The Abundance and Characteristics of Microplastics in Central Industrial Wastewater Treatment Plants

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***Abstract*—Central industrial wastewater treatment plants (WWTPs) are an important source of microplastics in the environment. This study investigated the microplastics present in WWTP from two industrial estates in Thailand. Both WWTPs (WWTP A and WWTP B) operate with an activated sludge process. The result showed that the abundance of influent, post sediment tank, and RO process of WWTP A was 101.87 ± 0.47, 11.04 ± 0.08, and 0.44 ± 0.04 particles/L, respectively. On the other hand, the abundance of influent and effluent of WWTP B was 148.44 ± 0.91 and 33.53 ± 0.55 particles/L. The removal rate of microplastics showed 89.22% for WWTP A, 77.54% for WWTP B, and the highest in the tertiary process (99.54% for reverse osmosis system (RO) process from WWTP A). In addition, shape, size, colors, and polymer were detected. Most of the microplastics from both WWTPs were pellet (46.14 and 56.82%), ranging (20-212 µm), and white/clear. Based on the FTIR result, polypropylene (PP) and polyethylene (PE) were the most common polymer types.**

***Keywords*—FTIR, Microplastics, Removal, Wastewater treatment plant**

I. INTRODUCTION

Plastic is the biggest problem in the world due to a large number of usages in the past and has increased every year. Most problems are caused by improper disposal that directly release into nature. Microplastics are particles resulting from plastic degradation and have a particle size of less than 5 micrometers [5], [9], [20]. Microplastics are categorized based on the type of polymer, such as polyethylene made from the combination of ethylene monomers. They can be classified into two categories: primary microplastic originated from plastic industrial or personal care products such as scrub with beads of plastic components and secondary microplastic resulting from the breakdown of large plastics. Because of its small particle, microplastic can be released into the environment and easily moved to a different phase. Microplastics have also been detected in various environments including mangroves [14], atmospheric [15], and aquatic ecosystems [11], [12], [24]. Additionally, they have been transferred and accumulated in a wide range of aquatic organisms including bivalves, seahorses, crustaceans, and fish by mistake and ingestion through the food web [1], [10]. Furthermore, microplastics can act as a carrier for pollutants such as pesticide chlorpyrifos [8] along with heavy metals such as copper and zinc [21] and contaminate the aquatic system. This may have direct physical and chemicals effects on aquatic life.

The rapid development of industries and wide application of plastics as important materials has led to the abundance of these pollutants. Effluent from WWTP is an important source that can directly discharge microplastics into the environment. Reference [13] collected effluent water from a lake with discharged waste from a municipal WWTP in Finland. The result found that a fraction of microplastics can pass out of the treatment plant. Reference [2] also highlighted the trophic transfer of microplastics and implications for human health by seafood.

Thailand is an important industrial source of plastic products. Consequently, several plastic particles release into the main river and the Gulf of Thailand. There are only a few studies on the presence of microplastics in the influent and effluent from WWTPs [9], [19], especially from industrial WWTPs which might be a huge source of microplastics contamination in the environment. This work is one of the first studies about the fate of microplastics in central industrial WWTPs in Thailand. Analyses of concentration, characteristics, and type of microplastics in two central WWTPs from industrial estates in Thailand were performed.

II. MATERIAL AND METHOD

A. Study site and sampling points

Wastewater was collected from two central industrial estates (WWTP A and WWTP B) in October 2020. WWTP A has a capacity of 20,500 m^3/day and serves wastewater from approximately 200 factories, mainly automotive, electronics, and industrial plastic. WWTP B can service wastewater up to 18,600 m^3/day from approximately 146 factories which are automotive, transportation, and electronics. Both WWTPs are operated based on an activated sludge system. WWTP A, in particular, has reverse osmosis (RO) unit to recycle some treated wastewaters.

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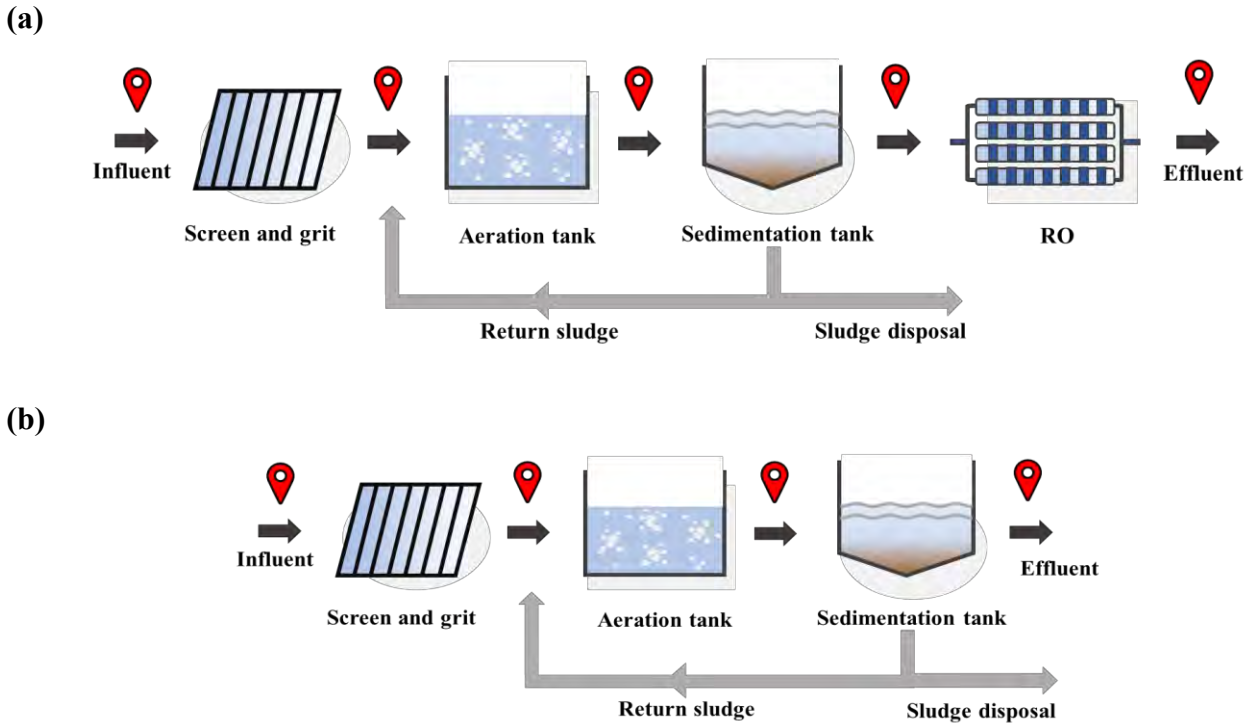

Fig 1. Flow chart of the central industrial wastewater treatment process in (a) WWTP A and (b) WWTP B with water sampling point ( ).

For WWTP A, water samples were collected from 5 points i.e., influent, post grit chamber, post aeration tank, post sedimentation tank, and RO. Water samples from WWTP B were collected from 4 points i.e., influent, post grit chamber, post aeration tank, and post sedimentation tank as effluent (Fig.1). All water samples were kept in 15 L containers at the depth of 12-15 cm from the surface. At each station, samples were sieved through an 8-in diameter steel sieve with 500, 212, 100, and 20 µm of mesh size and rinsed with deionized water into glass bottles. To prevent further microbial growth, samples were stored in a container at 4°C.

B. *Identify the characteristics of microplastics*

Samples were dried by oven at 60 ± 5 ºC for 24 hours. 30% H_2O_2 solution and 20 mL of 0.05 M Fe (II) solution, known as Fenton's reagent, were added to a beaker and accelerated the reaction by heating in a hot plate at 60 ± 5 ºC until the solution is clear. Samples were obtained through the density separation method with 20 mL of NaCl (1.2 g/cm^3) and settled in a separatory funnel for 24 h. Supernatants were filtered onto a 0.45 µm nitrocellulose membrane (Sartorius filter) by vacuum filtration. Residual sediment was added to 10 mL of NaI (1.69 g/cm^3) to ensure effective separation and filtered after the mixed solution settled in the separatory funnel. The funnel was then washed with distilled water and filtered. Residual microplastics on filters were dried in glass petri dishes at room temperature for identification. Processes were developed and supported by the National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program. In addition, the particles were classified into four shapes i.e., fiber, pellet, film, and fragment by stereomicroscope (NSZ-405J3 Olympus). During the analysis, attenuated total reflectance – Fourier Transform Infrared Spectroscopy (ATR-FTIR PerkinElmer Spectrum IR 10.6.2) was used to determine the types of microplastics for all samples with a resolution of 4 cm^{-1} in the scanning range of 800 – 4000 cm^{-1}. Spectra were then compared to the libraries provided by PerkinElmer.

C. *QA/QC*

To avoid contamination, all equipment was washed with tap water and twice with deionized water before use. In laboratory analysis, the operator wore a laboratory coat and gloves during sampling or analysis. The use of plastic lab materials was limited to the entry. Laboratory benches were wiped with deionized water and cellulose tissue before each measurement. Field blank samples for both sites were collected during sampling while laboratory blank was taken by nitrocellulose membrane placed in a petri dish without cover for 8 h.

D. *Data analysis*

Microplastic particles were reported as particles/L. The particle was characterized as triplicate and presented as mean ± standard deviation. A paired t-test with a p-value < 0.05 was conducted for the differences in microplastics content in each unit.

III. Result and Discussion

A. *Microplastics abundance and treatment efficiency*

Field blank tests of WWTPs A and B were 10 and 16 particles/L, respectively while background blank was undetected. These amounts were lower than 10% of the average microplastics found in this work, indicating proper contamination control as suggested by [16].

Microplastics were found in every unit of both WWTPs. The abundances of influent and effluent of WWTP A were 101.87 ± 0.47 and 11.04 ± 0.08 particles/L, respectively. The microplastic removal efficiency was 89.22% (P=1.19E-05). On the other hand, microplastics found in WWTP B from influent and effluent were lower than that of WWTP A which are 148.44 ± 0.91 and 33.53 ± 0.55 particles/L, respectively, with a removal efficiency of 77.56% (P=5.30E-05) (Fig. 2). The heightened removal percentage of microplastic particles was 84% and 58% through the sedimentation tank from WWTP A (P=2.44E-05) and WWTP B (P=6.10E-05), respectively. This is probably because microplastic particles may attach with microorganisms and tend to settle at the bottom of the unit [20]. From WWTP A, RO performed microplastic removal efficiency of 99.54% (P=7.014E-06). The removal efficiency within the secondary treatment process showed that WWTP A was higher than WWTP B and the highest by tertiary treatment process [4], [13], [17].

Microplastic particles slightly increased from influent and post grit chamber in both WWTPs (WWTP A from 101.87 ±

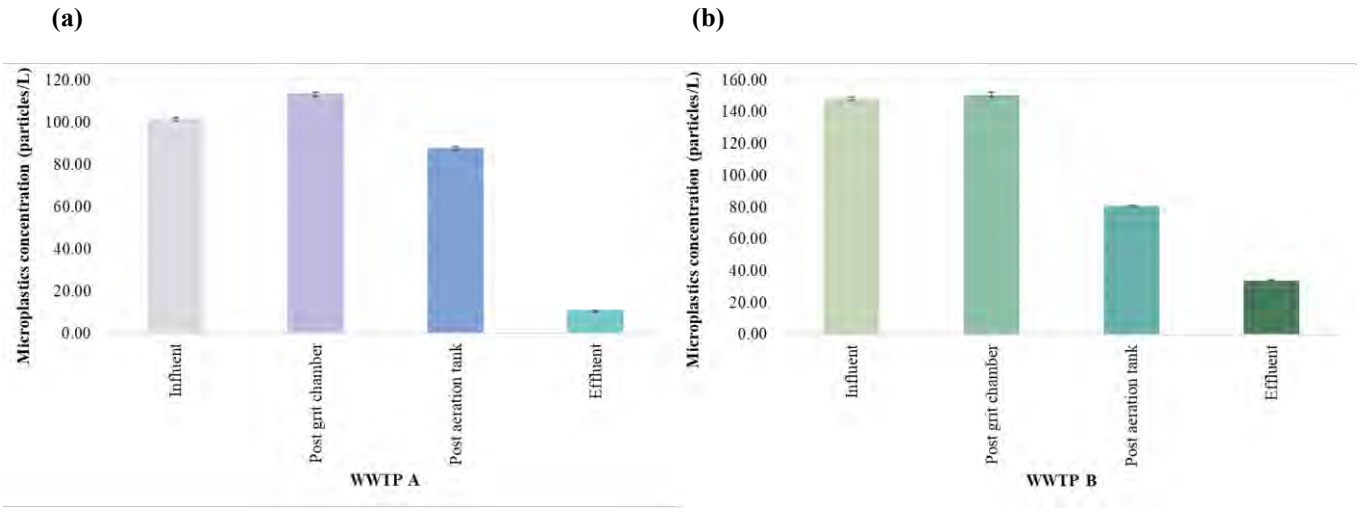

Fig 2. Abundance of microplastics in WWTPs.

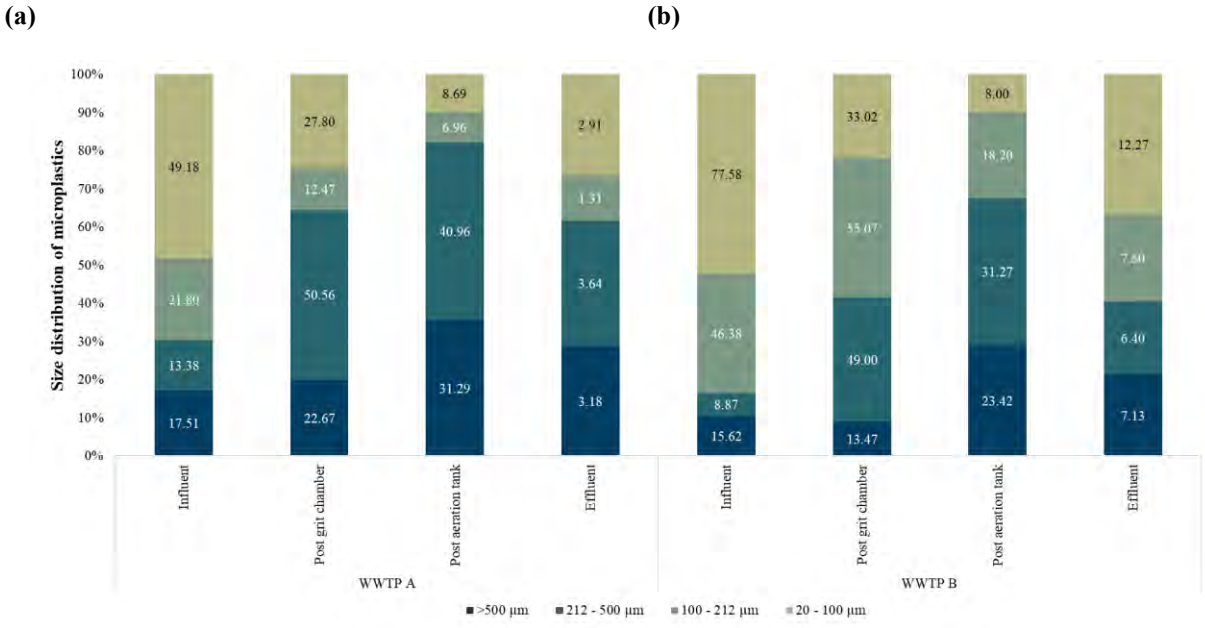

Fig 3. Size distribution of microplastics in wastewater units from both sites.

0.47 and 113.49 ± 0.71 particles/L, respectively and WWTP B from 148.44 ± 0.91 and 150.56 ± 1.83 particles/L, respectively) as shown in Fig. 2 and obviously decreased in the aeration tank. Reference [9] also found a similar concentration of microplastic particles in the influent and grit chamber. It was possible that primary treatment processes had no ability to remove microplastics. However, it may attach high density and large size of particles on sand and grit [23] and the light particles float before entering the next process [5], [22].

B. Characterization of microplastics

As shown in Fig. 3, the most detected size of microplastics found in WWTP A was 212-500 µm followed by 20-100 µm, > 500 µm, and 100–212 µm. In contrast, 20-100 µm was the size of most microplastics detected from WWTP B followed by 100-212 µm, 212-500 µm, and >500 µm. However, there was no significant difference in size distribution from both plants (P=0.315). The breakdown of large plastics leads to many sizes of microplastics. The size of most microplastics found in WWTP was different. For example, reference [19] found that the main size was 0.05-0.5 mm whilst reference [7] reported that the major size was 100–355 µm. in WWTP.

From both sites, trends in the microplastic distribution of various sizes were similar. At the influent, post grit chamber, and post aeration tank, the number of small particles was decreased while larger particles were increased in order. This could indicate that the flotation of small particles with low density and wide surface area was removed. In contrast, in the post aeration tank from both sites, smaller microplastic particles were increased and the larger was decreased. In addition, microplastic can crack and pit under physical and chemical actions such as wave, wind, and UV radiation bacteria [3], [12],

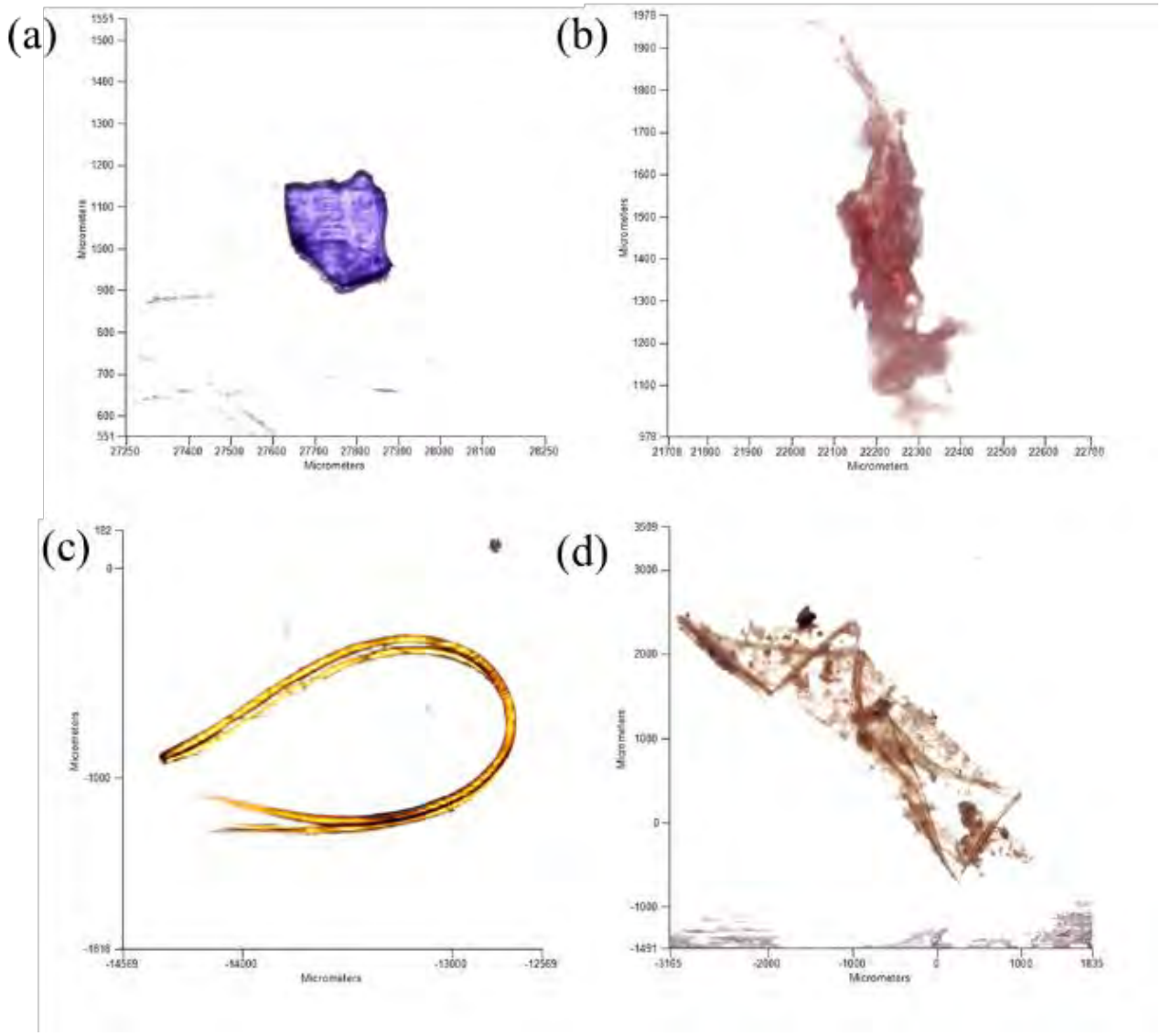

Fig 4. Characterization of microplastic particles (a) pellet, (b) fragment, (c) fiber, and (d) film from both WWTPs by FTIR.

[18]. Some larger particles can also be broken by the friction force of the aeration tank [22].

The characterization of microplastics from FTIR is shown in Fig. 4. This work categorizes the shape of microplastics as pellet, fragment, fiber, and film (Fig. 5a). Pellets presented the main shape of both study sites (56.82% from WWTP A and 46.17% from WWTP B) followed by fiber (26.18%), film (13.20%), and fragment (3.80%) from WWTP A and fragment (20.41%), fiber (17.44), and film (15.98) from WWTP B. Pellet is a secondary microplastic broken down from consumer products including construction materials, container, and decorating materials used in a variety of industrial processes. Fiber was the most frequently observed size of microplastics from several studies [4], [13]. However, reference [17] indicated that among the type of microplastics, fragment has the highest percentage (65%) in wastewater. Reference [20]'s study found that in the comparison of two WWTPs, less fiber and film were detected in one WWTP, while more microbead and fragments were found in another one.

As shown in Fig. 5(b), the colors of microplastics from WWTP A were mostly composed of white/clear (38.66%) > black (14.53%) > yellow (12.46%) > pink (11.72%) > red (9.59%) other (5.24) > green (3.91%) > blue (3.82%) > purple (0.08%). In WWTP B, the color range include purple (19.43%) > white/clear (19.31%) > black (13.21%) > pink (9.86%) > other (9.18%) > green (9.06%) > red (7.27%) > yellow (7.04%) > blue (5.67%). The observed microplastics were mostly white/clear and black (P=5.30E-05) similar to the study of [20] that found more than 80% of total microplastic particles were white/clear and black. Reference [6] also reported that the most

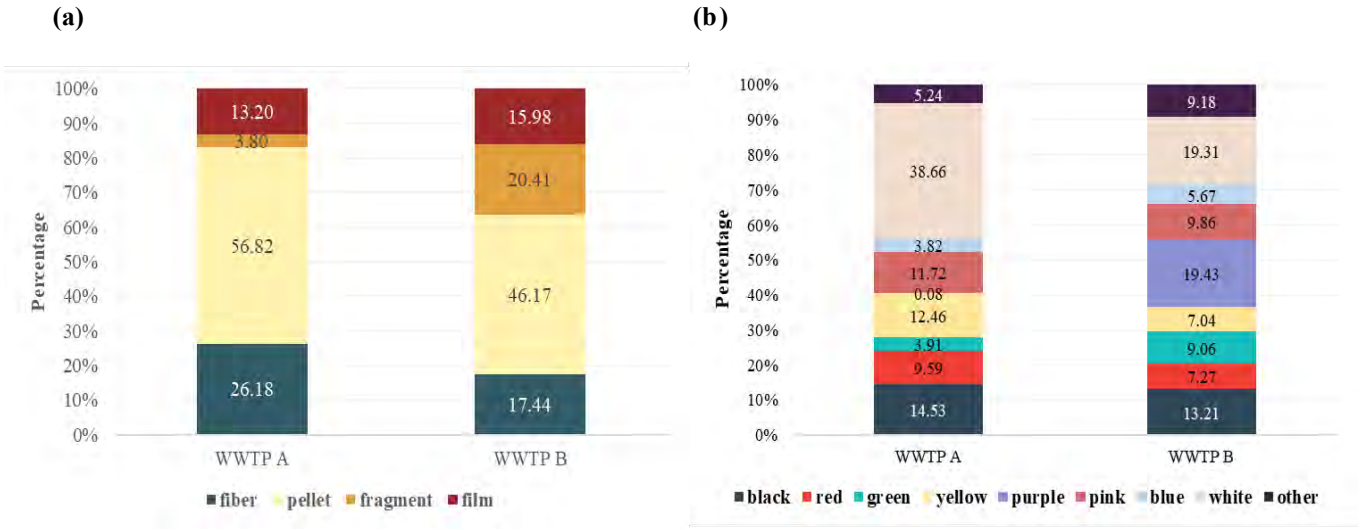

Fig 5. Percentage of (a) microplastics shape and (b) microplastics color from both WWTPs.

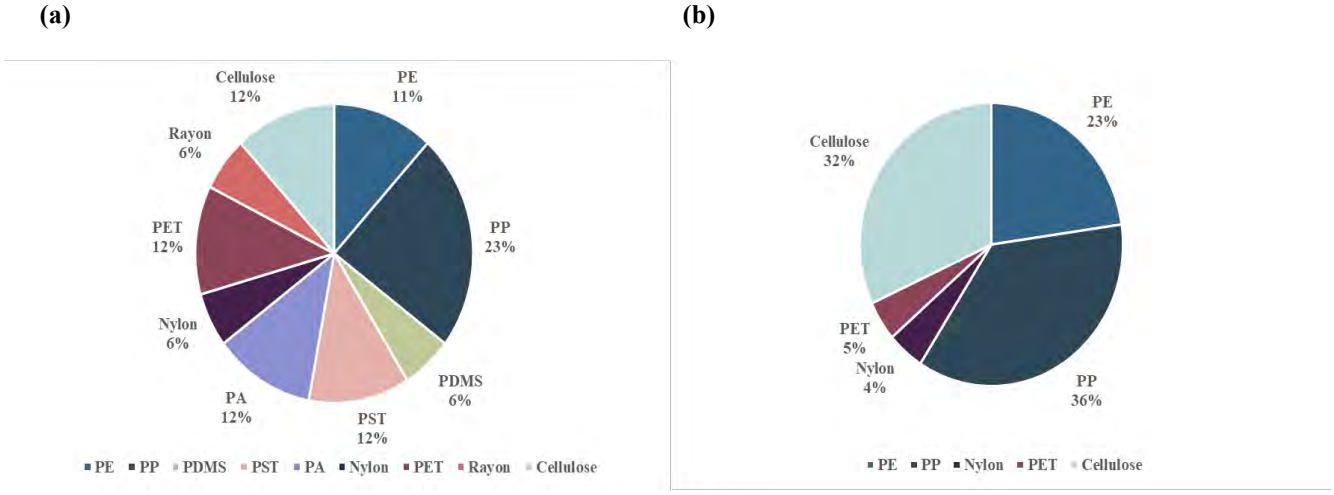

Fig 6. Proportion of microplastics (a) WWTP A and (b) WWTP B.

common colors were white/clear (60%) and black (22%). Colors can be used to identify the sources of microplastics. White/clear and black microplastics are from a wide range of sources such as packaging, plastic bag, and bottle. In addition, the original bright color of microplastics can be changed to white/clear and black due to oxidation, aging of the dye by UV irradiation, and soaking in the WWTP. Regardless of the different research, the results of microplastic colors were similar [22].

The suspected microplastic particles were randomly analyzed for identification by FTIR, as shown in Fig. 6. A total of 8 polymer types were detected: polyethylene (PE), polypropylene (PP), polydimethylsiloxane (PDMS), polystyrene (PS), polyamide (PA), polyethylene terephthalate (PET), Nylon, and Rayon. Non-microplastic particles were identified as paint, rubber, additives, cellulose, and others. The results showed that 75 samples were detected and 30 microplastics were found. The highest percentages of microplastic polymer from WWTP A were PP (23%) followed by PET (12%), PS (12%), and PE (11%), and PP (36%) followed by PE (23%) and PET (4%) from WWTP B. In addition, nylon was detected in both sites. PP, PE, and PET are commonly and widely used in packaging material. It has been suggested that some portion of these particles are likely to escape the drainpipe by clean surface.

IV. Conclusion

This study investigated the abundance and characteristics of microplastics in central industrial wastewater treatment plants in Thailand. The abundances of effluent were 11.04 ± 0.08 and 33.53 ± 0.55 particles/L from WWTP A and WWTP B, respectively, with heightened removal efficiency by sedimentation tank. The study also recorded a removal efficiency of 89.22% for WWTP A and 77.54% for WWTP B within the secondary process and the highest in the tertiary process (99.54% for RO process from WWTP A). The result showed that pellet was the main shape of microplastics. The main colors of microplastics were white/clear and black. Different range of sizes was observed; the most common size of microplastics found in WWTP A and WWTP was 212-500 µm and 20-100 µm, respectively. According to FTIR results, PP and PE were common polymer types. However, there were a large number of microplastics released into the environment with the effluent during the treatment process. We estimated that around 624 million and 226 million microplastics per day were discharged from WWTP A and WWTP B, respectively. Therefore, WWTP may be one of the most important sources of microplastics pollution in nature. Moreover, microplastics may adsorb other toxic substances such as heavy metals and increase toxicity on aquatic living. The removal efficiency of WWTP needs to be further improved for microplastic removal.

Acknowledgement

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