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Microplastic Pollution in an Urban Wastewater Treatment Plant: Unravelling Problems and Proposing Solutions

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ABSTRACT

Microplastics (MPs) are detected ubiquitously in aquatic environments worldwide, with wastewater treatment plants (WWTPs) serving as significant pathways for their entry. This study investigates MP removal efficiency and suggests improvements in a conventional municipal WWTP in Bangkok, Thailand. Wastewater samples were collected using a volume-reduced method and filtered into three size ranges (0.05-0.5, 0.5-1.0, and 1.0-5.0 mm). Particles bigger than 0.5 mm were assessed for abundance using an optical microscope and identified for polymer types using attenuated total reflection Fourier transform infrared (ATR-FTIR) spectroscopy, while smaller particles were analyzed using fluorescence microscopy and micro-FTIR. The average concentration of MPs entering the WWTP was 16.55±9.92 MPs/L, whereas the concentration discharged into the environment was 3.52±1.43 MPs/L. The resultant MP removal efficiency of the Bangkok WWTP stands at approximately 78%, a figure lower than that of WWTPs in developed countries. This discrepancy is attributed to the absence of a primary clarifier within the Bangkok WWTP and an under-designed grit channel. Thus, the implementation of a filter system using activated carbon is suggested. Based on the calculations, 21 filter units are required for the Bangkok WWTP to improve MPs' removal effectiveness. This study provides vital data on the presence of MPs in a Bangkok WWTP, emphasizing challenges that impede effective removal efficiency. Additionally, this study proposes potential solutions to enhance the removal of MPs and address these issues.

1. INTRODUCTION

Plastics have become integral to various aspects of human life, including packaging, textiles, construction, consumer goods, transportation, industrial processes, and medical uses. These items enhance our lives by providing increased comfort, convenience, and safety. The global production of plastics reached approximately 404.3 million tonnes in 2022 (PlasticsEurope, 2023). This results in continuously growing plastic waste entering freshwater and marine ecosystems. Recently, significant focus has been placed on distributing small-sized plastic particles, microplastics (MPs). MPs are plastic particles less than 5 mm in diameter and exist in two distinct forms: primary and secondary. Resin pellets and microbeads used in cosmetics are examples of primary MPs that are purposefully produced in this size range. Conversely, secondary MPs are generated from the breakdown of larger plastic materials through physical and chemical degradation processes (Ta et al., 2025).

Organisms ingest MPs because they cannot differentiate between MPs and actual prey or ingest other organisms containing MPs (De Sá et al., 2015;

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Ta et al., 2022). This could lead to physical harm for organisms, encompassing digestive system disruptions, hormone level imbalances, decreased feeding efficiency, and potential repercussions on reproductive processes (Carr et al., 2012; Lusher et al., 2013). The interaction between MPs and harmful substances presents another significant ecological concern. Due to their small size and high surface area-to-volume ratio, MPs effectively adsorb hazardous compounds onto their surfaces (De Sá et al., 2018; Ta and Babel, 2023a). These particles can transport toxic substances across long distances and accumulate within organisms after ingestion (Bakir et al., 2016). Additionally, MPs act as vectors for pathogens by providing surfaces for their attachment (Viršek et al., 2017). Studies have revealed that pathogens can form colonies on MP particles in marine environments (Kirstein et al., 2016).

An important pathway of MP input into aquatic environments has been found through WWTPs (Horton et al., 2017). Wastewater entering WWTPs originates from households, businesses, institutions, and occasionally urban rainwater overflow. These wastewater sources contain various types of MPs, such as microbeads and microfibers. Microbeads are commonly found in personal care products like toothpaste and face scrubs. Meanwhile, synthetic garments made from polyester and nylon can release hundreds of microfibers into wastewater during washing (Ta and Babel, 2020).

Recent research has focused on improving the detection, removal, and management of MPs in WWTPs, addressing the growing concerns over their environmental and human health impacts. Advances in sampling and analytical methods have significantly enhanced the reproducibility and applicability of MP detection in WWTPs, with improvements in techniques like Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy (Sadia et al., 2022; Ta and Promchan, 2024). In terms of removal technologies, preliminary and primary treatments are effective at removing MPs through physical processes. For example, MPs can be removed from raw wastewater during the grit and grease removal stage, with studies showing up to 79% removal efficiency in countries like Australia (Ziajahromi et al., 2021) and 69% in the UK (Murphy et al., 2016). Air flotation technology captures low-density MPs, while polyethylene (PE) microbeads can be skimmed off easily due to their buoyancy (Murphy et al., 2016). Primary treatment mainly eliminates MPs through sedimentation, where larger MPs settle in solid flocs. However, some studies from China suggest that grit and grease chambers are less effective than sedimentation (Liu et al., 2021). Combining grit and grease stage with primary sedimentation can enhance MP removal rates, with sedimentation achieving reductions of 91.7% in Vancouver, Canada, and 71.67% in Beijing, China (Gies et al., 2018; Liu et al., 2019). Factors like the density and morphology of MPs significantly affect removal efficiency, with fibers being particularly challenging to retain (Long et al., 2019). Secondary treatment utilizes biological processes to degrade suspended particles and dissolve solids in wastewater, causing MPs to accumulate within sludge flocs. In the activated sludge process, smaller MPs (106-300 µm) are more readily removed than larger ones (>300 µm) (Lee and Kim, 2018). However, configurations like the anaerobic-anoxic-oxic process show lower MP removal rates, with significant recirculation of MPs back into the aqueous phase (Liu et al., 2021). Tertiary treatment technologies enhance MP removal efficiency by 5-20%. Membrane bioreactors demonstrated up to 99.9% removal efficiencies in various studies (Talvitie et al., 2017). Sand filtration has shown a 97% removal rate, while advanced oxidation processes like ozonation significantly degrade MP structures, leading to high removal rates (Chen et al., 2018; Hidayaturrahman and Lee, 2019). However, not all advanced treatments effectively reduce MP concentrations, especially for smaller particles (Sutton et al., 2016).

While WWTPs in many parts of the world are achieving high MP removal rates, the situation is different in urban areas of developing countries, where rapid urbanization and inadequate upgrades to treatment technologies have led to overloaded systems with lower removal efficiencies (Chirisa et al., 2017; Nguyen et al., 2023; Zhang et al., 2016). Although primary and secondary treatment processes in well-functioning WWTPs can remove up to 99% of MPs (Murphy et al., 2016; Ta and Promchan, 2024), many of these facilities in developing countries struggle to achieve such performance levels. To address these challenges, research has explored the installation of activated carbon or biochar filters as a cost-effective solution, particularly suited for regions where these materials are abundant as agricultural byproducts (Lewoyehu, 2021). Studies indicate that granular activated carbon (GAC) filters are promising for removing MPs from wastewater. For example, Amirah Mohd Napi et al. (2023) demonstrated that GAC could remove up to 95.5% of MPs that range in size from 40 to 48 µm. Similarly, Kim and Park (2021) documented the effectiveness of GAC in a Korean WWTP as a tertiary treatment step, where a pilot-scale GAC filtration tower (10 m^3/day) achieved an MPs removal efficiency of 92.8%. In a larger pilot-scale GAC filtration system with a flow rate of 12 m^3/h (288 m^3/day), Sturm et al. (2023) reported removal efficiencies of 86.2% for both MPs and other micropollutants. These studies validate the use of GAC as an effective tertiary treatment option and indicate its feasibility for large-scale applications in wastewater management. The evidence presented in the literature supports the rationale for employing GAC as a critical component in advancing wastewater treatment technologies, especially in tackling the escalating issue of MP pollution.

The primary objective of this study is to evaluate the efficiency of MP removal in a conventional municipal WWTP from a developing country (Thailand) in the Southeast Asia Region. The abundance and properties of MPs in each unit operation of the WWTP were also examined. A comparison of the MP removal effectiveness in the studied WWTP and others from developed countries was conducted to indicate the advantages and disadvantages of the WWTPs. Then, a suggestion for improvement of MP removal in the studied WWTP by activated carbon filter is evaluated.

2. METHODOLOGY

2.1 Study sites and sampling

A conventional WWTP in Thailand was selected for investigation in this study. The WWTP serves an area of 37 km^2 with a population of about 1 million. The plant has a capacity of 350,000 m^3/day and uses the treatment technology of a biologically activated sludge process with nutrient removal. A flow diagram of the WWTP treatment processes is shown in Figure 1. Treated water is discharged into surrounding canals.

MP samples were collected at three points on the WWTP, including influent (S1), after grit channels (S2), and effluent (S3). Samples were collected using a volume-reduced method through on-site filtration. At each sampling point, triplicate 20 L wastewater samples were filtered through a 0.05 mm mesh sieve (n=3). The remaining materials on the sieve were rinsed with deionized water and then transferred into laboratory glass bottles for storage (Duran, 1 L).

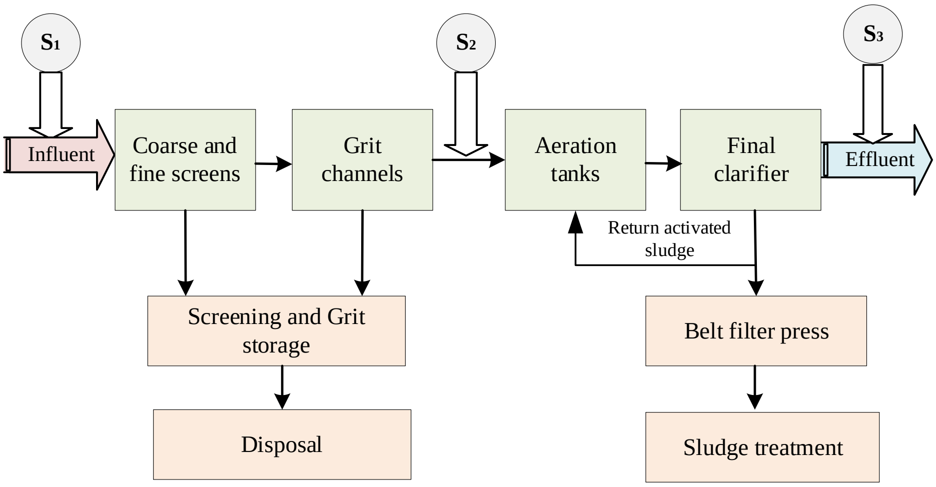


Figure 1. Flow diagram of the selected WWTP with sampling locations

2.2 Samples analysis

At the laboratory, MPs in wastewater were extracted and examined following the method suggested by Tadsuwan and Babel (2022), as shown in Figure 2. Particles in the wastewater samples were categorized into three size ranges: 0.05-0.50, 0.5-1.0, and 1.0-5.0 mm using sieves made of stainless steel. Fractions containing particles bigger than 0.5 mm (retained on 0.5 mm and 1.0 mm sieve meshes) were visually examined. Suspected plastic particles within this size range were manually removed using stainless-steel tweezers and transferred onto Petri dishes. The fractions with particles smaller than 0.5 mm in size (retained on 0.5 mm and 1.0 mm sieve meshes) were more challenging to examine visually due to their small size and the presence of sediment and organic debris. Thus, the organic debris was removed using Fenton's reagent (composed of 20 mL of 30% H_2O_2 and 20 mL of 0.05 M $FeSO_4·7H_2O$). The treated particles were then subjected to density separation using sodium iodide (NaI), which has a 1.5 g/cm³ density. The samples were combined with NaI solution and stirred thoroughly for 15 min. After settling for 24 h, the buoyant solids were carefully collected and passed through a 0.45 µm pore-size cellulose nitrate membrane filter.

Following pre-treatment, particles within the size ranges of 1.0-5.0 and 0.5-1.0 mm were visually assessed using an optical microscope (Olympus CX41). Polymer types were identified utilizing ATR-FTIR spectroscopy (Thermo Scientific - Nicolet iS50). Particles sized between 0.05 and 0.5 mm were split into two groups and filtered using the Whatman cellulose nitrate membranes (0.45 µm pore size). Due to their smaller dimensions, this size range posed a risk of underestimation when analyzed with an optical microscope. To address this, a Nile Red solution was prepared by dissolving Nile Red in chloroform at a concentration of 1 mg/mL, which was then used to stain the first set (Ta and Babel, 2023b). The stained filters were then analyzed using a fluorescence microscope (GE Healthcare - Delta Vision™ Elite Cell) to quantify MPs. The fluorescence microscope was equipped with a DAPI (4',6-diamidino-2-phenylindole) filter, facilitating visualization based on fluorescence properties. The setup was configured for blue fluorescence, utilizing an emission wavelength of 435/48 nm and an excitation wavelength of 390/18 nm to selectively detect fluorescently labeled particles. Images of the filter surfaces were captured at ×4 magnification with a camera attached to the Delta Vision microscope, aiding in identifying MPs. For quantification, visible fluorescent spots in the images were counted, with each spot corresponding to an individual MP particle. Micro-FTIR spectroscopy (Thermo Scientific - Nicolet iN10) was employed to determine polymer types for the second set of filters. The analysis was performed in ATR mode, with an aperture size ranging from 50 to 300 µm in height and length. The spectroscopy has an 8 cm^{-1} resolution and 64 scans encompassing a 4,000 to 650 cm^{-1} range. Using OMNIC Spectra Software, the ATR-FTIR and micro-FTIR spectra were compared to a library of polymer spectra, using a 70% minimum matching criterion to determine the types of polymers.

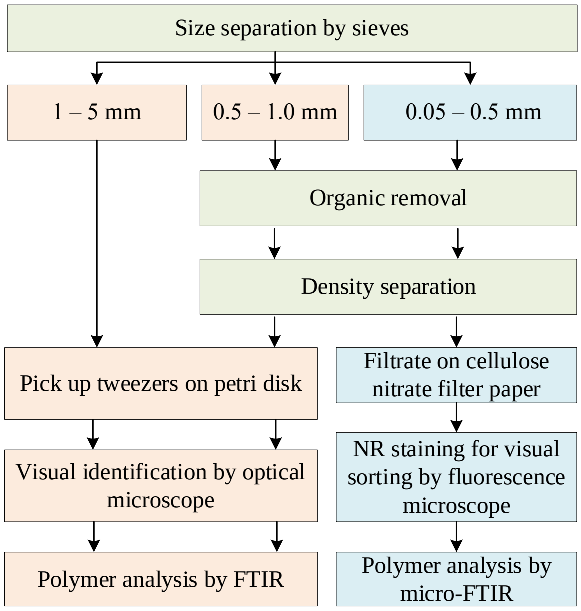


Figure 2. Procedure for analysis of MPs in wastewater samples

3. RESULTS AND DISCUSSION

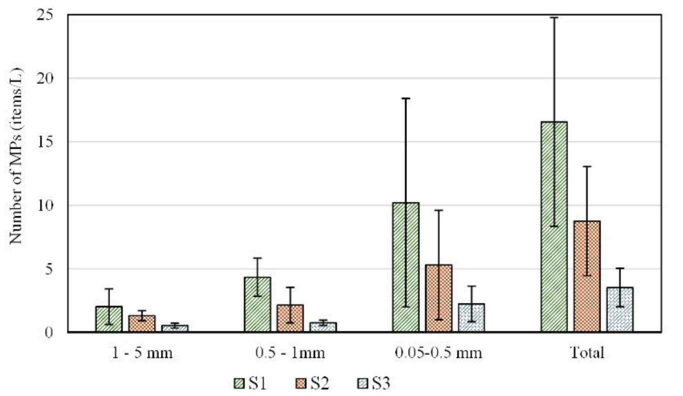
3.1 Microplastic characteristics and removal efficiency in the studied WWTP

Figure 3(a) illustrates the concentration of MPs per liter of wastewater across various sampling locations, categorized by size classes. On average, 16.55±9.92 MPs/L entered the WWTP, while 3.52±1.43 MPs/L were discharged into the environment. Most MPs were concentrated in the 0.05-0.5 mm size range at the WWTP inlet, with a measured concentration of 12.2 MPs/L. This was followed by the 0.5-1.0 mm size range, which had 4.33 MPs/L, and the 1-5 mm size range, with a concentration of 2.02 MPs/L. Similarly, the final effluent was dominated by MPs in the 0.05-0.50 mm range (2.23 MPs/L), followed by concentrations of 0.75 MPs/L in the 0.5-1.0 mm range and 0.53 MPs/L in the 1-5 mm range.

FT-IR and micro-FTIR fingerprint spectra were compared with reference databases, identifying polyethylene (PE) as the most abundant polymer, followed by polyethylene terephthalate (PET) and acrylic polymers (Figure 3(b)). Transparent fragments and films, frequently composed of PE, were likely linked to its widespread application in packaging and containers. These fragments were classified as secondary MPs, formed through plastic material breakdown and physical degradation.

The removal efficiencies of various size classes across the treatment units are shown in Table 1. The selected WWTP achieved an overall MP removal efficiency of 78.73%. Removal rates by size class were 73.76% for 1-5 mm, 82.68% for 0.5-1.0 mm, and 78.14% for 0.05-0.50 mm. The grit trap removed 47.13% of MPs, while secondary treatment achieved a higher reduction rate of 59.77% across all size ranges compared to earlier processes like screening and grit trapping. MPs in the 1-5 mm range were the least effectively removed after screening. However, the WWTP's daily treatment capacity of 350,000 m³ still releases an estimated 1.23 billion MPs into the environment daily.

(a)



(b)

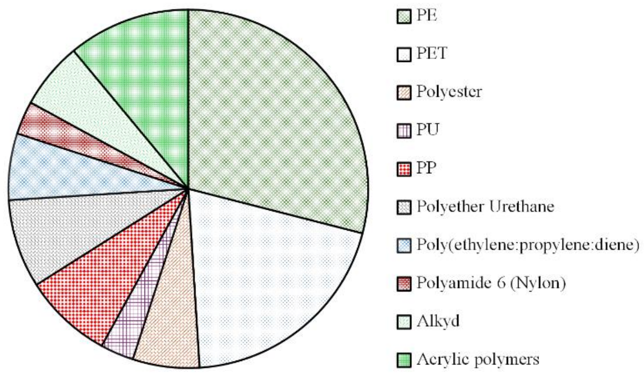


Figure 3. (a) Number of MP particles in each treatment step of the selected WWTP; (b) Polymer types of MPs at all sampling locations in the selected WWTP

Table 1. The efficiency of MP removal across size fractions in treatment units of the selected WWTP

Size range	Removal efficiency (%)		
	Screening and grit chamber	Secondary treatment	Overall
1-5 mm	35.64	59.23	73.76
0.5-1 mm	50.35	65.12	82.68
0.05-0.50 mm	48.04	57.92	78.14
Total	47.13	59.77	78.73

3.2 Comparison of MP removal from different WWTPs

A comparison of MPs extracted from various WWTPs worldwide is shown in Figure 4. The data indicate that the MP removal efficiency in the WWTP from Thailand is much lower than that of others. In a study conducted in South Korea, the wastewater treatment process began with preliminary treatment, which included a grit removal unit and a primary settling tank for screening the wastewater. The secondary treatment utilized a bioreactor containing activated sludge and a secondary settling tank. Tertiary treatment processes were implemented to enhance the removal of residual pollutants. This comprehensive treatment approach achieved an approximately 99% removal efficiency for MPs from the inlet wastewater (Hidayaturrahman and Lee, 2019). The selected WWTP in the Italian study featured multiple treatment stages, including screening, grit and grease chamber, biological treatment, sedimentation, sand filtration, and disinfection. This facility achieved an overall MP removal efficiency of 84% (Magni et al., 2019). The WWTP in Finland employed treatment technologies comprising primary clarification, a conventional activated sludge process, and rapid sand filtration. The removal efficiency was specifically reported for the rapid sand filtration stage (tertiary treatment), achieving a 97% reduction in MPs from the influent (Talvitie et al., 2017).

There are two main reasons for the selected WWTP's low MP removal efficiency in Thailand compared to the other studies. The first factor pertains to the under-design of the grit channels. Due to the short length of the grit channels, the surface loading with MP particles is too high. Furthermore, the standard flow velocity due to the mixed water inflow should be 25 m/h. However, the flow velocity in the Bangkok WWTP is 32 m/h. This means the MPs do not have enough time to settle or float on the water's surface, where they can be removed from the wastewater stream. The second reason is the missing primary clarifier in the selected WWTP from Thailand. As mentioned above, all the WWTPs have primary clarifiers, while the wastewater in the Thailand WWTP goes directly from the screening and the grit chamber to the secondary treatment (Figure 1). This contributes to a decrease in the WWTP's total MP removal efficiency.

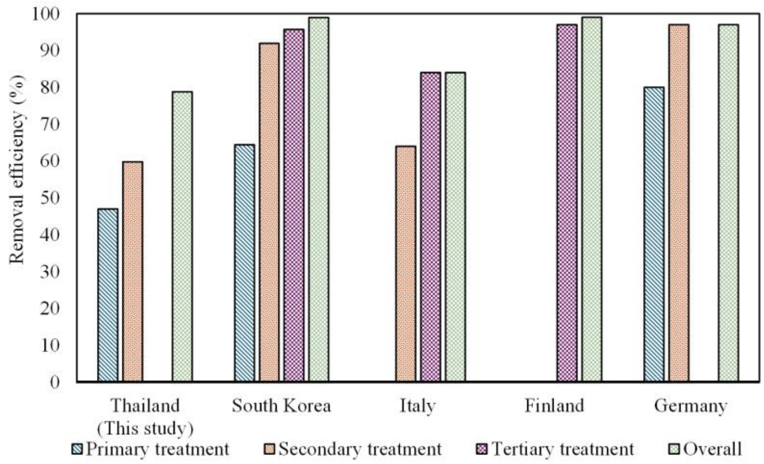


Figure 4. Removal efficiency of MPs in different WWTPs: South Korea (Hidayaturrahman and Lee, 2019), Italy (Magni et al., 2019), Finland (Talvitie et al., 2017), Germany (Mintenig et al., 2017).

3.3 Solutions for improvement of MP removal in the studied WWTP

3.3.1 Activated carbon filters as a potential solution for MP removal

As shown in the above section, most WWTPs from other developed countries are equipped with tertiary treatment. The treatment step has been proven to be an efficient technique for removing MPs. Thus, activated carbon filters are proposed as a tertiary treatment step to improve the MP removal efficiency at the Thailand WWTP. Activated carbon has been used to adsorb various micropollutants in wastewater, such as antibiotics, X-ray contrast medium, beta-blockers, and other human pharmaceuticals (Gidstedt et al., 2022; Khalidi-Idrissi et al., 2023). Since MPs also include sizes of <100 µm, activated carbon filters are proposed here as an efficient method to reduce the MPs in the WWTP effluent. According to Benstöm (2017), the parameters influencing activated carbon's adsorption efficiency include the molecular structure, molecular weight, solubility, and polarity of pollutants. In the context of the chemical composition and molecular weights of polymers, MPs can readily adsorb onto the surface of activated carbon, as common MPs found in wastewater are typically insoluble. A study by Wang et al. (2020) shows that activated carbon from biomass provides significant capacity for the removal of 10 µm diameter MPs (above 95%). Given the diverse chemical nature of MPs, the interactions with activated carbon should be studied in detail. This is so that precise knowledge can be gained of the required filtering characteristics to optimize the removal performance of granulated activated carbon (GAC) filters. However, no institutionalized guidelines for designing GAC filter units are published in the literature. The most important process values for sizing GAC units are L_B (height of filter bed) and filter velocity (ν_f). Another relevant parameter is the empty bed contact time (EBCT), which is calculated from ν_f and L_B values (Benstöm, 2017). The calculation approach for the dimensioning of a GAC filter unit is shown in Figure 5(a). The filter unit was finally dimensioned using iteration steps based on different filter flow rates.

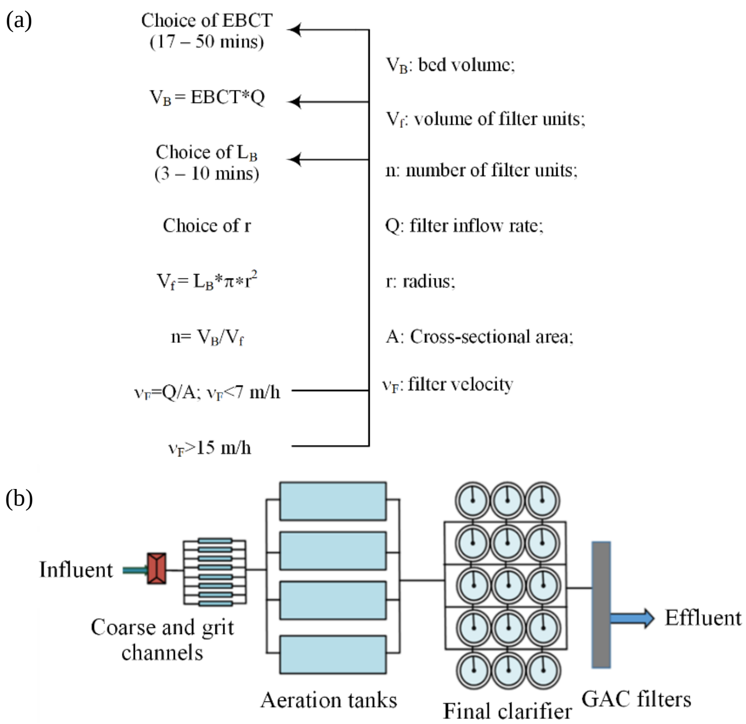


Figure 5. (a) Process of calculation for dimensioning the GAC filter; (b) Flow diagram of the selected WWTP in Bangkok, with the implementation of GAC filters.

3.3.2 Design of GAC filters

The wastewater flow of the Bangkok sewage treatment plant is 341,289 m^3/d. The selected contact time is 17 min. If the wastewater flow and the contact time are multiplied, the total filter volume is 4,029 m^3. However, to keep the number of filter units small, a filter radius per unit (3.9 m) was used with a filter bed height of 4.3 m. This results in a cross-sectional area of 47.8 m^2 and a filter bed volume per unit of 205 m^3. The calculated total volume of 4,029 m^3 divided by the filter volume of one single filter unit (205 m^3) results in 20 filter units. Regarding the proposed parallel operation of the filter units, one filter unit is added to reactivate each filter unit (one after the other) in a certain time sequence. Dividing the total wastewater flow of 341,289 m^3/d by 21 filter units results in a daily inflow per individual filter unit of 677 m^3/h. Referring to the cross-sectional area of each filter unit (47.8 m^2), the filter velocity is calculated as 14.2 m/h. This value is below 15 m/h, which is reported as the recommended upper limit (Benstöm, 2017).

Figure 5(b) shows the implementation of an activated carbon filter system on the Bangkok WWTP. With the implementation of the GAC units, the wastewater passes through the following treatment stages. First, the influent flows into 8 aerated grit channels. Each of them has a surface of 111 m^2. Then, the wastewater flows through 4 activated sludge channels of 96×32 m per channel, followed by 15 final clarifiers, each with a diameter of 31 m. The last step is the GAC filter units. Each of them has a radius of 3.9 m. Figure 6(a) shows the arrangement of individual GAC filter units in the selected WWTP. The filter units are arranged in parallel to ensure continuous operation of the plant. Details of the arrangement and the cleaning concept are explained in Section 3.3.

The structure of the GAC filter (Figure 6(b)) consists of granular activated carbon with a mesh size of 8×30 mm (grain diameter: 0.63-2.36 mm). This mesh size is usually used and is successful in many treatment systems (Benstöm, 2017). At the bottom of the filtration unit, different granulated activated carbon layers with a 4×8 mm mesh size (grain diameter: 2.36-4.75 mm) are installed. This layer prevents upper-layer GAC particles from being washed out of the filter unit and reaching surface waters.

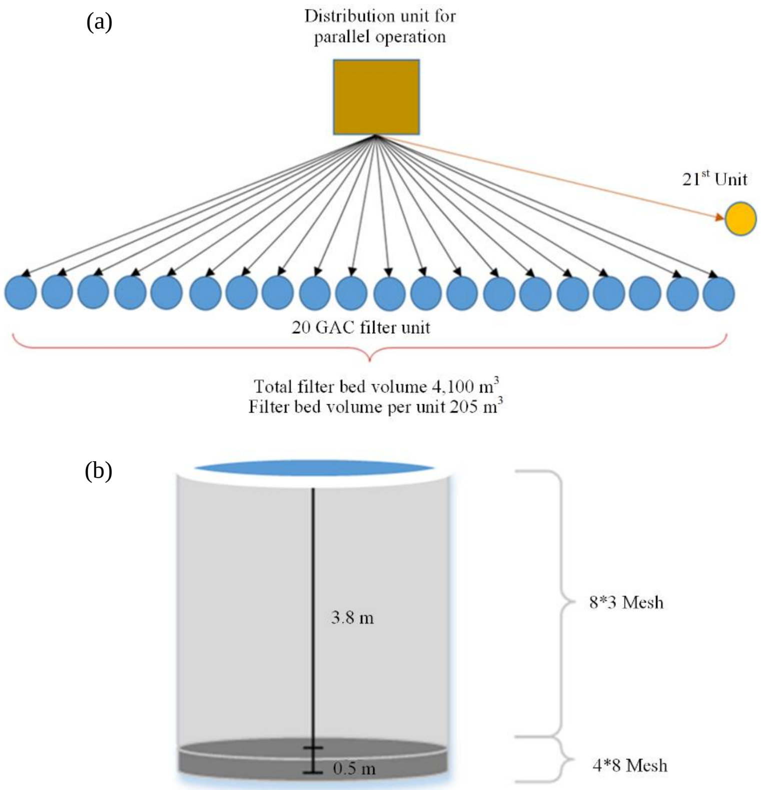


Figure 6. (a) Arrangement of GAC units in parallel operation; (b) Structure of a GAC filter unit

3.3.3 Operation of GAC filters

As shown in Figure 6, 21 units of GAC filters were operated in a parallel position. This operation removes MPs more efficiently than in serial operation. Parallel operation simplifies the procedure for operating and inspecting. Furthermore, parallel operation is less expensive because it has lower investment and operational costs (e.g., the pressure loss is lower compared to serial operation). Parallel operation also achieves the maximum availability for a load of activated carbon compared to serial operation (Fundneider et al., 2021).

3.3.4 Cleaning of GAC filter unit

The procedure for cleaning is shown in Figure 7. The first cleaning step involves cleaning the GAC filter with an airflow of 60 m/h for 90 s to loosen the material in the filter. The second step is to rinse the filter with clean water at 25 m/h for 300 s to remove pollutants from the filter. The last step is to rinse the filter with water again, but with a higher flow rate and in a shorter time (50 m/h for 180 s). However, the flow rate of cleaning water, which rinses the layers from the bottom to the top, should not exceed 60 m/h. Otherwise, the two layers (Figure 5(b)) would be mixed. It is also important to avoid the influence of abrasion. For example, in the case of lignite, hard coal, and coconut husk when used as the GAC, the abrasion losses are between 0.1 and 1.5 wt.% per year with a daily rinse (Çeçen and Aktas, 2011). Tests with GAC layers over a longer period show that it is sufficient to clean the GAC filter once a week (Çeçen and Aktas, 2011).

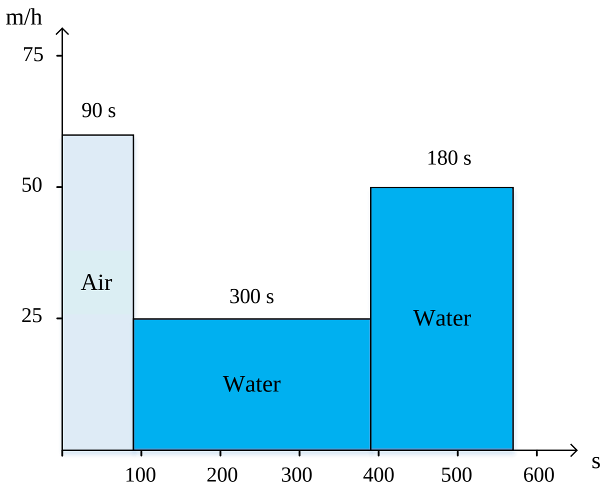


Figure 7. Cleaning of GAC filter unit

3.3.5 Regeneration and reactivation of GAC

The filtering efficiency of GAC decreases over time, necessitating determining when reactivation is required. Filtering efficiency is defined by the ratio of MP concentration in the filter outflow (S) to the MP concentration in the filter inflow (S0). The filter must be regenerated and reactivated if this ratio reaches 20% (S/S0=0.2). Experimental data for this process typically represented through breakthrough curves, are not readily available in the literature. The "bed volume number" (BVN) is a useful reference to mitigate potential overloading. Typical BVN values range between 22,000 and 31,400 (Çeçen and Aktas, 2011). For the Bangkok WWTP, we assume a BVN of 22,000, corresponding to a throughput of 4,520,327 m^3 (22,000×205 m^3) per filter unit.

To determine the specific timeline for exchanging or reactivating GAC in filters, the normalized throughput volume is divided by the inflow rate per filter unit, calculated as follows: 4,520,327 m^3 / 16,252 m^3/d. The inflow rate is derived from 341,289 m^3/d divided by 21 filter units. Thus, complete reactivation is needed after 278 days. Given the continuous operation of the treatment plant, one filter is reactivated every 13 days while maintaining 20 active filter units.

To establish a sustainable green cycle for GAC, selecting eco-friendly sources for activated carbon is crucial. Activated carbon produced from biomass provides an eco-friendly and cost-efficient substitute for traditional commercial activated carbon. Coconut husk, in particular, is an excellent raw material for activated carbon production, offering a more sustainable option compared to lignin or hard coal (Arena et al., 2016). The production process of activated carbon from coconut husk involves carbonization followed by activation, creating a porous structure that enhances its adsorptive capacity. After reaching the end of its life cycle in the filter, the used GAC can be reactivated through thermal processes, which restore its adsorptive properties and reduce waste. This green cycle minimizes the environmental impact and supports the circular economy by reintroducing reactivated GAC into the filtering system, thereby reducing the need for virgin materials and promoting resource efficiency (Arena et al., 2016).

4. CONCLUSION

MPs were found in all samples from Bangkok's selected WWTP. The average concentration of MPs entering the WWTP was 16.55±9.92 MPs/L, while the concentration in the discharged effluent was 3.52±1.43 MPs/L, indicating an overall removal efficiency of 78.73%. Higher removal rates were observed in the fractions of 0.5-1.0 mm. Despite this, the MP concentration in the treated effluent reveals that significant quantities, amounting to over one billion MPs daily, are still being released into the environment. The MPs' removal efficiency in this Bangkok WWTP is lower than that observed in WWTPs in South Korea, Italy, Finland, and Germany. The main factors influencing this outcome are likely the high flow rates in the grit channels, which hinder MP particle settling or flotation, and the absence of a primary clarifier in the Bangkok WWTP, a key step typically preceding secondary treatment. To address these limitations, this study proposes implementing GAC filters as a tertiary treatment step to enhance MP removal in the Bangkok WWTP. This recommendation includes detailed guidance on GAC filters' design, operational procedures, and regeneration processes. Since WWTPs serve as one of the primary routes through which MPs are released into the environment, this study provides essential data on MP occurrence in a Bangkok WWTP in one of Asia's major cities. Additionally, it highlights the challenges impeding MP removal efficiency and proposes solutions that could be adapted to other developing Asian countries facing similar challenges.

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