

Evaluating Microplastics Removal Efficiency of Textile Industry Conventional Wastewater Treatment Plant of Thailand

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ABSTRACT

Global plastic pollution is a serious problem. From manufacture to disposal, microplastics appear at every point in the textile life cycle. Numerous case studies demonstrated that wastewater treatment facilities cannot remove the microplastics they produce. The purpose of this study was to evaluate the amount of microplastics that leaks into the canal and adjacent water bodies from a wastewater treatment facility serving the textile industry in Thailand, as well as to discover the differences between the samples taken upstream and downstream. NOAA protected laboratory investigation based findings indicated that 590–601 microplastics particles per cubic meter (particles/m³) flowed into the canal; however, the upstream sample (344–349) had more particles/m³ than the downstream sample (246–252). The industry leaked microplastics on average 172 particles/m³ upstream and 123 particles/m³ downstream. Our research revealed that the wastewater treatment plant's ability to capture microplastics particles was insufficient. A reliable mechanism to remove microplastics particles from wastewater treatment is required to protect environment, aquatic life, and water quality without interfering with industrial operations. This research emphasizes the Sustainable Development Goals, Responsible Production and Consumption (Goal 12), and Life below Water (Goal 14).

Keywords: microplastics, microfibers, polyester, wastewater treatment, efficiency.

INTRODUCTION

Textile industries are the major primary microplastics leakage pathways in rivers and oceans (Mitrano, Wohlleben, 2020). The synthetic textile industry involves many complex operations, and each stage releases microplastics. Synthetic fibers and clothes release a certain amount of microplastics and microfibers throughout their lifecycle. According to an estimate, more than half of the synthetic fibers produced in the textile industry are polyester (PEs) (Cai et al., 2020). It is used in the textile industry because polyester is a strong fiber and is very cheap. Nylon is the 2nd most used fiber in the textile industry after PE (EEA, 2019). Sustainable Development Goals (SDGs) Goal 14 focuses on life

below water. This research can help achieve SDG 14 (Life below Water) and SDG 12 (Responsible Production and Consumption) through collaboration between institutes and industries.

Plastic particles such as polyethylene (PE), polypropylene (PP), and expanded polystyrene (PS), including polyvinyl chloride (PVC), nylon, and polypropylene terephthalate (PET), sink into the sea. It is estimated that 94% of the plastic that enters the sea winds up on its floor and in the silt, which adds up to a normal amount of 70 kg of plastic per square kilometre of the ocean bed (Boucher, 2019). Plastic sinks because the thickness of the polymer is greater than that of water. However, because of the presence of microplastics, their thickness can be expanded by the adsorption of heavy metals, which have a high

affinity for natural polymers (Brennecke, 2016). Particularly in plastics used in hardware, electrical gear, vehicles, and development, it is normal to use brominated fire retardants as added substances, which are somewhat thick, weighty, and perilous. A few investigations have reported that microplastics particles can act as vectors for the vehicle of toxins, such as plasticizers and fire retardants, since these substances can be available as added substances (De Falco, 2020). Microplastics particles found in marine climates comprise (PP), (PE), and (PET) (EEA, 2019), which are also called polyesters. These plastics are often used in buyer products and bundling (Stanton et al., 2019). Nylon is likely to start with fishing nets, while (PS) can be a consequence of the enduring floats or Styrofoam bundling. Fiber-formed PET, nylon, acrylic, and PP probably result from the washing materials (De Falco, 2019).

This study focused on the assessment of microplastics leakage from wastewater treatment plants in the textile industry with upstream and downstream variations. Although there is no legal standard for the threshold limit of microplastics leakage from industry, we can conclude that the concentration of microplastics leaked from the industry is within or above the standard. This study will help to fill the existing knowledge gap on the topic and help policy makers analyze the severity of microplastics leakage issues in the industrial sector and set standards, policies, and threshold limits. This study helps achieve SDGs 12 and 14 with SDG 17 (Partnership for Goals).

METHODOLOGY

Study area

This study was conducted on the textile industry in Thailand. General information about the industry is presented in Table 1. The main

products from this industry are greige and dipped tires, cord fabric, rubber products, belts, tapes, webbing, and nets. The Textile industry was spread over 12 acres of land, approximately 60 km from Bangkok.

Methodology framework

Figure 1 shows methodological framework for research.

Net sampling protocol using Albatross

A well-recognized strategy for microplastics inspection from water is net tow sampling (Koelmans et al., 2019). This strategy captures microplastics from enormous water volumes and is broadly utilized; it is explicitly intended for concentrating on microscopic fish (Figure 2). The NOAA protocol describes the sampling of microplastics from water bodies.

Laboratory procedures methodology

The methods used in this study were protected by international protocols. The methods used in this research were the National Oceanic and Atmospheric Administration (NOAA) based laboratory methods for microplastics analysis in the marine environment (Masura et al., 2015).

The sample was poured through a stacked arrangement of 5 mm (5000 microns) to 0.044 mm stainless steel mesh sieves. The sieves were rinsed thoroughly to ensure that the material had been well washed, drained, and sorted. The solids collected in the 0.044 mm sieve were transferred into the tarred beaker using a spatula. Steel mesh with exact sizes of (0.044 mm) were used for sample extraction and removal of large particles. Different size of stitches may affect the amount of microplastics detected based of stitching density,

Table 1. Information about the textile industry

Name of the industry:	Textile industry A
Capacity	9000 Ton/Annum
Start of the plant	October 2014
Commercial start up	March 2015
Land area	12 Acres (30 Rai)
Number of employees	Above 100
Products	Cord/Greige Fabric/Dipped Fabric N6 and N66 – 840D/2, 1260D/2, 1260D/3, 1680D/2, 1890D/3 and others
Location	Banglen, Nakhonpathom

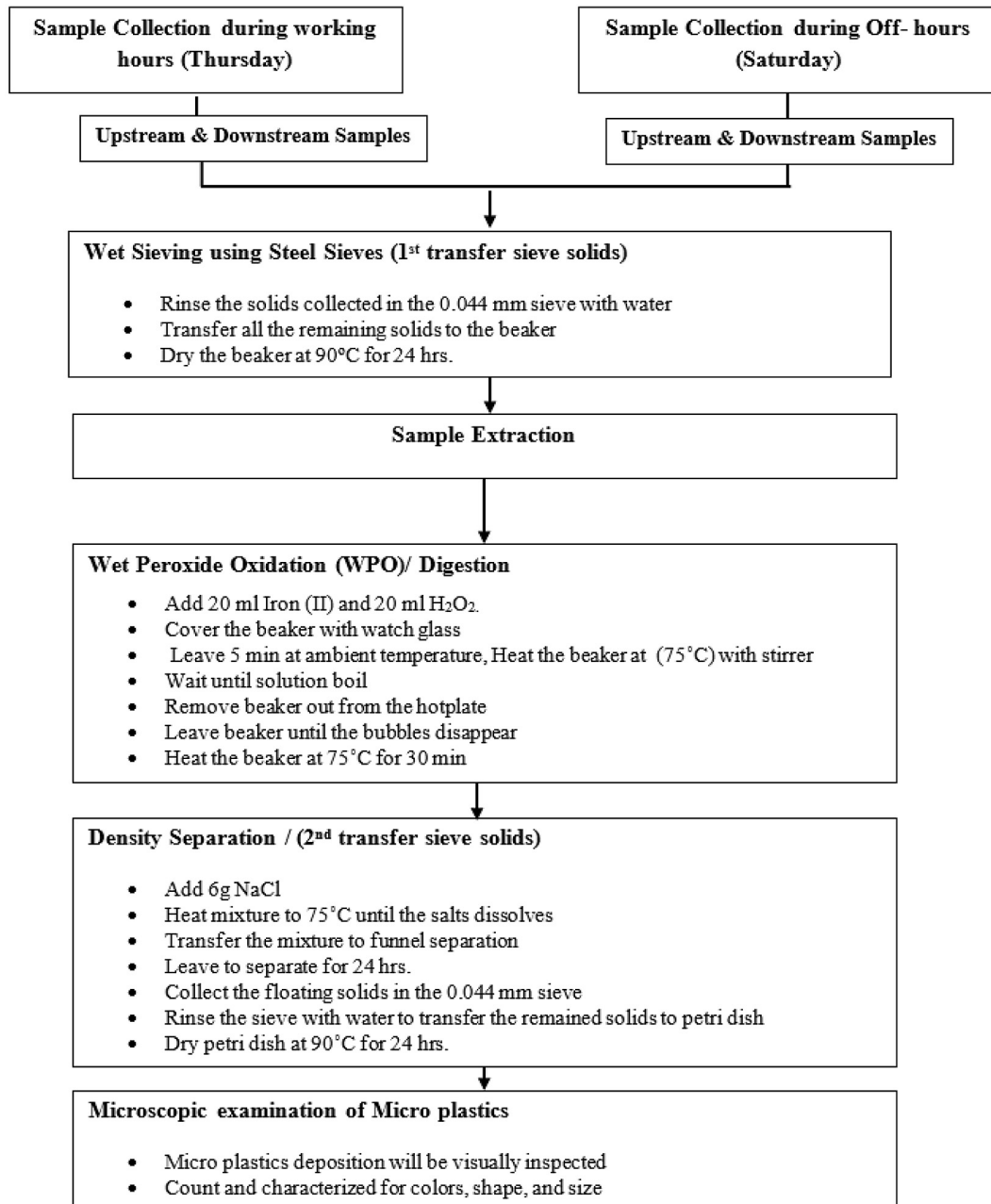


Figure 1. Methodological framework for research

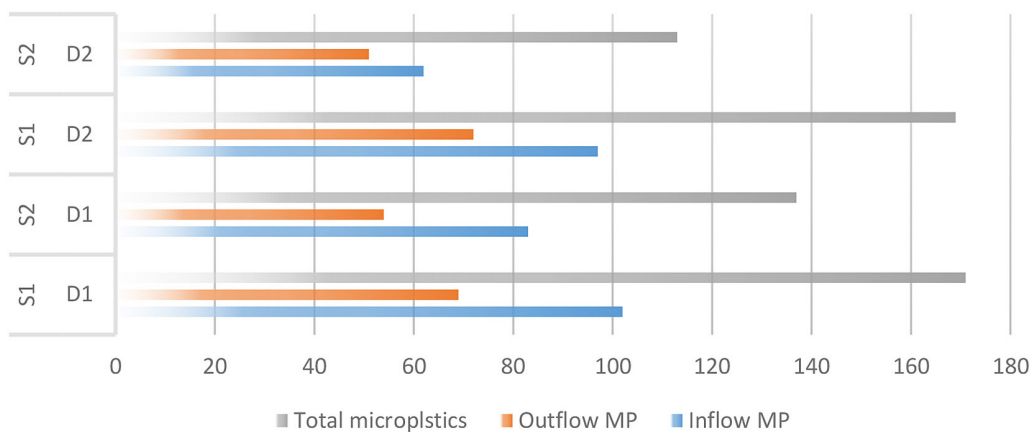


Figure 2. Microplastics contamination identified after visual inspection

yarn tension, surface area, and fabric stability. The solid particles were rinsed carefully with RO water to ensure that all solids fit into the beaker. The beaker was placed in 90 °C drying oven for 24 h to ensure sample dryness. Twenty milliliters of iron II (Fe (II)) and 20 ml of hydrogen peroxide (H₂O₂) were added and covered with watch glass. The beaker was left 5 min at ambient temperature, and then, the beaker was moved to the hotplate at 75 °C with a stirrer.

When gas bubbles were observed at the surface, the measuring utensil was removed from the hotplate and spotted in the smoke hood until bubbling was stopped. The measuring glass was moved back to the hotplate, and the combination was heated to 75 °C for 30 additional minutes. We added 6 g of sodium chloride (NaCl) per 20 mL of outstanding volume after processing to expand the thickness of the watery arrangement (~5 M NaCl) to eliminate higher-thickness particles, such as inorganic matter. The blend was warmed to 75 °C, moved to channel division, and left its difference for 24 h. The settled solids were depleted from the separator and disposed of, and the drifting solids gathered in a clean 0.3 mm custom sifter. Solids gathered in the 0.044 mm sifter moved into the drained petri dish using a spatula and insignificant flushing with a spurt bottle containing RO water, and the petri dish was set in a 90 °C drying stove for 24 h to test after drying.

RESULTS

Visual inspection under standard microscope

The total number of analyzed particles/m³ was 590–601 in both upstream and downstream samples. The first upstream sample on day 1 contained 102–109 particles/m³, while the second upstream sample on the same day with a time difference of 8 h contained 83–94 particles/m³. The average number of microplastics particles on the first day of the

upstream sample was 92.5. On the second day, the average microplastics particle leakage recognized in the upstream samples was 79.5.

For the downstream 1st sample, we obtained 69 particles, and on the same day, the second downstream sample contained 54 particles. On the second day, the first downstream sample had 72 microplastics pieces whereas the second sample on the same day contained 51 particles (Table 2). Upstream microplastics leakage (MP-U), downstream microplastics leakage (MP-D), day 1 sample average upstream (D1-U), day 2 average upstream (D2-U), day 1 sample average from downstream (D1-D), day 2 sample average from downstream (D2-D).

Data analysis by the shape of identified microplastics

Our findings showed that most of the microplastics were found in the fragments and filament structures. This means that during the manufacturing process of the fabric products, microplastics was released. The fragmented particles proved that the wastewater treatment plant is not efficient in effectively capturing microplastics pieces. The total analyzed microplastics in the upstream sample by shape is shown in Figure 3.

Data analysis by shape of identified microplastics

Our findings showed that most microplastics were found in the fragments. In the downstream sample, most of the recognized microplastics were in the fiber form shown in (B). The structure and shape of the microfibrils identified in the downstream sample were the same as those identified in the upstream sample. The microplastics discharge from the industry not only affects the canal but can also spread to other areas. This is an alarming situation for controlling microplastics releases in the industry (Figure 4).

Table 2. Total analyzed countable microplastics released from the wastewater treatment plant of industry into the canal

Total analyzed microplastics by counts from canal					
No	Samples	Days	MP-U [particle/m ³]	MP-D [particle/m ³]	Average
1	S1	D1	102	69	
2	S2	D1	83	54	D1-U 92.5 D1-D 61.5
3	S1	D2	97	72	
4	S2	D2	62	51	D2-U 79.5 D2-D 61.5

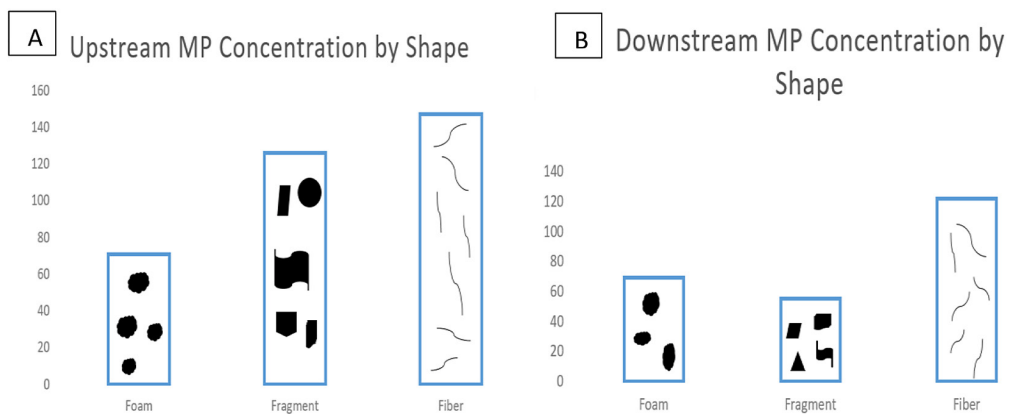


Figure 3. Data for the total identified microplastics in form, fragments, and fibers from the upstream and downstream sample

Comparison of microplastics between the upstream and downstream sample

The results show that the upstream sample contains more microplastics particles than the downstream sample. The number of microplastics particles/m³ upstream in the first sample on day 1 was 102, whereas the second sample on the same day contained 83 microplastics particles. The first

sample on day 2 contained 97 particles, and the second sample on the same day contained 62 particles. On the other hand, from downstream sample analysis, we have 69 particles from the 1st sample on day 1 and for the 2nd sample on the same day we get 54 microplastics particles. The first sample on the second day contained 72 particles whereas the second sample of the same day contained 51 microplastics particles. D1 refers to the sample collected from the

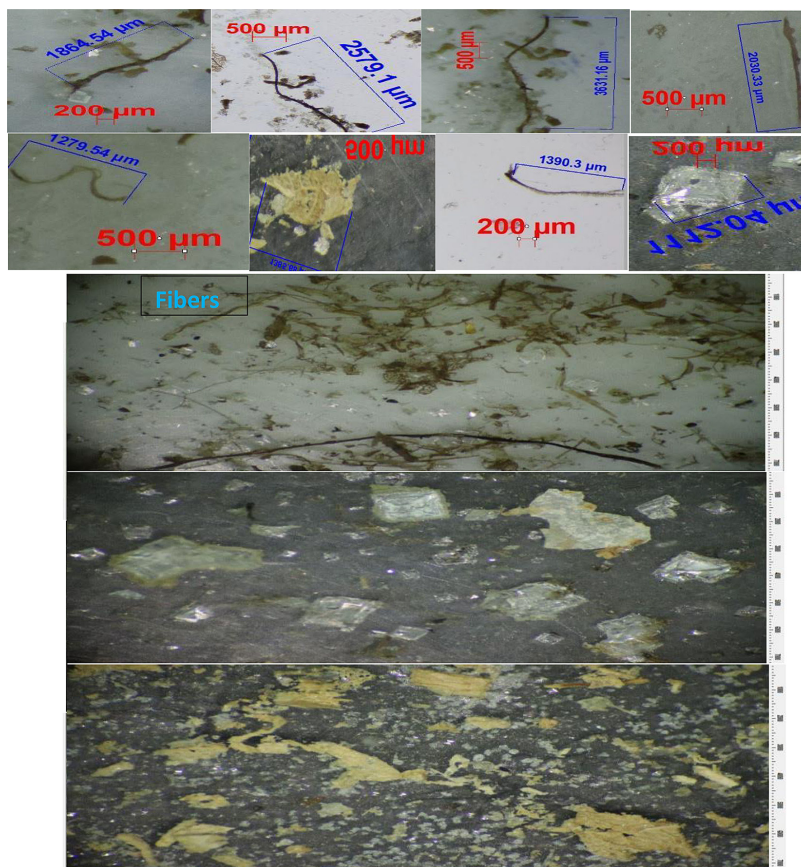


Figure 4. Microscopic photos of the analyzed microplastics in 3 forms

1st day while D2 refers to the sample collected both upstream and downstream. According to the study, samples tested upstream of the wastewater treatment plant had unexpectedly greater quantities of microplastics than samples taken downstream. There are a few possible reasons for this:

- additional sources – in addition to the treatment plant, there may be additional upstream pollution sources that contribute more microplastics, such as industrial discharges or urban runoff.
- WWTP efficiency – since microplastics are frequently smaller than the particles the plant normally targets, it's possible that the wastewater treatment plant is not built to properly catch and remove them.
- sampling variability – elevated amounts detected upstream may be caused by variations in sample location and timing.
- process at the WWTP – microplastics may appear to be at lower levels because they break down into smaller particles during the treatment process that are not picked up in downstream samples.

Comparison of microplastics between working and off days in industry

Microplastics leakage was more during the working days in industry as compared to the off

days of the industry. 308 particles/m³ were recognized in working day samples, while the number of particles/m³ was 282 in day samples (Figure 6).

DISCUSSION

Approximately 8% of European microplastics delivered to seas are from textile materials worldwide, this figure was assessed at 16–35%. Somewhere in the range of 200,000–500,000 tons of microplastics from materials enter the worldwide marine climate every year (Folbert et al., 2022). Many studies have shown the leakage of microplastics from the textile manufacturing industries to the nearest area, which may be any water bodies or some open landfill (Xu et al., 2018). The currently selected study area in this research study was situated near the canal, and research in this study showed microplastics leakage to the canal from the industry with evidence. Microplastics strands (MPFs) set free from materials are regularly found throughout the climate, demonstrating human effects on normal frameworks (Jiang et al., 2022). A less-concentrated, but possibly similarly important source is delivered further upstream in the material creation chain, e.g. Modern wastewater effluents from

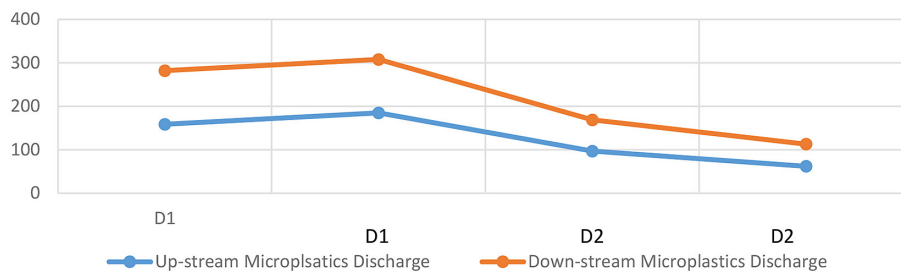


Figure 5. Comparison between captured microplastics from upstream and downstream samples

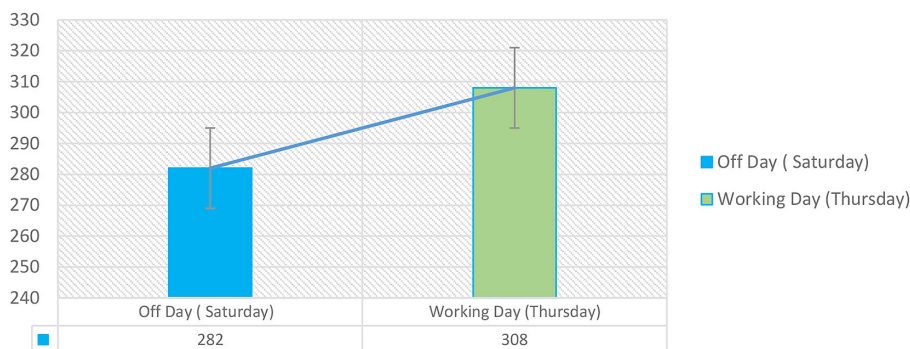


Figure 6. MP Leakage between working and off days of industry

material handling factories. In this specific situation, modern wastewater from a common material wet-handling factory in China was examined to gauge MPF discharge (Zhou et al., 2020). In 2021, Chinese researchers tested microplastics, and the MPF fiber number and length were evaluated by stereomicroscopy (Chan et al., 2021). A normal of 361.6 MPF L⁻¹ was distinguished in the plant profusion. In this study, we identified 590 MPFs in m³. MPF length was an exceptional factor; however, 92 % of all strands were less than 1000 μm . Moreover, the testing technique was used to distinguish the ideal volume important to sufficiently subsample the emanating (Yuan et al., 2021). They found that complete fiber counts directly corresponded with test volumes somewhere in the range of 1–10 L; however, examining volume of 5 L is recommended for good reproducibility, low standard deviation and simplicity of working volume. The huge overflow of MPFs in the modern wastewater affluent accentuates that in addition to the fact that consideration should be given homegrown deliveries, the creation phase of materials can likewise be responsible for MPF contamination. The capacity to target and treat modern effluents may essentially decrease a potentially significant point source (Lam et al., 2020).

In Indonesia, they identified microplastics from dams as concentrated areas. Plastics accounted for 85% of the riverine debris (5369–2320 items or 0.92–0.40 tons daily) (Astawa, 2022). They estimated macro debris releases of 6043–567 items or 1.01–0.19 tons daily with a microplastics concentration of 3.35–0.54 particles per m³ from the Citarum River to the sea (Cordova et al., 2022). In our research study, we identified 590–601 particles per m³, which are much higher in amount compared with the Indonesian case (Cordova et al., 2022).

Comparison between our case and indonesia case

In Indonesia they identified microplastics from the dams as industrial areas. Plastics accounted for 85% of the riverine debris (5369–2320 items or 0.92–0.40 tons daily) (Astawa, 2022). They estimated macro debris releases of 6043–567 items or 1.01–0.19 tons daily with a microplastics concentration of 3.35– 0.54 particles per m³ from Citarum River to sea. In our research study, we identified 590–601 particles

per m³, that are much higher in amount as compared to the Indonesia case:

- our case – 590 MPFs per cubic meter,
- Indonesia case – 3.35–0.54MPFs per cubic meter.

More identified microplastics in our study area as compared with the Indonesian case. The way in which present wastewater treatment systems eliminate microplastics varies greatly based on the type and size of the plastic particles in consideration. The following is a brief discussion of how different factors affect removal efficiency:

Microplastics types and shapes

Fibers: long and thin, they frequently pass filters designed to capture larger, bulkier particles. Fragments: in physical filtering systems, their irregular forms may enhance capture. Beads: unless they form clusters, little, round beads are able to bypass processes such as sedimentation. Films: they come in different sizes and can settle or float, making it harder to capture them with conventional methods.

Challenges in removal

Conventional wastewater treatment techniques, which are mainly aimed at controlling organic and bigger inorganic contaminants, deal with particular challenges due to the varied physical characteristics of microplastics, such as buoyancy and surface area. For example, sedimentation techniques might not impact lighter plastics, and filtration systems might not be able to capture nanoparticles.

Technology and strategy needs

Using cutting-edge technology, including membrane bioreactors, which can more effectively target a variety of microplastics kinds and shapes, is essential to improving microplastics removal. Capture rates may also be increased by modifying chemical treatments to change the buoyancy and agreeability of microplastics. This discussion emphasizes the necessity of a multifaceted strategy in wastewater treatment plans to efficiently handle the many types of microplastics contamination, matching technological advancements with best available technology. The study's findings are directly relevant to the United Nations' Sustainable Development Goals (SDGs), particularly Goal 12 (Responsible Production and Consumption) and

Goal 14 (Life Below Water). Here's how the results fit into these goals and what specific actions can be suggested:

Alignment with SDG 12 – responsible production and consumption

Findings

The study highlights the significant leakage of microplastics from textile industries into water systems, demonstrating inefficiencies in current waste management and production processes in the textile sector.

Actions

Enhance industry standards: implement tighter regulations and standards for the textile industry to minimize waste and pollution, including mandatory integration of microplastic filtration systems in wastewater treatment. Promote circular economy practices: encourage recycling and reuse of textile materials to reduce waste and extend the lifecycle of products. Innovation in material development: support the development and use of alternative materials that are less prone to shedding microplastics.

Alignment with SDG 14 – life below water

Findings: the leakage of microplastics into water bodies directly impacts aquatic ecosystems, contributing to the pollution that affects water quality and marine life health.

Actions

Improve wastewater treatment technologies: deploy advanced technologies such as membrane filtration and electro-coagulation to effectively capture microplastics before they reach natural water bodies. Monitoring and clean-up initiatives: establish regular monitoring of water bodies for microplastics pollution and fund clean-up projects to mitigate existing pollution. Public awareness campaigns: increase awareness about the impact of microplastics on marine ecosystems and encourage public participation in reducing plastic use and littering. By addressing these specific areas, the findings of this study can contribute to achieving SDG 12 and SDG 14, fostering a more sustainable approach to production and consumption while protecting

marine environments from the ongoing threat of microplastics.

CONCLUSION

We concluded that the textile industry releases microplastics into the canal daily and that these microplastics also travel to nearby water bodies. These identified microplastics were present in different forms, shapes, colors, and structures. Most of them are recognized as microfibers. More micro particles in the upstream sample and fewer in the downstream samples. Our findings show that the amount obtained after analysis is the amount of microplastics in the treated water from the industrial wastewater treatment plant. Therefore, the water treatment plant efficiency is also poor, and the original wastewater contains a lot of microplastics. The efficiency of the currently working treatment plant is not so good and not enough to capture all the microplastics and stop them from going to the canal. In the end, we recommend that the industry improve its wastewater treatment system by installing new technology, either membrane or electro-coagulation in the wastewater treatment plant to capture the microplastics release into the canal, such as membrane filtration and electrocoagulation technology. The textile industry should standardize manufacturing steps to better understand shedding mechanisms and assess their impacts. However, further research is needed to establish policies and regulations and to build standards for microplastics leakages from industrial procedures.

Study limitations with systematic errors including potential risk of microplastics loss during sample and lab processing, and shifting method limitation were included in this study:

- sifting method limitations: the study utilizes a stacked arrangement of sieves ranging from 5 mm to 0.3 mm in size to filter samples. This method might not capture all microplastics, especially those smaller than 0.3 mm, potentially underestimating the total microplastics count. This limitation can lead to significant discrepancies in the results, as smaller microplastics are known to be abundant in such environments.
- potential loss of microplastics during processing: the laboratory process involves several transfer and washing steps, including transferring solids to beakers, rinsing with reverse osmosis water, and processing with chemicals

for density separation. Each step carries the risk of losing microplastics particles, either through incomplete transfer of materials, adherence to equipment surfaces, or insufficient capture during sieving.

Acknowledgements

I would like to thank Asian Institute of Technology and all supportive characters in this research work. This research work was conducted with the support of Japan Government Scholarship under the Marine Plastic Abatement Program at Asian Institute of Technology (AIT). A budget of approximately 20000 Bhat was allocated for this research work.

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