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Characteristics of water quality and extracellular polymeric substances in trickling filter system using plastic fiber media

Seok Dockko[a]*, Han-Kyu Kim[a], Yuntao Guan[b], In-Hwan Hyun[c]

[a]*Dankook University, Deptartment of Civil and Environmental Engineering, Cheonan Campus, Choongnam, 330-714, Korea*
Tel. +82 (41) 550-3516; Fax +82 (41) 550-3520; email:dockko@dku.edu
[b]*Department of Environmental Science and Engineering, Tsinghua University, Beijing, China*
[c]*Dankook University, Department of Civil and Environmental Engineering, Jukjeon Campus, Gyeonggi-do, 448-701, Korea*

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ABSTRACT

In this study a trickling filter system was developed by using polypropylene media and polypropylene nylon media that has recently been developed. The experiment analyzed an ability of water purification of the two plastic media and the effects of biomass on the final effluence. As recycling ratio increased, polypropylene nylon suspender showed higher efficiency by 20%; and when media height was lengthened two times, the efficiency increased by about 10%. Extracellular polymeric substances (EPS) and biomass increased in proportion to the increase of recycling ratio, and bound-TOC showed a similar trend with bound-EPS concentration.

Keywords: Trickling filter system; Extracellular polymer substances; Biofilm; Plastic fiber media

1. Introduction

With the Cheonggaecheon project in Seoul, a trend to dismantle open rivers and lakes and create natural-style ecological watercourses is expanding nationwide. This kind of building natural watercourses is premised to improve the ability to purify water, but effective purification technology for an improvement of water quality in natural watercourses has not been sufficiently considered, and its current state is to solely rely on natural resolution of pollutants simply by plants.

This study attempts to make a trickling filter system using plastic fiber media that can improve water quality of rivers and lakes. Especially, the system would show a high efficiency for pollutant loading undergoing rapid changes by exposing bacteria with high degradability for sufficient DO supplication. In addition, by analyzing extracellular polymeric substances (EPSs) that have a great influence on the formation of biofilms that are adjoined to plastic fiber media, this study discusses the properties and states of those substances with regard to pollutant loading and recycling ratios. Also, the study carries out a comparative analysis of biomass removal through an interaction between EPS materials and biomass in forming biofilms by attaching the plastic media, and its removal efficiency.

In terms of biomass characteristics, the EPS and soluble microbial products (SMPs) are known to be the main fouling factors in membrane systems [1]. Smaller particle sizes have been reported to cause greater fouling rates [2], and flocculation mechanisms have been reported for bioflocculation which compared three theories to investigate the mechanism of bioflocculation. For example, some studies showed that the EPS concentration decreases as SRT increases in submerged conditions [3,4], whereas some other studies showed the exactly reverse trend [5] or no significant change in EPS [6,7].

On the basis of these methods, this study analyzes EPS that greatly affects biofilm attached to the trickling filter system in order to evaluate how quality of EPS cre-

* Corresponding author.

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ated by metabolism of microorganism changes by pollutant loading and recycling ratio.

2. Materials and methods

2.1. Materials

Contact media used in this experiment are rope-style contact materials that are main substance of suspenders of which are polypropylene (PP) media and polypropylene nylon (Nylon) media. Surface area of the two suspender are 2,625 m^2/m for PP media and 1.2 m^2/m for Nylon media.

2.2. Experiment

First, PP media and Nylon media were cut into 20 pieces, 35 cm each, and put them on a porous place of a reaction flask, and sludge was incubated. The MLSS of sludge was about 6 g/L, which was taken from a wastewater treatment plant. The F/M ratio was controlled to 0.1–0.4 kg COD/kg biomass/d (Table 1).

Pollutant loading of organic matters was divided into three types of samples based on previous literature, and they are:

Sample A 0.4–0.6 kg COD/m^3/d;
Sample B 1.8–2.1 kg COD/m^3/d; and
Sample C 3.9–4.2 kg COD/m^3/d.

Water trickled through a distributor in the reaction flask was 100–130 ml/min and its hydraulic loading was expressed as 0.9–1.17 m^3/m^2/d. Based on these conditions for the experiment, processing rate of two different plastic media was analyzed with 1, 3, and 6 recycling ratios (N) by pollutant loading as shown in Fig. 1. When recycling ratios (N) inside the reaction flask were 1, 3, and 6,

Table 1
Condition of sample

Sample No.	Average organic load (kg CODcr/m^3/d)	Average hydraulic load (m^3/m^2/d)
A (low conc.)	0.5	1.00
B (middle conc.)	2.0	1.00
C (high conc.)	4.0	1.00

it was operated with 0.87 h, 0.42 h, and 0.24 h contact time of recycled water for one time, respectively. In order to analyze concentration of organic matters for processing water, water was sampled totally for 12 h with a 2-h sampling interval, and basic items (pH, temperature, and DO) were measured for water samples [8]. Then, characteristics of processing rate were comparatively analyzed each with 35 cm (D35) and 70 cm (D70) of media length, and Lowry method and Phenol-Anthrone method were used to measure and analyze EPS changes [9].

3. Results and discussion

3.1. Resolution experiment by media materials

Fig. 2 shows the removal efficiency by recycling ratio of PP and Nylon media. Nylon media shows about 20% higher efficiency than PP media in all recycling ratios, and as the contact time declined, the efficiency increased. When the recycling ratio increased, the removal efficiency of Nylon media increased. Fig. 3 describes the results of the experiment that compares the efficiencies of the two media by inflow concentration. Inflow CODcr increases the loadings of 0.5, 2.0, and 4.0 kg COD m^3/d to low,

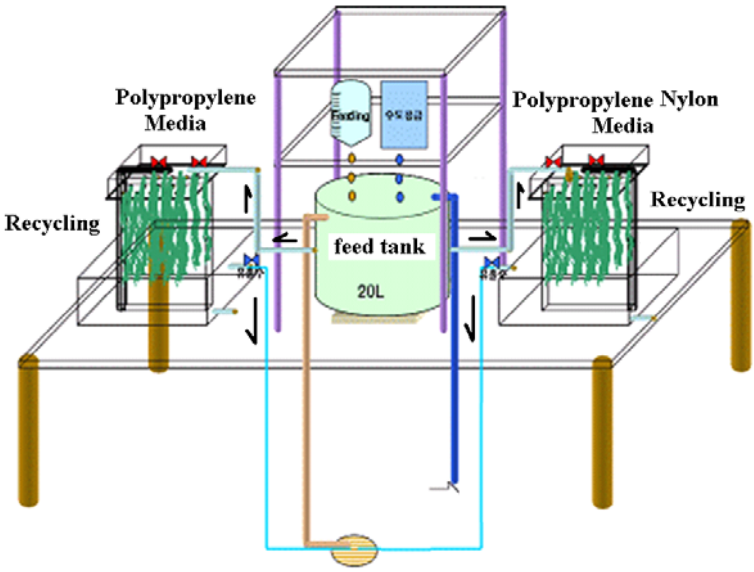

Fig. 1. Schematic of the system.

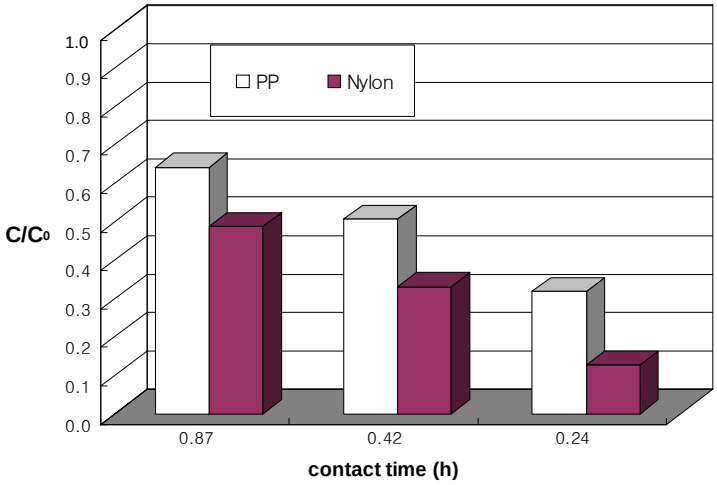

Fig. 2. C/C_0 comparison of attaching media on contact time.

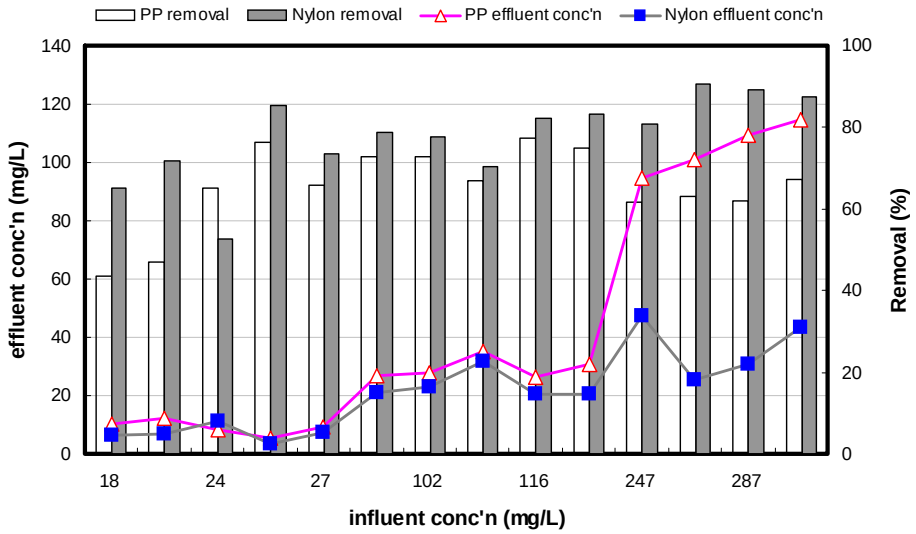

Fig. 3. Fiber media characteristic on concentration increase.

medium, and high concentrations, showing removal and effluence concentration of a system when it came in. With low and medium concentrations, both PP and Nylon media showed similar removal, while Nylon media had 2.5 times higher efficiency than PP media with high concentration. This is attributed to the fact that when biomass of micro-organisms increases with high concentration, sloughing off occurs easily with PP media while Nylon media with high adhesiveness has less of sloughing off.

Therefore, with inflow of high concentration, it is more stable to use Nylon media with less sloughing off and high efficiency.

3.2. Factors to Nylon media on contact time

Based on the above experiment, the media made from nylon material with higher efficiency than PP material was used. Fig. 4 shows CODcr, TN, and TP efficiencies by change in contact time of recycled water. In the case of CODcr, the efficiency was 52% at 0.87 h of contact time, 70% at 0.42 h and 92% at 0.24 h, resulting in 40% increase of efficiency. However, in the case of TN and TP, almost uniform change was shown without particular correlation with media material or contact time.

3.3. The effect of media height on DO change and processing rate

Fig. 5 shows the changes of DO concentration and processing rate in the water when recycling ratio is changed with media height of Nylon media of 35 cm and 70 cm.

When recycling ratio, N = 1, DO of D35 and D70 are

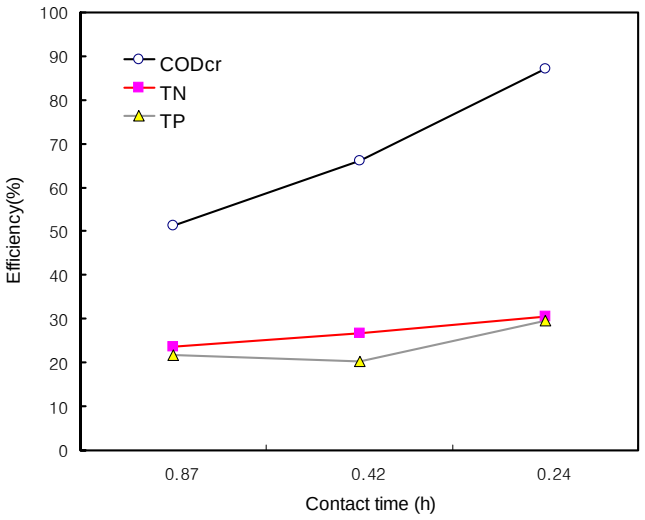

Fig. 4. Effect of removal of polypropylene Nylon media on contact time.

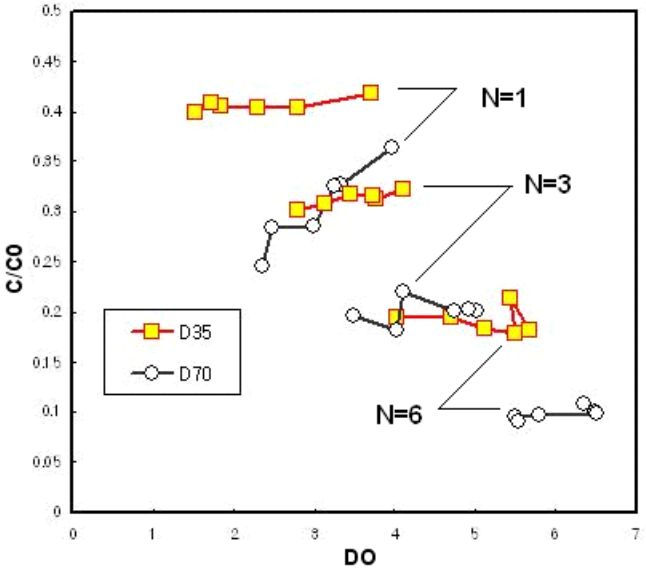

Fig. 5. Comparison of DO and *C/Co* in D35 and D70.

1–3 mg/L and 2–4 mg/L, indicating that when the height of media increased twice, DO increased by 150%. When recycling ratio, N = 6, DO increased to 3.5–5.5 mg/L and 5.3–6.6 mg/L, respectively, and C/C_0 increased from 0.4 to 0.2 more than two times. That is, an increase of recycling ratio brings an increase of DO, which contributes to an increase in processing efficiency.

3.4. Changes of biomass and EPS by pollutant loading

Nylon media of the reaction flask was cut in 4 cm and biomass of sludge attached inside the media was estimated. Fig. 6 shows the changes of biomass of sludge attached inside the suspender and of EPS when pollutant loading changed from low (sample A) –middle (sample B) – high (sample C).

When N = 1, biomass change by pollutant loading was examined to slightly increase from 14.4 to 14.8 and to 15.0 g/L; EPS added with protein and polysaccharide also increased from 202 to 202.7 and to 218.5 mg/L. When N = 3, biomass changed from 13.5 to 14.3 and to 15.6 g/L with an increment of 0.8–1.3 g/L; EPS increased from 204.8 to 214.5 and to 228.5 mg/L with an increment of 9.7–14 g/L. When N = 6, the change of biomass by pollutant loading was from 11.2 to 15.1 and to 18.9 g/L, somewhat higher than when N = 1 or 3; EPS correspondingly increased to 187.9, then to 242 and to 282.9 mg/L with a little bigger range. According to the overall analysis of the experiment, when recycling ratios (N) increase from 1 to 3 and to 6, pollutant loading increases, and biomass and EPS tend to increase proportionally.

The measured values of biomass varied by the change of recycling ratios and pollutant loading, and as shown in Fig. 7, along with an increase of biomass, protein and polysaccharide increased with a similar trend. The analysis revealed that during the 15-d experiment, biomass increased from 10.6 to 20.5 mg/L, and correspondingly, protein and polysaccharide proportionally increased from 168.9 to 266 mg/L and from 15.3 to 46 mg/L, respectively.

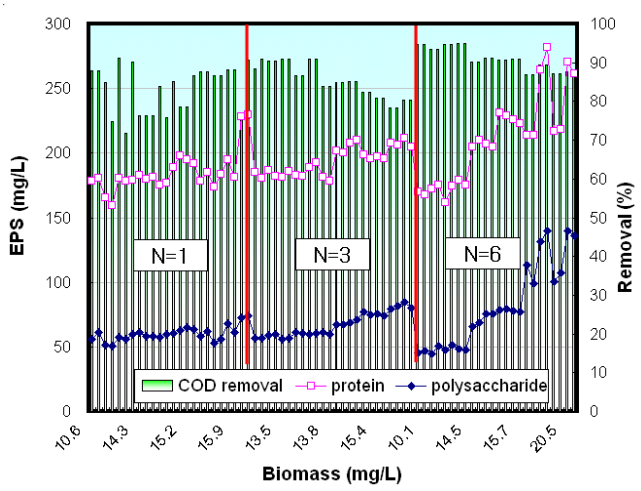

Fig. 6. Effect of EPS on biomass increase and recycling ratio (D70).

4. Conclusions

In this study, a trickling filter system using plastic fiber media is applied to ecological rivers and lakes, and the following conclusions were drawn regarding its effect on water quality and EPS that considerably affects the formation of biomass. In terms of processing effi-

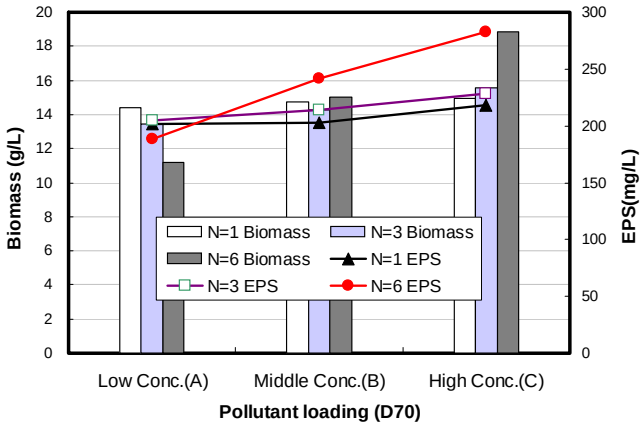

Fig. 7. Biomass and EPS on pollutant loading (D70).

ciency by materials, for recycling ratios (N = 1, 3, and 6), the fiber media made from nylon showed higher efficiency than PP media by CODcr 5.5–20%, TN 3.1–13.2%, and TP 3–12.6%.

As a result of comparing the characteristics of two suspenders, in the case of PP media, as a certain amount of sludge is attached inside suspender, its shape is falling and sloughing off occurs. On the contrary, polypropylene nylon suspender has strong durability and high adhesiveness of microorganisms, so it was able to maintain attachment for a longer period of time.

When the media height is increased by two times, the suspender with D35 cm was found to be more appropriate than that with D70 cm in an economic aspect. In the case of low concentration, processing efficiency was about 88% even when N = 1, so it was concluded that in an application to the actual watercourses, as long as the length of surface area of suspender is matched according to hydraulic loading, it could substantially reduce the power cost. As recycling ratio changes from 1 to 3 and to 6, pollutant loading also increases and EPS and biomass increase proportionally; and bound-TOC showed a similar trend with bound-EPS concentration.

Acknowledgements

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