumber, fish, and shellfish) from the area. Waste samples were analyzed using a stereo microscope to characterize morphology (type, color, and size). The polymer composition of four types (n = 4 waste samples of shrimp waste, sea cucumber waste, fish waste, shellfish waste) of representative particles was identified using Attenuated Total Reflectance–Fourier Transform Infrared (ATR-FTIR) spectroscopy. Results indicated that all waste samples were contaminated with microplastics, with the highest abundance observed in shrimp waste (45 particles). Fibers were the most dominant morphology, suggesting a source from secondary microplastics. Two color distribution patterns were identified: shrimp and sea cucumber waste were dominated by black particles, whereas other waste types were dominated by blue. FTIR analysis identified two distinct polymer profiles, with shellfish waste exhibiting a unique chemical composition compared to other samples. These findings confirm that the waste from sea catch processing serves as a direct pathway for microplastic entry into coastal aquatic environments. Therefore, improved waste management strategies are required to mitigate the microplastic pollution originating from the fisheries sector.

Keywords: contamination, fiber, microplastics, sea catch waste.

INTRODUCTION

The proliferation of plastic waste has become a worldwide concern, affecting aquatic environments on a global scale. The total waste production is estimated to reach between 4.8 and 12.7 million metric tons that have been discharged into the global seas and oceans (Kurtela and Antolović, 2019). The presence of marine plastic debris varies in abundance across surface, midwater, and seabed zones (Kurtela and Antolović, 2019). Marine plastic waste primarily originates from domestic activities, industrial processes (Xia et al., 2021), and inadequate waste management systems (Goli et al., 2024).

Plastics can undergo degradation into smaller particles, one of which is microplastics (Almola et al., 2024). Microplastics are defined as plastic particles measuring less than 5 mm in size (Chamas et al., 2020). They can be classified into primary and secondary categories (Albazoni et al., 2024). Primary microplastics are intentionally designed and manufactured at sizes around 5 mm, commonly used as microbeads in consumer products, such as abrasive explosives, drug delivery systems, fertilizers, and plastic coatings. Secondary microplastics, on the other hand, are by-products of the decomposition of larger polymer waste (Hirt and Body-Malapel, 2020; Yee et al., 2021).

Every year, an estimated 9–14 million tons of plastic enter the sea and are fragmented into microplastics that spread from the surface to the ocean floor (Zhao et al., 2025). These particles are found in various marine organisms – from plankton, fish, to marine mammals – which cause digestive disorders, oxidative stress, and decreased reproductive ability (Ziani et al., 2023). The entry of microplastics into marine ecosystems poses a significant threat to marine environments. The varying sizes, shapes, and polymer types of microplastics across aquatic regions have been shown to negatively affect marine biota (Issac and Kandasubramanian, 2021). Microplastics are toxic and capable of adsorbing persistent organic compounds from the environment (Mei et al., 2020). In addition, microplastics can cause internal bleeding and obstruct the digestive system (Wright et al., 2013). The presence of microplastics in living organisms may have harmful effects on humans and other species involved in the food chain (Browne et al., 2011).

Microplastic particles smaller than 20 μm can stimulate cytokine production in human immune cells (Huang et al., 2021). The rresearch on microplastics in aquatic organisms is crucial because their presence may have adverse effects on humans and other living organisms. Findings from such studies provide insights into the prevalence, morphology, dimensions, and color of the microplastics detected in aquatic biota as a result of plastic waste pollution. Consequently, these findings can serve as a reference for developing effective plastic waste management strategies in aquatic ecosystems.

The Sukolilo Baru Kenjeran coastal area in Surabaya represents a suitable location for examining anthropogenic pressures on marine environments (Ni'am et al., 2019). As a center for fisheries-based economic activity and a popular tourism destination, this region experiences high population pressure along its coastline. Intensive interactions among fishing activities, sea catch processing, and recreation create significant threats to coastal ecosystems, making environmental mitigation and protection urgent priorities (Chen et al., 2021). One of the major challenges identified in this area is the management of the waste generated from sea catch processing activities.

Post-processing waste management in the Sukolilo Baru Kenjeran area remains inadequate, as waste from primary catches such as shrimp, sea cucumbers, and sea slugs is often discharged directly into water bodies (Bahri et al., 2020). This waste includes shrimp heads and shells, as well as cleaning water from sea cucumbers, all of which have high potential to pollute the ecosystem and negatively affect marine biota (Xia et al., 2024). Given the absence of specific studies on the microplastic content in sea catch waste from this location, this research is essential. Therefore, the objective of this research was to identify and characterize the microplastics contained in the shrimp, sea cucumber, and sea slug waste from the Sukolilo Baru Kenjeran Coast, Surabaya.

MATERIAL AND METHODS

Research site

Sea catch waste, consisting of shrimp, sea slug, and sea cucumber residues, was collected from the Sukolilo Baru Kenjeran Coast, Surabaya, as shown in Figure 1.

Sample and data analysis

Microplastic testing was conducted at the Ecoton Laboratory in Surabaya. The number of biota samples for each fish catch waste for microplastic testing is 800 mL. Pretreatment of the sample by removing the water content. The samples were heated using an oven at a temperature of 70–90 °C for 2 × 24 hours. The dry sediment sample was removed and if there was still a lot of gravel, the sample was sifted until you fine sediment was obtained. The sample weighed as much as 50 grams. The 50 gram sediment sample was transferred into a new glass sample container and 2x the sample volume of NaCl was added to each sample. The samples was incubated for 24 hours, the clear top of each sample was taken and then transferred to a new sample container.

A 2 mL aliquot of 30% H_2O_2 solution was added using a pipette until the sample was fully submerged and left for 15 minutes to react. Subsequently, 5 mL of 30% Fe_2SO_4 solution was added to each sample, followed by incubation for 24 hours until the sample was completely digested. If undigested material remained, it was separated

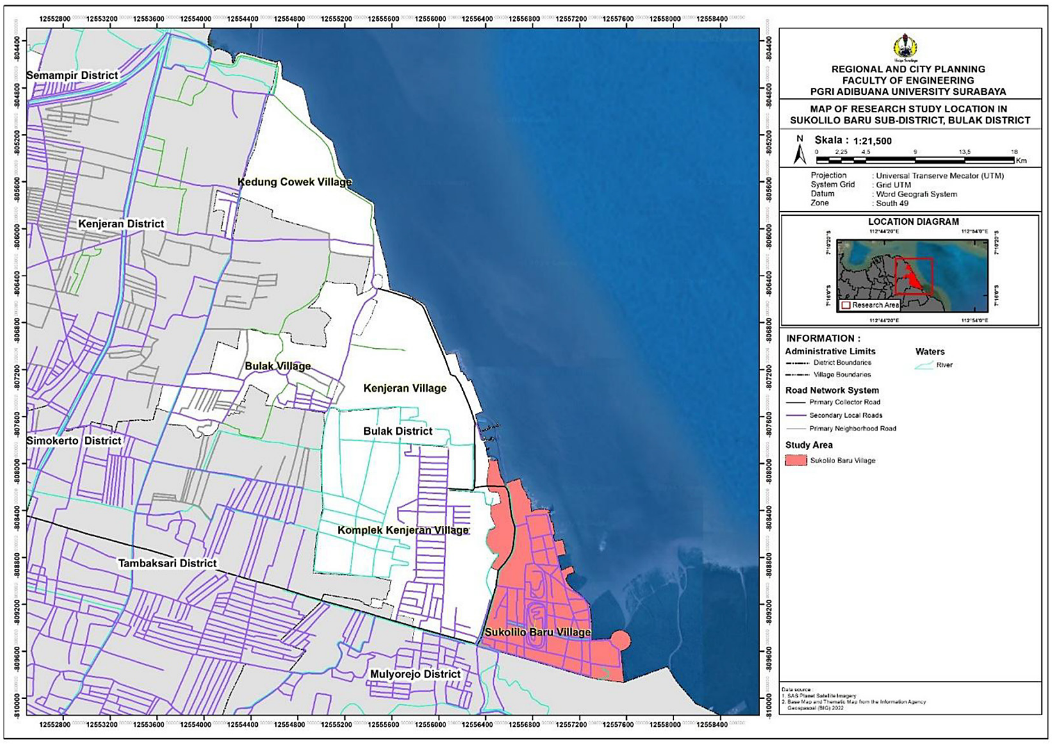


Figure 1. Location of waste content of sea catches in Sukolilo Baru Kenjeran Coast, Surabaya City

using a centrifuge for 30 minutes at 350 rpm. The centrifuge method was used at the sample separation stage to accelerate the separation of microplastic particles from the water or sediment matrix based on density differences. This process helped separate plastic fragments from organic or mineral materials, thereby reducing the risk of contamination and increasing sample purity before FTIR analysis was performed (Tirkey and Upadhyay, 2021). The supernatant from each sample was transferred to a sterile glass container and heated on a hotplate for 30 minutes at 70 °C. After cooling, the samples were filtered using Whatman filter paper. Microplastic identification was then carried out using a stereo microscope (RAMAN microscopy).

Sample analysis consisted of microplastic particle characterization. Visual characterization was used to identify microplastic morphology (fiber, filament, fragment, granule, and foam), color, and size. To distinguish polymeric particles from organic materials, a mechanical probing test was performed using a preparation needle. The particles that did not disintegrate or break upon pressure were identified as microplastics. Each microplastic particle was then measured using millimeter paper placed beneath a Petri dish as a reference scale.

Microplastic identification

The ATR-FTIR (Attenuated Total Reflectance – Fourier Transform Infrared) spectroscopy technique was selected because it allows for rapid and reliable identification of microplastic polymers without the need for complex sample preparation. This method works by detecting the unique infrared absorption patterns of chemical functional groups within plastics, enabling the identification of polymers, such as PE, PP, and PET through their characteristic spectral "fingerprints" (Primpke et al., 2020). Compared to other analytical techniques, ATR-FTIR offers several advantages, including the ability to analyze small particles down to approximately 20 μm in size without damaging or dissolving the sample. It is also user-friendly, time-efficient, and produces consistent and stable quantitative data (Käppler et al., 2016).

In this study, the chemical composition of selected microplastic particles was analyzed using ATR-FTIR spectroscopy. Individual particles were visually picked from the filter membrane and placed directly onto the ATR crystal of the spectrometer. Infrared spectra were recorded over a wavenumber range of 4000–400 cm^{-1} at a resolution of 4 cm^{-1} across 24 scans. The resulting spectra were then compared with a polymer spectral library using OMNIC software (Thermo Fisher Scientific). A polymer type was positively identified when the spectral similarity index exceeded 70%, indicating a reliable match between the sample and reference spectrum.

RESULTS AND DISCUSSION

The abundance of microplastics in the waste content test of sea catches

Figure 2 shows that microplastics were detected in all sea catch waste samples. The total microplastic counts in shrimp, sea cucumber, ball see cucumber, fish, and shellfish waste were 45±4.24 particles, 4±1.41 particles, 26±2.12 particles, 20±3.54 particles, and 14±2.83 particles, respectively. The presence of microplastics in these wastes indicates contamination originating from their natural habitats (Musa et al., 2024). This also implies that microplastic accumulation reflects the continuous input and retention of plastic debris in the aquatic environment (Fauzi et al., 2023).

Microplastics can enter the food chain through phytoplankton, zooplankton and benthic organisms that accidentally ingest them (Sandra and Radityaningrum, 2021). These particles then move to higher trophic levels, including fish and shellfish for human consumption (Saeedi, 2024). In addition, microplastics can carry dangerous chemicals, such as phthalates and PCBs, which have the potential to accumulate in the tissues of marine biota (Ziani et al., 2023).

Long-term exposure to microplastics can cause digestive disorders, oxidative stress, and decreased reproductive function in marine organisms. This ecological impact can reduce the diversity and productivity of local fisheries. For coastal communities who consume marine products from the Kenjeran area, the risk of exposure to microplastics increases, both through the plastic particles themselves and the chemicals adsorbed on their surfaces (Oza et al., 2024).

Type of microplastic

On the basis of Figure 3 and Table 1, the types of microplastics identified in sea catch waste from the Sukolilo Baru Kenjeran Coast consisted of fragments, filaments, and fibers. Fibers were the most dominant type, accounting for 62.90% (39 particles) in shrimp waste, 32.26% (20 particles) in sea cucumber waste, and 4.84% (3 particles) in sea slug waste. Filaments were found mainly in sea cucumber waste (60%, 6 particles), followed by shrimp waste (40%, 4 particles), and none in sea slug waste (0%). Fragments were detected in shrimp waste (66.67%, 2 particles), sea slug waste (33.33%, 1 particle), and were absent in sea cucumber waste (0%).

This research identified only three types of microplastics – fibers, filaments, and fragments – all of which are derived from secondary microplastic sources (Lehtiniemi et al., 2018). Secondary microplastics originate from the breakdown of larger plastic items, such as fibers or pieces detached from fishing nets, household tools, or degradable plastic bags, before entering aquatic systems (El Hadri et al., 2020). Secondary microplastic fragments can come from fishing nets, household items, and plastic bags that are designed to degrade in the environment (Freeman et

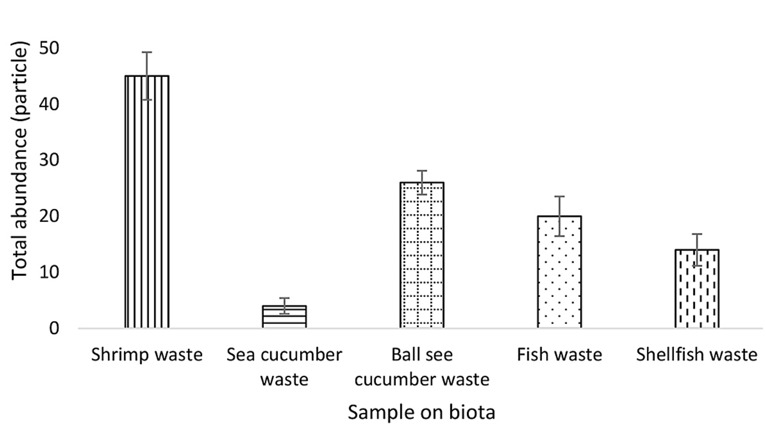


Figure 2. Total abundance of microplastics on biota

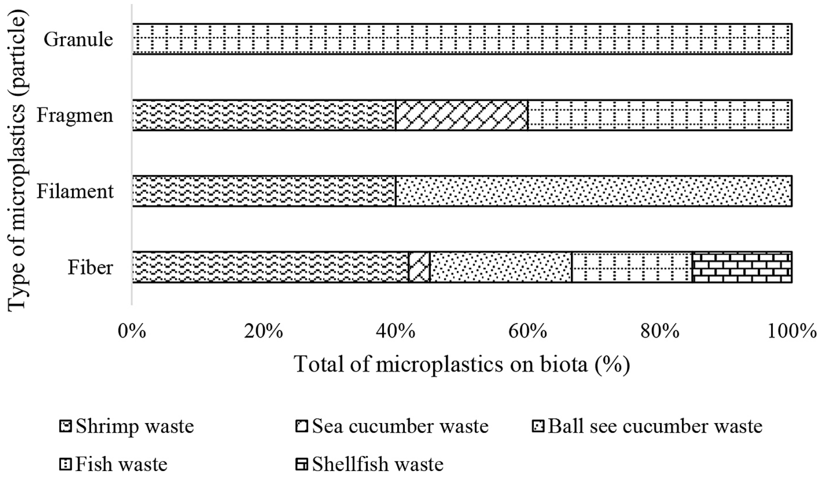


Figure 3. Type of microplastic on sea biota

Table 1. Abundance and shape of microplastic particles in waste content of sea catches in Sukolilo Baru Kenjeran Coast, Surabaya City

Sample	Microplastic forms (Particles/100 gram)				Abundance of microplastics (Particles/100 gram)
	Fiber	Filament	Fragmen	Granule	
Shrimp waste	39	4	2	0	45
Sea cucumber waste	3	0	1	0	4
Ball sees cucumber waste	20	6	0	0	26
Fish waste	17	0	2	1	20
Shellfish waste	14	0	0	0	14

al., 2020). These secondary particles tend to have longer residence times in both natural and artificial water bodies (Hinata et al., 2017).

The dominant type of microplastic identified in this research was fiber, which exhibited the highest abundance across all sea catch waste samples. In contrast, fragment and filament types were the least frequently detected in all waste categories. These results are consistent with the previous studies reporting that fiber-type microplastics are the most prevalent form in marine environments (Güven et al., 2017).

Fiber-shaped microplastics originate from the washing of synthetic textiles, synthetic polymer threads, and the fragmentation of monofilament fibers from fishing nets and ropes (Liu et al., 2019). Fragments, on the other hand, are typically thick, rigid, and irregularly shaped pieces of plastic (Andrady and Koongolla, 2022). In this study, fragments were likely introduced into the aquatic environment through the human activities near the sampling area, such as the breakdown of plastic items, buckets, and other large polymer-based tools (Sorasan et al., 2022).

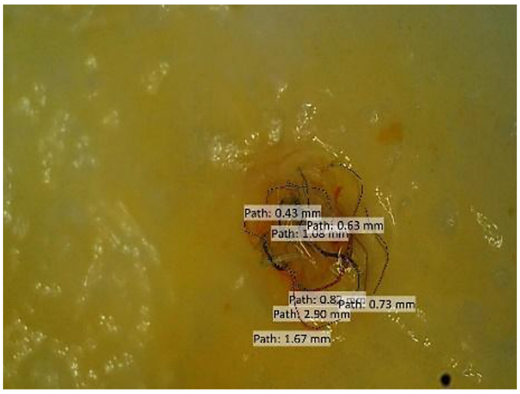
Microplastic visual data

Visual data of the microplastics found in shrimp, ball sea cucumber, and sea cucumber waste are presented in Figures 4 to 8. Fiber-shaped microplastics are the most commonly found in the Brantas River, Surabaya, Indonesia.

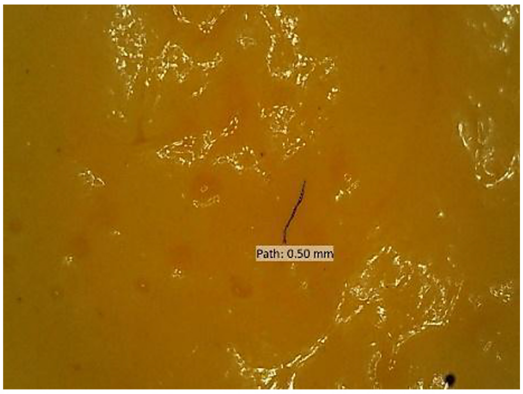
The color of microplastics

Table 2 presents the comparative percentage distribution of microplastic colors identified from five different types of sea catch waste. The data reveal distinct variations and dominant color patterns across sample types. In shrimp waste, microplastics were predominantly black, accounting for 71% of total particles. Other detected colors included gray (16%), red (9%), and green (4%). A similar dominance of dark-colored microplastics was observed in sea cucumber waste, where black particles constituted 75%, followed by green (25%).

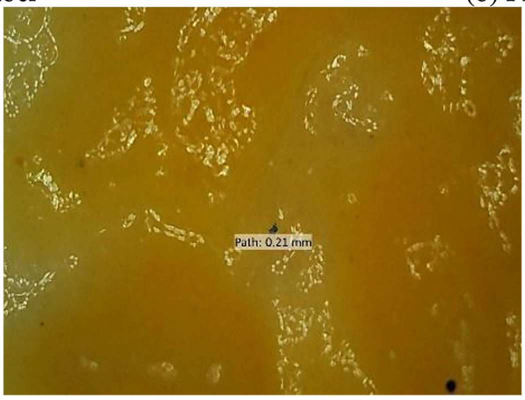
Conversely, three other sample types exhibited a dominance of blue-colored microplastics. In ball sea cucumber waste, blue microplastics were the most abundant (65%), followed by red



(a) Fiber



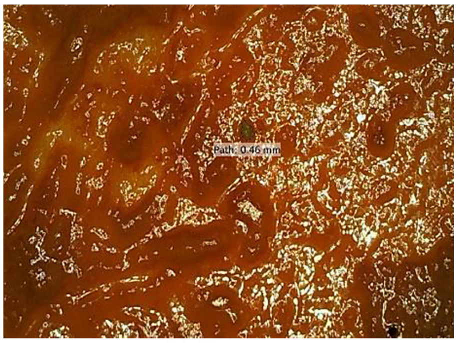
(b) Filament



(c) Fragment

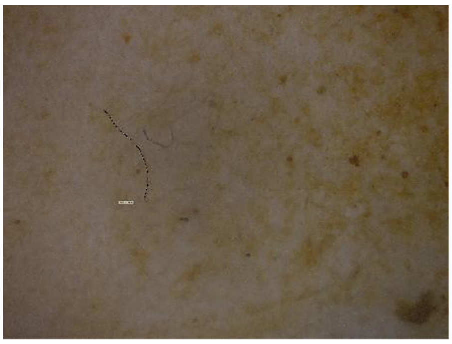
Figure 4. Microplastics from shrimp waste

(a) Fiber

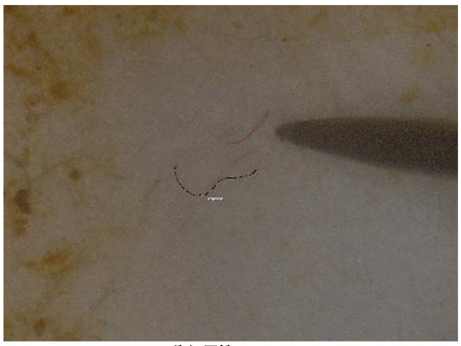


(b) Fragment

Figure 5. Microplastics from sea cucumber waste



(a) Fiber

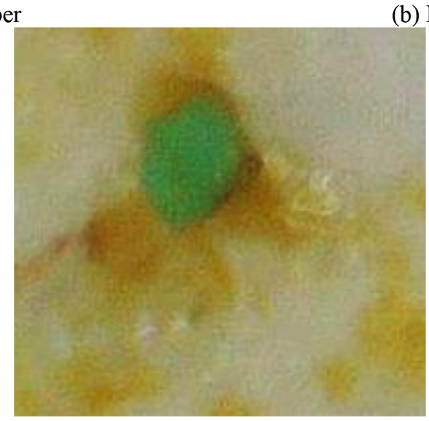


(b) Filament

Figure 6. Microplastics from ball sea cucumber waste

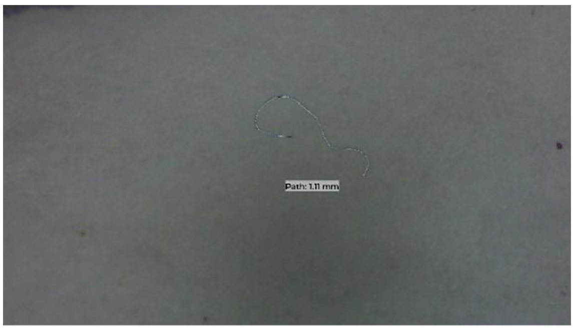
(a) Fiber

(b) Fragment



(c) Granule

Figure 7. Microplastics from fish waste



(a) Fiber

Figure 8. Microplastics from shellfish waste

(19%), and equal proportions of black and purple (8% each). This trend continued in fish waste, where blue remained dominant (60%), followed by red (20%), as well as smaller proportions of black and gray (10% each). The most pronounced dominance of blue microplastics was found in shellfish waste, with blue particles comprising 93% of all detected microplastics and the remaining 7% being red.

Overall, these findings indicate two primary patterns of microplastic color distribution. Shrimp and sea cucumber waste were mainly contaminated by dark-colored (black) microplastics, whereas ball sea cucumber, fish, and shellfish waste were dominated by blue-colored microplastics. These differences likely reflect the variations in plastic pollution sources across the habitats of each biota or differences in plastic fragmentation processes that produce specific color profiles.

In general, the darker the color of a microplastic, the more likely it is that the particle has undergone aging or weathering processes in the environment. When plastic is in the ocean for a long time, it is exposed to ultraviolet (UV) light, oxidation, and mechanical friction with sand or seawater. This process causes chemical and physical changes to the plastic surface – including discoloration, roughness, and brittleness (Tirkey and Upadhyay, 2021). Initial colors, such as light blue or green can fade or darken to dark blue to black as the rate of degradation increases. In addition, the microplastic particles that have been in the sea for a long time often absorb organic materials, heavy metals and chemical pollutants from sea water. This absorption process also makes

Table 2. Comparison on percentage of different colours of microplastics from different waste content test of sea catches

Sample	The Colour of Microplastics (%)					
	Black	Grey	Red	Blue	Green	Purple
Shrimp waste	32	7	4	0	2	0
Sea cucumber waste	3	0	0	0	1	0
Ball sees cucumber waste	2	0	5	17	0	2
Fish waste	2	0	4	12	2	0
Shellfish waste	0	0	1	13	0	0

the plastic surface turn darker. Therefore, black microplastics are generally associated with older age and longer environmental exposure than light colored microplastics (Oza et al., 2024).

The size of microplastics

The microplastic particles identified in this research exhibited a wide size range, varying from 0.05 mm to 3.96 mm, as shown in Table 3. This size range indicates the presence of continuous fragmentation processes occurring in the marine environment. The findings of this research are consistent with previous studies, which reported an inverse relationship between particle size and abundance. Those studies classified particle sizes into three categories, with particles smaller than 500 µm (0.5 mm) being the most dominant, accounting for 96.7% in mulched fields and 89% in non-mulched fields (Zulkarnain et al., 2025).

The predominance of small-sized particles can be attributed to multiple factors. First, continuous abiotic and biotic degradation processes break down larger plastic particles into smaller fragments (Dudek et al., 2025). Second, smaller particles exhibit higher bioavailability, making them more likely to be ingested by marine organisms (Shamskhany et al., 2021). Consequently, filter-feeding organisms – such as shellfish – and deposit feeders – such as sea cucumbers – inadvertently ingest these small particles from the water column or sediment, which may then be transferred through trophic levels to higher organisms such as fish and shrimp.

The largest particles found in this research were consistently identified as fibers measuring 3.96 mm and 3.18 mm. This observation is likely, because fibers originate from the fragmentation of linear materials (e.g., ropes or threads), which tend to produce elongated and larger fragments during the early stages of degradation (Silva and Nanny, 2020). In contrast, fragments and granules, which are derived from the breakdown of brittle plastic materials such as packaging or bottles, generally start with smaller dimensions and degrade more rapidly into fine particles (Fiore et al., 2022).

The polymer composition of microplastics

Figure 9 presents the infrared spectra obtained from Fourier Transform Infrared (FTIR) spectroscopy of representative microplastic particles isolated from four types of sea catches: shrimp (a), sea cucumber (b), fish (c), and shellfish (d). The FTIR analysis aimed to identify characteristic chemical functional groups to determine the potential polymer types. The infrared spectra of shrimp (Figure 9a), sea cucumber (Figure 9b), and fish (Figure 9c) samples exhibited highly similar absorption patterns. These three spectra consistently displayed several distinctive absorption peaks.

A broad absorption band in the wavenumber region of 3288–3289 cm^{-1}, corresponding to O–H (hydroxyl) or N–H (amine/amidic) stretching vibrations. A strong and sharp peak in the region of 2110–2116 cm^{-1}, attributed to the stretching vibration of alkynes (C≡C) or nitriles (C≡N). A prominent peak at 1643–1650 cm^{-1}, generally associated with the stretching vibration of double bonds, such as C=O in amide groups (Amide I band) or C=C in alkenes or aromatic compounds. Multiple absorption peaks of varying intensity in the fingerprint region (<1500 cm^{-1}), reflecting a complex molecular structure. The strong spectral similarity among these three samples indicates that the microplastic particles contaminating shrimp, sea cucumber, and fish wastes likely originate from the same type of polymer.

In contrast, the FTIR spectrum of microplastics isolated from shellfish (Figure 9d) displayed

Table 3. Size distribution of microplastics in marine biota collected from the Sukolilo Baru Kenjeran Coast, Surabaya City

Sample category	Type of microplastic	Smallest size (mm)	Largest size (mm)
Shrimp head	Grey fiber	0.43	2.16
	Black fiber	0.29	3.96
	Red fiber	1.08	2.90
	Black filament	1.62	1.62
	Red filament	0.70	0.70
	Green fragment	0.21	0.31
Sea cucumber	Black fiber	0.11	0.33
	Green fragment	0.46	0.46
Sandfish	Blue fiber	0.42	2.35
	Purple fiber	0.93	1.32
	Blue filament	0.44	1.71
	Red filament	0.67	1.44
	Black fiber	1.07	3.18
	Red fiber	0.52	1.61
Fish	Blue fiber	0.05	1.14
	Black fiber	0.13	1.33
	Red fiber	0.12	1.27
	Blue fragment	0.58	0.58
	Green fragment	0.31	0.31
	Green granule	0.30	0.30
Shellfish	Blue fiber	0.10	1.35
	Red fiber	0.20	0.20

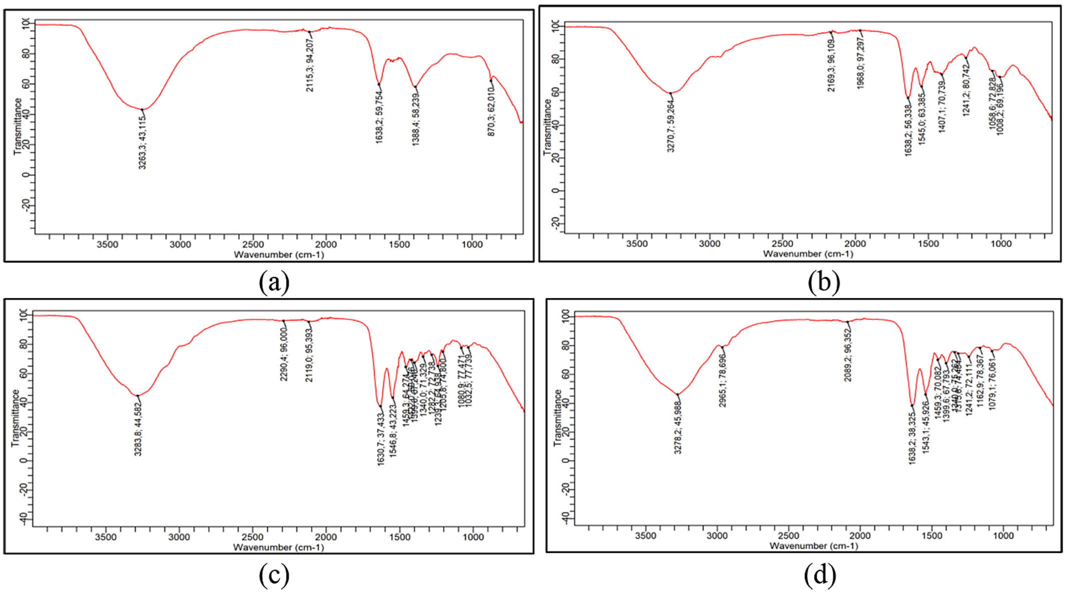


Figure 9. FTIR spectra of the representative microplastic found in: shrimp waste (a), sea cucumber waste (b), fish waste (c), shellfish waste (d)

a distinctly different profile. Although broad absorption was also observed at 3278 cm^{-1} (indicative of O–H or N–H groups) and a peak appeared at 1643 cm^{-1} (corresponding to C=O or C=C groups), the characteristic sharp peak around 2110 cm^{-1} was absent. The absence of this diagnostic peak, which is present in the other three spectra, clearly suggests that the microplastics in shellfish waste are composed of a different chemical structure and polymer type.

Future perspective

The results of the study show that the microplastic pollution in the coastal area of Sukolilo Baru, Kenjeran has become a real threat to marine ecosystems and the health of coastal communities. This condition emphasizes the importance of better and sustainable waste management, especially in activity-dense urban coastal areas such as Kenjeran. A waste management system that is not yet optimal, the use of single-use plastics, and a lack of public awareness are the main factors that worsen this situation. As a concrete step, an integrated policy is needed which includes:

a) Implementation of an integrated waste processing system based on environmentally friendly technology, such as biofiltration and microplastic capture systems in drains before waste water reaches the sea (Salman et al., 2024).
b) Education and training programs for fishermen and coastal communities regarding the impact of microplastics and the importance of reducing single-use plastics (Khorsandi et al., 2025).
c) Strengthening local regulations to monitor the use and disposal of synthetic nets and industrial plastics in port areas and fish markets.

Through a cross-sector approach and community participation, the efforts to reduce microplastic pollution can be carried out in a sustainable manner and have a positive impact on environmental health, the fishing economy and coastal food security. Tackling this problem effectively requires the involvement of various stakeholders in designing and implementing microplastic pollution reduction strategies. Local governments, environmental NGOs, and coastal communities collaborate in integrated waste management programs, such as developing community-based waste sorting and collection systems, implementing environmentally friendly processing technologies, and public education programs to reduce the use of single-use plastics. Through sustainable cross-sector collaboration, it is hoped that this effort can strengthen shared responsibility, increase the capacity of coastal communities in environmental management, and create long-term solutions to reduce microplastic pollution originating from the fisheries sector.

CONCLUSIONS

All waste samples were contaminated with microplastics, with the highest abundance observed in shrimp waste (45 particles). Fibers were the most dominant morphology, suggesting a source from secondary microplastics. Two color distribution patterns were identified: shrimp and sea cucumber waste were dominated by black particles, whereas other waste types were dominated by blue. FTIR analysis identified two distinct polymer profiles, with shellfish waste exhibiting a unique chemical composition compared to other samples. These findings confirm that the waste from sea catch processing serves as a direct pathway for microplastic entry into coastal aquatic environments. Therefore, improved waste management strategies are required to mitigate microplastic pollution originating from the fisheries sector.

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