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Performance Assessment of the Onsite Wastewater Treatment System at High-rise Condominium in Bangkok: A Case Study

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Abstract

Condominiums in Bangkok increase annually to accommodate the growing population. The wastewater generated from residents' activities could potentially impact natural water quality. This study aims to assess the efficiency of onsite wastewater treatment from the high-rise condominium in Bangkok and investigate the presence of microplastic contamination in discharged wastewater. The revealed removal efficiencies of SS, VSS, BOD, COD, NH_4-N, and TN at 82.75%, 81.55%, 94.80%, 85.60%, 75.0%, and 21.4%, respectively. The *E. coli* could be treated at $1.44\log_{10}$. The effluent's pH, SS, and BOD values met the wastewater effluent standards according to the notification of the Ministry of Natural Resources and Environment on effluent standards from buildings of certain types and size. The presence of microplastics in wastewater originating from the high-rise condominium building is detected in both influent and effluent, at quantities of 4 pieces/L and 2 pieces/L, respectively. Fiber-shaped microplastics were found the most, followed by fragments, films, and granules, in that order. The random sampling of microplastics for analysis to identify the polymer type revealed the presence of Polyethylene terephthalate (PET), Polypropylene (PP), Low Density Polyethylene (LDPE), and detected Polydimethylsiloxane (PDMS).

Keywords : Bangkok; condominium; onsite treatment; process performance; treatment efficiency; microplastic

Introduction

Bangkok has witnessed a significant surge in condominium construction. From 2017 to June 2023, the number of condominium registrations has increased, with 506 projects, 1,050 buildings, and 223,815 units being registered during this period [1]. Government regulations mandate on-site wastewater treatment facilities for condominiums to address environmental concerns [2].

The growing number of condominiums serves as a significant source of wastewater discharge that undergoes treatment through onsite wastewater treatment systems (OWTSs) before being discharged into the aquatic environment, specifically into canals. Thus, the efficiency of OWTSs plays a pivotal role in relation to water quality in canals. Canal water quality monitoring in Bangkok from 2010 to 2021 shows a rising trend in Biochemical Oxygen Demand (BOD) concentration [3], indicating a deteriorating water quality trend. This study focuses on OWTS in Bangkok condominiums, which is considered as one of the significant sources of wastewater generation. The inadequate performance of the OWTS may result in the release of high-strength wastewater into the aquatic ecosystem, consequently deteriorating the water quality within the environment.

Even though OWTS effectively treat wastewater to meet regulatory standards, other pollutants may still be present in wastewater. Recently, plastic wastes measuring less than 5 mm in length, which are commonly known as 'microplastics (MPs)' have garnered considerable attention as an emerging threat, with consequential implications in terms of ecotoxicology and ecology for water ecosystems [4, 5]. The presence of microplastics in aquatic environments can be investigated by analyzing effluent obtained from wastewater treatment plants (WWTPs) [6], which serve as crucial receptors of MPs before releasing them into natural water bodies [7].

This study aims to investigate the source of wastewater discharge, with a specific focus on assessing the efficiency of high-rise condominium's OWTS and examining the release of MPs from OWTS into the surrounding environment.

Methodology

Sampling site

The sampling site selected for this study was an activated sludge OWTS installed at a high-rise condominium "A" in On-nuch district, Bangkok, Thailand. Out of the total 987 units in the building, 936 units were occupied at the time of the study. The location of the sampling site is shown in Figure 1.

The wastewater treatment system has a capacity of 615 m^3/day. The flow diagram of wastewater treatment plant shown in Figure 2. Water samples were collected at 2 sampling points to analyze water quality and microplastic contamination in wastewater. The first sampling point was the influent from septic tank (No.1), the second sampling point was the effluent from clarifier tank (No.2).

Water quality characterization analysis

The sampling process for water quality characterization analysis took place on a weekly basis, spanning from January 2023 to June 2023. The pH measurement was carried out by using pH meter. Concentrations of suspended solids (SS) and volatile suspended solids (VSS) were determined using a glass fiber filter (GB140; pore size 0.4 μm, Advantec Co. Ltd., Japan). The BOD with additional allylthiourea (ATU) were determined according to the standard method [8]. The COD was analyzed using a HACH DR900 spectrophotometer (Hach Co, USA). Persulfate Digestion Method were used for analyzing the total nitrogen (TN) concentration. Ammonia, Nitrite and Nitrate (NH_4-N, NO_2^--N and NO_3^--N) concentrations were analyzed by a spectrophotometer (DR1900, Hach Co, USA). The *Escherichia coli.* (*E. Coli*) concentration in wastewater was analyzed using a Nissui Compact Dry EC plate (Nissui, Japan).

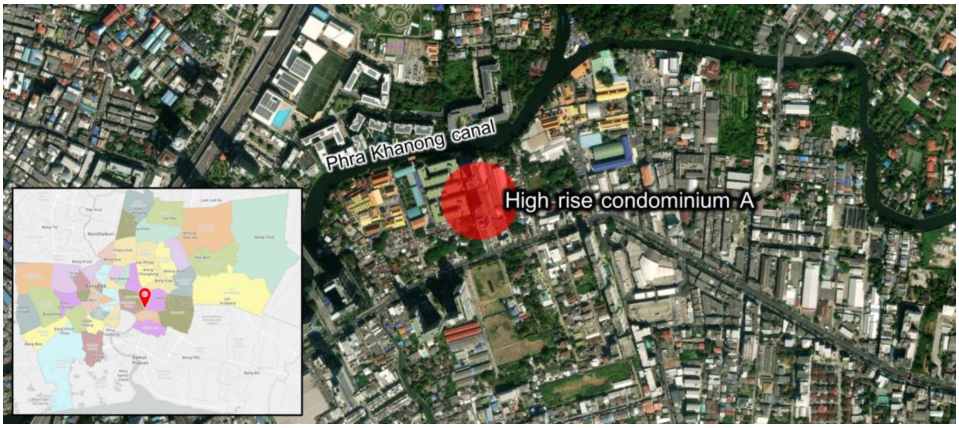

Figure 1 The location of high-rise condominium A

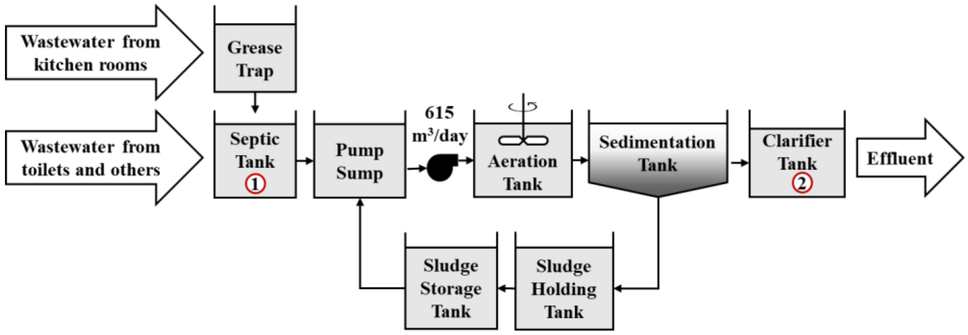

Figure 2 Flow diagram of a high-rise condominium A's onsite WWTP (Completely Mix)

Microplastic analysis

The MP sample collection was conducted on four occasions: twice during the dry season (late January and late March) and twice during the wet season (mid-May and mid-June) of 2023. A rotary pump with a 12 V/DC 8 A power supply was used for the sampling process. The water was pumped through a 0.3 mm (No. 50) stainless steel sieve. Analysis samples were obtained from 50 liters of influent wastewater and 100 liters of effluent wastewater, with a total of 5 replicates per sample. After collection, the residue retained on the sieve was carefully transferred into individual glass jars and subsequently stored at 4 ºC to maintain the integrity of the samples for subsequent laboratory analysis. The analysis of MPs in wastewater was adapted from a method developed by National Oceanic and Atmospheric Administration (NOAA) [9]. The number of MPs present and MP shapes were analyzed by using a stereomicroscope (Olympus, SZ61TR) at a magnification of 45X. The polymer types of MPs were identified using a Fourier transform-infrared spectrophotometry (FT-IR, Bruker Alpha II) in attenuated total reflectance (ATR) mode.

Results and Discussions

Wastewater characteristics and removal performance

Wastewater characteristics and removal performance of high-rise condominium A's OWTS are shown in Table 2. In accordance with wastewater effluent standards for buildings in Thailand, the pH values, SS concentration, and BOD concentration of OWTS effluent met the required quality standards. The pH values of wastewater in the OWTS were near neutral, ranging within the suitable range for the growth of bacteria (between 6.5 and 7.5) in the biological treatment process [11].

The efficiency of OWTS in removing SS, VSS, BOD, and COD in wastewater was relatively high (>80%) and the NH_4-N removal rate was 75%, the removal performance of condominium A's OWTS was similar to the removal performance of mini-sewage treatment plants with activated sludge that operating normally in the study of Marzac et al. [10]. Conversely, Micek et al. [12] found that household WWTPs with activated sludge achieved removal efficiencies of 17% and 48% for TSS, these low efficiencies are due to the significant proportion of TSS (>60%) was removed in the preliminary settling tanks (septic tanks), in addition to the mechanical treatment occurring in preliminary settling tanks, the wastewater retention time has also improved the sedimentation process of solids in each stage.

Over the course of a 20-week monitoring period, the BOD concentration in the effluent did not surpass the building effluent quality standard, which dictates that it must not exceed 20 mg/L [2] as shown in Figure 3. Throughout this duration, the BOD treatment exhibited an average efficiency of 94.8±3.21%. In the research study investigating the efficiency of two household WWTPs with activated sludge conducted by Micek et al. [12], it was found that the BOD removal efficiency was 83% and 66%. In addition, Rodrigues Mesquita et al. [13] also found effective removal of high BOD levels in three decentralized WWTPs consisting of septic tanks and anaerobic filters, with average annual efficiencies of BOD removal at 78%, 80%, and 93%. The higher BOD removal efficiency (97%) was found in the study on the use of a low-cost ceramic filter bioreactor (CFBR) for treating effluent from septic tanks in small communities in Saudi Arabia, conducted by Alresheedi et al. [14].

In general, untreated wastewater typically has a BOD/COD ratio ranging from 0.3 to 0.8 and treated wastewater has a BOD/COD ratio ranging from 0.1 to 0.3. If untreated wastewater has a BOD/COD ratio greater than or equal to 0.5, the wastewater is considered easily treatable by biological treatment, if the ratio is below approximately 0.3, it suggests that the wastewater might contain some toxic substances or may be required the acclimated microorganisms in its stabilization [11]. The influent wastewater entering the OWTS has a BOD/COD ratio of 0.32±0.12, while the effluent wastewater from the OWTS has a BOD/COD ratio of 0.13±0.10. Although the BOD/COD of the influent wastewater was not less than 0.3, but the biological degradation process of the activated sludge system in Condominium A's OWTS may proceed slowly. Therefore, it might be necessary to consider adding suitable bacterial strains to support the biological treatment [15].

The conventional process for nitrogen removal from wastewater includes nitrification followed by denitrification process [16]. The influent nitrogen primarily exists as soluble ammonia. In the process of nitrification, ammonia nitrogen is oxidized to nitrite nitrogen, which is relatively unstable, and then nitrite nitrogen is further oxidized to nitrate nitrogen. This process relies on nitrifying bacteria and occurs under conditions with oxygen [11, 17]. From the concentration of NH_4-N, NO_2^--N, and NO_3^--N in the influent and effluent in Table 1, The decrease in NH_4-N concentrations, along with the increase in NO_2^--N, and NO_3^--N concentrations in wastewater demonstrates that the nitrification process proceeded properly within the OWTS of condominium A.

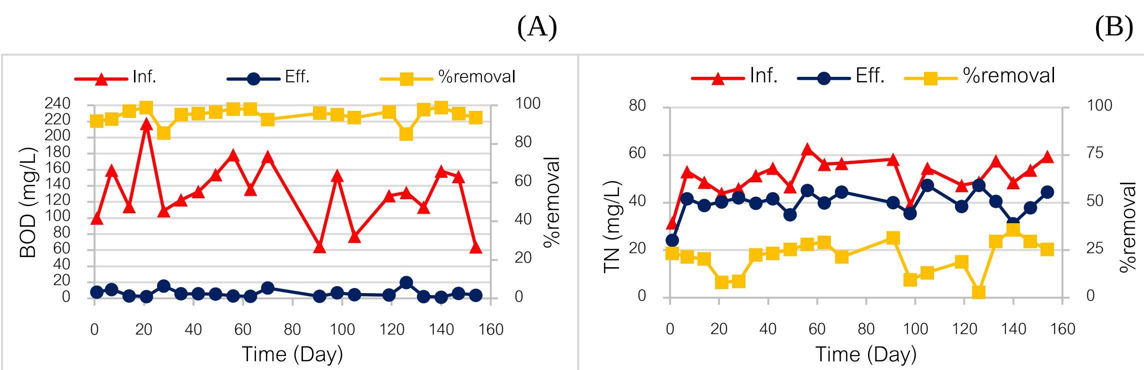

Figure 3 BOD removal performance (A); TN removal performance (B)

Table 1 Laboratory study results of wastewater characteristics

No.	Parameter	STD*	Sample**		Removal rate
			Influent	Effluent	
1	pH	5 - 9	6.66±0.29	6.71±0.21	
2	SS (mg/L)	30	180.84±83.78	24.23±20.01	82.8±15.59
3	VSS (mg/L)	-	151.41±72.03	21.42±17.63	81.5±16.59
4	BOD (mg/L)	20	132.25±38.87	6.48±4.84	94.8±3.81
5	COD (mg/L)	-	437.07±127.51	58.38±32.89	85.6±8.58
6	NH_4-N (mg/L)	-	51.26±15.29	13.10±10.65	75.0±19.61
7	NO_2^--N (mg/L)	-	0.03±0.04	5.30±4.88	
8	NO_3^--N (mg/L)	-	3.74±4.67	17.80±14.51	
9	T-N (mg/L)	-	50.92± 7.44	39.76±5.46	21.4±8.85
10	*E. coli* (CFU/mL)	-	$5.39\times10^4\pm5.97\times10^4$	$4.70\times10^3\pm8.04\times10^3$	$1.44log_{10}$

* STD= water quality standards of building effluent in Thailand [2]

**20 samples of influent and 20 samples of effluent were analyzed for all parameters

The efficiency of TN removal by the OWTS reached a maximum of 35.67% throughout the sampling period as shown in Figure 3. The TN removal performance of the OWTS in condominium A is relatively low, similar to the research conducted by Micek et al. [12], which found that the efficiency of TN removal in two household WWTPs utilizing activated sludge systems was at 21% and 34%, resulting in high concentrations of TN, NO_2^--N, and NO_3^--N in the effluent due to the insufficient capability of WWTPs with activated sludge to create suitable conditions for the denitrification process.

The average efficiency of *E. coli* elimination by the onsite treatment system in condominium A was $1.44\log_{10}$. Throughout the sampling period, the efficiency of *E. coli* elimination by the onsite treatment system ranged from $0.22\log_{10}$ to $3.23\log_{10}$. The modification of septic tanks with anaerobic and aerobic chambers for onsite wastewater treatment provided by Abbassi et al. [18], included two modified septic tanks (MST) operated in different configurations: suspended growth biological treatment system (MST-S) and attached growth biological treatment system (MST-A), the *E. coli* removal in MST-S achieved a $2\log_{10}$ reduction, which is higher than in MST-A, where the efficiency of *E. coli* removal was approximately $1\log_{10}$, the higher *E. coli* removal in MST-S may be attributed to the formation of bioflocs, which can aggregate *E. coli* and settle them out in the sedimentation tank. However, the concentration of *E. coli* in the effluent from MST remains relatively high, ranging from 10^3 to 10^6 MPN/100mL, which may require further tertiary treatment utilization. According to the study provided by Takemura et al. [19], the down-flow hanging sponge (DHS) reactor has been utilized as a post-treatment process for sewage treatment systems operating under short hydraulic retention times (HRT) of 1 to 3 hours, the DHS reactor could reduce the concentration of *E. coli* from an order of 10^4 CFU/mL in the influent to a range of 10^1 to 10^3 CFU/mL of *E.coli* concentration in the effluent, and the removal of *E. coli* was higher than $2\log_{10}$. The integration of tertiary treatment within the OWTS of condominium A may potentially serve as a viable strategy for mitigating the concentration of *E. coli* in the effluent.

Microplastics contamination

The microplastics contamination in wastewater from high-rise condominium A is shown in Table 2. From the collection of MP samples in the influent and effluent of the OWTS of high-rise condominium A the presence of MP contamination was detected in the wastewater generated by the condominium. The concentration of MPs in the effluent water was lower than the MPs concentration in the influent water in all sampling events. This demonstrates a reduction in MPs in the wastewater after treatment by the OWTS. Rajsiri and Leungprasert [20] reported that the amount of microplastics in untreated wastewater from two high-rise condominiums near Bang Khen canal was approximately 1.48±0.06 pieces/L and 1.80±0.19 pieces/L during the dry season from December 2021 to March 2022, which differs from the concentration of microplastics detected in the untreated wastewater generated from the high-rise condominium in this study. This might be due to the varying activities of residents in different areas.

Table 2 MPs concentration in wastewater from OWTS during dry season and wet season in 2023

MPs (pieces/L)	Dry season		Wet season	
	January	March	May	June
Influent	4±0.70	5±1.15	4±0.69	3±1.23
Effluent	2±0.19	2±0.67	2±0.49	1±0.25

Remark: Each sample was analyzed with a total of 5 replicates.

The MPs in the effluent from condominium A's OWTS are eventually discharged into the environment. According to the analysis of MPs contamination in the effluent of condominium A's OWTS during the dry season and wet season, the average quantity of MPs in the effluent was 2±0.53 pieces/L and 1±0.51 pieces/L, respectively. The t-test results indicated that the average quantity of MPs in the effluent during the dry season was significantly higher than the average quantity observed in the influent. Furthermore, the abundance of MPs in the effluent of OWTS significantly differs between the dry and wet seasons ($p < 0.05$). These results are consistent with the findings of Kittipongvises et al. [21], which reported that the presence of microplastics in wastewater from the wastewater treatment plant in Nonthaburi, Thailand, was lower during the wet season compared to the dry season in both 2019 and 2020 due to the dilution caused by rainfall during the wet season. The study conducted by Flores-Munguía et al. [22] presented the counterexample, which found that the quantity of MPs in wastewater from three WWTPs in Mexico were higher during the wet season compared to the dry season and the MP removal efficiencies of WWTPs were decreased during the wet season. The high concentrations of MPs in wastewater during the wet season might result from the urban surface runoff carrying microplastics into the water cycle and the poor settleability of the MP particles due to the higher flow velocity during rainfall events [23]. In addition, heavy rainfall may induce the resuspension of microplastics in WWTP [24], resulting in a higher quantity of MPs in wastewater samples during the wet season. In this study, the presence of MPs in wastewater samples during each season may be related to the activities of resident in the condominium, particularly those related to laundering items other than clothing (such as blankets, quilt, curtains, and various fabric covers), which are often less frequent during the rainy season, possibly contributing to a lower presence of microplastic fibers released during this season. Consequently, the quantity of microplastics detected during the rainy season may be reduced compared to other seasons.

Although the analysis of MP samples has shown a decrease in the quantity of MPs in wastewater generated from the condominium after being treated by OWTS, there remains a high level of MPs in the effluent released into the environment. The discharge rate of wastewater from the OWTS of high-rise condominium A is 280.17 m^3/h. It is estimated that during the dry season, the average release of MP items into the environment per day is 13,448,160 pieces. During the wet season, an average of 6,724,080 pieces of MP are released into the environment per day. In the study conducted by Hidayaturrahman and Lee [25] which investigated the quantity of MPs in wastewater from three centralize full-scale WWTPs in South Korea, it was observed that all three WWTPs exhibited high efficiency in microplastic removal (>98%). However, despite their high removal efficiency, there was still a release of MPs averaging 47.24 billion pieces/L with an average flow rate of 172,211.3 m^3/day. Another example of a study that aligns with the finding was reported by Magni et al. [26], who found that the WWTP was not completely remove MPs from the wastewater, approximately 160,000,000 pieces of MPs were released into freshwater daily by the selected WWTP located in Italy.

In this study, it can be observed that the quantity of MPs released into the environment by OWTS of condominium A was lower than the quantity of MPs released by Centralized WWTPs. This difference may depend on the flow rate of wastewater within each wastewater treatment system, the characteristics of the wastewater sources (such as residential areas, rural regions, and industrial sources), and the distinct treatment processes employed by each wastewater treatment systems.

Shape of microplastics

The MP in this study were categorized into four shapes: fiber, film, fragment, and granule. Figure 4 shows the MP shapes found in this study. The most common shape of MPs found in the wastewater generated from high-rise condominium A was fiber. The analysis of MP samples collected from OWTS revealed that fiber was the predominant shape observed in the influent, accounting for 96.17% of total

MPs detected in the influent. Meanwhile, fragments, films, and granules were found in proportions of 3.01%, 0.74%, and 0.08%, respectively. The proportions of MP shapes found in the effluent were similar to the MP shapes found in the influent. Fibers accounted for 93.17% of the MPs detected in the influent, while fragments, films, and granules were found to be 4.90%, 1.84%, and 0.08% in the effluent, respectively. The highest proportion of fibers may be due to the shedding of synthetic textile fibers into wastewater during laundry [27, 28]. While granules, which is the spherical shape MP that may originate from breakage during production processes or be microbeads, which are primary microplastics produced for use in personal care products [29] have rarely been found in this study, align with Thailand's law effective since January 1, B.E. 2563. This law was introduced through Notification of the Ministry of Public Health (No.2) B.E. 2562, which banned the manufacture, import, or sale of cosmetics containing microplastic components [30].

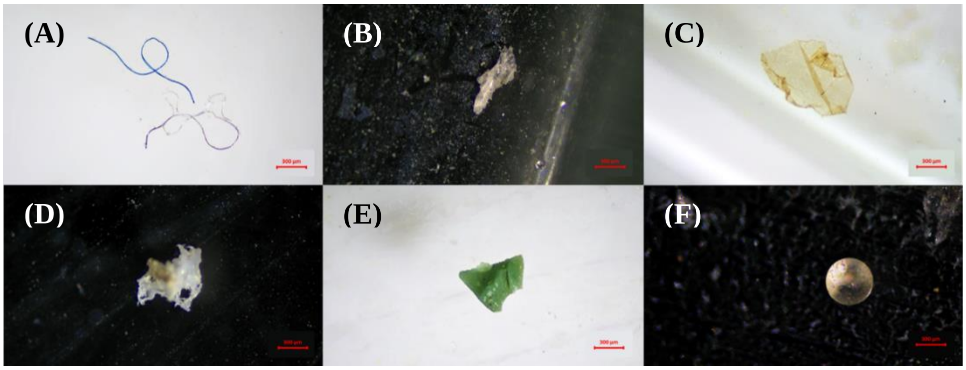

Figure 4 Shapes of microplastic (from influent wastewater) captured from stereomicroscope (Olympus, SZ61TR): Fiber (A); Film (B, C); Fragment (D, E); Granule (F)

Polymer of microplastics

From a random sample of 12 pieces of MPs for analyzed using Fourier transform-infrared spectrophotometry, the identified types of MP polymers were Polyethylene terephthalate (PET), Polypropylene (PP), and Low Density Polyethylene (LDPE) in quantities of 7, 2, and 2 pieces respectively, consistent with the findings of Rajsiri and Leungprasert [20], which indicated that PE, PP, and PET were the polymer types most commonly found in the highest proportions in domestic wastewater. Furthermore, this study also found 1 piece of the MP samples was Polydimethylsiloxane (PDMS), which is classified as a silicon elastomer polymer commonly used in various fields such as microfluidic systems, medical devices, electronic components, coatings, and may be found in daily life products such as plastic bags and synthetic fibers [31]. Similarly, Me Maw et al. [32] also detected the PDMS microplastic in wastewater from a WWTP located at a university in Thailand. However, PDMS has been rarely reported due to its minimal presence in the environment [33].

Conclusion

The performance of OWTS from the high-rise condominium building was relatively good with a removal rate for SS, VSS, BOD, COD, and NH_4-N at 82.75%, 81.55%, 94.80%, 85.60%, and 75.0% respectively. The *E. coli* could be treat at 1.44$\log_{10}$. However, the total nitrogen removal rate was low with 21.4%. The nitrogen content in wastewater released into aquatic ecosystems becomes nutrients for phytoplankton. High levels of nutrients accelerate alga blooming, increasing the amount of algae covering the water surface. Consequently, the dissolved oxygen levels in the water decrease, leading to the decay of aquatic ecosystems. To achieve higher nitrogen removal performance, adding a treatment unit specifically designed for nitrogen removal could be suitable.

The presence of MPs in wastewater generated from the high-rise condominium building was detected in both influent and effluent of OWTS. The amount of MPs in wastewater decreased after being treated by the OWTS. Nevertheless, a significant amount of MPs in wastewater are still released in to the environment daily, even when treated by the OWTS. Fiber-shaped MPs were the most found, followed by fragments, films, and granules, respectively. Although there has been a law banning the manufacture, import, or sale of cosmetics containing MP components in Thailand that has led to a rare presence of granule-shaped MPs, but other shapes of MPs are still generally present. To reduce the amount of MPs in domestic wastewater that could be released into the environment, it might be achieved through legislation to reduce the production and sale of plastic products, especially synthetic fabrics, which are the origin of MP fibers that were commonly found in the highest proportions in wastewater. Additionally, studies and standards established for wastewater treatment systems should include considerations the effective removal of microplastics from wastewater before discharge into the environment, minimizing environmental impact.

The polymer type of MPs in wastewater was PET, PP, and LDPE, which are commonly polymers found in domestic wastewater. Additionally, another polymer type detected was PDMS.

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