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CHARACTERIZATION OF MICROPLASTICS AT GREY WATER WASTEWATER TREATMENT PLANT IN SOUTH JAKARTA CITY

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Domestic Wastewater, Microplastics, WWTP, Efficiency removal

Abstract
Microplastics (MPs) are <5 mm synthetic polymer particles that are emerging contaminants and have been found widely in various water bodies. Wastewater treatment plants (WWTPs) play an important role in containing the release of MPs into the environment, but studies on the effectiveness of greywater-based WWTP, especially in dense urban areas such as Jakarta, are still limited. This research was conducted on a greywater WWTP with Moving Bed Biofilm Reactor (MBBR) technology in South Jakarta to analyze the abundance, efficiency of dispensation, and characteristics of microplastics based on shape, color, size, and material. Samples were taken from five points on weekdays and holidays, analyzed using NOAA methods and FTIR spectroscopy. The abundance of MPs at the inlet reached 942 particles/L (weekdays) and 675 particles/L (holidays), while at the outlet there were 290 particles/L and 211 particles/L, resulting in a dispensing efficiency of 69%. Five types of MPs (foam, fragment, fiber, film, microbead) were found with color variations (white-transparent, yellow, red, blue, green, black), as well as the content of PVFM, PVB, PVA, silicone, and POM polymers. This study contributes to the understanding of the distribution and character of MPs in greywater treatment systems that are still rarely explored, as well as supporting the development of mitigation strategies based on WWTP technology.

INTRODUCTION

Microplastics are small plastic particles that have a very small size, which is less than 5 mm in size (Lusher & Hollman, 2017). Microplastics are categorized into two types, namely primary microplastics and secondary microplastics. Primary microplastics are microplastics derived from microparticles such as raw materials, industrial plastics and *Microbread* at *Scrub* cosmetics. Meanwhile, secondary microplastics are the result of the degradation of plastic waste that is not handled properly and is disposed of directly into the environment, then fragmented into small particles (Faujiah & Wahyuni, 2022). Microplastics have several commonly found forms such as fibers, film fragments, fibers, pellets, sheets, and *Foam* (Faujiah & Wahyuni, 2022). The types of microplastic polymers that are in the general environment are *Polystyrene (PS), Polypropylene (PP), Polyethylene (PE), Polyethylene-Terefthalat (PET), Polyvinyl Chloride (PVC), Nylon, Arcylonitrile Butadiene Styrene (ABS), Polymethyl Methacrylate (PMMA),* and *Polycarbonate (PC)* (Faujiah & Wahyuni, 2022).

Microplastics are widely found in the environment, especially in water bodies. Microplastics found in the waters usually come from the disposal of plastic bags, rice wrappers or *Styrofoam* ready-to-eat food packaging, or plastic beverage bottles that have undergone a process of decomposition by the environment, including sunlight (Rahmawati, 2023). The presence of microplastics in the aquatic environment can be a serious threat to the environment. Microplastics in the environment can be ingested by microorganisms such as bacteria, plankton, and amoeba which are then eaten by fish or other aquatic animals, causing hoarding in fish. When fish that have accumulated microplastics are eaten by humans, it can cause a variety of long-term health problems (Vivekanand, Mohapatra, & Tyagi, 2021).

Problems that can arise due to the accumulation of microplastics in the human body are the presence of deposits in the respiratory tract, digestion, or absorption through the skin. Microplastic deposits in the body are foreign deposits that cannot be digested or absorbed by the body so that they can cause irritation. If left for too long, it can cause inflammation that can cause tumors or cancer (Rahmawati, 2023). In addition, microplastics can also cause allergic reactions, triggering nervous system disorders, hearing, decreased immune function, reproductive system disorders, damage to body cells, or metabolic and hormonal disorders in the body (Fadli, 2022).

Wastewater Treatment Plants (WWTPs) play an important role in breaking the chain of microplastic pollution (MPs) from wastewater before it is discharged into the environment. The effectiveness of WWTP in setting aside MPs is crucial to prevent water bodies from becoming the end point of contaminant accumulation. Previous research has shown that the microplastic content in WWTP can reach 2×10^6 particles per day, with the most common types of polymers being polyester, polyethylene (PE), polyethylene terephthalate (PET), and polyamide (nylon) (Nurhasmi et al., 2021). In domestic wastewater management systems, black water wastewater sewers *are* generally closed, while *greywater is* often drained through open channels that are susceptible to contamination by MPs from the surrounding environment, such as road surfaces and surrounding environments. Therefore, WWTP that treats *greywater* has a strategic role in preventing the release of microplastics into water bodies and needs to be a focus in sustainable urban waste management.

In the WWTP the object of study, wastewater treatment technology is used in the form of bar screens, inlet ponds, equalization tanks, biological treatment with MBBR *(Moving Bed Biofilm Reactor),* and chlorination ponds. MBBR biological processing is a secondary processing technology or biological processing by utilizing biofilms with a system of microorganisms that are inherent and multiply in the media (Anisa & Herumurti, 2017). In the previous study on the Setiabudi WWTP with the same secondary processing, namely MBBR, the amount of microplastic content at the *inlet* could reach 4275 particles/day and at the *outlet* was 352.5 particles/day. The majority of the types of microplastics found are *fibers* with a size of 1001-5000 µm. Meanwhile, the color of the most common microplastic particles found is transnational color (Setiadewi, et al., 2023). Thus, the existence of Wastewater Treatment Plants (WWTP) plays an important role in controlling the release of microplastics into the environment.

Studies on the characteristics of microplastics in domestic wastewater have been widely conducted in various countries. In Indonesia, several studies have been carried out including Microplastic Abundance in Domestic Wastewater and its Disposal at the

Bojongsoang WWTP in Bandung City (Setiadewi, et al., 2024), Detection of Microplastic Pollution in Leachate Water at the Piyungan Landfill in Yogyakarta Indonesia (Utami & Agustina, 2024) and Microplastic Abundance Analysis in the Liquid Waste Outlet of the Brantas River Runoff Industry in Mojokerto, Jombang and Pasuruan (Larasati, 2024). Thus, along with the study of microplastics in domestic wastewater, the purpose of writing this study is to determine the abundance of microplastics, particle characteristics, and microplastic reduction efficiency in the units in the WWTP The object of the study is by *sampling* method at five sample points, namely *inlet,* equalization tank, biological treatment tank, sedimentation tank, and chlorination tank (outlet).

METHOD

A. Research Location

Wastewater sampling was carried out at the study object WWTP located in Cipedak Village, Jagakarsa District, South Jakarta City, Indonesia with coordinates 6° LS, 106° E, elevation 60 m. The following is the wastewater treatment flow at the study object WWTP.

B. Water sampling

The tools and materials needed include a 1 L glass bottle, a glass funnel, a coolbox, a cooling gel, a refrigerator, a 5 mm mesh, an analytical scale, an erlenmeyer flask, a pipette, a bulb, a magnetic stirr, a vacuum tool, a centrifuge device, a test tube, a petri dish, a 1 L beaker, an optical microscope, a pH meter, an optilab microscope camera, Fourier-transform infrared spectroscopy (FT-IR), a mercury thermometer, aluminum foil, label paper, wastewater sample, 30% H2O2%, 10% NaCl%, tissues, filter paper, and gloves. The water sampling procedure is carried out using references from SNI 6989.59:2008 regarding Wastewater Sampling Methods.

C. Sample analysis

The calculation of the abundance of microplastics by observing samples on filter paper that has been divided into four quadrants of equal size using a binocular microscope that has been modified into a digital microscope by adding a digital camera. Its objective lens is set in such a way that it becomes a quadruple magnification and also its focus is on the eyepiece. Microplastic calculations were carried out after taking pictures of each filter paper reading captured by the digital camera screen. The abundance of microplastics is calculated using a formula from NOAA, which is a reading of the number of particles present divided by the amount of filtered water as a water sample.

Large measurements of microplastics use the imageJ application, which is widely used software to visualize, examine, measure, and validate scientific image data (Schroeder et al., 2021) and photos that have been captured by digital camera screens and calibrated with millimeter eyepieces.

Each microplastic has a different constituent material. Through the FTIR test, the polymers that make up microplastics can be known. FTIR testing produces graphs in the form of infrared spectrum and checks the compatibility of the data with the list of materials in the database. The higher the score value in the FTIR results, the more accurate the sample material with the recorded sample material.

RESULTS AND DISCUSSION

The following are the results of the calculation of microplastic abundance at 5 points, namely inlets, equalization ponds, MBBR ponds, sedimentation ponds, and outlet (chlorination) ponds on weekdays and holidays.

Table 1. Total Microplastics on Working Days and Holidays at WWTP Study Object

Yes	Processing Unit	Total Microplastics (Particle/L)	
		Workday	**Holiday**
1	Inlet	942	675
2	Equalization	718	488
3	MBBR	474	353
4	Sedimentation	417	320
5	Outlet	290	211

Based on Table 1, the most samples are found on weekdays with the number of microplastics entering is 942 Particles/L. While on holidays it is only 675 Particles/L. At the time of sampling, there is rain on holidays with moderate intensity which has rainfall between 100 mm to 300 mm (BMKG of the Republic of Indonesia, 2024). Thus, the debit on holidays is greater than on weekdays. Due to the inlet channel which is an open channel, the concentration of microplastic inlets is diluted because it is mixed with rainwater. When rain occurs, the volume of water will increase so that microplastics seem to be swept away and moved to another place (Wulandari, et al., 2022). Thus, the amount of microplastics entering the holiday inlet channel is less compared to weekdays.

The following is the efficiency of microplastic particle removal on weekdays and holidays.

Table 2. Efficiency of Microplastic Disposal on Weekdays and Holidays

Yes	Processing Unit	Efficiency of Dispensing (%)	
		Workday	**Holiday**
1	Inlet	-	-
2	Equalization	24	28
3	MBBR	34	38
4	Sedimentation	12	9
5	Outlet	30	34
	Total	69	69

Based on Table 2, it can be seen that the total efficiency of Weekdays and Holidays is both at 69%. This efficiency value has exceeded the success of microplastic reduction in other conventional WWTP such as in tests in Meuraxa District, Banda Aceh City, which is only at 50-65% (Liza, 2023). However, in the use of MBBR technology, the value of microplastic disposal efficiency in the study object WWTP tends to be lower than the Setiabudi WWTP which has a microplastic removal efficiency of 91% (Setiadewi, et al., 2023).

Based on Table 2, it can be seen that the abundance of microplastics in each unit is always decreasing. However, the microplastic allowance between the MBBR 1 pond and the sedimentation pond is not very significant. This may occur due to additional microplastic release from biofilm media in MBBR ponds due to friction on the walls or degradation due to sunlight (Multi Umwelttechnologie AG, 2023).

The following is the amount of microplastics in wastewater based on its shape on weekdays and holidays.

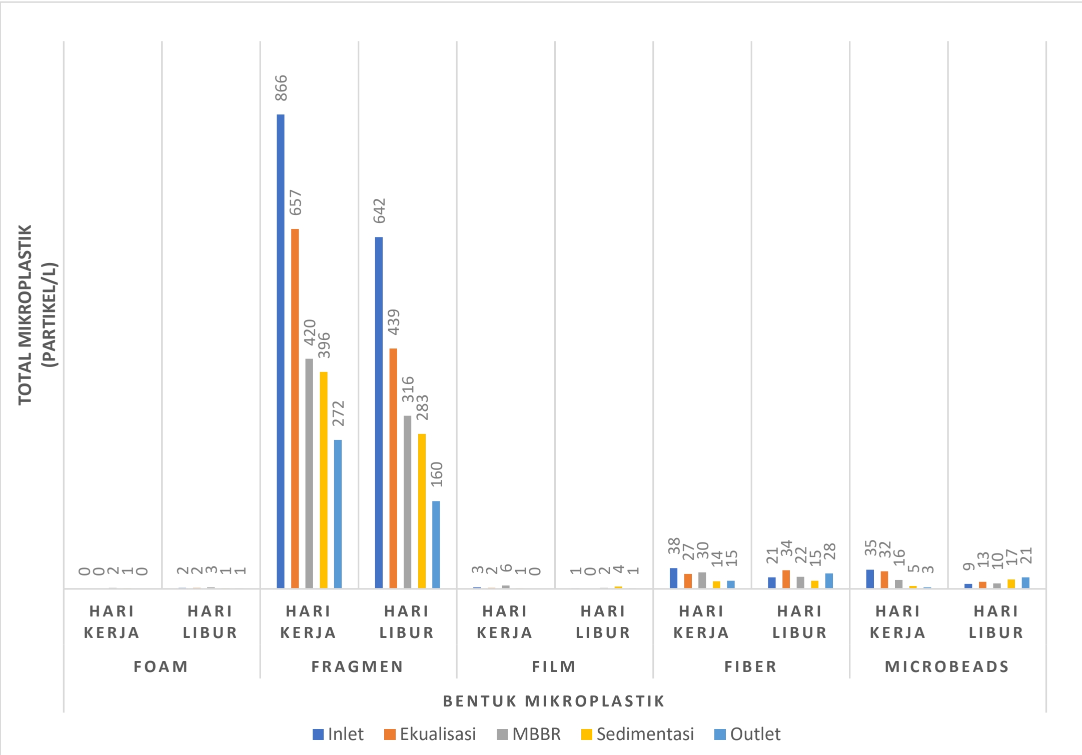

Figure 2. Abundance of Microplastics Based on Shape in Wastewater Samples on Weekdays & Holidays

Figure 2 shows the total abundance of microplastics based on the distribution of their shapes. The most common form found on both days was fragments. Based on previous research on WWTP in Lithuania, fragment-type microplastics are the most common type of microplastics found in WWTP (Uoginte, et al., 2022). However, this is different from WWTP with Moving Bed Biofilm Reactor (MBBR) technology at the WWTP in Setiabudi, which has the most abundance of fiber types (Setiadewi, et al., 2023). This high number of fragments is caused by the type of inlet channel, which is an open channel, so that a lot of plastic waste can enter the channel. Plastic waste that enters the channel can be degraded by sunlight to form other smaller plastics (Sulastri, et al., 2023).

The following is the amount of microplastics abundance based on color in the wastewater.

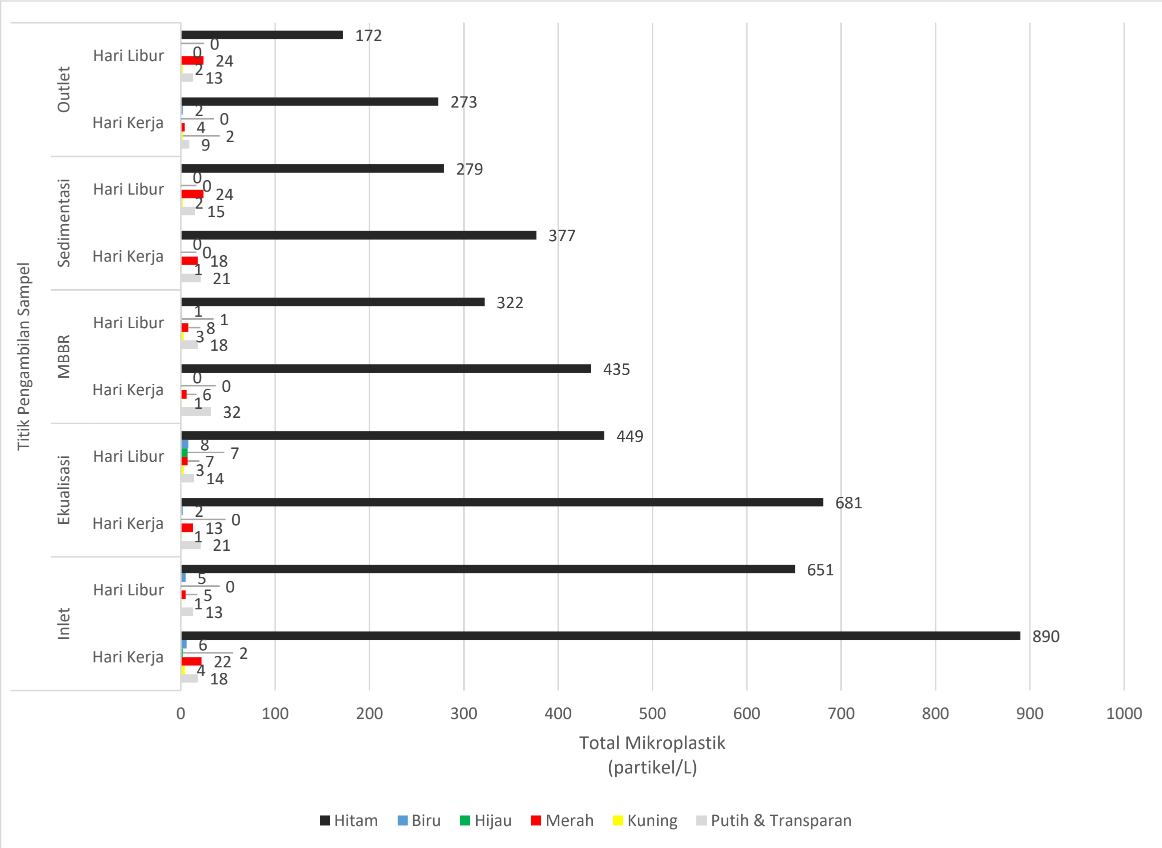

Figure 3. Color-Based Microplastic Abundance in Wastewater on Weekdays & Holidays

Based on Figure 3, the most common color found on weekdays and holidays, both in wastewater is black. Black products can contribute 15% of plastic to domestic wastewater. This plastic can come from single-use packaging, vehicle tires, and trays for food (Turner, 2018). In addition, the color black can also indicate a large number of other organic particles that are absorbed into microplastics. The absorption ability of black color to organic particles or other pollutants can affect the surface texture possessed by microplastics (GESAMP, 2015).

The following is a range of microplastic sizes in wastewater based on the shape per sample point.

Table 3. Microplastic Size in Wastewater Samples

No.	Microplastic Shape	Sample Point	Wastewater Sample Size Range (mm)	
			Workday	Holiday
1.	Foam	Inlet	1,299 – 0,842	0,332 - 0,276
		Equalization	1,398 - 0,304	0,784 - 0,036
		MBBR	0,915 - 0,519	0,61 - 0,169
		Sedimentation	1,658	0,869
		Outlet	-	0,338
2.	Excerpt	Inlet	1,194 - 0,033	1,020 - 0,030
		Equalization	0,267 - 0,052	0,772 - 0,031
		MBBR	0,957 - 0,025	0,763 - 0,039
		Sedimentation	0,932 - 0,029	0,528 - 0,034
		Outlet	0,137 - 0,028	0,192 - 0,034

3.	Movie	Inlet	-	0,675
		Equalization	-	-
		MBBR	0,677 - 0,355	0,551 - 0,530
		Sedimentation	0,970	2,522 - 0,557
		Outlet	-	1,482
4.	Fiber	Inlet	5,366 - 0,073	5,916 - 0,351
		Equalization	5,160 - 0,148	5,327 - 0,141
		MBBR	6,996 - 0,147	5,209 - 0,336
		Sedimentation	5,433 - 0,071	6,528 - 0,081
		Outlet	5,128 - 0,173	4,418 - 0,056
5.	Microbead	Inlet	0,058 - 0,023	0,138 - 0,028
		Equalization	0,065 - 0,020	0,128 - 0,030
		MBBR	0,075 - 0,018	0,134 - 0,034
		Sedimentation	0,045 - 0,026	0,079 - 0,024
		Outlet	0,049 - 0,031	0,042 - 0,021

Based on Table 3, the types of microplastics that have the largest size are fibers. The difference in size in microplastics can occur due to the degradation process at the source. The longer the degradation time, the smaller the microplastics produced will be (Sutanhaji, et al., 2021). In the outlet part of the WWTP Object of study, it can be seen that the size of the microplastics carried is getting smaller compared to the inlet part. So it can be concluded that the size of microplastics is the determinant of the process of disposal in wastewater.

The following are the results of the identification of microplastic polymers using Fourier Transform Infrared Spectroscopy (FTIR) at the inlets and outlets on holidays and workdays.

Table 4. Polymer Identification of Microplastic Materials by FTIR Test

Yes	Score	Library	Name	Description
1	634, 637, 646	166 –ATR – Polymer2	D_PVFM	Formal Polyvinyl (PVFM) is a material used for plastic mixtures and reinforcing resins that have the characteristics of being easily brittle (Fitzhugh, et al., 2020).
2	594, 619	163 –ATR – Polymer2	D_PVB	Polyvinyl Butyral (PVB) is a resin widely used in coating applications that require strong bonding, optical clarity, and strong adhesion to many surfaces (Henan Jinhe Industry CO., LTD., 2024).
3	591, 617	175 –ATR – Polymer2	D_Vinyl_Alcohol _Vinyl_Butyral	Vinyl Alcohol (PVA) is a polymer used in industry as raw materials for adhesives, stabilizers, paper, and mixtures in the textile, pesticide,

				cosmetic, and fertilizer industries (El Discha, 2014)
4	601, 605, 608	66 – IRs Polymer2	Silicon	Silicone *rubber* is a polymer resin used as a component of automotive products that have elastic properties (Sujana & Widi, 2013)
5	587	58 –ATR – Polymer2	D_POM3	Polyacetal (POM) or *polyoxymethylene* is a thermoplastic polymer that is widely used in the industrial molding industry, medical applications, and mechanical equipment industries (Kaifeng Bell Stainless Steel Ball Manufactur Co., LTD, 2023)

CONCLUSION

The microplastic abundance in weekday water samples at various points in the wastewater treatment plant (WWTP), including inlets, equalization ponds, MBBR ponds, sedimentation ponds, and outlet ponds, were 942, 718, 474, 417, and 290 particles/L, respectively. All types of microplastics, such as foam, film, fragments, fibers, and microbeads, were categorized into six colors: white-transparent, yellow, red, green, blue, and black, and were present in all wastewater samples. Fragment particles were the most abundant across all parts of the WWTP, with the highest concentration of 866 particles/L at the inlet on weekdays and 642 particles/L on holidays. The predominant color was black, with the highest concentration of 890 particles/L at the inlet on weekdays and 651 particles/L on holidays. The microplastic with the largest size was fiber, measuring 6.996 mm in the MBBR pool on weekdays, while the smallest was microbeads at 0.028 mm at the inlet on holidays. The polymers identified were PVFM, PVB, PVA, Silicon, and POM. The overall efficiency of microplastic disposal was 69% on both weekdays and holidays, with efficiencies in the equalization tank, MBBR pond, sedimentation tank, and outlet being 24%, 34%, 12%, and 30% on weekdays and 28%, 38%, 9%, and 34% on holidays, respectively.

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