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Identify Water Treatment Plant Capability in Removing Microplastic: Lab Scale Simulation and Direct Sampling

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The challenges of Drinking Water Treatment Plants (DWTP) are increasing due to the presence of new types of pollutants that can contaminate raw water and increase the processing load on the installation. One of the pollutants that is currently being discussed a lot is plastic particles measuring < 5 mm which are called microplastics. Based on these factual conditions, it is also important to identify the generation of microplastics at the raw water treatment plant in Bandung-Indonesia. In this study, laboratory-scale water treatment simulations and sampling at two drinking water treatment plants in Bandung City were carried out using the grab sampling method to identify their generation in the laboratory. The results showed that microplastics were still found in all processing units, this was in line with laboratory-scale processing which showed that the processing still left residue at the final stage of the experiment. So, it can be concluded that further research is needed to optimize the performance of conventional water treatment units in removing microplastics and the mechanism that can be applied to prevent the spread of microplastics into water bodies.

Keywords: Microplastic Removal, Microplastic Abundance, Characteristics, Water Treatment Plant, Bandung – Indonesia.

1. INTRODUCTION

Microplastic was first defined by The National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program as a plastic with a size smaller than 5 mm [6]. It classified into two categories: (1) Primary microplastics, which are plastics manufactured of microscopic size, some researchers consider that primary microplastics are those that add new micro-sized plastic materials to the environment [36], and (2) secondary microplastics, which are microscopic plastics derived from the breakdown of larger plastics after being degraded in the environment [5]. According to Wang et al, 2018 [37], secondary microplastics, these are produced from larger plastics that undergo physical (e.g., wave action and mechanical abrasion), chemical (e.g., photodegradation), and biological degradation after disposal. Lestari, 2013 [16] research states that the majority of the Indonesian population living on riverbanks still disposes of their domestic waste water directly into rivers so that the quality of river water decreases drastically, one of which is evidenced by the presence of microplastics in water bodies. Based on the latest research, plastic particles have been reported in food consumed by humans as well as drinking water, raising global concerns on food safety [12]. Several raw water samples from selected drinking water treatment plants have been investigated for microplastics and their presence has been confirmed [26], where the number of microplastics reaches up to >4000 items per liter. Microplastics have also been reported to be present in lakes, rivers and dams globally [3, 15, 37], even found in remote areas although in small numbers [8, 40]. Thus, it can be said that water treatment plants must face the presence of new polluting agents in at least some of the areas that have been observed [23]. Large plastic fragmentation or used plastic goods are the most common sources of microplastics, although until now the level of

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*Email Address: wrsitamahapati@gmail.com fragmentation in natural conditions is still unknown [12,19]. Despite the fact that the impact of microplastic on human health is unknown, efforts should be taken to prevent the spread of microplastic so that human drinking water can be free of contamination. Based on the description, it can provide a little picture of how critical the condition of our water treatment plant is today. Identification of microplastics in drinking water treatment plants in Bandung City which will provide an overview of microplastic removal capability in conventional water treatment plants in a city in Indonesia.

2. METHODOLOGY

The field research was conducted in the Water Treatment Plant A and B, Bandung City. Laboratory scale research was carried out at the Water Quality Laboratory and Pharmaceutical Laboratories. The samples used in this study were water in the pre-sedimentation, coagulation-flocculation unit, sedimentation, filtration and reservoir. On a laboratory scale which was adjusted to the stages of processing in the drinking water treatment plant, using microplastic artificial. The microplastic samples made from clothing fibers, plastic food containers, flute boards and bath sponges that mashed using a blender. Water samples that have been collected are then filtered with GF/C Whatman paper using a vacuum filter. The filter paper is transferred in a petri dish and dried using an oven at 105^{o} C in 30 minutes to remove the moisture content in the filter paper [2]. The number and size of microplastics identified by using a light binocular microscope with a lens magnification of 10x (total magnification of 100x). OPTIKA series B-383FL is the microscope used in this research. Identification of microplastics based on the SCS (Size and Color Sorting System) technique based on technical guidelines of Crawford and Quinn,2017 [6].

3. RESULT AND DISCUSSION

A. *Lab Scale Simulation Results*

This simulation uses artificial microplastic (Figure 1). The artificial microplastic samples came from several types of plastic, including LDPE, HDPE and Polypropylene. The densities of LDPE and HDPE are around <1 g/mL, while polystyrene, nylon 6, PVC, and PET have densities > 1 g/mL, where the plastics commonly used are at density range 0.85 to 1.41 g/mL. Its range includes materials ranging from lower to higher density than water, microplastics can be distributed through the water column which will affect the transport or dispersal of microplastics in water areas up to the end of the sea [20].

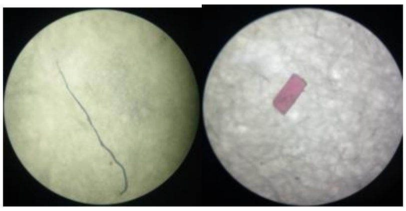
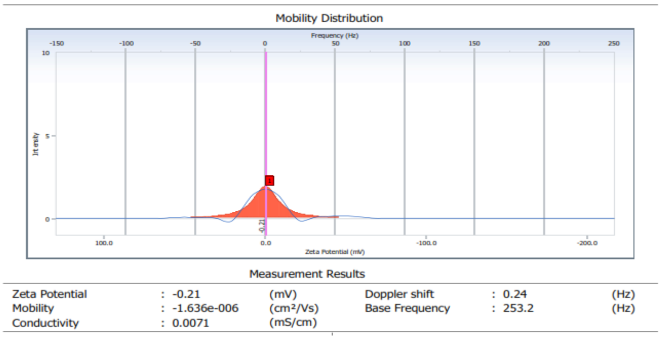


Figure. 1. Artificial Samples (a) Fiber (b) fragment

In the Laboratory scale, two different treatments were carried out on the artificial samples used, namely with the addition of bentonite and without bentonite. The purpose of adding bentonite is to represent TSS in raw water originating from rivers. Next, a t-test was conducted to determine the significance of the difference between the two treatments. This statistical test was carried out using the R application by comparing the test results with the values in the t table or based on the p value. Ho in this test, that is, there is no difference in the average value of the removal of the two types of microplastics either with the addition of bentonite or without bentonite.

The first stage of microplastic removal is pre-sedimentation. Pre-sedimentation unit is a unit where the process of deposition of discrete particles occurs. Discrete particles are particles that do not change in shape, size, or weight when they settle [10]. This pre-sedimentation is included in type I, Metcalf and Eddy, 1941 [18] explained that this type I sedimentation settles individually without any interaction between particles. However, there are differences between ordinary discrete particles and microplastic particles. Several things that affect the deposition of microplastics are specific density, surface area, shape and mass. Although microplastics have the same mass, different shapes will cause differences in surface area and deposition time. Based on the observations, it is known that the percentage of removal of microplastics with added bentonite (29.22%) is higher than without bentonite (23.95%). The results of the t-test in this experiment showed that the p-value was 0.08921 (p-value > 0.05). This means that there is no difference between the average removal of microplastics with bentonite and without bentonite.

The next stage is Coagulation – Flocculation. The supernatant of the pre-sedimentation process was then used to this process. The microplastics that were still present in the supernatant were then added as coagulant in the form of 1% alum as much as 30 ppm. Plastics and several other types of materials such as cloth and glass are the types of objects that do not easily release electrons. Objects of this type are called insulators. The addition of coagulant (alum) in this study had no effect on microplastics. During the flocculation process, microplastics do not stick together so that microplastic flocs are not formed. The formation of floc only occurs in bentonite because it has a negative charge [7]. This can be influenced by the ionic charge (zeta potential) of the microplastic and bentonite which are both negative. The higher the zeta potential value, the higher repulsion between particles so that the particles are dispersed and become very stable in water. In testing the zeta potential value carried out on artificial microplastic samples, a value of -0.21 mV was obtained (can be seen in Figure 2). This is because the artificial microplastic sample is not well dispersed in the solvent due to the density of the microplastic sample is smaller than the density of the solution which causes the particles to float on the surface so that the test instrument cannot read the zeta potential value of the sample perfectly. While the potential zeta value of bentonite in aquadest solution also shows a negative value in the pH range of 4 to 10 [22]. According to Na et al, 2021 [21] the zeta potentials of MPs before coagulation were negative under all examined pH conditions, and after the addition of $AlCl_3$, they became − 11.6(±3.2), 1.9 (±4.1), and − 7.5(±1.7) mV at pH 4.3, 6.0, and 8.5. The final zeta potential of MPs at pH 6.0 was closer to zero than those at pH 4.3 and 8.5, indicating that slightly acidic conditions maximize the aggregation of MPs.



Measurement Results

Zeta Potential	: -0.21	(mV)	Doppler shift	: 0.24	(Hz)
Mobility	: -1.636e-006	(cm²/Vs)	Base Frequency	: 253.2	(Hz)
Conductivity	: 0.0071	(mS/cm)			

Figure 2. Zeta Potential Test Results

The supernatant resulting from coagulation – flocculation was then allowed to stand as a continuation for the sedimentation process so that the formed flocs could settle. The deposition process was carried out for one hour. In the sedimentation process, the removal of microplastics with the addition of bentonite was 46.40%. While without bentonite is 47.91%. The results of the t-test showed that there was no difference between the average removal of microplastics with bentonite and without bentonite, based on the p-value = 0.7156 (p-value > 0.0). The last stage in this simulation is sedimentation. Referring to the water treatment process in general, the next step that must be done is filtration. Based on research by Na et al, 2021 [19], sand filtration could completely remove MPs > 20 μm, whereas a small portion of the MPs ≤ 20 μm passed through the sand media, suggesting the need for introducing processes, specifically targeted at MPs < 20 μm in the conventional water treatment systems.

B. *Direct Sampling Results*

The drinking water supply system of the city of Bandung serves the provision of clean water as the most basic need for the community which is of course demanded to have a high ability to meet customer needs both in terms of quantity and quality. The source of raw water came from 1) Cisangkuy River, the discharge taken was ± 1400 l / sec, processed at the A Treatment Plant from the plan of ± 1800 l / sec, 2) Cikapundung River, the flow rate taken is ± 840 l / sec, 200 l / sec processed at the A Processing Plant, 600 l / s processed at the B Processing Plant and 40 l / s processed at the B Mini Plant. Today, the current problem is that surface water has also become the source of the discovery of microplastic particles, which is a new problem that must be faced. Therefore, this study also conducted sampling on the drinking water supply system of the city of Bandung to determine the microplastic generation in each operating unit before being distributed to residents' homes. Figure 3 shows the results of the identification of microplastics from Water Treatment Plants (WTP) A and B in Bandung City. Referring to the identification results using a binocular microscope, the most commonly found particles are fibers, which are mostly sourced from human activities, such as washing processes of synthetic clothes. Pahl and Wyles, 2017 [25] state, "people contribute to the problem, they can help address it, and they may experience negative impacts of microplastics in the environment." In the first part of this chapter, in the sections dealing with "occurrence," we've outlined ways in which humans are associated with the presence of microplastics in the environment. Wright and Kelly, 2017 review and discuss the potential risks of microplastics to human health. Avenues for risk include direct interaction between microplastics and human tissues. If ingested, microplastics could have similar effects in tissues (e.g., stress responses and immune responses) as seen for other animals [43].

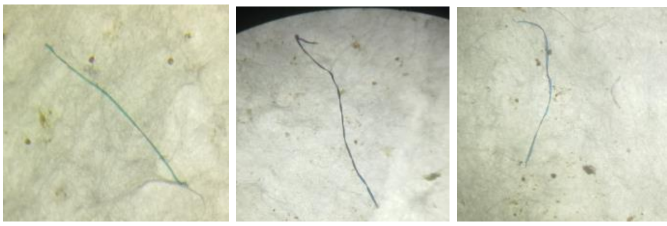


Figure 3. Types of MPs in Water Treatment Plant A and B

In other side, Abuwatfa, 2021 [25] state that it is also important to note that microplastics have been detected in drinking water. Studies on the removal of microplastics from drinking water are scarce and thus more research is required for efficient removal implementation in industry. A review of the different sources of potable water and the feed water to the municipal DWTP showed that the danger of MP of our drinking water is real [11]. Basically, evidences abound on the occurrence of MP in the raw and treated drinking water at varying magnitude. The magnitude of MP contamination is far higher in surface water than in the GW system. The source of the feedwater to the municipal DWTP greatly affects the magnitude of MP contamination in the drinking water produced. The surface water fed DWTP produced drinking water with undesirable MP concentration, while very low MP contamination was observed in the GW-fed DWTP [24]. Overall, although there are only limited data available on the efficacy of microplastic removal during drinking-water treatment, such treatment has proven effective in removing far more particles of smaller size and at far higher concentrations than those of microplastics.

Conventional treatment, when optimized to produce treated water of low turbidity, can remove particles smaller than a micrometer through processes of coagulation, flocculation, sedimentation/flotation, and filtration [27]. Further research is needed in tracking the MPs fluxes of MPs in the various processes within drinking water production i.e., those procedures aimed at routinely removing biofilm from sand filtration beads or flocculator reactors as formed biofilms are likely to act as major trap of floating MPs in the processed raw water [41]. The percentage of microplastic generation by type, color and particle size can be seen in Figures 4,5, and 6 below.

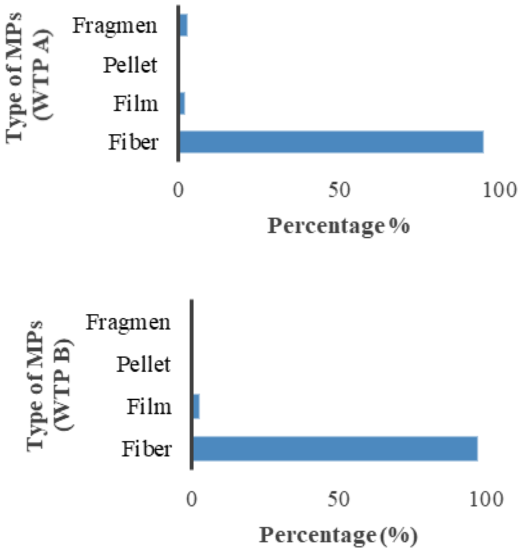


Figure 4. Percentage of MPs by type on WTP A and WTP B

Based on Figure 4, WTP A shows that the most common types of microplastics found during identification were fiber (95.33%), while fragments and films were 2.8% and 1.87%, respectively. For pellet type microplastics were not found at all in WTP A. Fiber type microplastics are usually sourced from clothing fibers that come out during the process of washing clothes and then enter water bodies. In WTP B, there were no fragments and pellets of microplastics, 2.5% of film microplastics and 97.5% of fiber were found. Based on Kosuth et al., 2018 [14] suggested the potential background contamination of fibers may also arise from water purification systems itself. One study found that the fragmentation rate and size of fragments produced by ultraviolet exposure and subsequent mechanical abrasion differed among PE, PP, and expanded PS [31]. Microscopical observations revealed the two types of microplastics in drinking water obtained at 42 free public fountains: fibers and fragments. Fibers (long, thin line with a slender shape particles) were common in the sampling stations, whereas fragments (a piece of plastic from a larger plastic item) were found very few in number. The shape of the plastic fragments identified by microscope observation is generally influenced by the fragmentation process and the residence time in the environment. The sharp end of the fragment can be considered as a fragment that has recently undergone a split from a larger piece of plastic, while the fine end of the fragment is generally considered an old fragment that has undergone a continuous process of friction by other particles or sediments. According to UNEP, 2016 [34] the form of films usually comes from plastic bags and packaging so that they are shaped like sheets. When compared with other types of microplastics, film has the lowest density [13]. The low film density makes it easy for the film to move from one location to another when carried by water currents. Meanwhile, fiber type microplastic is a type of microplastic that looks more like yarn. In a water treatment plant, the Czech Republic also found microplastics of fiber and fragments [26]. Browne et al., 2011 [4] in his research explained that the shape in microplastics is composed of irregular fibers to long and round fibers. Plastic pellets have a tablet-like appearance. Many studies reporting high abundances of fibers have watersheds that are urbanized, experience agriculture, and/or have large populations [36]. In addition, there can be encountered pellets with square, cylindrical, spherical, and disc shapes.

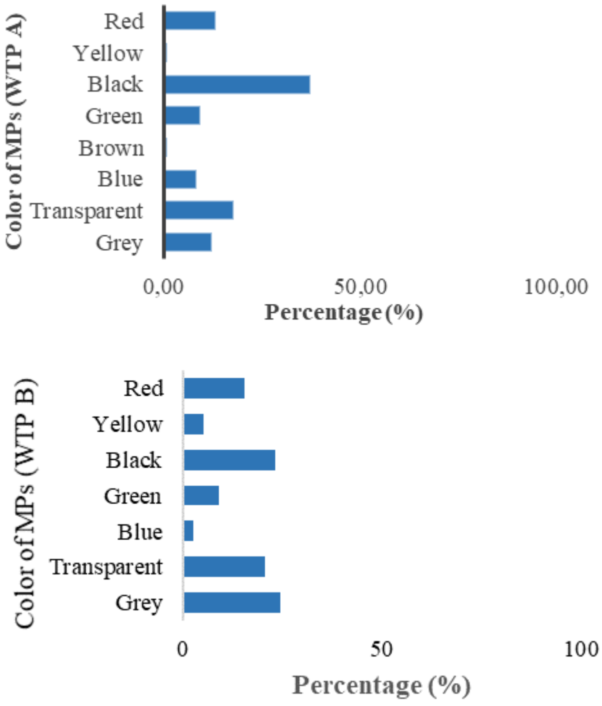


Figure 5. Percentage of microplastics by color on (a) WTP A (b) WTP B

Figure 5 shows the percentage of microplastics based on color in WTP A and WTP B. In WTP A, the most dominant color of microplastics is black, which is 37%, then clear is 17.7%, red is 13.1%, gray is 12.1%, green is 9.3%, blue 8.4%, brown and yellow 0.9%. In WTP B found the most dominant color is gray 24.4%, black 23.1%, transparent 20.5%. Other colors identified were 15.4% red, 8.9% green, 5.1% yellow, and 2.6% blue.

Based on other studies, it was found that transparent fibers (69%) were the most predominant in the collected microplastics followed by blue (24%) and red colored (7%) fibers [30]. Crawford, 2017 [6] states that the color of microplastics can provide an indication of the extent to which particles are contaminated with chemical pollutants, where many colored particles might decolorize during or after entering water bodies as a consequence of either degradation or bleaching [33]. Furthermore, the toxicity of additive chemicals in different types of plastic debris (and their leachates) differed among plastic products and polymer types [28]. The researchers found the highest levels of pollutants in the yellow and black microplastics. In addition, the color of plastic has a significant effect on marine life. The color of the microplastic particles which tend to be the same as the natural food sources of marine life being a major factor in misidentification by aquatic organisms and thus affecting the possibility of ingestion of this plastic material is still a matter of debate. However, given the fact that many aquatic species are visual predators, this would seem intuitive.

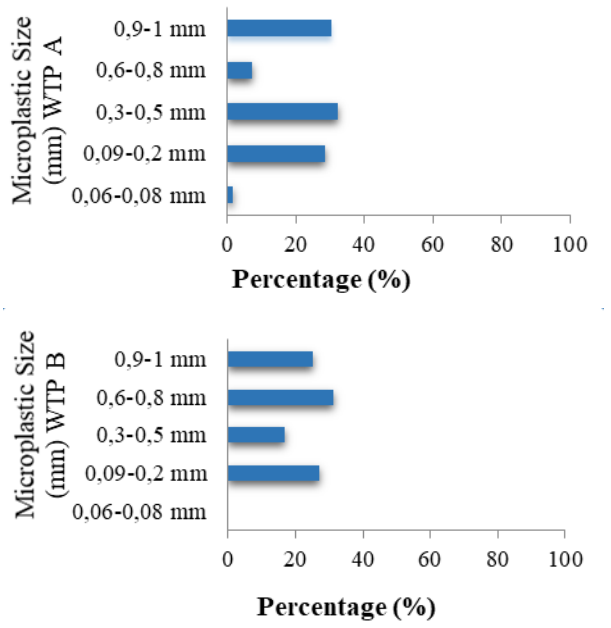


Figure 6. Percentage of microplastics by size on (a) WTP A (b) WTP B

Microplastics are distributed in the water column depending on their properties, one of which is size. Percentage of microplastics by size on WTP A and B can be seen in Figure 6. In WTP A found 30.4% microplastic measuring 0.9 -1 mm, 32.1% measuring 0.3-0.5 mm, 28.6% measuring 0.09-0.2 mm, 7.1% measuring 0.6-0.8 mm, 1.8% measuring 0.06-0.08 mm. In WTP B, 31.3% of microplastics were found with a size of 0.6-0.8 mm, 27.1% measuring 0.09-0.2 mm, 25% measuring 0.9-1 mm, 16.7% measuring 0.6-0.8 mm. Microplastics measuring 0.06-0.08 mm were not found in WTP B. The percentage of microplastics based on color, size, and type is the total microplastic found in all processing units, namely pre-sedimentation, coagulation-flocculation, sedimentation, filtration and reservoir. Referring to each treatment unit in WTP A, it was found that 35 MPs/L in the pre-sedimentation unit, 17 MPs/L in the coagulation flocculation unit, 19 MPs/L in the sedimentation and filtration unit, and 12 MPs/L in the reservoir. In WTP B, found 24 MPs/L in the pre-sedimentation unit, 18 MPs/L in the coagulation flocculation unit, 14 MPs/L in the sedimentation unit and 9 MPs/L in the reservoir. If viewed in general terms, basically there is no significant reduction in the generation of microplastics even though they have gone through various processing stages. More specific observations are needed to find out more about what factors cause the lack of ability of each drinking water treatment unit to remove microplastics. Referring to various studies, it can be an illustration of the characteristics of microplastics that affect the dispersion or distribution model on the ability of the processing unit to remove these particles, and can be used as material for comparison with this study.

Basically, the quantity and quality of recovered microplastics is highly dependent on the sampling location and depth [27]. The vertical distribution of microplastics from surface water to bottom water was expected to be governed by complex interactions among density, size, shape, and attached biofilm mass of microplastics and the intensity of waves, and turbulence [29]. The spreading speed and range of river plumes near river mouths can influence short-term spatial distribution of microplastics and movement of flotsam patches. In addition, the location of sewage treatment plants can also affect the spatial distribution because sewage outfall is a source of microplastics [9]. Based on research conducted by Crawford, 2017 [6] explains that the density of microplastics is a key factor that will affect its spatial distribution in the aquatic environment. Thus, it is possible that microplastics with densities much greater than seawater could be found in surface waters, albeit in small quantities. There are two main reasons why this could happen. First, the presence of microplastics with high density on the water surface can be caused by strong up and down movement of water, as a result of temperature differences at different depths (vertical mixing), this can also be caused by microplastics with higher density. larger than seawater may contain air pockets or bubbles in it, increasing its buoyancy and allowing it to float to the surface. Interestingly, although polyvinyl chloride (PVC) and polyamide (nylon) had high density (1.15-1.70 g / cm3) and (1.12-1.38 g / cm3) at several locations were found to be floating on the surface. This suggests that wind and tidal currents are likely contributing factors. Once microplastics enter the aquatic environment, their behavior tends to fall into three categories: a) Physical behavior, such as accumulation, sedimentation and migration, b) Chemical behavior, such as adsorption and absorption of pollutants, 3) Biological behavior, such as ingestion by biota, translocation and trophic transfer. Wang et al., 2020 [39] have investigated a water treatment plant (CSF and ozonation combined with GAC filtration) and have reported a similar concentration and removal rate of MPs. However, Zhang et al., 2020 [44] used a filter that consisted of cheesecloth and anthracite, which is not widely used in water treatment compared with a sand filter composed of quartz sand. Moreover, it has been reported that industrially produced MPs are mechanically/photochemically weathered after being emitted to the environment [32]. Given that one of the possible sources of MP ingestion is drinking water, we need to investigate if drinking water treatment plants can reduce the level of MPs in the water when operated efficiently. The MPs might be treated while passing through a series of drinking water treatment processes that are typically composed of coagulation/sedimentation, filtration, and disinfection. At present, few existing studies on MP removal in water treatment plants focus on the coagulation and filtration processes [17, 26, 45]. The studies by Vinge et al, 2021 [35] showed that a significant proportion of MPs were removed by coagulation and filtration, and the removal efficiency depended on the coagulant type, background solution chemistry, MP properties, and filtration method.

4. CONCLUSIONS

The identification results of microplastic abundance in the Water Treatment Plants A and B, respectively, the average abundance of microplastics is 18.7 ± 0.5 MP / L and 15.7 ± 3.1 MP / L. The types of microplastics that were mostly found were fiber, film and fragments were found in small amounts, while pellets were not found in both locations. So it can be concluded that further research is needed to optimize the performance of conventional water treatment units in removing microplastics and the mechanisms that can be applied to prevent the spread of microplastics into water bodies. Based on the simulation of the removal of microplastics on a laboratory scale, it shows that the water treatment step can remove microplastics but not significantly, in this case there are still microplastic residues found after the processing.

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