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Levels of Microplastics in Common Carp (*Cyprinus carpio*), Apple Snails (*Pila ampullacea*), and Macroalgae (*Filamentous Algae*) in the Kedung Ombo Reservoir, Central Java, Indonesia

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ABSTRACT

Microplastic pollution in Indonesian waters is a critical environmental issue. The Kedung Ombo Reservoir, which contributes to the economic well-being of the surrounding community, is one of the affected water bodies. Poor management of plastic waste can lead to microplastic contamination, which threatens aquatic organisms such as algae, snails, and fish through respiratory and food chain processes. In addition to being a source of high-quality protein, fish can serve as a media for microplastic contamination in humans. One fish species in high market demand from this reservoir is the carp. This study aimed to determine the concentration of microplastics in carp (*Cyprinus carpio*), snails (*Pila ampullacea*), macroalgae (*filamentous algae*), water, and sediment in the Kedung Ombo Reservoir, Central Java. The research used laboratory tests and Fourier Transform Infrared (FTIR) analysis. The results revealed significant differences ($P< 0.004$) in microplastic concentrations in carp from cages and fishermen's catch based on sampling time, with the digestive system exhibiting the highest microplastic exposure. Snail specimens from the reservoir and outlet showed significant differences in microplastic concentrations ($P< 0.012$), whereas macroalgae from the outlet and tourist areas did not differ significantly ($P> 0.342$). Sediment samples exhibited the highest average microplastic concentration of 31.3 particles/g. The identified microplastics were categorized into five morphological forms (fibers, fragments, films, pellets, and foam), nine colors (black, red, purple, yellow, brown, gray, blue, transparent, and green), and five polymer types (PA, PE, PET, PS, and PVC).

INTRODUCTION

Reports indicate that Indonesia generates 4.8 million tons of improperly managed plastic waste, with an estimated 0.62 million tons ending up in aquatic environments

(Kamaruddin *et al*., 2022; Isfarin *et al*., 2024). This plastic waste is broken down into microplastics and particles smaller than 5mm **(GESAMP, 2019; Celmar *et al*., 2024)**, posing a significant threat to the health of organisms and humans. These microplastic contaminants can enter the food chain, affecting human cells and potentially leading to increased long-term illness and mortality **(Bamigboye *et al*., 2024)**. Microplastics have been identified in various human tissues, including placenta **(Ragusa *et al*., 2021)**, lungs, blood **(Amato-Lourenço *et al*., 2021; Jung *et al*., 2022)**, and infant feces **(Liu *et al*., 2023)**. Microplastics are considered the primary pollutants infiltrating freshwater ecosystems **(O'Connor *et al*., 2022; Bexeitova *et al*., 2024)**. These freshwater systems serve as transitional ecosystems, characterized by high ecological productivity and provide crucial habitats for flora and fauna while offering economic benefits **(Borah *et al*., 2024; Chatterjee *et al*., 2024)**.

Kedung Ombo Reservoir in Central Java (Fig. 1) is one of the important freshwater ecosystems in Indonesia. The reservoir has extensive aquaculture using floating net cages (FNC), with 3,978 plots that exceed its carrying capacity of 1026 plots **(Pamali Juana River Basin Center, 2017)**. The reservoir has multiple functions, including agricultural irrigation, raw water supply, power generation, aquaculture, fisheries, and tourism, and covers a water area of 60,965 ha **(Novandi *et al*., 2019)**. The intense human activity in this area makes the reservoir a likely place for microplastic accumulation **(Di & Wang, 2018)**. In addition, the reduced flow rate in the reservoir promotes the deposition of microplastics, leading to higher concentrations in the water **(Saarni *et al*., 2023)**. Not only in water, sediments also provide a potential accumulation of microplastics of about 70-90% over a long period of time **(Booth *et al*., 2016; Su *et al*., 2016; Huang *et al*., 2021; Duong *et al*., 2023)**.

Microplastic build-up can negatively impact the well-being of aquatic organisms in reservoirs, both directly and indirectly **(Azizi *et al*., 2021)**. The effects of microplastics extend across multiple trophic levels in the food chain, from algae to fish, triggering stress responses in these organisms **(Li *et al*., 2024b)**. Algae and macroalgae can facilitate the transfer of microplastics to fish and invertebrates via herbivory **(Huang *et al*., 2023)**. *Filamentous macroalgal* species have a greater ability to retain microplastics than non-filamentous species **(Ng *et al*., 2022; Ji *et al*., 2024)**. This type of *filamentous macroalgae* is attached to floating net cages and to the tourism area of the Kedung Ombo Reservoir. However, microplastics can inhibit algal photosynthesis and cause other detrimental effects in freshwater ecosystems **(Zhang *et al*., 2017)**. Microplastics can also enter snail bodies, leading to increased toxicity and reduced protein content **(Bour *et al*., 2018; Song *et al*., 2019; Qu *et al*., 2020)**. As gastropods, snails are commonly used as bioindicators of environmental pollutants, making them effective for detecting microplastics **(An *et al*., 2022)**. **Zhang *et al*. (2024)** showed that microplastics can be efficiently transferred to freshwater food chains, such as snails (*B. aeruginosa*) and black carp (*M. amblyceph piceus*), and accumulate in various tissues. *Pila ampullacea* is a type of snail found in this area. Microplastics in water can enter the fish body through gill filaments, attach to the gill surface, or penetrate blood vessels and cell membranes, thereby disrupting the normal respiratory function **(Zheng *et al*., 2024)**. When fish ingest microplastics, they can cause decreased energy reserves, impaired reproduction and growth**,** intestinal inflammation, metabolic problems, oxidative stress, and death **(Qiao *et al.,* 2019; Hasan *et al*., 2021; Jaafar *et al*., 2021; Onaji *et al*., 2025)**. Therefore, studying microplastics in macroalgae, snails, and fish at different trophic levels is essential for research in this area.

According to the **Ministry of Marine Affairs and Fisheries (2019)**, carp ranked as the 6th highest in production value among 20 fish species in Central Java. This high ranking is due to the popularity of this fish among farmers and consumers, owing to its robust disease resistance, low cultivation risk, and desirable quality **(Ma *et al*., 2018; Chen *et al*., 2022; Luo *et al*., 2024)**. The potential for human exposure to microplastics through fish consumption has become a major public health concern **(Hasan *et al*., 2023; Borah *et al*., 2024)**. Investigating microplastic contamination in commercially important fish species is crucial, especially in regions with high microplastic potential, such as the Kedung Ombo Reservoir tourist area, where carp are highly sought **(Wijianto & Effendi, 2022; Lestari *et al*., 2023)**. Consequently, this study aimed to measure microplastic concentrations in carp (*Cyprinus carpio*), snails (*Pila ampullacea*), macroalgae (*filamentous algae*), water, and sediment within the Kedung Ombo Reservoir in Central Java. This study offers insights into the current health status of aquatic biota, particularly carp affected by microplastic contamination. The findings could inform policy decisions for enhancing water quality management and aquatic biota conservation in the Kedung Ombo Reservoir while raising public awareness of environmental protection.

MATERIALS AND METHODS

1. Research area and sampling

The research materials comprised samples of aquatic biota (carp, snails, and macroalgae), water, and sediment. Data were collected in September and October 2024, at the Kedung Ombo Reservoir in Central Java, which encompasses the districts of Grobogan, Boyolali, and Sragen (Fig. 1). Eight fish specimens were obtained directly from floating net cages and fishermen's catches, for a total of 16 fish. Snail samples were collected from cages and outlets, four from each location, while macroalgal specimens were gathered from cages and tourist stations, with four samples per station. The cages were situated in the Sragen district (Fig. 1), and the fish were procured from fishermen as catches across the three districts.

Four stations were used for water and sediment sampling based on areas with the highest human activity as the basic source of microplastics. The positions of the four stations are as follows: station 1 (Floating Net Cage: 7° 18' 13.27"S; 110° 50' 5.7"E), station 2 (tourism: 7° 15' 4.84"S; 110° 49' 30.83"E), station 3 (reservoir inlet: 8° 42'

2.64"S; 110° 45' 44.34"E) and station 4 (reservoir outlet: 7° 15' 46.96"S; 110° 50' 38.41"E) each station has three sub-stations. Each station also measured the water quality (temperature, pH, dissolved oxygen, brightness, and depth) as supporting data. Water and sediment samples were collected using a Nansen water and sediment grab sampler, with a total of 24 samples. All samples were placed in a cool box and transported to the laboratory for microplastic identification.

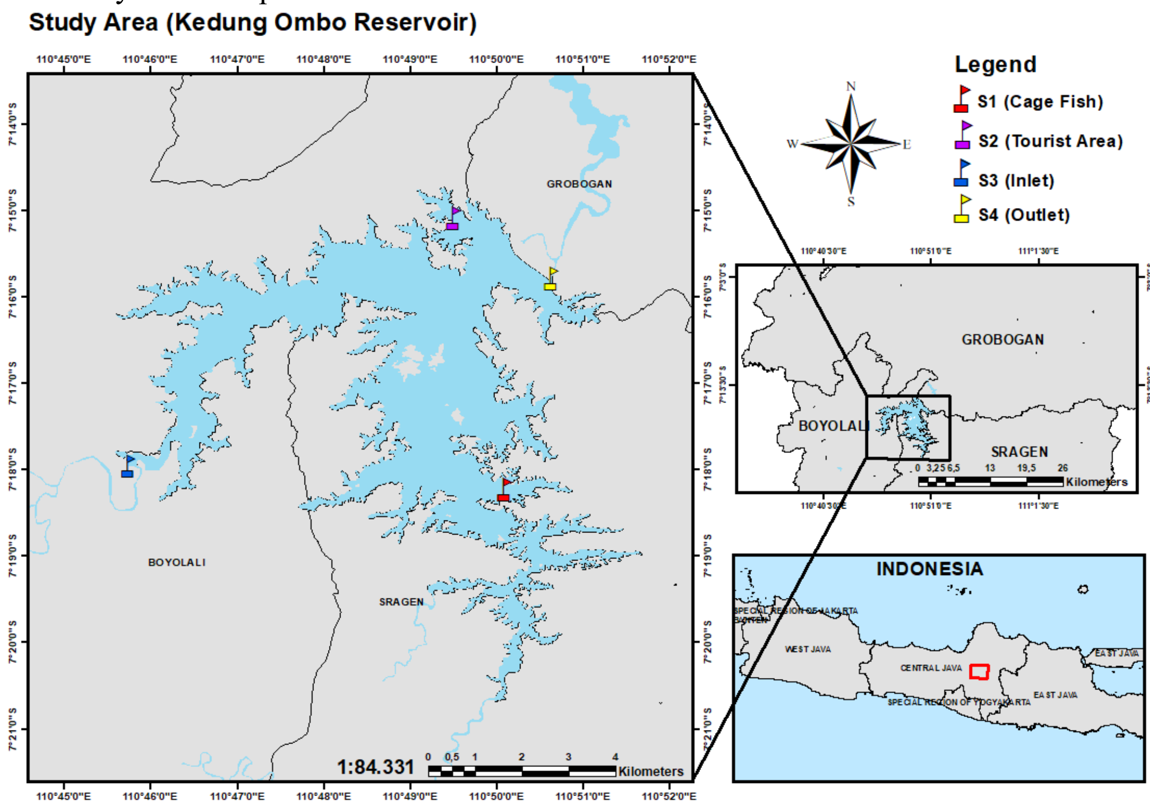


Fig. 1. Research map

2. Microplastic identification procedure

2.1. Destruction stage

- **Aquatic biota**

Prior to destruction, fish and snails were measured for their length and weight. Subsequently, the fish were dissected to separate the digestive organs and muscle tissue, and the snails were separated into body and shell components for further analysis. The destruction stage of the muscle tissue and digestive organs involved placing them in 250mL Erlenmeyer flasks containing 10% KOH solution, equivalent to two-thirds of the sample weight, to remove organic matter **(Ding *et al.*, 2018)**. Erlenmeyer flasks were covered with aluminum foil and were stored at room temperature for 48h **(Hassine *et al.*, 2024)**. Subsequently, NaCl (140g per 1 liter) was added to each sample, which was then stored at room temperature for 48h. This procedure was intended to facilitate the flotation of microplastics on the surface. Then, for the macroalgae extraction process, the first step taken was weighing. After weighing, the macroalgal samples were treated with 1mL of

30% H_2O_2 in enlemeyer flask covered with aluminum foil and maintained at room temperature until sample degradation occurred **(Taurozzi *et al.*, 2024)**.

- **Water**

A 100mL water sample was transferred to a 250mL Erlenmeyer flask and treated with 100ml of 30% H_2O_2 solution to eliminate organic matter, leaving only inorganic material and microplastics. The Erlenmeyer flask was then wrapped in aluminum foil and kept in the dark for 3 days **(Haque *et al.*, 2023)**.

- **Sediment**

A wet sediment sample (approximately 100g) was dehydrated in an oven at 60°C until being completely dry. A sieve shaker with <5mm mesh was used to filter the sample, from which approximately 3g was extracted **(Haque *et al.*, 2023)** and placed in a glass beaker. The extraction process involved adding 30% H_2O_2 in a 1:20 ratio (3g sample to 60mL of H_2O_2 solution) **(Anjeli *et al.*, 2024)** and allowing it to settle for 6h. The extracted material was then separated by introducing NaCl (60g NaCl dissolved in 100ml of distilled water), followed by centrifugation for 2min. The resulting supernatant underwent filtration. Microplastic particles retained on the filter were analyzed for quantity, color, and shape based on NaCl addition. The remaining sediment from the density separation was mixed with $ZnCl_2$ (d = 1.70g/ mL) for further density separation **(Haque *et al.*, 2023)**, followed by centrifugation and filtration. The particles collected on the filter paper were examined for the number, color, and shape of microplastics based on the $ZnCl_2$ dilution.

2.2. Filtering stage of destruction results

Samples of aquatic biota, water, and sediment that were destructed subsequently underwent sample filtration using Whatman No. 42 paper (size 2.5µm) with the assistance of a vacuum pump. The filter paper was then desiccated in an incubator at 35-40°C for 4h. Subsequently, the filter paper was placed on a Petri dish for examination using a binocular microscope to identify the concentration, color, and shape of the microplastics.

2.3. Calculation of microplastic concentration

The microplastic concentration in aquatic biota, water, and sediment **(Anjeli *et al.*, 2024)** was calculated using the following formula:

$$\text{Microplastic concentrations (biota)} = \frac{\text{number of microplastics (particles)}}{\text{organism wet weight (g)}}$$

$$\text{Microplastic abundance (water)} = \frac{\text{number of microplastics (particles)}}{\text{volume of filtered water (mL)}}$$

$$\text{Microplastic abundance (sediment)} = \frac{\text{number of microplastics (particles)}}{\text{weight of filtered sediment (gr)}}$$

3. Statistics and FTIR analysis

The data were subjected to several statistical tests, including normality, homogeneity, analysis of variance (ANOVA), and correlation tests. If the data exhibited a normal distribution, the analysis was proceeded with the ANOVA test using the IBM SPSS software. ANOVA was used to compare the results from various locations and sampling times **(Chatterjee *et al*., 2024)**. A correlation test was conducted to determine whether a significant relationship existed between variables. Pearson's correlation test was used for normally distributed data, whereas Spearman's correlation test was used for non-normally distributed data.

FTIR (Fourier transform infrared spectroscopy) analysis was employed to identify polymer content in microplastics present in carp, snail, macroalgae, water and sediment samples. The FTIR results were obtained in the form of absorption wavelengths for each type of microplastic polymer, which were subsequently compared with the FTIR reference spectra. The spectrum range utilized for this analysis ranged from 4500 to 500cm^{-1} **(Anjeli *et al*., 2024)**.

RESULTS AND DISCUSSION

1. Microplastic concentration

1.1. Common carp

The mean microplastic concentrations observed in carp from cages and catches were 2.04±1.32 and 1.83±1.20 particles/g, respectively. A statistically significant difference (P< 0.004) was found between the microplastic concentrations of carp from floating net cages (FNC) and those from fishermen's catches, with the former exhibiting higher concentrations at the time of collection. This disparity can be attributed to aquaculture practices that utilize floating net cages, which facilitate the degradation of fishing nets, fishing lines, and synthetic pellets into small fragments (microplastics) due to prolonged exposure to solar radiation **(FAO, 2021)**. Furthermore, the confined area of floating net cages and reduced water flow contribute to the entrapment and accumulation of microplastics in the vicinity. **Aunurohim *et al*. (2024)** reported that among the three areas investigated (floating net cages, rivers, and lakes), the highest abundance of microplastics was observed in the floating net cages, with a microplastic concentration in tilapia of 28.96 particles/individual in Ranu Grati Lake, East Java.

Further investigation related to microplastic concentrations and carp size, where the average weight of cage carp was greater than that of wild carp at 412±145 and 321±98g, respectively (Table 1). Despite the difference in weight between the two types of fish, statistical analysis revealed no significant correlation (P> 0.389) between microplastic concentrations and carp length/weight. This observation may be attributed to various factors, such as differences in diet and metabolism among fish, which affect variations in microplastic absorption and impact individual specimens. Consistent with this study, **Wang *et al*. (2021)** and **Borah *et al*. (2024)** reported no significant relationship between ingested microplastics and body weight/length of fish species. Fish ingest microplastics not only by perceiving them as food but also through passive respiration **(Su *et al.* 2019)**. Another study posited that large fish require substantial energy and thus consume higher quantities of feed; therefore, it was hypothesized that more microplastics are ingested **(Khan *et al.*, 2023)**. In contrast, **Haque *et al.* (2023)** found a negative relationship between microplastic concentration and fish weight and length, suggesting that smaller fish ingest more microplastics.

The concentration of microplastics in the digestive system was significantly higher than that in the flesh (Fig. 2). The mean microplastic concentrations in the digestive system and flesh were 1.61 ± 1.09 and 0.33 ± 0.21g, respectively. Analysis of variance (ANOVA) revealed a statistically significant difference in microplastic concentrations between the two regions ($P< 0.001$). This finding suggests that the digestive tract serves as the primary site for microplastic accumulation, with the potential for translocation to other body tissues **(Abbasi *et al.*, 2018; Akhbarizadeh *et al.*, 2018; Su *et al.*, 2019; Bora *et al.*, 2025)**. The presence of microplastics in the digestive tract poses potential risks, including obstruction and damage to the digestive system, and the release of microplastics through pseudo-feces may disrupt energy transfer in organisms **(Muhib & Rahman, 2023)**. **Wang *et al.* (2021)** posited that fish dried without removal of the digestive system present a higher risk of microplastic exposure upon human consumption, a concern particularly relevant to small fish due to dissection challenges. Furthermore, the inhalation of microplastics demonstrates their capacity for dissemination to various body tissues and organs via the circulatory system, rendering muscle tissue or flesh a potential site for microplastic accumulation **(Utomo & Muzaki, 2022)**.

Table 1. Results of average length/weight and microplastic abundance of carp

Carp sample type	Average weight (g)	Average length (cm)	Average microplastic concentration (particles/gr)	Average microplastic concentration per site (particles/gr)
FNC P1[1]	442±183	28±4.4	0.99±0.52	2.04±1.32
FNC P2[2]	381±114	29±3.1	3.09±1.05	
Catch P1[1]	219±25	23±1.1	0.95±0.29	1.83±1.20
Catch P2[2]	179±25	21±1.8	2.71±1.11	

[1]**P1**: First Repetition
[2]**P2**: Second Repetition

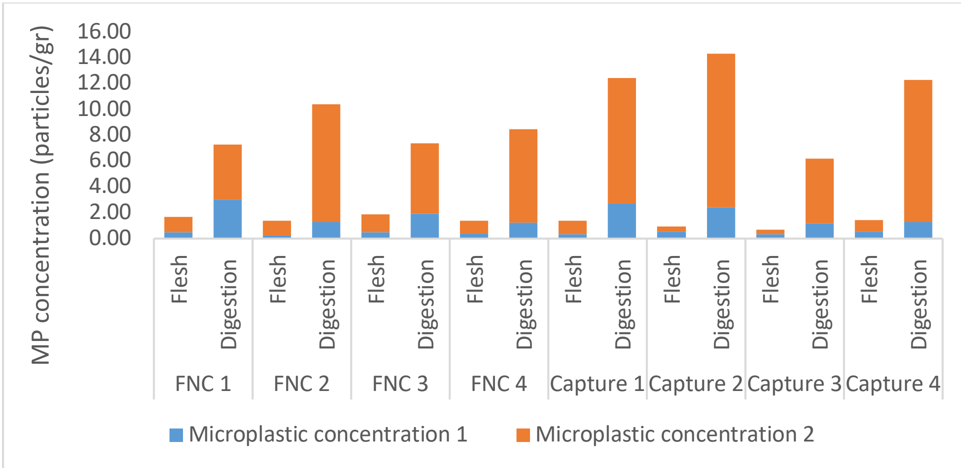


Fig. 2. Diagram of microplastic concentration in the flesh and digestive system of carp

1.2. Apple snail (Pila ampullacea)

The mean concentration of microplastics in snails from cages (FNC) and outlets was 5.9 ± 0.99 and 3.2 ± 1.33 particles/g, respectively (Fig. 3). A statistically significant difference was observed (*P*< 0.012), with the microplastic concentration in snails from cages being higher than that in snails from the reservoir outlet. This disparity can be attributed to the fact that cages are located in areas of the reservoir characterized by slower water flow, and the abundance of microplastics in the sediment is greater than that in the reservoir outlet area (Fig. 5). Reservoirs exhibit relatively weak hydrodynamics, which facilitates the deposition of microplastics in sediments, in contrast to river areas with strong hydrodynamics that promote microplastic transport **(Chen *et al*., 2024)**. Microplastic sedimentation increases the absorption rate of benthic organisms **(An *et al*., 2022)**. In comparison to snails (*Pila ampullacea*) in the Rawa Jombor reservoir, where the concentration of microplastics ranges from 2.5-11 particles/g **(Rahmayanti *et al*., 2022; Khoshmanesh *et al*., 2023)**, the concentration values observed in this study fall within this range, as shown in Fig. (3).

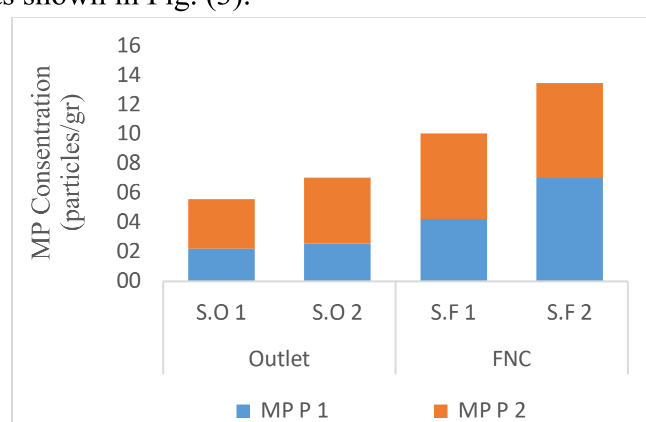


Fig. 3. Diagram of microplastic concentration in snails

1.3. Macroalgae (Filamentous algae)

The average microplastic concentrations in macroalgae from cages (FNC) and tourism (T) areas were 2.0 ± 0.2 and 3.4 ± 1.6 particles/g, respectively. The microplastic concentrations of macroalgae from cages were lower than those from tourism areas. This variation may be attributed to the reduced abundance of microplastics in water and sediment near cages compared with that in tourism areas (Fig. 5). **Xiong *et al.* (2018)** and **Han *et al.* (2024)** observed significantly higher levels of microplastics in waters near tourism sites than in other locations. Macroalgae contribute to the distribution and transport of microplastics through physical mechanisms such as entanglement or entrapment **(Huang *et al.*, 2023)**. Microplastics not only adhere to the surface of algae but can also be trapped in the air sacs of filamentous algae, thereby increasing their capacity to trap filamentous algal cells **(Feng *et al.*, 2020; Peller *et al.*, 2021; Li *et al.*, 2024b)**. However, the difference between cages and tourism in this study was not statistically significant ($P > 0.342$). Furthermore, microplastics negatively affect aquatic plants by affecting their growth and development **(Yao *et al.*, 2024)**. For instance, the exposure of *Hydrilla verticillata* to microplastics for 16 days significantly reduced the growth rate and chlorophyll content, which elicited an antioxidant response **(Yu *et al.*, 2022)**. Fig. (4) provides detailed information for each sample.

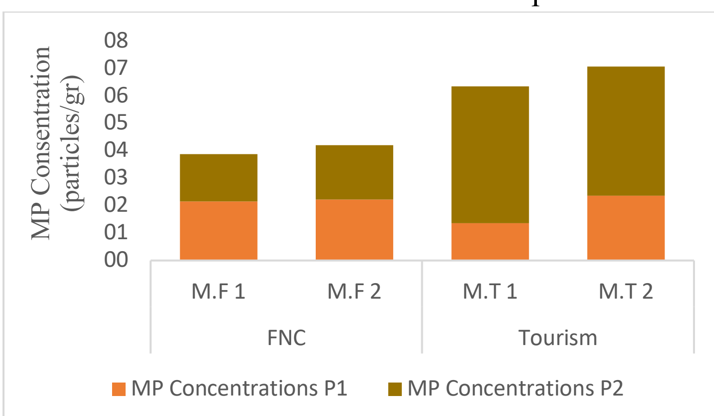


Fig. 4. Diagram of microplastic concentrations in macroalgae

1.4. Water and sediment

The average abundance of microplastics in the first and second repetition water was 0.21±0.15 and 0.42±0.12 particles/ml, respectively (Fig. 5). The average abundance was comparable to the microplastic abundance of water samples in the Koto Panjang Hydroelectric Power Reservoir, Riau ranged 0-1,2 particles/ml, and Buriganga River, Bangladesh which ranged from 0.12-0.25 particles/ml **(Friadi *et al.*, 2023; Haque *et al.*, 2023)**. The difference in the abundance of water microplastics in this study was statistically significant ($P < 0.01$). This discrepancy can be attributed to the high rainfall during the second collection, which influenced water quality parameters (temperature, depth, transparency, pH, and dissolved oxygen). However, based on the correlation analysis, only temperature was significantly correlated with the microplastic abundance

(P< 0.007). The water temperature during the second measurement, ranging from to 31-32.6°C, was higher than that during the first measurement, which ranged from to 30-31.3°C. Temperature significantly affects the distribution of microplastics, because it can influence water hydrodynamics and microplastic degradation mechanisms **(Buwono *et al.*, 2021)**. **Chang *et al.* (2024)** projected that from 2025 to 2100, an increase in the global average temperature of 4.2°C would result in a substantial increase in microplastic concentration in Indonesia, reaching 111.27%. This projection indicates that the risk of microplastic contamination may escalate further with increasing temperatures, particularly during extreme weather conditions. Furthermore, the combination of increasing temperature and microplastic contamination can lead to a decline in the health of aquatic organisms owing to increased metabolism and toxicity, potentially causing oxidative stress and mortality **(Martins *et al.*, 2023)**.

The concentration of microplastics in sediments varied from 13.7-51.3 particles/g, which is less than that observed in the Brantas River, East Java, where it ranged from 28-77 particles/g **(Wijayanti *et al.*, 2021)**. Nevertheless, this finding differs markedly from studies on sediment microplastic abundance in other reservoirs and rivers, such as the Three Gorges Reservoir in China, with 0.025-0.864 particles/g **(Di & Wang, 2018)**, and the Billings Reservoir in Brazil, with 1.67-6.69 particles/g **(Queiroz *et al.*, 2024)**. This elevated concentration may be attributed to intensive human activities in the reservoir area, including tourism, offshore floating net cages, and docks. **Queiroz *et al.* (2024)** proposed that extensive urbanisation surrounding the reservoir, fishing, industrial activities, waste disposal, and inflowing upstream rivers could be potential microplastic sources. However, no significant difference was observed between the stations based on the repetition time (P > 0.136) in this study. This is likely due to reservoir characteristics, such as slow flow and extended hydraulic time, which facilitate the settling of suspended particles from the water column, thus promoting microplastic accumulation in sediments **(Dhivert *et al.*, 2022; Cheng *et al.*, 2024)**. Other studies have shown that reservoir sediments can retain a substantial portion (approximately 47%) of the microplastic flux that would otherwise reach the sea via rivers **(Gao *et al.*, 2023)**. Moreover, sediments act as the primary repository for particles of various sizes originating from eroded soil material, litter, and organic matter that settle at the bottom of waterbodies **(Anjeli *et al.*, 2024)**. Fig. (5) shows the concentration of water and sediment microplastics at stations 1 (FNC), 2 (Tourism), 3 (Inlet), and 4 (Outlet) in repetition 1 (P1) and repetition 2 (P2).

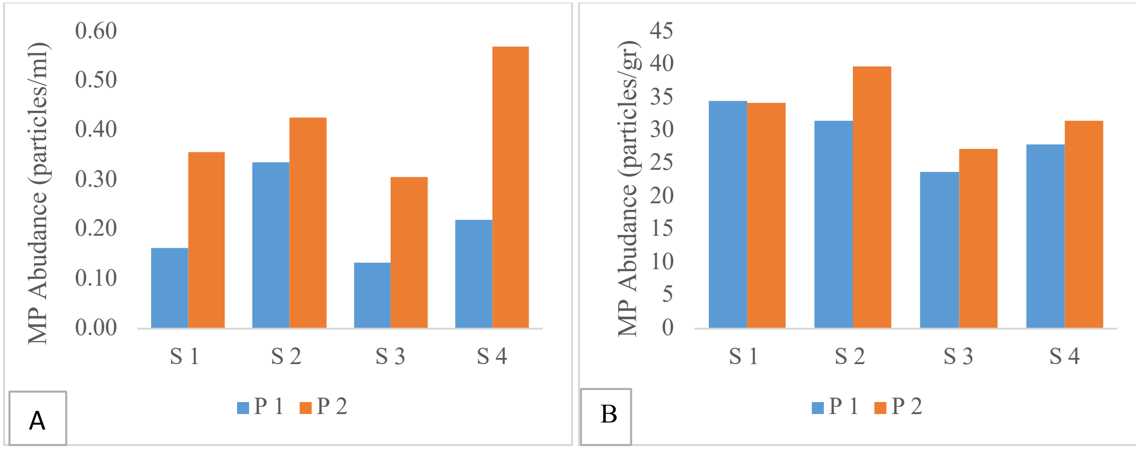
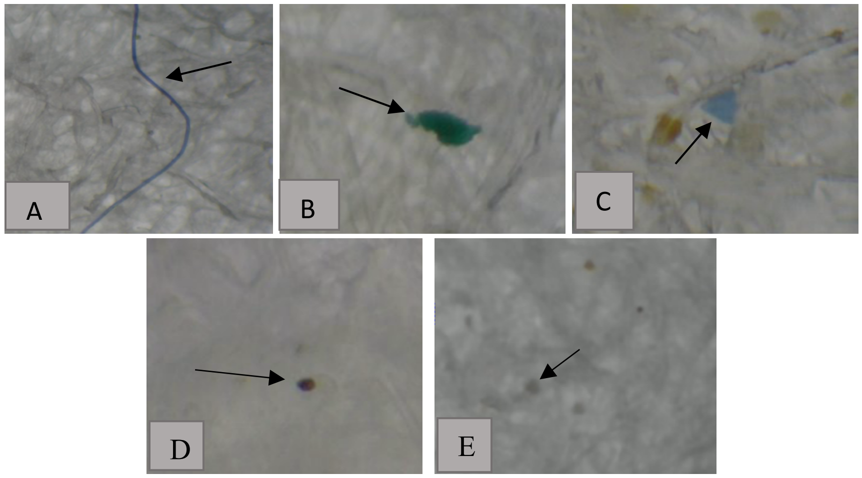


Fig. 5. Microplastic abundance diagram of **(A)** water and **(B)** sediment samples

2. Shape of microplastics

Microplastics were discovered in all samples and exhibited five distinct forms: fiber, fragment, film, pellet, and foam (Fig. 7). Fragments constituted the highest proportion of microplastic shapes in carp and sediment (29-52%), typically originating from the breakdown of plastic wraps and bags **(Chatterjee *et al*., 2024)**. This finding aligns with the microplastic shapes observed in Buriganga River sediments, where fragments accounted for 34.51% **(Haque *et al*., 2023)**. In contrast, fibers were the predominant form in snails and algae (29-31%), resulting from the fragmentation of fishing equipment **(Cole, 2016; Haque *et al*., 2023)**. This prevalence mirrors the microplastic shapes found in Buriganga River snails, with fibers comprising 43.33% **(Haque *et al*., 2023)**, and in Ranu Grati Lake, Pasuruan, where they made up 80.21% **(Aunurohim *et al*., 2024)**. Water samples primarily contained pellets (41%), derived from industrial microbeads used in beauty products with polyethylene polymers **(Lenaker *et al*., 2019; Anjeli *et al*., 2024)**. Foam, often used as a packaging material in various industries **(Haque *et al*., 2023)**, such as laundry soap and waste residue, which are the least common form in goldfish samples (1%). In snails and sediments, film is the least prevalent form (7-9%), resulting from the decomposition of thin plastic waste **(Imanuel *et al*., 2022)**. Fig. (8) shows a detailed breakdown of the microplastic shapes for each sample in this study.



Figs. 7. Microplastic shape (**A**: Fiber; **B:** Fragment; **C**: Film; **D**: Pellet; E: Foam)

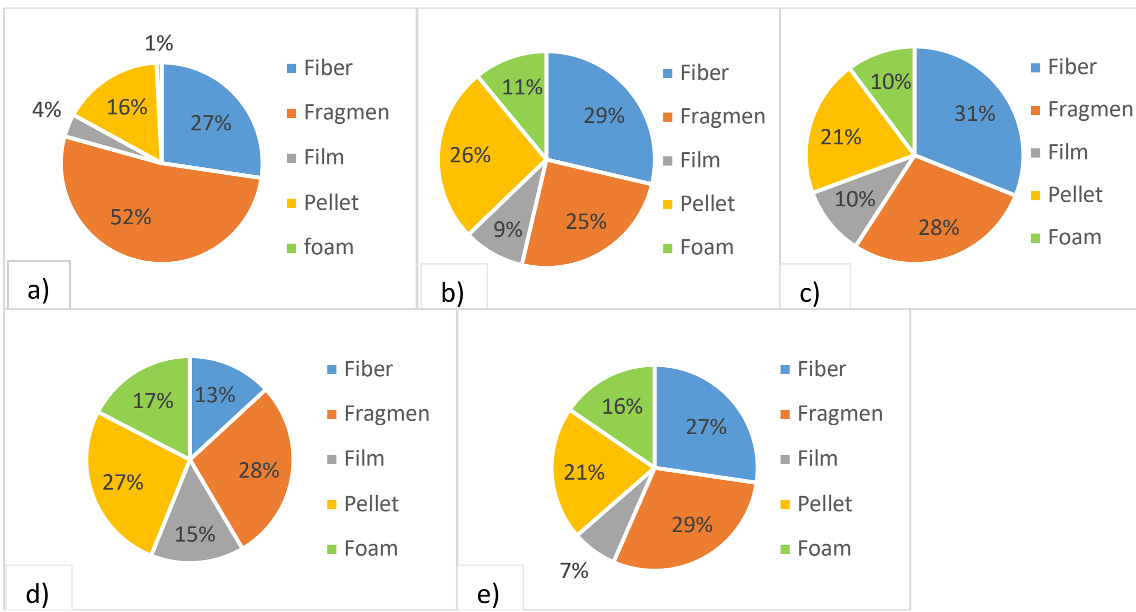


Fig. 8. Percentage of microplastic shapes in samples of **a)** carp, **b)** snail, **c)** macroalgae, **d)** water, and **e)** sediment

3. Microplastic color

Microplastic analysis of all samples revealed nine distinct colors: black, red, purple, yellow, blue, brown, gray, transparent, and green (Fig. 9). This finding closely resembles the microplastic color distribution observed in the Gresik aquaculture region of East Java, where eight colors were identified (black, purple, red, blue, yellow, pink, green, and transparent) **(Anjeli *et al.*, 2024)**. Black microplastics were predominant across all sample types (carp, snails, algae, water, and sediment), comprising 51-33% of the total. This aligns with microplastic studies conducted on fish, snails, and crabs in the Buringaga River, where black particles accounted for 36.6% of the findings **(Haque *et al.*, 2023)**, as well as water samples from Ranu Grati Lake, which showed a black microplastic percentage of 56-39% **(Aunurohim *et al*., 2024)**. In carp samples, brown microplastics represented the second highest percentage (19-25%). Darker hues, such as black and brown, typically originate from plastic waste that has not undergone significant color alteration owing to photochemical degradation caused by ultraviolet exposure **(Anjeli *et al*., 2024)**.

Transparent microplastics were the second most prevalent color found in snails, algae, water, and sediment samples, accounting for 15-29% of the total. This transparency may be attributed to extensive fishing activities that utilize colorless plastic fishing lines and nylon nets, which can be mistaken for zooplankton and consumed by fish and other aquatic organisms **(Di & Wang, 2018)**. Transparent microplastics are commonly found in commercial plastic bags and textile materials **(Haque *et al*., 2023)**. Green microplastics were the least common in carp, snails, and sediment samples (1-2%), whereas purple was the least frequent color in algae and water samples (1%). The occurrence of other microplastic colors varied: yellow (3-13%), blue (6-11%), purple (3-5%), red (2-11%), and gray (4-11%). Fig. (10) shows a detailed breakdown of the microplastic colors. Brightly colored plastics, often used in packaging bags, textile materials, and fish traps, closely resemble zooplankton and other aquatic organisms **(Haque *et al*., 2023)**.

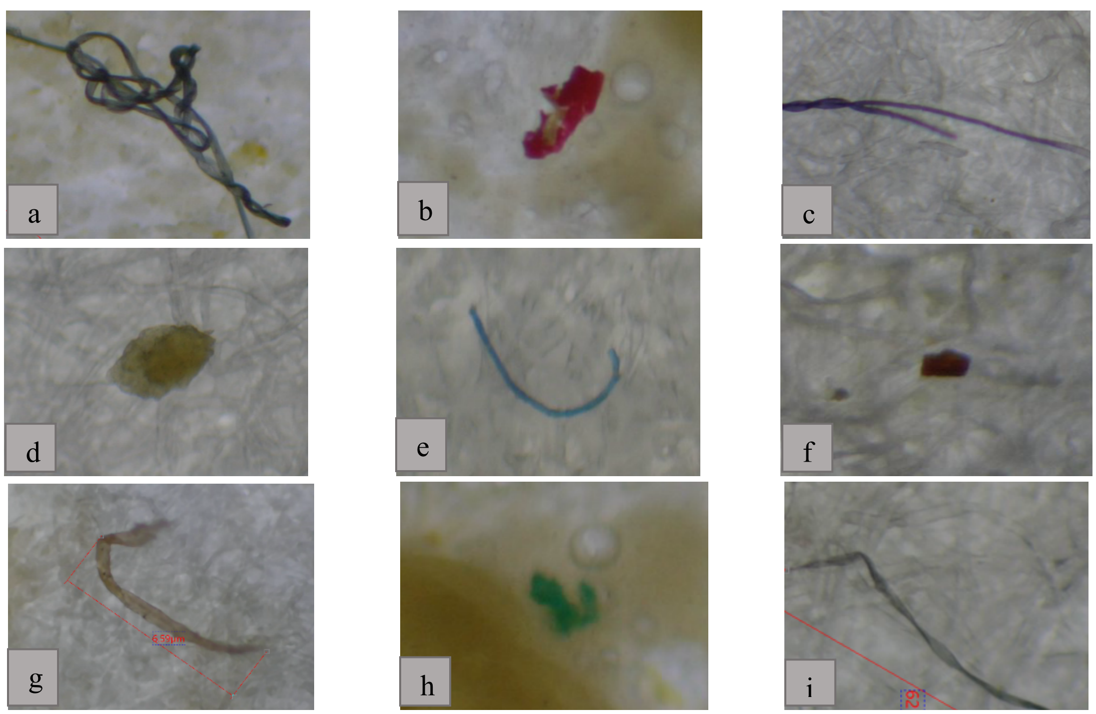


Fig. 9. Microplastics color **(a)** black; **b)** red; **c)** purple; **d)** yellow; **e)** blue; **f)** brown; **g)** transparan; **h)** green and **i)** grey

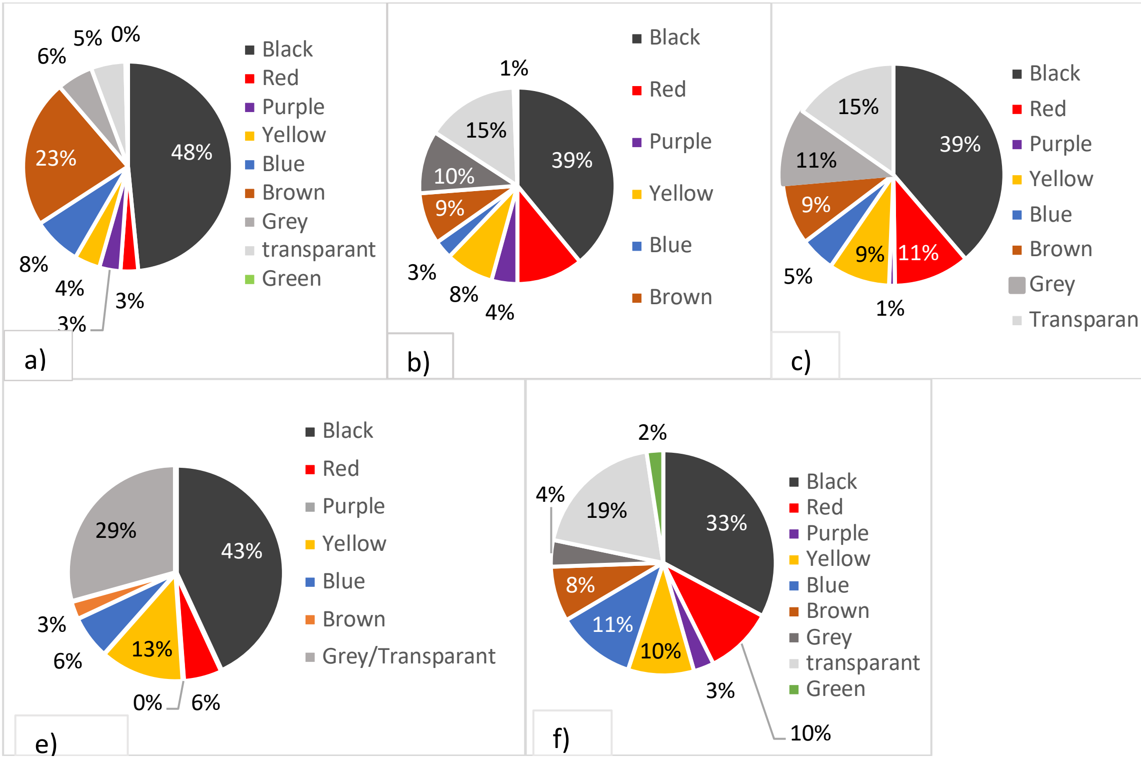


Fig. 10. Color diagram of microplastics in samples: **a)** carp, **b)** snails, **c)** macroalgae, **d)** water and **e)** sediment

4. Microplastic polymers

In the analysis of microplastics from five distinct samples (carps, snails, algae, water, and sediment), five primary polymer types were identified: nylon (PA), polyethylene terephthalate (PET), polystyrene (PS), polyvinyl chloride (PVC), and polyethylene (PE). Microplastics act as vehicles for harmful chemicals, including biochemically unstable monomers released from polymers (Borah et al., 2024). PE and Nylon were consistently present in all samples. Polyethylene (PE) is the most widely produced plastic polymer, largely because of its cost-effectiveness **(Ronca, 2017; Yao *et al.*, 2022; Queiroz *et al.*, 2024)**. The prevalence of black microplastics in this study aligns with the dominance of PE polymers, which, according to **Aunurohim *et al.* (2024)**, typically exhibit dark, intense colors and are commonly used in plastic garbage bags, contributing significantly to microplastic debris. In contrast, nylon microplastics are primarily sourced from laundry waste and discarded fishing equipment **(Yuan *et al.*, 2019; Anagha *et al.*, 2023; Aunurohim *et al.*, 2024)**.

Polyethylene terephthalate (PET), another type of polymer, was detected in carp, macroalgae, and sediment samples. PET is primarily utilized as a packaging material **(Issac & Kandasubramanian, 2021)** because of its safety, light weight, affordability, and low production costs. PS and PVC were exclusively identified in carp specimens. These polymers typically originate from fish containers, with PS specifically used in insulated floats, whereas PVC serves as the primary component in water pipes, cable insulation, and construction applications **(Chatterjee *et al.*, 2024; Liu *et al.*, 2024)**. Various microplastic forms are associated with different polymer types: fibers contain PA, PET, and PP; fragments composed of PET, PE, PP, PS, and PVC; films consist of PE and PVC; and pellets made of PE.

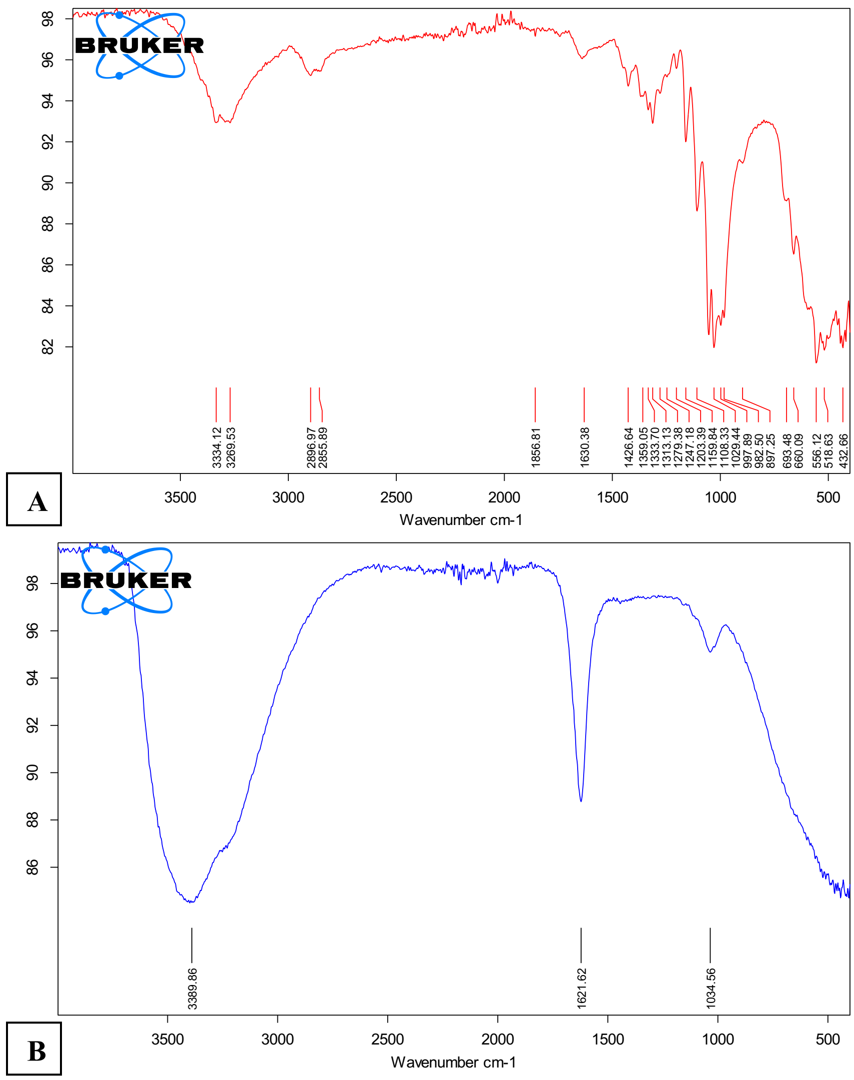


Fig. 11. Wavelength results on samples: **A**) PS, PE, PET, PVC; **B**) PA

CONCLUSION

Microplastic levels were higher in carp from cages than in those caught by fishermen. This discrepancy could be due to damage in the floating nets caused by prolonged exposure to sunlight. The digestive system of carp accumulated the most microplastics, indicating potential contamination via the food chain. Snails in cages showed higher microplastic concentrations than those at the outlet, reflecting the higher levels found in cage water and sediment than in the outlet. In contrast, the macroalgae collected from tourism sites showed higher microplastic concentrations than those collected from cages. This pattern was consistent with the levels of microplastics in water and sediment, which decreased in the following order: tourism, cage, outlet, and inlet. Microplastics were observed in five forms (fibers, fragments, films, pellets, and foam) and nine colors (black, red, purple, yellow, blue, brown, gray, transparent, and green). Five types of polymers were identified: nylon (PA), polyethylene (PE), polyethylene terephthalate (PET), polystyrene (PS), and polyvinyl chloride (PVC). The prevalence of black flakes indicates PE polymers, which are commonly associated with plastic wastes. The detection of microplastics in this study can provide the government with advice on policies to educate tourists and the surrounding community in the future regarding the impact of poor waste management.

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