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Distribution of Microplastics in Domestic Wastewater and Microplastics Removal Potential in Wastewater Treatment Plants

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ABSTRACT
Microplastics in domestic wastewater are detrimental to living organisms and appear in a variety of sizes, colors, and shapes. The purpose of this study is to examine the distribution of microplastics in domestic wastewater, as well as the possibility for microplastic removal in wastewater treatment plants (WWTP). The sampling method used is SNI 6989.59:2008 concerning Wastewater Sampling Methods that Apply in Indonesia. To remove organic compounds in the sample, 0.05 M Fe (II) and 30% H_2O_2 solution were added by the digestion process at 75 °C for 30 minutes and cooled. Samples were filtered using Whattman GF/C filter paper with the help of a vacuum pump and dried. To identify the concentration, shape, size, color of microplastics, visual analysis was used with the help of a microscope using the zig-zag technique. The concentration of microplastics in domestic wastewater in Gampong Garot is 30.17 ± 0.75 particles/100 mL sample. The most commonly found microplastic size is 1,001–5,000 µm, while the dominant color is transparent. The forms of microplastic found in the samples were fiber, fragments and microbeads with a percentage of 65.20%, 23.16% and 11.64%, respectively. These microplastics come from local community activities such as washing clothes, bathing, washing dishes, and other activities. So, it is necessary to treat domestic wastewater using WWTP. Not only does it remove organic matter and nutrients, WWTP also has the potential of microplastics removal around 7–99% depending on the processing unit.

Keywords: distribution, domestic wastewater, microplastics removal, possibility, WWTP.

INTRODUCTION

Microplastics (MPs) with sizes ranging from 0.3 mm to 5 mm have been detected in water locations all over the world (Hidalgo-Ruz et al., 2012; Kramm et al., 2018). It is found not only in the sea (Law, 2017), soil (Liu et al., 2018), and lakes (Su et al., 2016), but also in waste water (Mintenig et al., 2017; Gies et al., 2018). The high concentration of MPss detected in home wastewater will have an impact on the environment of the water source. MPs that accumulate in the bodies of animals and cause physical and chemical harm such as organ damage and digestive tract blockage are carcinogenic and induce endocrine problems (Revel et al., 2018). Humans, at the highest trophic level, will accumulate the most MPs concentration.

MPs are derived from two sources: primary and secondary. Household and industrial sewage are the principal sources of microplastics. While washing clothes made of synthetic textile materials, often in the form of fibers, is a secondary source (Browne et al., 2011). Fibers, fragments, films, pellets, sheets, and foam are all examples of MPs (Gies et al., 2018; Lares et al., 2018; Nor and Obbard, 2014). MPs in wastewater are caused by synthetic clothing and cleaning products including polyester fibers and beads (Ziajahromi et al., 2017; Nur et al., 2022).

Several prior research on MPs have been conducted, with the results indicating that MPs of all forms, sizes, and colors are detected in diverse waters originating from human activities such as housing and other industries (Murphy et al., 2016). Furthermore, MPs were discovered in the city of Bandung at a concentration of 7,666.67 ± 513.16 MP/kg of septic tank sludge. The most common MPs discovered were less than 300 m in size, in the shape of fibers (80.87 ± 44.8%), and clear in color (55%). It is known that for MP sizes that have been documented, it is 42% for sizes 20–100 μm, 28% for sizes 101–300 μm, 16% for sizes 301–500 μm, and 501–1000 μm and 1,001–5,000 μm (Nur et al., 2022). Aside from that, several MPs have been discovered in WWTPs around the world, including Denmark with a concentration of 7,216 MP/L (Simon et al., 2018), Spain with 451 106 MP/L (Edo et al., 2018), Finland with 180 and 430 MP/L (Talvitie et al., 2015), and China with 80 MP/L (Liu et al., 2019).

Because community activities cannot be separated from water regions, the possibility of MP intake from activities near inland waters cannot be overlooked. The Gampong Garot wastewater management system is a distribution system for a network of pipelines that transports wastewater to receiving water bodies. As a result, WWTPs is required for the treatment of domestic wastewater. In addition to organics and nutrients removal, WWTPs have the ability to remove microplastics from domestic wastewater. Microplastics contained in domestic wastewater need to be identified (sizes, shapes and colors) , so as to facilitate the elimination of these contaminants in WWTP. This research will examine into the possibilities of eliminating microplastics from wastewater treatment plants (WWTP). Because microplastic is a pollutant that is dangerous for organisms.

MATERIALS AND METHODS

Sampling location

Sampling is located in Gampong Garot, Darul Imarah District, Aceh Besar District, Indonesia. The sampling locations which are considered to represent the condition of the Gampong Garot waste water area are divided into 3 stations. Each observation station was sampled 2 times. The location of the sampling points can be seen in Figure 1.

Sampling methods

Purposive sampling was used to select sampling points. At sample point 1, there were 90 households that disposed of domestic wastewater, 70 houses at sampling point 2, and 120 houses at sampling point 3. Because the three sites of this research location are strategically located and easily accessible to researchers, they were chosen as research samples. SNI 6989.59:2008, Wastewater Sampling Methods, was employed for sampling in this study. The following are the steps followed in sampling domestic wastewater: 1) Wastewater samples are collected from three study sites; 2) Waste water samples are placed in each bottle at each research site; 3) Place name labels on the sample bottles based on the study location; 4) Repeat two times at each sampling location.

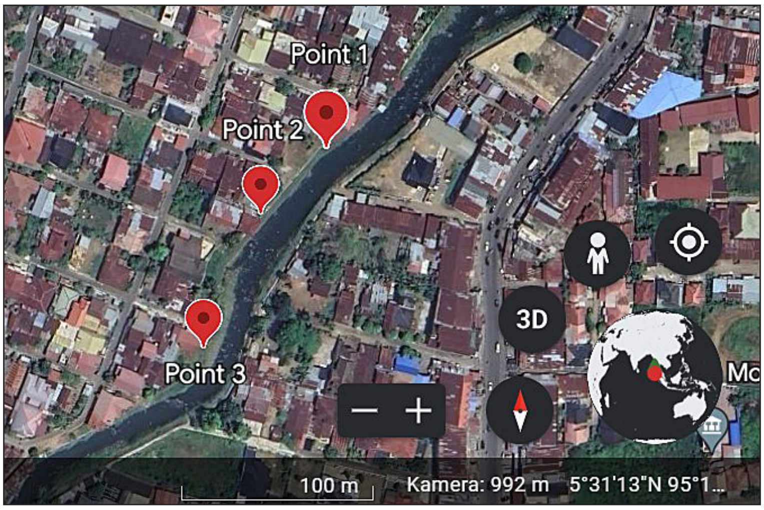


Figure 1. Sampling location

Analysis of microplastics

Microplastics were identified by first eliminating organic chemicals from the samples using 30% H_2O_2 and 0.05 M Fe (II) at 75 °C for 30 minutes (Free et al., 2014). It was then vacuum filtered through 1.2 µm GF/C Whatman paper (Hidayaturrahman & Lee, 2019). A binocular microscope with a magnification of 100 was used to identify microplastics (Hidayaturrahman & Lee, 2019). The abundance of microplastics was determined using equation 1 (Nugroho, 2018), where C is the abundance of microplastics (particles/100 mL), n is the number of particles, and m is the sample volume (mL).

$$C\text{ (particles/100 mL sample)} = \frac{n}{m} \tag{1}$$

RESULTS AND DISCUSSIONS

MPs concentrations

The concentration of MPs identified in each sample was similar to the average of 30.17 ± 0.75 particles/100 ml sample, according to the data. The MPs concentration measured at point 2 was lower than at points 1 and 3 due to the lower number of residences disposing of wastewater, namely 70 houses. Points 1 and 3 have 90 and 120 dwellings, respectively. Waste water at point 2 comes from more diverse community activities. This can also cause point 2 to have slightly more concentration. However, each site has a concentration that is nearly same and not significantly different. The MPs discovered were discovered during ordinary actions such as washing clothes, washing dishes, showering, and other activities. The community's waste water is directly released into the pipes where the sampling is done. The number of MPs discovered is comparable to other countries. MPs discovered in WWTPs around the world range from 260 to 320 MP/L in France (Dris et al., 2015), 160 to 467 (MP/L) in Russia (Talvitie et al., 2014), and 80 MP/L in China (Liu et al., 2019). However, this is significantly lower than the 7,216 MP/L recorded in Denmark (Simon et al., 2018).

Table 1. MPs Concentrations

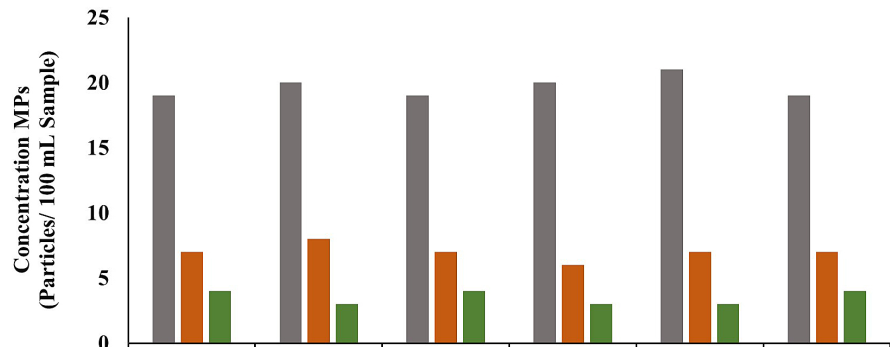
Sample	Concentrations	Unit
1a	30	Particles/100 mL sample
1b	31	
2a	30	
2b	29	
3a	31	
3b	30	
Average ± SD	30.17 ± 0.75	

MPs shapes

According to Figure 2, fiber forms predominate over fragments and microbeads, hence the microplastic content in fiber forms is extremely high. Microbeads have a very low composition that is 5 times lower than fiber on average. Sample 3a had the highest fiber content, at 21, whereas samples 1a, 2a, and 3b had the lowest, at 19, correspondingly. Sample 1b had the maximum number of fragments, namely 8, while the rest were relatively the same, with a total of 7 except for sample 2b, which had 6. The results revealed that the shape of the fiber was detected in the sample an average of 65% of the time. This is nearly in accordance with the findings of Talvitie et al. (2017), who reported that 70% of microplastics discovered in home wastewater are in the form of fibers. This fiber-shaped microplastic is derived by the washing of textiles. Microplastic fibers are released from clothes during the washing process, according to studies (Falco et al., 2018). Because garments manufacture 1900 polyester (polyethylene terephthalate) fibers per wash (Almroth et al., 2018). Because garments manufacture 1900 polyester (polyethylene terephthalate) fibers per wash (Almroth et al., 2018). Samples 1a, 2a, and 3b had the greatest content levels in the microbead form, totaling 4. The least content levels in samples 1b, 2b, and 3a totaled 3.

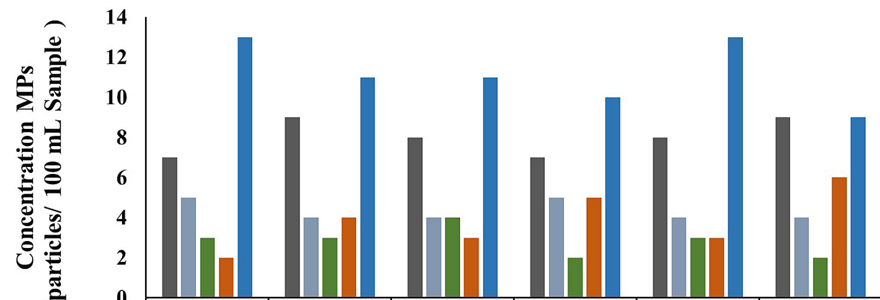
MPs sizes

The size of 1,001–5,000 µm has a high dominant value for all samples, in contrast to the size of 301–500 µm which is relatively less. In addition, the size of 20–100 µm is also widely detected. This size is most commonly found in the form of microbeads and fragments. While sizes 1,001–5,000 are found in the form of fiber. The size of the MPs found in each sample is not much different (Figure 3). When compared to previous studies the size of the MPs in the sample has similarities ranging from 0.3 mm-5 mm (Kramm et al., 2018).



	Sample 1a	Sample 1b	Sample 2a	Sample 2b	Sample 3a	Sample 3b
Fiber	19	20	19	20	21	19
Fragment	7	8	7	6	7	7
Microbead	4	3	4	3	3	4

Figure 2. MPs shapes



	Sample 1a	Sample 1b	Sample 2a	Sample 2b	Sample 3a	Sample 3b
20-100 µm	7	9	8	7	8	9
101-300 µm	5	4	4	5	4	4
301-500 µm	3	3	4	2	3	2
501-1000 µm	2	4	3	5	3	6
1001-5000 µm	13	11	11	10	13	9

Figure 3. MPs sizes

MPs colors

According to Figure 4, transparent colors had considerably larger yields than all other hues, with sample 3b having the greatest yields, namely 13. (Zhang et al., 2020) discovered that transparent hues are the most prevalent in waste water after studying microplastics in home wastewater. In addition to the translucent color, the researchers discovered microplastics in a variety of different colors, including blue, red, brown, green, purple, yellow, and others. However, the least yellow color discovered. The yellow color is only discovered in samples 1b and 3b, which have outcome 1, and it is not detected in any other samples. Because yellow is inversely related to transparency, it is practically unnoticeable.

MPs visualizations

Figure 5 depicts the shape and color of MPs that may be viewed using a microscope and detected in the sample. The most prevalent types of MPs discovered were filaments and pieces. This fiber is in the shape of threads with the colors associated with microplastics. While the fragment's shape is similar to a little piece of plastic, it is in the form of fragments. These MPs are the outcome of Gampong Garot community activities, which resulted in a variety of MPs.

Potential of MP removal in WWTP

Domestic waste water in Gampong Garot is still not properly managed. Domestic wastewater

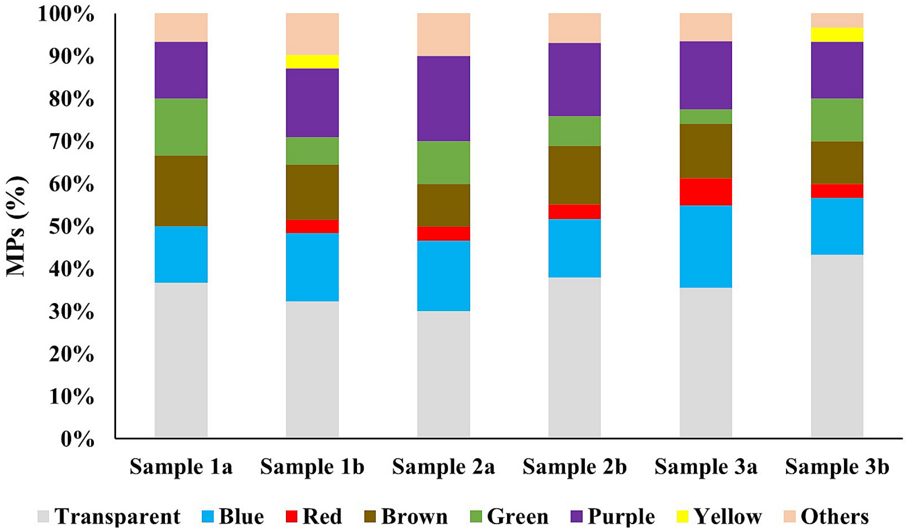


Figure 4. MPs colors

is released untreated. Several studies have discovered that urban WWTPs is one of the entry points for MPs into the aquatic environment (Alvin et al., 2019; Iyare et al., 2020; Cheung et al., 2016). As a result, domestic wastewater from Gampong Garot will become a source of MPs in aquatic bodies and must be cleaned before being dumped into them. WWTPs in various countries are capable of removing up to 98% of MPs (Carr et al., 2016). Several other studies claim that the MP removal efficiency in WWTPs ranges between 50% and 99% (Yang et al., 2019; Ziajahromi et al., 2017; Gies et al., 2018; Lares et al., 2018). Figure 6 depicts an MPs removal strategy for a WWTP, demonstrating that the removal efficiency for each treatment phase in a WWTP is quite high.

The best removal efficiency is achieved through pre-treatment and primary treatment. MPs can be removed by 78–98%. The secondary treatment method has a lower elimination efficiency, which is approximately 7–20%, while the tertiary treatment has the lowest, around 7%. The use of carrier medium in WWTP has the potential to improve MPs removal efficiency. This is related to the adhesion of MPs to biofilms (Nur et al., 2022). PET plastic bottle waste, being the world's second largest producer of plastic garbage (Jambeck et al., 2015), can be employed as a carrier medium in household wastewater treatment (Fauzi et al., 2023a). This is because PET

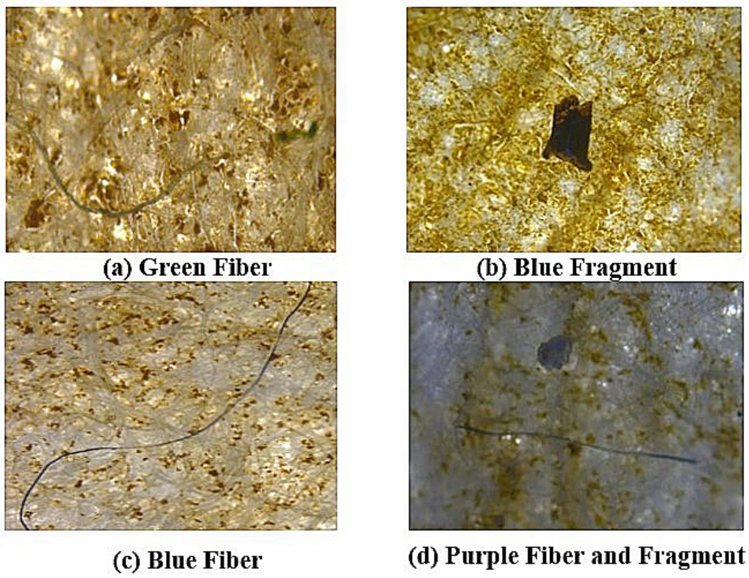


Figure 5. MPs visualizations

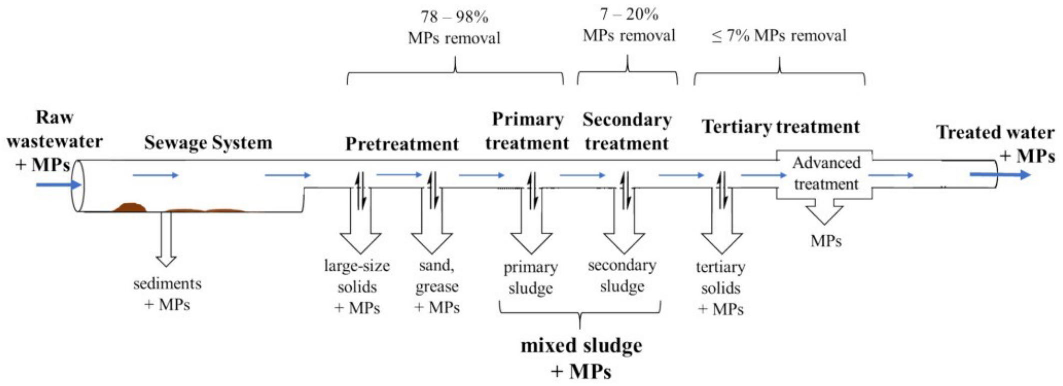


Figure 6. WWTP process schematic and MPs removal (Masia et al., 2020)

has hydrophilic qualities that allow a large number of microbes to attach (Setiyawan et al., 2023), as well as being easily produced and producing a relatively large specific surface area (Fauzi et al., 2023b). PET plastic bottle waste are also easy to find in domestic (Fauzi et al., 2022), hotels (Dewilda et al., 2022), restaurants (Dewilda et al., 2019), food industry (Dewilda et al., 2023).

CONCLUSIONS

The average concentration of MPs in residential wastewater is 30.17 ± 0.75 particles/100 mL sample. Point 2 had the smallest concentration of MPs of the three sampling stations, owing to the significant number of residences that dispose of wastewater to this point. The concentration of MPs at the three sampling points, however, is not significantly different. The most prevalent type of MPs discovered in the samples was fiber 65.20%, which was inversely proportionate to fragments 23.16%, and microbeads 11.64%. The most often discovered MPs ranged in size from 1,001 to 5,000 m, with translucent being the most common color found. Apart from removing organics and nutrients, WWTP also has the potential to remove up to 98% of microplastics.

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