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THE THREAT OF MICROPLASTIC WASTE IN DUMAI WATERS, PROVINCE OF RIAU, INDONESIA

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Abstract: The abundance of microplastic (particles <5 mm) and its danger in marine ecosystems has been reported in numerous studies. This work aimed to quantify microplastic accumulation in seawater, sediment and commercial fish of Dumai waters. Purposive sampling was performed to collect sample, enabling to gain a variety of microplastics and carried out on 5 sampling stations along the coast. Surface water sample was collected using plankton net (mesh size of 0.4 mm), the sediment was collected using a sampling tube (4 inch in diameter) at depth of 0 – 10 cm, and the fish sample was obtained from local fish-landing site of Dumai Port. This study revealed that the microplastics in water and sediment of Dumai waters, reaching up to 61.80-102 particles/m^3 and 72 particles/100 g, respectively. Three items of microplastic were identified, namely fiber, the highest (81.9%), filament at 13.9% and fragment was at 4.2%. Microplastic particles were existed in digestive tract of 12 commercial fish samples caught from Dumai waters. The highest level of microplastic pollution was attributed to pelagic fish *Atropus atropos* (10.3 particles/individual) and the lowest level was found in *Setipinna breniceps* (3 particles/individual).

Keywords: microplastic, commercial fish, Dumai waters, pollution, sediment, seawater

1. INTRODUCTION

The contamination of plastic debris including in ocean has been inextricably linked with anthropogenic activities, people's knowledge and understanding of plastic pollution (Borja et al., 2020). The plastics degrade gradually as impact of environmental and physical factors, and some of them enters the ocean which threatens the marine quality and food safety regarding plastic accumulation in fish and other marine organisms (Padervand et al., 2020; Wang et al., 2020). Fragmentation and degradation converting plastics into smaller pieces, then called as microplastic, in coastal areas could be accelerated because of exposure to sunlight, temperature and wave action (Andrady, 2015). Definitely, microplastic is defined as plastic particle under 5 mm in size. Anthropogenic activity has led to microplastic contamination throughout the marine environment and is ingested by many wildlife species including fish and shellfish (Smith et al., 2018; Verla et al., 2019).

Marine pollutants such as toxic chemicals, particles, industrial, microplastics, agricultural and residential waste cause harmful effects when enter the ocean and exists in water, sediment and marine biota (Chubarenko et al., 2016; Ilie et al., 2017; Wang et al., 2018). Microplastic toxicity has received serious concern since the ingestion of these small particles by aquatic organisms may occur extensively. The detrimental impacts of ingested particles to the digestive, reproductive, endocrine and blood system of the organisms result from presence of additives incorporated during manufacture of plastic (Anbumani & Kakkar, 2018; Wang et al., 2019). Previously, numerous studies reported the death of biota with stomach containing plastic pieces (Kühn et al., 2015), indicating that microplastic pollution seriously polluted marine food chains. Indonesia accounted for the second greatest plastic waste entering the ocean (Jambeck et al., 2015). Unfortunately, there is an inconclusive understanding on how the microplastics substantially affect population of marine biota (Lusher, 2015).

In the last decade, studies have found microplastic deposit in stomach of commercially important pelagic and demersal fish (Bellas et al., 2016; Nadal et al., 2016). The deposited microplastics include fiber, fragment and filaments (Compa et al., 2018). Current report by IUCN revealed that microplastic fragments polluting the environment could originate from erosion of tyres while driving or abrasion of the synthetic textiles during washing (Boucher & Friot, 2017). Meanwhile, the presence of microfiber is more often found in marine ecosystem close to urban areas (Alomar & Deudero, 2017; Taylor et al., 2016).

Dumai waters is located in the eastern coast of Sumatera Island, Indonesia and now suffer serious anthropogenic pressures (Ariani et al., 2016). The pressures come from activities in port, industries and residents, which may significantly contribute to the increment of microplastic pollution in Dumai waters. Therefore, this current work aimed to estimate microplastic accumulation in that site, focusing on three samples, i.e. water, sediment and fish.

2. METHODS

2.1 Sampling

Dumai city has coastline of 135 km and comprises of sub-districts, i.e. Medang Kampai, Dumai Timur, Dumai Kota, Dumai Barat and Sungai Sembilan. Purposive sampling was performed to collect sample, enabling to gain a variety of microplastics and carried out on 5 sampling points with three replications. Water and sediment samples, 500 mL and 500 g, respectively were collected from each station and with 3 times replication. The locations of the sampling coordinate points are presented in Table 1 and their positions are depicted in Figure 1.

Table 1. Coordinate of sampling points of water and sediment.

Station	Point 1	Location
1	1°43'2.31"N 101°23'25.03"E	Mangrove
2	1°41'56.95"N 101°24'30.24"E	Beach
3	1°41'40.91"N 101°24'53.09"E	Fish port
4	1°41'21.76"N 101°26'0.68"E	River embouchure
5	1°41'17.54"N 101°26'18.27"E	Sea

2.2 Data collection procedures

Surface water sample was collected using plankton net (mesh size of 0.4 mm) with capacity of 10 L. The water was transferred into sterile bottle and stored in cool box for further analysis. The sediment was collected using a sampling tube (4 inch in diameter) at depth of 0 – 10 cm, then moved into plastic container and stored in cool box for analysis. Fish sample was obtained from local fish-landing site of Dumai. The fish were stored in cool box and transported to laboratory (stored at -18°C) for further analysis.

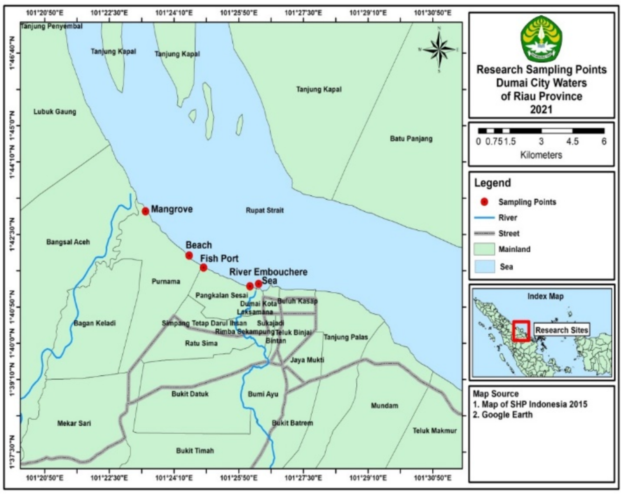

Figure 1. Sampling points of water and sediment.

2.3 Laboratory analysis

Microplastic processing in water and sediment samples involved a separation procedure. For water sample, the microplastic was separated from water using multi-layer filtration (stainless steel mesh sleeves) with size of 5.0 mm and 0.3 mm respectively. The filtrate was dried using oven at 70°C for 48 h (Masura et al, 2015). Before extraction, sediment was dried using oven at 70°C for 48 h. Furthermore, microplastic was extracted from sediment using mesh (20 cm in diameter) with pore size of 5 mm (Kyoung et al., 2015) and treated with 20 mL of 0.05 M Fe (II) and 20 mL of 30% H_2O_2 for removing organic materials (Masura et al., 2015). Meanwhile, density-based separation of microplastic was carried out by adding 10 mL of 1 M NaOH. Microplastic was identified by using light microscope.

In the laboratory, the weight (g) and body length (cm) of each fish were determined. Moreover, from each fish, the digestive tracts were dissected, following procedure prescribed by former studies (Lusher et al., 2013; Rocha-Santos & Duarte, 2015). Surgical procedures were conducted under sterile condition by alcohol 96% to ensure contaminant-free conditions. Fish stomach was observed under light microscope for 10 min. A sharp tweezer was used to separate microplastic items and natural fiber in fish stomach, and transferred them into petri dish containing deionized water (Battaglia et al., 2016). Content of fish stomach was also collected and oven-dried at 70 °C for 48 h, then digested using alkaline solution (10 mL of NaOH 1 M) (Cole et al., 2014) in density separator. The particles were identified and categorized as either fiber, fragment or particles, under light microscope. The observed microplastics were counted and compared with either volume of filtered water, sediment weight, or fish (Masura et al, 2015).

$$\text{Microplastics in water } = \frac{\text{Number of microplastic particles counted}}{\text{Filtered water volume } (\text{m}^3)}$$

$$\text{Microplastic in sediment } = \frac{\text{Number of microplastic particles counted}}{\text{Filtered sediment weight (100 gram)}}$$

$$\text{Abundance of Microplastics (fish)} = \frac{\text{Number of microplastic particles counted}}{\text{Number of fish sample}}$$

2.4 Statistical analysis

The data were statistically analyzed using One Way ANOVA in SPSS 17 software to evaluate the quantity of microplastics in water samples, in sediment for each station and their abundance between fish species. Significance was determined at $p < 0.05$.

3. RESULTS AND DISCUSSIONS

3.1 Microplastics in water and sediment

Our experiment in Dumai waters successfully quantified the microplastics in water and sediment, reaching up to 61.80×10^2 particles/m^3 and 72 particles/100 g, respectively. The highest abundance of microplastic was found in mangrove wetlands (station 1). The microplastic content in the mangrove ecosystem reached 19.0×10^2 particle/m^3 in water and 20 particle/100 g in sediment (Table 2). Root system in mangrove ecosystem enabled to retain more plastic items than in other areas. Meanwhile, the microplastic content levels in beach, fish port, river embouchure and sea did not differ greatly. The dissimilarity may result from local current, wind, geographical feature of the coastline and port activity in the Dumai waters (Barnes et al., 2009).

Dumai waters constitutes one of the busiest shipping lanes, with a strong current 0.06 – 0.2 m/s, temperature 30.1 – 30.7°C and pH 6.7 – 7.3. Such hydrodynamic condition affects waste material fluxes including distribution of microplastics in water and sediments being not drastically differed ($p > 0.05$). Microplastic with a density higher than sea water was accumulated in sediment. In addition, aggregation of microplastic was formed with other waste particles and phytoplankton, leading to high abundance of microplastics in sediment (Long et al., 2015*). On the other hand, microplastic also exists in water surface due to its low density and biofouling as impact of interaction with microorganism (Kowalski et al., 2016).

In general, there are 4 shapes of microplastic: fiber, fragment, filament and pellet. In this regard, we found microplastics in the form of fiber, filament and fragment (Fig. 2) that polluted Dumai waters. The pellet was not found in the site. A total of 402 microplastic items were recovered from the study site: fiber (81.9%), filament (13.9%) and fragment (4.2%) as depicted in Figure 3 and Figure 4. Presence of pellet as a plastic pollutant often links to the plastic manufacturer nearly the study site, considering that it is a pre-form plastic (Moreira et al., 2016). This is in accordance with the fact that no plastic manufacturer exists near the Dumai waters. Pollution by pellet could be recognized by the increase of pH in the water as it enables to react with other metals (Holmes et al., 2014).

Table 2. Variety of microplastic abundance in water samples and sediments collected from 5 stations

Station	Microplastic abundance	
	Water (10^2 particle/m^3)	Sediment (particle/100 g)
1	19.0	20.0
2	10.6	17.3
3	9.6	13.0
4	13.6	14.3
5	9.0	7.7

Fibers are one of the microplastic debris typically manufactured from nylon, polyethylene terephthalate and polypropylene, which are commonly released from synthetic garments during washing and fragmentation of fishing gears (e.g. ropes and nets) (Henry et al., 2019). Human activities in resident and fishing port near the sea provide immense impacts on the accumulation of fibers, while fishing activities are also main contributor to the pollution, as also depicted in Figure 5. In addition, filament (e.g. from plastic bottles) and fragment (e.g.

from plastic bags) items are attributed to waste generated from households; the plastic items underwent fragmentation in rivers, then ultimately entering the sea (Hidalgo-Ruz et al, 2012).

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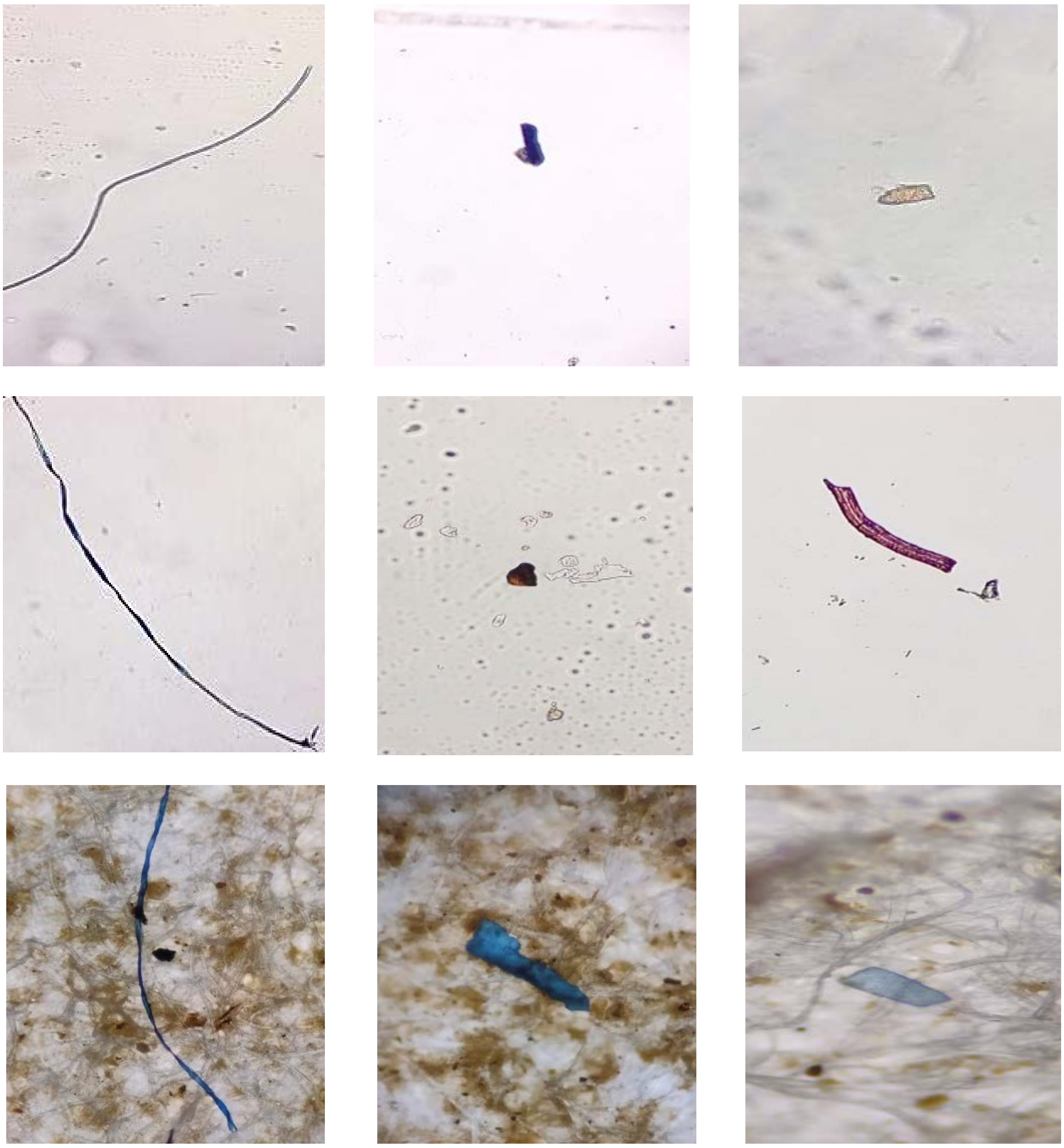

a b c

Figure 2. Microplastic shapes found in Dumai waters; (a) fiber; (b) filament; (c) fragment in fishes (1), water (2) and sediments (3).

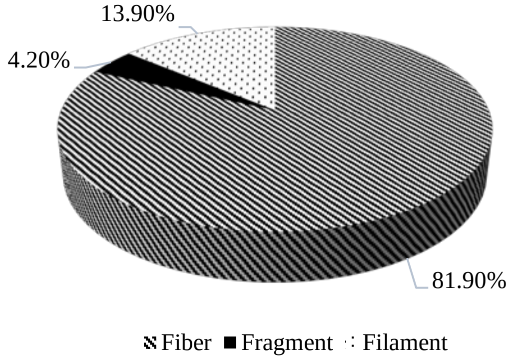

Figure 3. Percentage of microplastic abundance by shapes

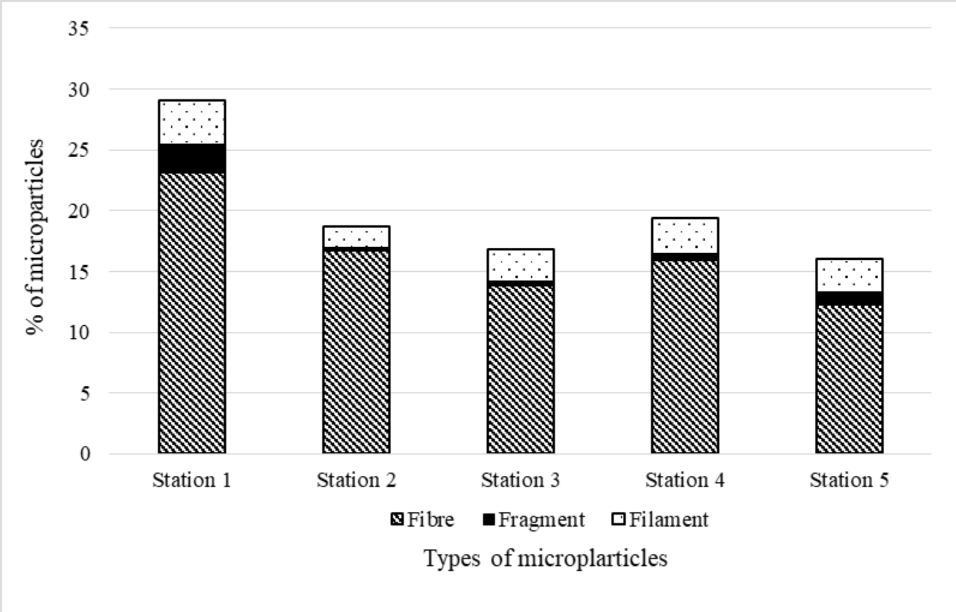

Figure 4. Abundance of microplastics by shapes found in each sampling station

3.2 Microplastics in the marine fish

Microplastics can accumulate in the marine biota such as commercial fish, as an evidence that they transfer into the food chain (Table 3). This present work detected microplastic items in stomach of 12 commercial fish samples collected from Dumai waters. The fish specimens were obtained from fish port in Dumai. Due to the size of microplastics, they are often mistakenly ingested as food by fish, impinging on digestive tracts even causing toxicity and other serious health disorders though the mechanism remains unclear (Barboza et al., 2020; Idrees et al., 2017).

The highest level of microplastic pollution was attributed to pelagic fish *Atropus atropos* (10.3 particles/individual) and *Sillago sihama* (10 particles/individual). Their habitat includes coastal waters and estuaries in which phytoplankton and plastic litters from domestic uses accumulate in a large scale. Furthermore, microplastic items in *Eleutheronema tetradactylum* were recorded at 10 particles/individual being one of the heavily polluted species, in which the species spend mostly in mud and sands. However, statistical analysis revealed that the results did not differ significantly ($p > 0.05$). Various studies have explained the negative effects of microplastics on human health. Starting from disrupting the nervous, hormonal and immune systems, to increasing the risk of cancer. A researcher from Italy also found that microplastics can interact

Table 3. Microplastic found in digestive organs of 12 marine fish species captured in Dumai waters.

No.	Species	Habitat (White et al, 2013)	Length (cm)	Weight (g)	Microparticles mean/fish ± SE
1.	*Pseudocienna amovensis*	coastal waters and estuaries	21.2 ± 0.11	163.3 ± 0.33	6 ± 1.73
2.	*Eleutheronema tetradactylum*	mud and sand bottoms	19.0 ± 0.18	237.0 ± 0.14	10 ± 3.46
3.	*Caranx crysos*	close to reefs	15.6 ± 0.25	195.2 ± 0.08	6 ± 0.57
4.	*Selaroides leptolepis*	schooling on soft bottoms	14.2 ± 0.15	158.4 ± 0.32	7.3 ± 3.18
5.	*Atropus atropos*	shallow coastal waters	9.5 ± 0.45	120.3 ± 0.12	10.3 ± 3.48
6.	*Sillago sihama*	coastal waters and estuaries	13.2 ± 0.13	18.6 ± 0.21	10 ± 3.05
7.	*Scataphagus argus*	estuaries and coastal waters	17.7 ± 0.27	158.7 ± 0.40	7.7 ± 0.88
8.	*Tenuolosa toil*	coastal pelagic	21.2 ± 0.32	223.9 ± 0.21	7.3 ± 2.03
9.	*Harpodon nehereus*	sand and mud bottoms	20.7 ± 0.16	150.1 ± 0.33	5 ± 2
10.	*Drepane punctata*	soft and hard bottoms	11.4 ± 0.55	195.8 ± 0.18	6 ± 1.53
11.	*Plotosus canius*	inshore, reefs and soft bottoms	22.8 ± 0.19	164.1 ± 0.22	4.7 ± 1.76
12.	*Setipinna breniceps*	coastal pelagic	13.6 ± 0.14	19.3 ± 0.23	3 ± 1.15

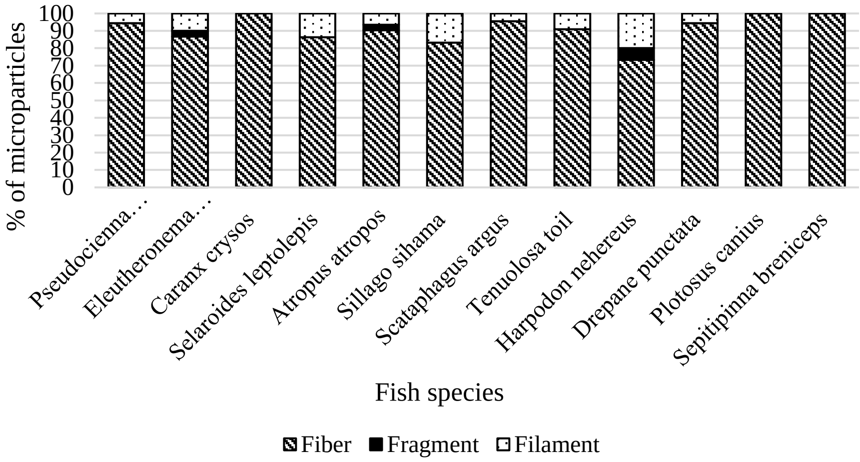

Figure 5. Abundance of microplastics in 12 commercial fish species collected from fish port of Dumai

with particles in the blood. These compounds change important proteins in the blood, such as albumin, globulin, and fibrinogen to become unable to function properly (Campanale et al., 2020),

In this work, fiber microplastics are found as the highest pollutant in fish compared to filament and fragment (Figure 4). The finding is in line with the high distribution of microplastic items in Dumai waters (water and sediment). Besides fish, the microplastics can accumulate in other organisms such as sea cucumber, mussels, lobster, amphipods, lugworms and barnacles (Thompson et al., 2004). At the higher level, pollution of microplastic may occur in marine biota through food chains (McMahon et al., 1999).

4. CONCLUSION

This present work successfully quantified the microplastics in water and sediment of Dumai waters, reaching up to 61.80 $\times$ 10^2 particles/m^3 and 72 particles/100 g, respectively. The type of microplastics was identified as fiber, filament and fragment. Among microplastic items identified, fiber was found as the highest (81.9%), while filament at 13.9% and fragment was at 4.2%. Microplastic items were detected in stomach of 12 commercial fish samples collected from Dumai waters. The highest level of microplastic pollution was attributed to pelagic fish *Atropus atropos* (10.3 particles/individual) and the lowest level was found in *Setipinna breniceps* (3 particles/individual). However, statistical analysis revealed that the results did not differ significantly ($p > 0.05$).

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