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Nutrient Removal Efficiency of a Fibrous Polypropylene Biofilm Reactor in Pilot Scale

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***Abstract* -** Dong Hai shopping district's discharge wastewater polluted the Dong Da stream. Therefore, The wastewater treatment plant was established to solve the problem, it decomposed the pollutant by biofilm that attaches to fibrous polypropylene(FB) in biological treatment process. Biofilm growth can directly affect the efficiency of wastewater treatment, but it was affected by the organic loading rate(OLR). This study referred to the wastewater treatment plant's biological process to set up the pilot scale. The purpose of setting up a pilot scale is to simulate the wastewater treatment plant's operation and observe biofilm's performance under different OLR. The average amount of COD removal in anaerobic reactor and aerobic was 129.2 mg/L and 310.6 mg/L when OLR was high, respectively, because the biomass was growing well. Biomass decreased when OLR was decreased, the average amount of COD removal in anaerobic reactor and aerobic was 15.2 mg/L and 13 mg/L, respectively. This indicated the removal efficiency of COD and the growth of biofilm were affected by OLR. Therefore, the relationship between the OLR and the growth of biofilm can be understood, and good wastewater treatment efficiency can be achieved.

***Keywords*:** organic loading rate, biofilm, COD removal, wastewater treatment, pilot scale

1. Introduction

Dong Hai shopping district has many restaurants, households, and shops. Due to that district's large visitor flow rate, the amount of wastewater discharged varies greatly and polluted the Dong Da stream seriously. Therefore, a wastewater treatment plant was built to solve the pollution problem of Dong Da stream. The wastewater treatment plant used pebbles and fibrous polypropylene(FP) as the biofilm adherence carriers and used biofilm to decompose the organic pollutants in water. Biofilm played an important role in biological wastewater treatment. Its growth can directly affect the efficiency of wastewater treatment, but the growth of biofilm was affected by the organic loading rate(OLR). In order to explore the efficiency of biofilms under different OLRs, a bioreactor of the wastewater treatment plant in pilot scale was set up in this study. Since the FB carrier has a larger specific surface area than the natural pebbles, more biofilm could grow on it, so the removal efficiency of the FB was higher than pebbles. Therefore, this study mainly discussed the removal efficiency of the reaction tank with FB carriers.

2. Materials and Methods

The purpose of establishing the pilot plant was to simulate the operation of the biological process in the wastewater treatment plant. The pilot plant consisted of an anaerobic reactor, two aeration tanks with FB carriers, a sedimentation tank, an aeration tank with pebbles, an anoxic tank and a sludge storage tank. The bioreactor of the wastewater treatment plant is underground as shown in Figure 1 and the real pilot plant and schematic diagram are shown in Figure 2.

Fig. 1: wastewater treatment plant's pretrement system is shown in right figure and the bioreactor is underground as left figure.

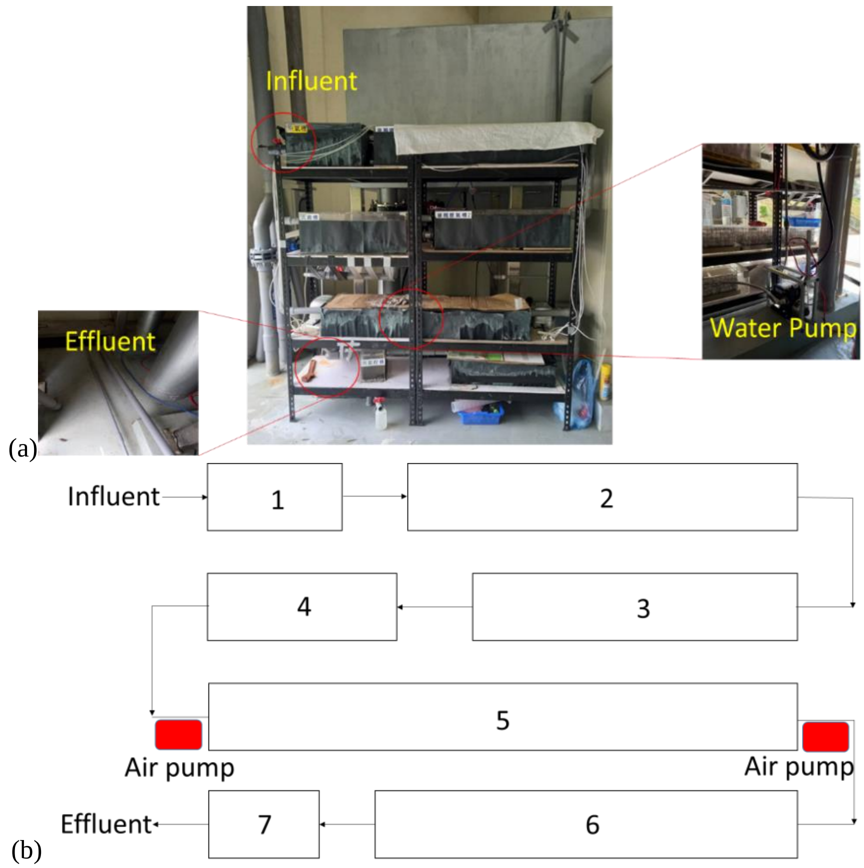


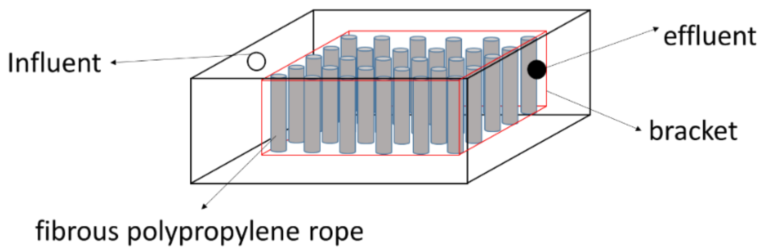
Fig. 2: (a) Real pilot plant (b) The schematic diagram of pilot plant
1: Anaerobic Reactor;2: Primary Aerobic Reactor with Fibrous Polypropylene Biofilm;3: Secondary Aerobic Reactor with Fibrous Polypropylene Biofilm;4: Sedimentation Tank;5: Aerobic Reactor with pebbles Biofilm;6: Anoxic Reactor with pebbles Biofilm;7: Sludge Storage Tank

2.1 The structure of the bioreactor

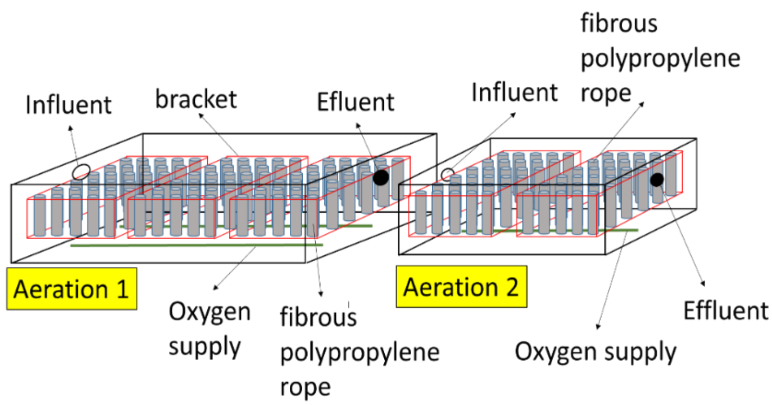
In the bioreactor, biofilm was growing on FB adherence carriers for of pollutants in the wastewater. The FB carrier is a rope shape material, shown in Figure 3, with a specific surface area of 3.1 m^2/m^3.


Fig. 3: FB carriers

To simulate the environment in the reactor of wastewater treatment plant, the FB carrier was fixed on the metal bracket first and then the bracket was put into the anaerobic reactor and aeration reactor. The volume of the anaerobic reactor and aeration reactor were 0.0380 m^3 and 0.132 m^3 , respectively, and the structure of each reactor is shown in Figure 4.



(a)



(b)

Fig. 4: (a) The structure of anaerobic reactor in pilot plant; (b) The structure of aeration reactor in pilot plant

2.2 Pilot plant operation

The wastewater was taken from the wastewater treatment plant at Tung Hai University as the influent of pilot plant. The pilot plant used continuous gravity flow for water flowing and the influent's flow rate was adjusted to control the hydraulic retention time (HRT) by valves. The total HRT of the FB reactor was 4 hours and 43 minutes, which was set up according to the HRT of biological reactor in wastewater plant, and the flow rate was 0.864 m^3/d. The aeration method was carried out by air pump with an air flow rate of 400 L/min.

2.3 Wastewater sampling and analysis

The effluent water samples of the reaction tank were taken according to the HRT of each reaction tank, and the HRT of the anaerobic tank and aeration tank of the pilot scale was 1 hour 3 minutes and 3 hours 40 minutes, respectively. The Influent flow rate was obtained by the container method [5]. To check the wastewater quality, this study analyzed COD concentration in wastewater by COD digestion method [8], suspended solid by total dissolved solids and suspended solids in water—drying at 103-105°C method [4] and dissolved oxygen by electrode method [3].

2.4 Biofilm sampling and analysis

Due to the difficulty in collecting biofilm from the reactor, it was necessary to prepare another carrier made of the same material as the FB carrier in the pilot reactor as the biofilm adherence carriers, with the FB carriers provided by Kai Shin Incorporation company. Generally, it takes at least ten days for sludge to grow to a steady state [2]. After the biofilm incubation was completed, the biofilm samples were taken directly from the anaerobic tank and the aeration tank according to each HRT. The biofilm from FB carriers was analyzed by the analytical method of total solids, fixed and volatile solids in sludge [7].

2.5 Formula

The HRT of the pilot scale was calculated by equation (1), where Q is the influent flow rate (m^3/day), and V is the reactor's volume (m^3). The HRT was adjusted by controlling the influent flowing valve. The removal efficiency is indicated by equation (2) and equation (3), where OLR is the organic loading rate(kg COD/m^3/day), C is the COD concentration (mg/L), C_{inf} is the COD concentration in influent and C_{eff} is the COD concentration in effluent. The biofilm concentration was determined by equation (4), where X is the biofilm concentration on the carrier (mg SS/g FB carrier), m_2 is the mass of the dry carrier that includes biofilm and m_1 is the mass of the dry carrier without biofilm.

$$\mathrm{HRT} = \frac{V}{Q} \tag{1}$$

$$\mathrm{OLR} = \frac{Q \times C}{V} \tag{2}$$

$$\Delta\mathrm{COD} = C_{inf} - C_{eff} \tag{3}$$

$$X = \frac{(m_2 - m_1) \cdot 1000}{m_1} \tag{4}$$

3. Results and Discussion

The water quality of the discharged water from Dong Hai shopping district was easily affected by the water consumption of residents and restaurants in that area, resulting in large changes in water quality as shown in Figure 5. It was found that the concentration of COD in the water at 8 am and 9 am was low because residents and restaurants did not use too much water. The water consumption of Dong Hai shopping district increased due to restaurants' opening and residents' activities, which caused the high COD concentration in discharge water, and resulted in a peak concentration around 1 pm.

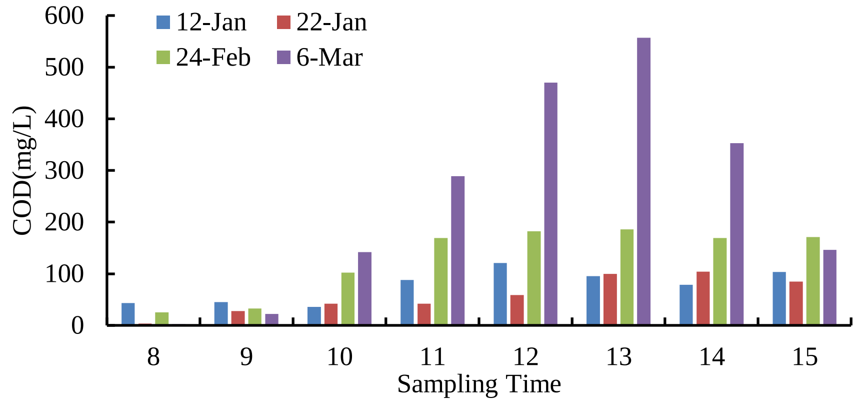
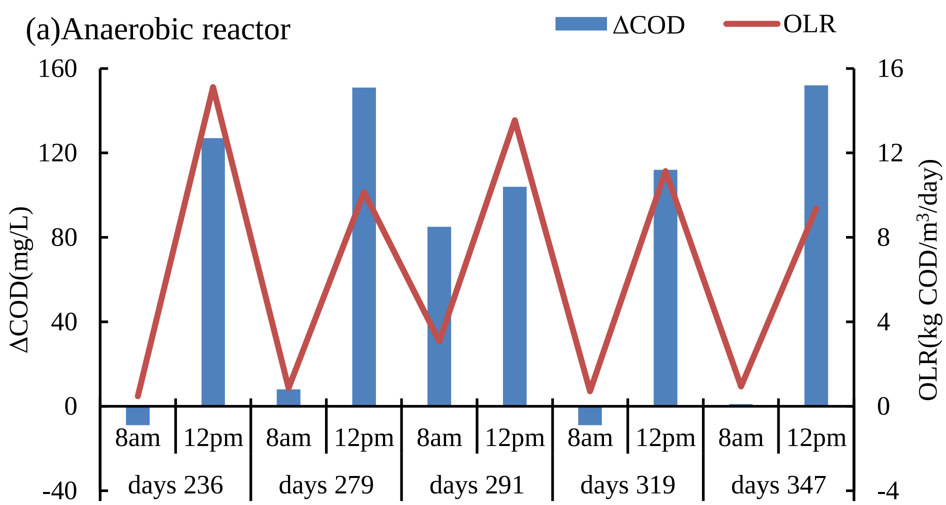


Fig. 5: The COD concentration of discharge water from 8 am to 3 pm on January 12th, January 22nd, February 24th and March 6th.

To reduce the research time and analysis costs, the discharge water at 8 am and 12 pm were chosen as representatives samples in this study. The OLR of these two periods were different, and it could be clearly observed that the treatment efficiency of the biofilm that attaches to FB carriers in the pilot was affected. Through sampling and analysis, it could be found that the biomass and COD removal rate of each FB carrier was significantly different under different OLRs, and the results are shown in figure 6.



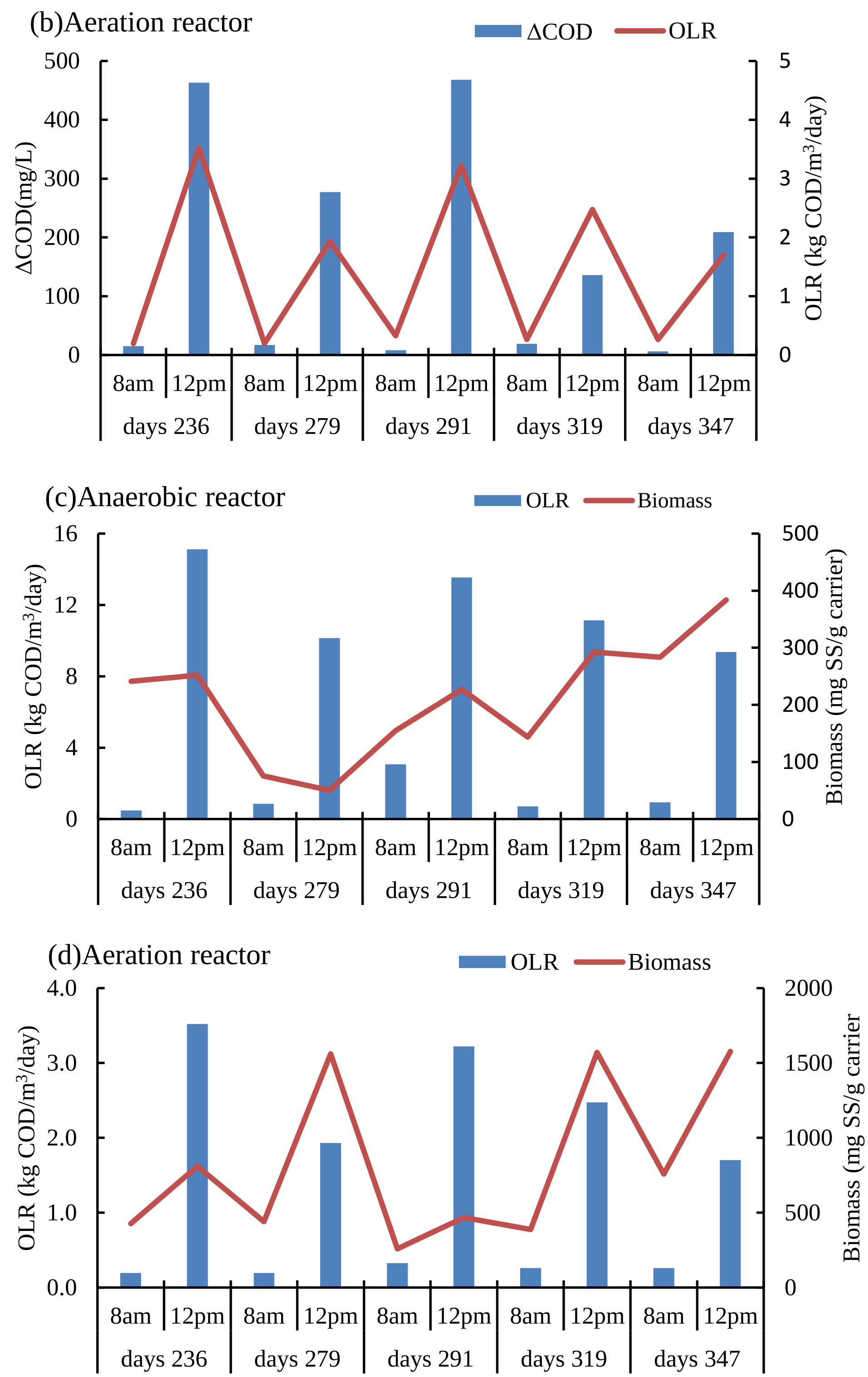


Fig. 6: (a)COD removal under different OLRs in anaerobic reactor and (b)aeration reactor on days 236, 279, 291,319 and 347; (c)Biomass growth under different OLRs in anaerobic reactor and (d)aeration reactor on days 236, 279, 291, 319 and 347

The results show that the average OLR in the anaerobic reactor and in the aeration reactor were 11.9 kg COD/m^3/day and 2.6 kg COD/m^3/day, respectively. The average COD removal and average biomass of anaerobic reactor were 129.2 mg/L and 241.1 mg SS/g FB carrier, respectively, and that of aeration reactor was 310.6 mg/L and 1196.9 mg SS/g FB carrier, respectively. When the average OLR of anaerobic reactor and aeration reactor decreased to 1.2 kg COD/m3/day and 0.2 kg COD/m^3/day, the average COD removal and average biomass of anaerobic reactor were 15.2 mg/L and 179.8 mg SS/g FB carrier, and the average COD removal and average biomass of aeration reactor were 13 mg/L and 454.4 mg SS/g FB carrier, respectively.

Biomass could grow well when OLR was high, but biomass was low when OLR decreased. At the same time, the growth of biomass also affected the COD removal capacity in the reaction tank. When OLR was less than 1 kg COD/m^3/day, the biofilm was loose and unstable, which affected the growth of biofilm. When the OLR was 4 kg COD/m^3/day, the growth of biofilm was stable and robust [1]. Therefore, the lower OLR of the influent water results in a decrease in biomass and a decrease in COD removal. The influent water in the afternoon had a higher concentration of COD also provided sufficient substrate concentration for the growth of biofilm, which improved the COD removal capacity of the bioreactor tank.

Although the COD concentration of the influent water in the morning was not enough to allow the biofilm to grow well to achieve good removal efficiency, the COD concentration of effluent water in the morning still met the legal standards for discharge water, because the COD concentration of influent water already met the discharge standard. The COD concentrations of the influent and effluent water are shown in figure 7.

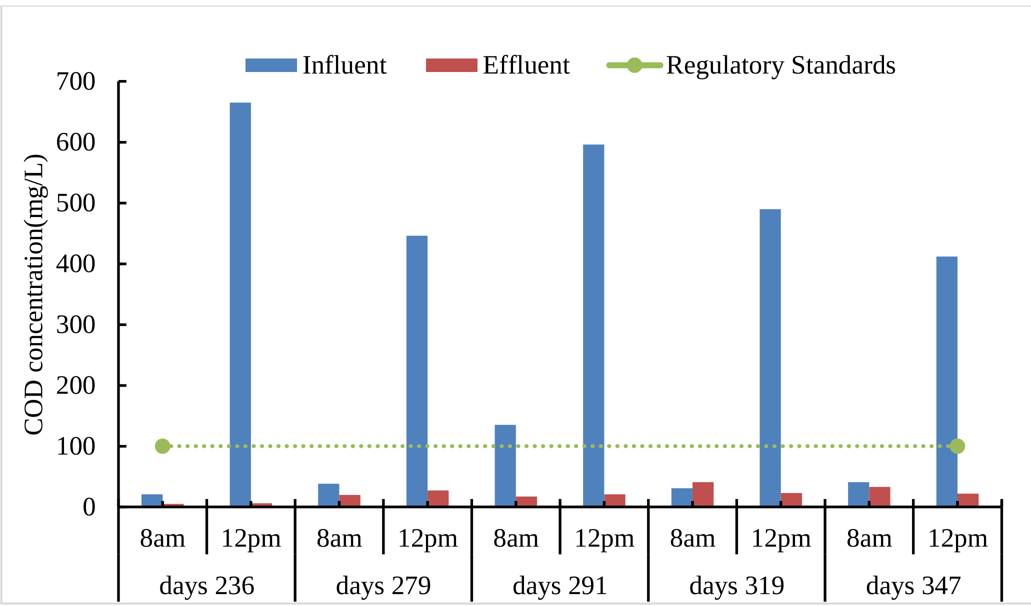


Fig. 7: COD concentration in the influent and effluent. The dotted line shows the regulations and standards for discharge water in Taiwan (100mgCOD/L)

4. Conclusion

Due to the large change in water consumption in Dong Hai shopping district, the COD concentration of the discharge wastewater varies greatly. Under high OLR, the biofilm grows better and has a good treatment efficiency; otherwise, the treatment efficiency will be reduced. The biofilm is mainly affected by the concentration substrate in the influent, and the biomass determines the COD removal efficiency. In the future, this study will observe the treatment efficiency of biological reactors in the pilot scale under different HRT by adjusting the influent's flow rate to see whether the treatment time can be reduced. In addition to HRT, this study will also study the treatment efficiency of biological reactors under high ammonia nitrogen concentration and high COD concentration.

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