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Analysis of Abundance and Distribution of Microplastics in Sediments of Sail River, Pekanbaru City, Riau

Gunadi Priyambada, Lita Darmayanti*, Ummi Nazhirah Syathiri & Nudya Maulana

Department of Environmental Engineering, Universitas Riau, Kampus Bina Widya Jl. H.R Subrantas, Simpang Baru Pekanbaru 28293, Riau, Indonesia

**Corresponding author: litadarmayanti@eng.unri.ac.id*

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ABSTRACT

Microplastics are flakes or pieces of plastic that are less than or equal to 5 mm in size. Microplastics can be found in the river due to the degradation process of plastic waste that is dumped into the river. Microplastics can settle in sediments for a long time, and their very small size has the potential to threaten biota through the food chain. If microplastics enter the lumen (channels in the body's vessels), they can affect the immune system and cause intestinal swelling. Pekanbaru City is one of the areas that has the potential to be polluted by microplastics due to its rapid population growth. The city of Pekanbaru is crossed by the Siak River and several of its tributaries. This study aims to analyze the abundance of microplastics in the sediments of the Sail River, which is a tributary of the Siak River. Human activities around the river continue to increase, such as housing, workshops, kiosks, shops, restaurants, and others. The study was conducted in 3 sections, namely upstream, middle, and downstream, and each section had 3 sampling stations. Sediment samples were taken with an Ekman grab sampler. The results of the study indicated the presence of microplastic contamination in the sediments of the Sail River. The abundance of microplastics ranges from 5,335–21,374 particles/kg of dry sediment, where the value gets higher downstream. The types of microplastics found were fragments (39%), fibers (30%), and films (31%). The types of microplastics identified based on the Differential Scanning Calorimetry (DSC) test are nylon, polyester, polypropylene (PP) and polytetrafluoroethylene (PTFE). Statistical analysis was carried out to determine the correlation between microplastic abundance and environmental parameters (temperature, pH, and flow velocity). From the correlation test, it was found that flow velocity and temperature had a significant effect on the value of microplastic abundance ($p<0.05$). Awareness and collective action are required to address this issue. This study emphasizes the urgency of controlling microplastic pollution in rivers to protect the ecosystem and public health in Pekanbaru.

Keywords: Abundance; Differential Scanning Calorimetry (DSC); microplastics; sail river; sediments

INTRODUCTION

The dependence on the use of plastic in human life causes the use of plastics to be at risk of increasing. The global plastic production rate in 2020 had reached 367 million tons of plastic (Plastic Europe, 2021). About 5% of the plastic waste generate each year has increased; it was recorded that Indonesia produces 6.8 million tons of plastic waste per year. It is estimated that 10% of all plastics ever produced are at risk of being dumped into the ocean (Betty et al. 2014). Plastics disposed of in the sea will degrade due to exposure to ultraviolet radiation along the river water flow, so that microplastics are formed (Crawford & Quinn 2016).

Microplastics are polymer plastics that have particle sizes less than 5 mm (Alam et al. 2019). Microplastics can be divided into two types, which are primary and secondary. Primary microplastics are plastics produced in small sizes and usually found in cleansers and skincare products. Revised to: Secondary microplastics are smaller fragments or fragments of plastics in the environment (Ramadan & Sembiring, 2020). Microplastics can be in the river in several ways: plastic fragments in the river into smaller particles, and microplastics are directly released into the river through domestic waste, microplastics that are accidentally lost in the processing process, and the results of sewage treatment discharged into the environment (Kershaw & Rochman 2015).

Microplastics have a specific gravity that allows them to be transported into the water body and settle in the sediment over time. Microplastics can settle in sediments due to river dynamics processes such as the flow of streams, wind, waves, and tides (Oktavia & Adi 2020). Microplastics can be easily ingested by marine organisms because they are similar to plankton, which results in the risk of biomagnification, namely entering the food chain, and thus can lead to humans, who are the top predators in the food chain (Widianarko & Hantoro 2018). The risk that will occur in humans is that if microplastics are in the channel in the body's vessels (lumen), they can interact with blood through the adsorption process and will fill proteins and glycoproteins. This can affect the immune system and cause swelling of the intestines. In addition, the very small size of microplastics also allows transportation to other organ tissues (Hollman et al. 2013).

Pekanbaru City is a potential area for microplastic contamination because it has a high population density and is passed by the Siak River and several other river flows. Pekanbaru City has an area of ± 632.26 km2 and a population of 983,356 people (Badan Pusat Statistik, Pekanbaru, 2020). Based on the National Waste Management Information System (SIPSN), the amount of waste generated in Pekanbaru City in 2021 will be around 885.02 tons per day as much as 23.97% plastic waste. The plastic waste is often found piled up on the shoulder of the road, illegally dumped, and on the banks of the river until it has a great potential to enter the river water bodies.

One of the rivers in Pekanbaru City that is susceptible to microplastic pollution is the Sail River. The Sail River is one of the Siak River tributaries that stretches across four sub-districts, namely Sail, Bukit Raya, Lima Puluh, and Tenayan Raya sub-districts. The Sail River has a length of 29 km, a depth of 5 m and a width of 10 m which has turbid water with a bottom of sand, mud, and gravel (Putra et al. 2013). According to the Regional Environmental Status Report (SLHD) of Pekanbaru City in 2015, the Sail River is divided into 3 areas, namely Sail I, which is located in Lima Puluh District and Sail District; Sail II, which is located in Bukit Raya District; and Sail III, which is located in Tenayan Raya District. Of the three Sail River areas, the Sail I and II areas with a length of ± 9.6 km have a heavily polluted condition because they are in the middle of the city with an increasing population, while the Sail III area is in an oil palm plantation area and there are not many settlements, so it has a moderately polluted condition. From the three areas of the Sail River, the Sail I and II areas were taken as research case studies because they have heavily polluted conditions. In addition, the activities around the river continue to increase from time to time, such as the construction of settlements, workshops, shops, restaurants and so on, causing a high probability that the buildings will discharge various kinds of pollutants into the water. With such diverse activities, the potential abundance of microplastics produced will also produce diverse types. Therefore, there is a need for research to determine the distribution of microplastic abundance based on type in sediments in the waters of the Sail I and II Rivers.

METHODOLOGY

RESEARCH LOCATION

This research was conducted in Sail Rivers I and II, which cross several sub-districts such as Kecamatan Lima Puluh, Kecamatan Sail, and Kecamatan Bukit Raya, Pekanbaru City. The observation and sampling locations of this study were divided into 3 parts of the river flow segment, namely upstream, middle and downstream segments. Each segment was divided into 3 sampling points with a total of 9 samples, with a distance of 0.4-2.0 km at each sampling point.

EQUIPMENT

The tools used are a microscope, Sedgewick Rafter Counting (SRC), oven, porcelain cup, mortar, desiccator, sieve with mesh sizes 4 (5mm) and 18 (1mm), measuring cup, analytical balance, stirring rod, drop pipette, 250 ml beaker glass, and aluminum foil. The sampling tools used are ekman grab sampler, ziplock, Global Position System (GPS), thermometer, pH meter, and floater.

MATERIALS

The materials used were 9 sediment samples from the Sail River, 100 ml of NaCl solution, 20 ml of H2O2 30%, and distilled water.

SEDIMENT SAMPLING

Sediment sampling was conducted using the integrated sampling method, combining locations from the left, right, and center of the river. Sediment samples were taken using an Ekman Grab Sampler with a weight of 3 kg, a volume of 3.5 L, and a height of 20 cm.

DRYING

Wet sediment samples weighing as much as 200 grams were put into the oven at 90 ℃ for 24 hours. Warming is done to separate the water contained in the sediment so that it is completely lost, and the dry sample weight is obtained.

VOLUME REDUCTION

Dry sediment samples were pulverized using a mortar and then filtered using a sieve that has a size of 4 mesh and 18 mesh. This process aims to reduce the volume of sediment, sort macro sediments, and identify micro sediments (≤5mm). Then microplastic particles that are between 1 nm and < 5 mm in size are sorted and analyzed using a microscope.

DENSITY SEPARATION METHOD

Dried samples that passed the 18-mesh sieve were weighed and taken as much as 50 g, then immersed in a 100 ml NaCl solution to separate the natan and supernatant. Then the mixture was stirred for 2 minutes and then allowed to stand for 24 hours so that the mixture would settle (Covernton & Cox, 2019). After settling, the light-sized microplastics will be lifted into the supernatant because it has a lower density than the NaCl solution.

WET PERIOXIDE OXIDATION (WPO)

The WPO stage is carried out by mixing the supernatant from the previous process with a 30% H2O2 solution of 20 ml, which aims to remove organic matter from microplastic particles. After adding a 30% H2O2 solution, the sample was stirred and then allowed to stand for 12 hours (Addauwiyah, 2021).

MICROSCOPE ANALYSIS

The supernatant solution was taken using a 1 ml drop pipette and then dripped onto a glass preparation chamber (Sedgewick Rafter) to be observed under a binocular microscope at 10x10 magnification. This stage is done to determine the type of microplastic. Then the DSC test was carried out to determine the type of microplastic so that it could be grouped based on the type of polymer.

DATA ANALYSIS AND PROCESSING

Microplastic abundance was calculated as the number of microplastic particles per unit weight of dry sediment. The abundance of microplastics in sediments was calculated using a modification of the (American Public Health Association (APHA), 2017) equation as follows:

$$N = n \times (1/V) \times (X/Y) \times (Asrc/Aa) \quad (1)$$

Where N is the Microplastic abundance (particles/kg dry sediment), n is the number of microplastic particles (particles), X is the Volume of sample solution (ml), Y is the Volume of observed sample (ml), V is the Weight of dry sediment sample (kg), Asrc is the SRC area (mm^2), Aa is the area of the observed field (mm^2).

RESULTS AND DISCUSSION

ABUNDANCE OF MICROPLASTICS AT EACH STATION

Microplastic observations were carried out by two methods, those that can be observed directly visually and those that can be observed using a binocular microscope with a 10x10 magnification. The average abundance of microplastics observed visually was 41 particles/dry sediment. Microscopic observations were made on microplastics <1mm in size. The average microplastics obtained at all stations are 13,333 particles per kg of dry sediment as described in Table 1. The abundance of microplastics of sizes 1< 5mm and < 1mm was then summed up to obtain a total abundance with an average of 13,353 particles per kg of dry sediment.

The total abundance of microplastics in the sediments of the Sail River ranged from 5,335 to 21,374 particles per kg of dry sediment. If the results of the study are compared with previous studies, the average abundance of microplastics obtained by (American Public Health Association (APHA), 2017), which is located on the Loji Coast, Sukabumi, is higher at 33,333-117,667 particles per kg dry sediment. The lower abundance of microplastics was obtained by Saputra (2019) in Muara Badak Sediment, Kutai Kartanegara Regency, with an abundance ranging from 69.3-90.12 particles/kg dry sediment. The difference in microplastic abundance in various regions is caused by several things, such as regional characteristics, and the presence of anthropogenic activities that are more intensive in other regions.

The highest abundance of microplastics was found in segment 3 at 21,374 particles per kg dry sediment. This is because segment 3 is the downstream part of the river that gets microplastic input from the upstream and middle of the river. Similar to the results of direct observations made in the field, the downstream area of the river is the area where the most floating garbage is found in the waters. In addition, based on the results of paramater measurements, the flow velocity in the last 3 station segments has a slow current of 0.13 m/s, which can cause microplastics to settle in the sediment. The lowest abundance in this study was found in segment 1, which is the upstream part of the river, amounting to 5,335 particles per kg of dry sediment. Microplastic pollution in segment 1 comes from residents' drainage channels and other activities such as workshops and farms. Microplastic input in segment 2, apart from originating from residents' house drains, is also thought to be carried by currents originating from the Tangkerang River estuary, trading activities (markets), and fishing activities.

The correlation between abundance and temperature variables has a Pearson correlation coefficient of 0.677, which is in the range of 0.60-0.799 and has a positive coefficient number. This means that the correlation between temperature and microplastic abundance is strong and unidirectionally correlated (if the temperature parameter value rises, the microplastic abundance value also rises). This is also consistent with the research conducted by Layn & Emiyarti (2020) on the sediments of Kendari Bay, which found a positive correlation coefficient of 0.273. This means that the abundance of microplastics and temperature are directly proportional. The significant relationship observed is due to one of the factors contributing to the formation of microplastics in aquatic environments being photodegradation.

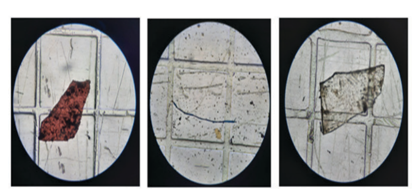
TABLE 1. Measurement results of environmental conditions at Sail River

Station	Segments	Coordinate	Water Condition				Abundance of microplastics		
			Temp. (^{0}C)	pH	Flow (m/dt)	Width (m)	1 - < 5mm (visual) (Particle)	< 1mm (microscopic) (Particle)	Total (Particle)
1		$0^0$47'55"N & $101^0$48'61.7"E	29	6.85	0.43	11.11	2	5.333	5.335
2	1	$0^0$48'74.3"N & $101^0$47'89.4"E	30	6.66	0.30	13.95	4	6.667	6.671
3		$0^0$48'74.5"N & $101^0$47'32.8"E	30	7.11	0.30	13.27	8	9.333	9.341
4		$0^0$49'40.4"N & $101^0$46'78.3"E	30	6.38	0.28	16.02	22	12.667	12.689
5	2	$0^0$51'39.9"N & $101^0$46'98.0"E	29	6.22	0.27	16.42	23	14.000	14.023
6		$0^0$52'01.8"N & $101^0$46'78.3"E	30	6.39	0.24	14.26	27	16.000	16.027
7		$0^0$52'45.6"N & $101^0$46'74.1"E	31	6.41	0.17	13.51	31	16.667	16.698
8	3	$0^0$53'31.9"N & $101^0$46'79.5"E	31	6.40	0.18	16.59	32	18.000	18.032
9		$0^0$54'14.5"N & $101^0$46'77.8"E	31	6.63	0.13	21.25	41	21.333	21.374
Average			30.11 ±0.78	6.56 ±0.28	0.26 ±0.09	14.39 ±1.88	21±13.61	13,333 ±5354	13,355 ±5367
Pearson correlation test			0.667	-0.537	-0.928	-	-	-	-

TYPES AND POLYMERS OF MICROPLASTICS

This study found three types of microplastics, namely fragments, films, and fibers (as shown in Figure 1 ((a) fragment (b) fiber (c) film). The following is an image of each type of microplastic and a table of microplastic abundance based on its type.

The abundance of microplastics by type across segments one to three in the Sail River is presented in Table 2. The total abundance of microplastics observed varies significantly, with segment one having the lowest abundance and segment three having the highest. Detailed data on the distribution of microplastic abundance in each segment can be found in Table 2.



(a) (b) (c)

FIGURE 1. Types of microplastics found in Sail River (a) fragment; (b) fiber and; (c) film

Fragments are the most common type of microplastic found in the Sail River, with an average abundance of 5,269 particles per kg (39%). The same thing was found in the research on Kartini Beach, Jepara Regency, Central Java, where the fragment type dominated the most among all stations with a total of 506 particles/kg (Azizah et al. 2020). However, the research on Naras Hilir Village Beach, Pariaman City, revealed that the type of microplastics found most frequently was the film type, accounting for 33.53% (Yolla et al., 2020). The large abundance of fragment-type microplastics is in accordance with the statement of Peng et al. (2017) that urban river inputs are the main factor for microplastics entering the sea. The abundance of fragment types is due to the dominant amount of waste on the banks of the rivers, which is plastic bottles and other household plastic waste, which is the source of fragment -type microplastics. Macro-sized plastic waste will undergo fragmentation and size reduction while flowing in the river and become fragment-type microplastic waste (Hidalgo-Ruz et al. 2012). In the field observations, the condition of the Sail River is filled with plastic bags and used bottles found from upstream to downstream of the river, which allows fragments to be more dominant than other types.

The research location consists of three segments, each with three sampling points spaced ± 0.4-2.0 km apart. Segment one is the upstream part of the river, located in the administrative area of Tangkerang Labuai Village, Bukit Raya Sub-district. Segment two is the middle section of the Sail River, situated in Tangkerang Labuai Village, Bukit Raya Sub-district, and Rejosari Village, Sail Sub-district. Segment three is the downstream part of the river, located in Sekip Village and Tanjung Rhu Village in Kecamatan Lima Puluh.

Based on Figure 2, the distribution of microplastics increases from upstream to downstream. In segment 1, located upstream at S1T1, the abundance of microplastics is only 5.335 particles per kg. However, the abundance of microplastics increases in each subsequent segment, with the highest abundance found in the downstream segment of the river, S3T3, at 21.374 particles per kg. Figure 2 also shows that microplastics of the fragment type are identified with a red marker in each segment, fiber type with a blue marker, and film type microplastics with a gray marker.

TABLE 2. Abundance type of microplastics at Sail River

Segment	Station	Abundance of microplastics (particles per kg dry sediment)			Total
		Type of microplastics			
		Fragment	Fiber	Film	
	1	2000	1333	2002	5335
1	2	2669	2002	2000	6671
	3	3335	2671	3335	9341
	4	5338	3344	4007	12689
2	5	6014	3338	4671	14023
	6	6011	5345	4671	16027
	7	5349	6005	5344	16698
3	8	6681	5341	6010	18032
	9	10021	6682	4672	21374
Total		47.418	36.061	36.713	120.191
Average		5.269	4.007	4.079	13.355
Percentage (%)		39	30	31	

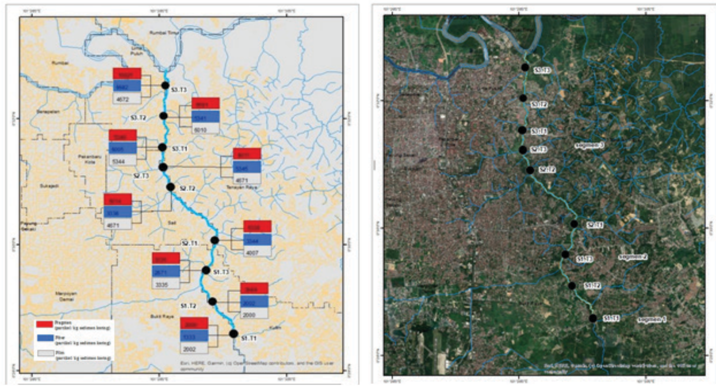


FIGURE 2. Microplastics distribution map by type in Sail River sediments

DIFFERENTIAL SCANNING CALORIMETRY (DSC)

In this study, DSC was used to test the thermal properties so that the type of polymer in the sample is being tested. DSC is an analytical technique that involves measuring the difference in heat in the sample as a temperature comparison. Samples are analyzed in a dry state. If the sample is wet, it will interfere with the analysis by causing the appearance of unwanted thermogram peaks.

Results of the DSC thermogram in Figure 3 show that the type of polymer tested does not melt below a temperature of 300°C, which means that the melting temperature of the polymer type is >300 °C. When compared to the table of polymer types based on their melting points, the microplastic fragment type tested is a polytetrafluoroethylene (PTFE) polymer type. PTFE is known by the trade name Teflon and is commonly used as a nonstick coating for pots, pans, and other cooking utensils. In addition, PTFE can also be used to coat other materials, such as cables or fabrics, to make them waterproof. PTFE is highly non-reactive and is often used as a container and pipe material for reactive chemicals.

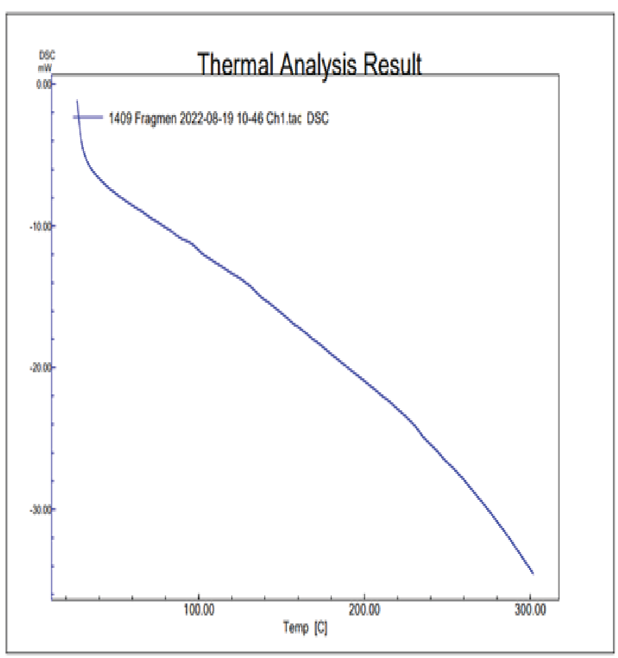


FIGURE 3. DSC Thermogram of microplastic fragment type

CONCLUSION

According to the results of research on microplastics in Sail River sediments in Pekanbaru City, it can be concluded that the abundance value of microplastics in Sail River sediments ranges from 5,335-21,374 particles per kg dry sediment, with the highest abundance located in segment 3, which is 18,701 particles per kg dry sediment. Then the microplastics found in the Sail River sediments consisted of 3 types, namely fragments, fibers, and films, with the most dominant type of microplastic being the fragment type at 39%. There are 4 types of polymers found in Sail River sediments based on DSC tests, namely nylon, polyester, polypropylene (PP) and polytetrafluoroethylene (PTFE). Microplastic pollution in the Sail River comes from household waste, clothes washing waste, plastic waste (straws, plastic bags, plastic sacks, plastic bottles, plastic spoons, toys, helmet glass, etc.), and fishing activities. For further research, it is recommended to expand the study to include water, biota, and sediment analysis in the Sail River, and to examine how sediment characteristics correlate with polymer types and microplastic abundance. This will offer a clearer picture of microplastic distribution and impact.

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DECLARATION OF COMPETING INTEREST

None.

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