CHARACTERISTICS MICROPLASTICS AND ESTIMATED DAILY INTAKE (EDI) IN KUPANG PUTIH (*Corbula faba* Hinds.) AND KUPANG MERAH (*Musculista senhousia*)

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ABSTRACT

Microplastics are plastic polymer particles smaller than 5 mm that can enter aquatic organisms through ingestion or trophic transfer. Bivalves are particularly vulnerable to microplastic contamination due to their filter-feeding behavior, which may pose potential risks not only to aquatic ecosystems but also to human health through seafood consumption. However, information on microplastic characteristics and human exposure assessment in locally consumed bivalves from the Madura Strait remains limited. This study aimed to analyze the physical and chemical characteristics of microplastics and to estimate human exposure using the Estimated Daily Intake (EDI) approach in two edible bivalve species, namely white mussel (*Corbula faba* Hinds.) and red mussel (*Musculista senhousia*), collected from the Madura Strait, Indonesia. A total of 30 individuals per species were analyzed. Physical characteristics of microplastics, including shape, size, and color, were observed using a stereomicroscope, while polymer types were identified using ATR–FTIR analysis. The EDI method was applied to estimate the potential daily intake of microplastics by humans through mussel consumption. The average microplastic abundance was higher in *C. faba* (104.6 ± 33.23 particles/individual) than in *M. senhousia* (53.46 ± 18.91 particles/individual). Fragment-shaped, black-colored microplastics with sizes of 10–50 µm were dominant in both species. Polypropylene (PP) and nylon or polyamide (PA) was the main polymer types identified. The estimated daily intake of microplastics was 1,067.24 particles/person/day for *C. faba* and 335.55 particles/person/day for *M. senhousia*. This study provides new insights by integrating microplastic characterization with human exposure assessment using EDI, highlighting the potential risks associated with bivalve consumption and supporting future environmental monitoring and food safety management.

Keyword: Bivalves, *Corbula faba*, EDI, Microplastics, *Musculista senhousia*

Introduction

Plastic waste pollution, particularly from plastic-based materials, has spread across aquatic environments worldwide and has become a pressing global issue. The continuous increase in plastic production, coupled with inadequate waste management, has led to the accumulation of plastic debris along coastlines, water surfaces, various water depths, and sediments. The presence of waste in marine environments poses the potential risk of contaminating aquatic biota in both surface and marine waters, including through plastic debris [1,2]. Plastics that enter the environment as waste can degrade into microplastics (MPs) and nanoplastics (NPs). Microplastics are formed as a result of structural changes in plastics caused by sunlight exposure, thermal oxidation, or microbial activity [3]. These microplastics may be distributed across surface waters, coastal sediments, beach sand, freshwater sediments, and even deep-sea environments [4]. Microplastics in aquatic environments originate from various human activities such as household waste, industry, fisheries, and tourism. Once accumulated in the environment, the likelihood of biota contamination increases. This occurs through the food chain process, whereby microplastics ingested by small organisms can transfer and accumulate in organisms at higher trophic levels [5,6,7]. Due to their widespread distribution and extremely small size, microplastics can easily adhere to and be ingested by aquatic organisms [8].

One of the marine organisms that is highly vulnerable to microplastic exposure due to its polluted habitat is the clam [7]. According to [9], clams are categorized as both filter feeders and suspension feeders, as their survival depends on plankton and organic particles. They typically live at the bottom of aquatic environments by burying themselves in the sediment. Clams obtain food by pumping water through their mantle cavity and using their siphons to capture food particles, which are then filtered by the gill surfaces. When the concentration of particles is excessive, the surplus is expelled as pseudofeces through ciliary channels [10]. With the increasing levels of microplastic pollution in both seawater and sediments, clams are more likely to absorb and accumulate microplastics within their bodies. This occurs because clams are continuously exposed to microplastics in their habitat, allowing these particles to enter and accumulate in their digestive system and other body tissues [11,7]. According to [12], there are two types of clams commonly consumed by local communities, namely the kupang putih (*C. faba*) and the kupang merah (*M. senhousia*). Most of the clam stock used for consumption is harvested from the waters around the Madura Strait, an area already contaminated by pollution. This condition is considered one of the factors influencing the accumulation of microplastics in these clams [13].

Microplastics contain various hazardous compounds, such as Polychlorinated Biphenyls (PCBs), heavy metals, and Polybrominated Diphenyl Ethers (PBDEs). These substances may become harmful when accumulated in the human body [14]. According to [15], clams have the potential to transfer microplastics into the human body. The threat posed by microplastics arises not only from their physical properties, which can induce toxic effects, but also from their ability to act as carriers of toxic substances such as heavy metals and persistent organic pollutants (POPs) present in the environment [16]. Given the high global demand for clam consumption, humans cannot completely avoid exposure to microplastics [17]. Once consumed, microplastics present in clams may enter the human body and potentially induce oxidative stress as well as disrupt hormonal metabolism [18]. Microplastics may also cause toxicity through several mechanisms, including cell membrane damage, pore blockage, increased production of reactive oxygen species (ROS), DNA damage, lysosomal destabilization, and mitochondrial depolarization. After entering the body, microplastics may interact with the lungs and gastrointestinal tract, and subsequently spread to other organs. Nevertheless, the long-term effects of microplastic exposure on human health remain not fully understood, particularly due to varying levels of individual susceptibility [19].

Based on the study conducted by Firmansyah (2021), information was obtained regarding the distribution and characteristics of microplastics found in sediments, water, and kupang putih (*C. faba*) in the waters of Kepetingan, Sidoarjo. However, studies on the abundance of microplastics in kupang putih (*C. faba*) and kupang merah (*M. senhousia*), as well as the determination of safe daily intake limits of microplastics, remain limited. Therefore, further research is required. In this context, the present study was conducted to investigate the physical and chemical characteristics of microplastics and to calculate the Estimated Daily Intake (EDI) in kupang widely consumed by the community, namely kupang putih (*C. faba*) and kupang merah (*M. senhousia*) obtained from the waters of the Madura Strait.

Methodology

Time and Place

The research was conducted from December 2024 to May 2025. Sampling of kupang putih (*C. faba*) and kupang merah (*M. senhousia*) was carried out in the waters of the Madura Strait. Sample preparation, morphometric measurements, physical analysis of microplastics, and calculation of the Estimated Daily Intake (EDI) were performed at the Ecology Laboratory, Department of Biology, Faculty of Science and Data Analytics, Institut Teknologi Sepuluh Nopember, Surabaya. Subsequently, the chemical analysis of microplastics was conducted at the Industrial Biotechnology Laboratory, Department of Industrial Chemical Engineering, Faculty of Vocational Studies, Institut Teknologi Sepuluh Nopember, Surabaya.

Tools and Materials

The instruments used in this study included a dissecting set, vial tubes, a buchner funnel, aluminum foil, a digital caliper, an analytical balance, an oven, petri dishes, an ATR-FTIR spectrometer, a stereo microscope, Optilab Viewer 2.2 software, Image

Raster 3 software, Microsoft Excel, and Tableau Public 2024. The materials used were kupang putih (*C. faba*), kupang merah (*M. senhousia*), Whatman No. 42 filter paper with a pore size of 2.5 µm, distilled water, and 10% KOH solution.

Work Procedure

This study began with morphometric measurements of shell length and width using a digital caliper, as well as body weight measurements of both clam species using an analytical balance. The procedure was then followed by sample preparation, which involved separating the tissue from the shell, followed by a digestion process using 10% KOH. The samples were then oven-dried at 60°C. The digested samples were subsequently filtered using Whatman No. 42 filter paper.

The visual characterization of microplastics was carried out using a stereo microscope at 4.5× magnification connected to an Optilab device to identify their shape, color, and size. The abundance of microplastics was then calculated using the following formula:

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

where **K** represents the abundance of microplastics, **Ni** is the number of microplastic particles, and **N** is the sample weight.

Subsequently, the Estimated Daily Intake (EDI) was calculated to determine the potential amount of microplastics that may enter the human body through food consumption, using the following formula:

$$EDI = \frac{C \times IR}{BW}$$

where **C** is the average number of microplastics detected in the tissue sample per kilogram, **IR** is the daily per capita consumption rate, and **BW** is the average body weight used.

Subsequently, polymer characterization was carried out using ATR-FTIR to identify the types of plastic polymers based on their infrared absorption spectra.

Result and Discussion

Abundance of Microplastics in Kupang

The results of the total microplastic abundance calculations in the soft tissues of mussels were divided into two sample categories, namely kupang putih (*C. faba*) and kupang merah (*M. senhousia*), with each category consisting of 30 individual mussels. The microplastic abundance data obtained from a total of 30 mussel individuals, as well as the average microplastic abundance per individual in each sample category, are presented in the following table:

Table 1. Microplastic Abundance in Mussels

	Sample Categories	
	Kupang Putih (*C. faba*)	**Kupang Merah (*M. senhousia*)**
Total abundance of microplastics in 30 individuals (particles)	3138	1604
Mean abundance of microplastics (particles/individual)	104,6±33,23	53,46±18,91
Mean abundance of microplastics (particles/g)	2493, 56±932,57	783, 99±332,97

Based on Table 1, the total microplastic abundance in 30 individuals of kupang putih (*C. faba*) was 3,138 particles, whereas in kupang merah (*M. senhousia*) it was 1,604 particles. The average abundance per individual was also higher in *C. faba* (104.6 particles/individual) compared to *M. senhousia* (53.46 particles/individual). When measured per gram, *C. faba* contained 2,493.56 particles/gram, while *M. senhousia* contained only 783.99 particles/gram. This indicates that *C. faba* has a greater potential to accumulate microplastics. The difference is associated with their feeding strategies: *C. faba*, as an active filter feeder, pumps water to filter particles, whereas *M. senhousia*, as a suspension feeder, is more passive and depends on natural water flow. In addition, the shorter siphon of *M. senhousia* limits the volume of water filtered, thereby reducing the likelihood of microplastic intake [20,21].

Physical Characterization of Microplastics

The physical properties of microplastics identified in this study consisted of abundance, morphological shape, color, and particle size, as detailed in the following section:

Microplastic Morphology

The observations revealed that in kupang putih (*C. faba*) and kupang merah (*M. senhousia*), two microplastic shapes were identified, namely fragments and fibers. Fragments were characterized as large and thick pieces of plastic [22], while fibers appeared as thin and elongated synthetic threads [23].

The following graph illustrates the total abundance of these two microplastic shapes in each mussel species.

Based on the observations, the dominant microplastic shape found in *C. faba* and *M. senhousia* was fragments. In 30 individuals of white mussels, the number of fragments was recorded at 2,894 particles and fibers at 205 particles. In red mussels, fragments accounted for 1,396 particles and fibers for 208 particles. These findings indicate that fragments were the most prevalent microplastic shape in both species. The high number of fragments is presumed to originate from household waste and coastal community activities around the Madura Strait [24].

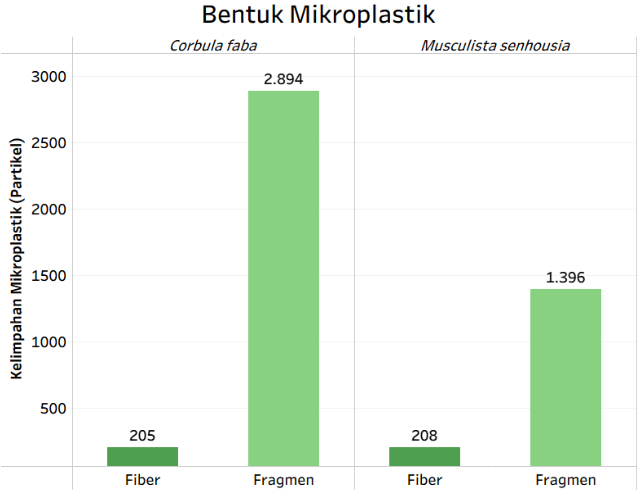

Figure 1. Total microplastic abundance in mussels based on microplastic shapes

Fibers and fragments are the most commonly found types of microplastics in mussels. This is because both are classified as secondary microplastics, which originate from the breakdown or degradation of larger plastic materials due to mechanical stress or sunlight exposure in the environment [25]. These two forms of microplastics dominate coastal waters, as such areas are typically located near residential settlements where human activities occur around the sea. Intensive fishing activities, household waste disposal, and inadequate waste management practices further increase the potential for microplastic contamination in coastal waters [26].

Microplastic Colors

Based on the observations, ten microplastic colors were identified in the soft tissues of mussels, namely blue, brown, gray, black, yellow, red, transparent, green, white, and purple. Each color type of plastic has a different capacity to absorb sunlight and transmit ultraviolet (UV) radiation, which ultimately affects the rate of degradation or photoaging of plastics in the aquatic environment [27].

Based on the observations of microplastic colors in the soft tissues of kupang putih (*C. faba* Hinds.) and kupang merah (*M. senhousia*), black microplastics were the most dominant color found in both species, with 1,135 particles in white mussels and 511 particles in red mussels. Other frequently observed colors were gray and blue. In *C. faba*, gray microplastics accounted for 792 particles and blue for 770 particles, while in *M. senhousia*, blue microplastics reached 647 particles and gray 281 particles. The least abundant colors were purple and transparent, with only 2 and 19 particles found in white mussels, and 1 particle in red mussels. The variation in color reflects differences in sources and the duration of exposure to environmental factors. Microplastics with solid and vivid colors indicate that the particles have not undergone significant discoloration, suggesting their presence in the environment is relatively recent. In contrast, microplastics with dark or dull colors indicate a higher degree of degradation due to oxidation and prolonged exposure to UV radiation [28].

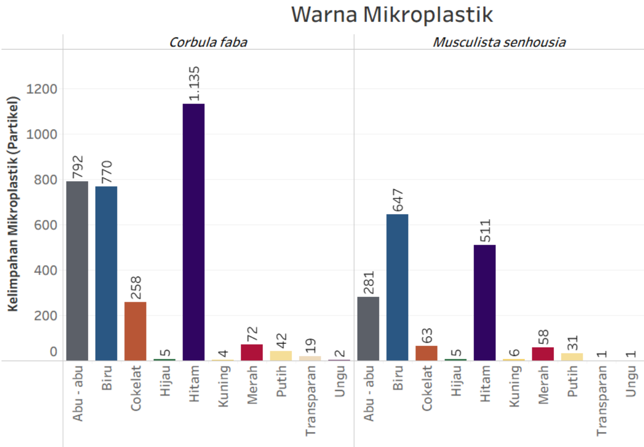

Figure 2. Total microplastic abundance in mussels based on color.

The dominance of black and gray microplastics is presumed to originate from plastics degraded by sunlight exposure and oxidation processes. Black microplastics are also associated with their ability to adsorb pollutants, thus often indicating a higher level of contamination [29,30]. Nevertheless, black color can also represent the original color of the plastic. Brown microplastics generally derive from weathered household plastics, reflecting prolonged UV exposure, and are potentially associated with pollutants such as PAHs and PCBs [31]. Meanwhile, blue, green, and yellow microplastics are likely derived from plastic bags, fishing lines, and detergents, while white microplastics are presumed to originate from bottles, food containers, or styrofoam [32]. Blue microplastics degrade more rapidly due to their low UV absorption, and are therefore often found in smaller sizes [27].

Microplastic Size Distribution

The microplastics identified were visually analyzed based on their size using a stereo microscope with the aid of Optilab Viewer 2.2, while the measurements were conducted using Image Raster 3. The observations revealed four size categories of microplastics in the soft tissues of mussels: A (0–10 µm), B (10–50 µm), C (50–100 µm), and D (>100 µm) [33]. All of these categories fall within the size range that can be accumulated in filter-feeding organisms. According to [2], microplastics are classified into large microplastics (1–5 mm) and small microplastics (<1 mm). The following graph presents the total abundance of microplastics by size in each mussel species.

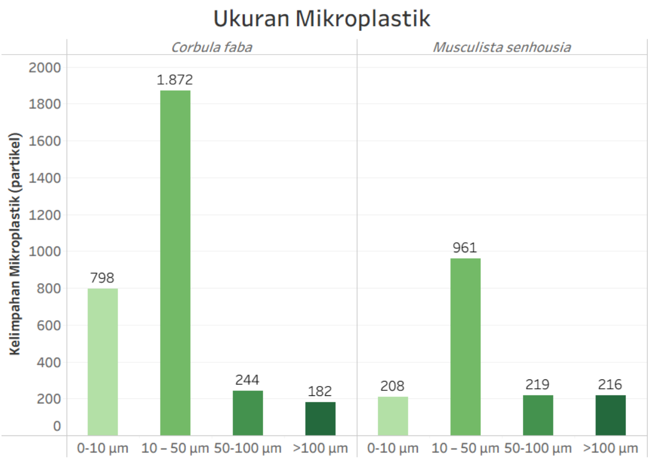

Figure 3. Microplastic abundance in mussels based on size

The observations showed that microplastic sizes of 10–50 µm dominated in both mussel species, namely *C. faba* (1,872 particles) and *M. senhousia* (961 particles). In *C. faba*, the next most abundant sizes were 0–10 µm (798 particles), 50–100 µm (244 particles), and >100 µm (182 particles). In *M. senhousia*, these were followed by 50–100 µm (219 particles), >100 µm (216 particles), and 0–10 µm (208 particles). The dominance of the 10–50 µm size range indicates that smaller particles are more easily ingested. Microplastics smaller than 250 µm are presumed to originate from daily-use products, while those larger than 250 µm are generally derived from the fragmentation of larger plastics [34].

The variation in microplastic sizes within the soft tissues of both mussel species is influenced by the degree of fragmentation in the aquatic environment. The longer plastics are exposed to UV radiation, abrasion, and wave action, the smaller the resulting particles become. The large proportion of small-sized microplastics indicates that these particles generally originate from plastics that have undergone prolonged degradation [28]. Moreover, due to their low density, smaller microplastics are easily suspended, transported by currents, and widely dispersed, thereby increasing the likelihood of ingestion by mussels as filter-feeding organisms [34].

Polymer Characterization of Microplastics

The characteristics of microplastic particles in aquatic environments vary depending on their polymer type. To identify the polymers, Fourier Transform Infrared Spectroscopy (FTIR) was employed. According to [35], FTIR detects infrared absorption patterns to determine the functional groups or chemical bonds present in a sample. The results are presented as IR spectra, which are then compared with reference wavenumbers from standard FTIR tables to determine the polymer type. The analyzed samples consisted of microplastics in the form of fragments and fibers from kupang putih (*C. faba*) and kupang merah (*M. senhousia*), with the results as follows:

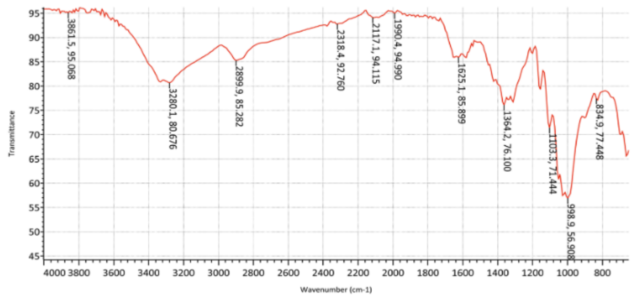

Figure 4. FTIR Results for Fragment Microplastics in *C. faba* and *M. senhousia*

The analysis showed that fragment-shaped microplastics in both mussel species were composed of polypropylene (PP). The presence of PP was identified through absorption peaks at 998.9 cm^{-1} (CH_3 bending and CH bending), 1346.2 cm^{-1} (CH_3 bending), and 2899.9 cm^{-1} (C–H stretching) [35]. These peaks indicate the main structure of PP, which consists of carbon–hydrogen chains [36]. Polypropylene is a polymer of propylene monomers without cross-linking, giving it chemical resistance, high mechanical strength, high crystallinity, and low density [37]. PP is widely used in products such as buckets, bottles, medical devices, and packaging materials [38]. Its low density causes PP to float, making this type of microplastic particle easily dispersed in marine environments [39].

The analysis showed that fiber-shaped microplastics in both mussel species were composed of polyamide (PA), or nylon. Nylon is a polymer with repeating amide (-CONH-) groups along its molecular chain [40]. Identification via FTIR was indicated by characteristic absorption peaks, such as N–H stretching at 3280.17 cm^{-1}, C–H stretching at 2899.9 cm^{-1}, and CH_2 bending at 1364.2 cm^{-1} [35]. The PA spectrum also exhibits strong absorption bands at amide I and amide II, which are its distinguishing features. Polyamide is commonly used in fishing nets and lines. The presence of PA in the samples is associated with fishing activities in the surrounding water areas [41].

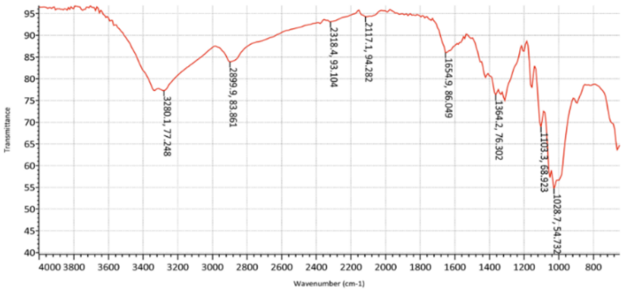

Figure 5. FTIR Results for Fiber Microplastics in *C. faba* and *M. senhousia*

Estimated Daily Intake (EDI)

The Estimated Daily Intake (EDI) of microplastics in kupang putih (*C. faba*) and kupang merah (*M. senhousia*) was calculated using the EDI formula in Microsoft Excel. This calculation aims to estimate the potential amount of microplastics ingested by individuals through the consumption of contaminated food [42]. The EDI results for both mussel species are presented in the following table (table 2).

The Estimated Daily Intake (EDI) results indicate that the average abundance of microplastics in *C. faba* was 2,493,568.85 particles/kg wet weight (w.w), while in *M. senhousia* it was 783,995.97 particles/kg w.w. These values were used to calculate the EDI, representing the estimated number of microplastic particles that could enter the human body through mussel consumption. The universal EDI (based on standard assumptions) was 17.78 particles/kg/person/day for *C. faba* and 5.59 particles/kg/person/day for *M. senhousia*. When adjusted to the average body weight of Indonesian adults (60 kg), the specific EDI was 1,067.24 particles/person/day for *C. faba* and 335.55 particles/person/day for *M. senhousia*. These results provide an estimation of potential human exposure to microplastics through mussel consumption in Indonesia.

The higher the average abundance of microplastics per kilogram of wet weight in mussel soft tissue (particles/kg w.w), the higher the resulting Estimated Daily Intake (EDI) values. This indicates that consumption of mussels with high EDI may increase human exposure to microplastics, thereby elevating the risk of microplastic accumulation through the food chain, particularly from regular seafood consumption. The EDI calculation method may vary between studies, depending on the parameters used. In principle, however, EDI is calculated by multiplying the microplastic abundance in the organism by the average daily intake and then dividing by the average human body weight, which may differ between countries [43].

Table 2. Calculation of Estimated Daily Intake (EDI) Values in Mussels

	Sample Categories	
	Kupang Putih (*C. faba*)	**Kupang Merah (*M. senhousia*)**
Average microplastic abundance per kilogram of wet weight (particles/kg w.w)	2.493.568,854	783.995,972
Estimated Daily Intake (EDI) (particles/kg/person/day)	17,78	5,59
Estimated Daily Intake (EDI) (particles/person/day*)	1.067,24	335,55

Conclusion

Based on the results of the study, it can be concluded that the kupang putih (*C. faba*) has an average microplastic abundance of 104.6 ± 33.23 particles per individual, while the kupang merah (*M. senhousia*) contains 53.46 ± 18.91 particles per individual. The dominant microplastics found in both clam species were characterized by a fragment shape, black color, and size of 10–50 µm, with the identified polymer types being polypropylene (PP) and nylon or polyamide (PA).

Furthermore, the Estimated Daily Intake (EDI) values of microplastics indicate that the consumption of kupang putih may expose humans to 1,067.24 particles per person per day, while kupang merah may contribute 335.55 particles per person per day, suggesting a potential risk of microplastic exposure to humans through clam consumption.

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