REJECTING MICROPLASTICS WITH A GRAVITY-DRIVEN DYNAMIC MEMBRANE FILTRATION SYSTEM FROM WASHING WASTEWATER OF A PLASTIC RECYCLING FACILITY

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ABSTRACT

This research aimed to apply a gravity-driven dynamic membrane (GD-DM) filtration system to treat the washing water containing microplastics (MP) from a plastic recycling facility. A 9 L volume rectangular plexiglass reactor was used in the GD-DM system with 100, 200, and 300 µm stainless steel meshes as the support layer. Batch experiments were conducted to investigate cake layer formation with constant water height (50 cm). Primary and secondary sludges were taken from an industrial wastewater treatment plant to create a DM layer. Influent and effluent samples and the added sludge were taken to measure suspended solids (SS). A dynamic layer was successfully created at each mesh size (100-200-300). While the flux started with 4.760 LMH and decreased suddenly to 17 LMH in the 100 µm mesh module, it was decreased to 34 LMH for 200 µm mesh. In the experiment conducted with a 300 µm sieve, although the final flux was around 14 LMH, turbidity decreased only from 1100 to 800 NTU. In addition, the MP content of the influent and effluent samples was also examined because the wastewater used in these experiments contained microplastics. The most observed shape of microplastics in the influent samples was fiber. However, it was observed that the increase of these fibers in the effluent water was due to the accumulation of these microplastics in the dynamic membrane layer, which contributes to the production of DM.

Keywords: Plastic recycling facilities, Washing water treatment, Microplastics, Dynamic membrane, gravity-driven reactor

INTRODUCTION

Recently, dynamic membranes (DMs) have been considered as an emerging technology in wastewater treatment (Hou et al., 2017). DM is based on the formation of a cake layer on a supporting membrane, where suspended solids or colloids accumulate and act as a secondary membrane/barrier. This layer formed on a support material (large size) act as the main barrier in the removal of pollutants. In current DM research, mesh (nylon or stainless steel), woven or non-woven fabric are widely used. In the DM process, it has become a preferred treatment system in recent years due to its advantages such as using relatively lower cost materials compared to conventional membranes (MF, UF, etc.), using gravity as the

driving force, and having low energy requirements (Li et al., 2018; Poerio et al., 2019). In a study about DM, it was aimed to remove micro-particle pollutants in synthetic wastewater by establishing a laboratory-scale DM system operating with continuous filtration flux. While the turbidity of the inlet water was approximately 195 NTU, it was determined as <1 NTU after 20 minutes of filtration. This result showed that DM filtration increased the filtration resistance and TMP and that a wastewater containing microparticles contributed to the treatment of wastewater by forming DM (Li et al., 2018b). When using gravity as the driving force, usually polymeric membranes are used. There are studies about pretreatment for seawater desalination, river water treatment, drinking water treatment, and gray water treatment, and there are very few studies in which a support layer is used (Pronk et al., 2019). In a study that proved that dynamic membranes are more advantages than polymeric membranes with a gravity-operated nylon sieve, it was shown that this support layer coated with nanofibers by electrospinning provided a similar removal efficiency at a higher flux than a polymeric membrane (Chen et al., 2022). Therefore, new studies are needed for dynamic membranes operating with gravity. Microplastics, called plastic particles smaller than 5 mm, are among the most notable pollutants in recent studies. Although there are many sources of microplastics (Golwala et al., 2021), one of the most important of these is the washing waters formed in plastic recycling facilities (PRFs). In a study conducted with the conventional activated sludge (CAS) process, it was found that the quality of the granular activated carbon (GAC) added reactor effluent was better than the CAS system (Altieri et al., 2021). In another study, plastic contaminated wastewater was treated with a flocculant synthesized from waste polystyrene (PS), good effluent quality was obtained (Ozdemir and Yel, 2023). Therefore, we used washing water generated in PRFs containing microplastics in a GD-DM reactor to examine dynamic layer formation.

MATERIAL METHOD

PRF wastewater samples were taken from the wash water of one facility that only recycles mixed plastics, and the experimental procedures were initiated. The dynamic layer was formed by mixing the pre-sedimentation (15,000 to 25,000 mg/L) and final clarifier (3,500-5,000 mg/L) sludges taken from Kayseri Organized Industrial Zone Wastewater Treatment Plant at optimum ratios as in our previous study (Elbir et al., 2024). Stainless steel meshes with different sizes (100, 200 and 300 µm) were used as the support layer (active area: 0.016-0.018 m^2). The reactor is a rectangular plexiglas material with a height of 0.6 m (active height: 50 cm). The maximum capacity of the reactor is 9 L (Figure 1). COD (1500-2000 mg/L), TSS (2000-4000 mg/L), pH (6-7) and conductivity (1400-1500 µs/cm) analyses were carried out on samples taken from PRF effluent. Constant water height or pressure (50 cm) were used in all experiments. Experimental studies were carried out as follows: PRF wastewater + sludge were added to the reactor with a magnetic stirrer to provide mixing. After complete mixing was achieved, samples were taken from the effluent of the reactor to measure effluent parameters and the flux. SS and MP samples were taken before the experiment started and at certain intervals during the experiment. Flux, water volume passing through the membrane per m^2 area per hour ($L/m^2.h$) (LMH), turbidity (NTU, WTW TURB 430IR turbidimeter) and pH (Hach HQ40D) were measured with a pH probe. SS (mg/L) in reactor and the effluent was analyzed according to Standard Methods (SS: 2540). The microplastics in the influent and the effluent samples were calculated by applying the procedure specified inÇolakoğlu and Uyanık (2024). The dynamic layer was examined using an optical microscope (LEICA, DM750M).

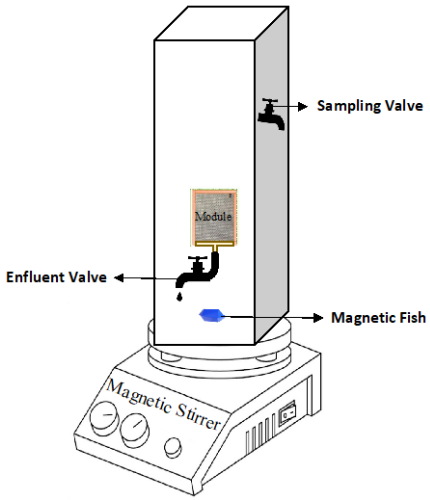

Figure 1. Experiment design

RESULTS and DISCUSSION

The first batch study conducted with PRF wastewater on a 100 µm sieve, it was observed that the initial flux suddenly decreased from 3,717 LMH to 18 LMH (Figure 2-a). It was a complete fouling as in the next batch experiment conducted with a 200 µm sieve. A sudden flux decrease occurred from 1,990 LMH to 34 LMH, and approximately 1.1 L of water was filtered (Figure 2-b). It is thought that the reason for the sudden flux decrease is due to the high SS concentration (1,500 mg/L) of PRF wastewater. Since the layer formation was rapid in these experiments, no turbidity other than the initial turbidity data could be measured. Since the SS concentration was high in PGDT wastewater, a control experiment was conducted on a 300 µm sieve and 8 L of water was filtered during the experiment (Figure 2-c). It was observed that, after the formation of the cake layer, more MPs was measured in the effluent wastewater than in the inlet wastewater. The pressure formed on the layer caused the MPs to escape from the module, thus preventing the MPs to be rejected and accumulating in the reactor. DM layer and effluent samples were examined with a microscope, and it was observed that particles and fibers were dominant as MP shapes, and the fibers were attached to the DM layer (Figure 3).

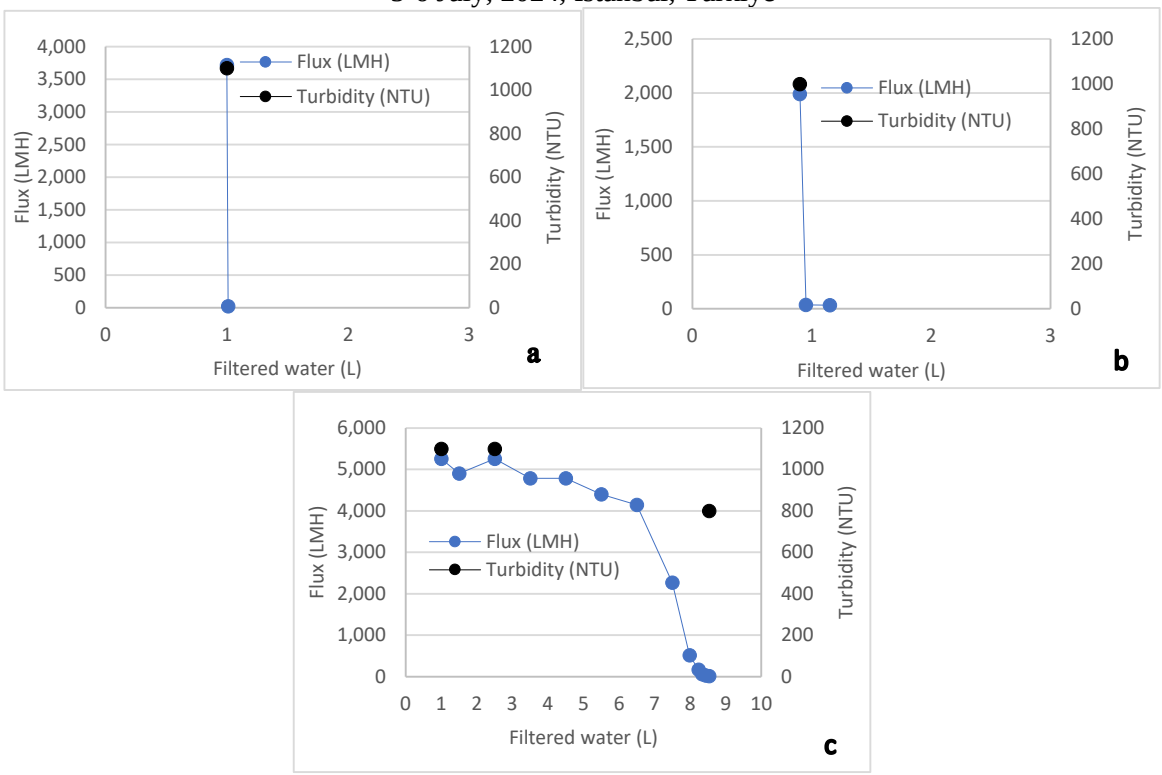

Figure 2. Flux performances of meshes: a) 100 µm, b) 200 µm and c) 300 µm

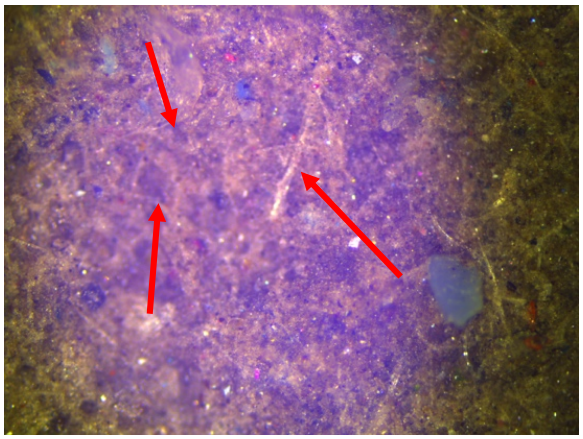

Figure 3. 100 µm: Dynamic membrane (cake layer)

CONCLUSION

It is the first study using a GD-DM reactor and real MP rich wastewater to remove MPs. A dynamic layer was created at each stainless-steel mesh module and flux values decreased to around 15-35 LMH values. MP rich cake layer could not be stable as the pressure is high, it resulted to observe MP fibers in effluent. As a result of MP characterization, it was determined that the most common shapes were particles and fibers. The effect of microplastics on dynamic layer formation requires more research.

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REFERENCES

Altieri, V. G., De Sanctis, M., Sgherza, D., Pentassuglia, S., Barca, E., & Di Iaconi, C. (2021). Treating and reusing wastewater generated by the washing operations in the non-hazardous plastic solid waste recycling process: Advanced method vs. conventional method. Journal of Environmental Management, 284, 112011.

Chen, G., Wen, J., Yu, Y., Liu, M., & Liu, G. (2022). Dynamic membranes with sparse nanofibers as the skeletons yield better and more stable effluent quality without sacrificing the flux in bioreactors. Journal of Membrane Science, 650, 120414.

Çolakoğlu, E. B., & Uyanık, İ. (2024). Plastic waste management in recycling facilities: Intentionally generated MPs as an emerging contaminant. Waste Management, 181, 79-88.

Elbir, H., Uyanık, İ., Çolakoglu, E. B., Sahinkaya, E., & Yurtsever, A. (2024). Pre-coating of stainless-steel mesh support material with wastewater treatment plant sludges in a dynamic membrane filtration process. Journal of Water Process Engineering, 64, 105673.

Golwala, H., Zhang, X., Iskander, S. M., & Smith, A. L. (2021). Solid waste: An overlooked source of microplastics to the environment. Science of the Total Environment, 769, 144581.

Hou, C., Shen, J., Zhang, D., Han, Y., Ma, D., Sun, X., ... & Liu, X. (2017). Bioaugmentation of a continuous-flow self-forming dynamic membrane bioreactor for the treatment of wastewater containing high-strength pyridine. Environmental Science and Pollution Research, 24, 3437-3447.

Li, L., Xu, G., & Yu, H. (2018). Dynamic membrane filtration: formation, filtration, cleaning, and applications. Chemical Engineering & Technology, 41(1), 7-18.

Li, L., Xu, G., Yu, H., & Xing, J. (2018b). Dynamic membrane for micro-particle removal in wastewater treatment: performance and influencing factors. Science of the Total Environment, 627, 332-340.

Ozdemir, N. C., & Yel, E. (2023). Synthesis of a New Flocculant from Waste Polystyrene: Plastic Recycling Industry Wastewater Treatability. Water, Air, & Soil Pollution, 234(2), 88.

Poerio, T., Piacentini, E., & Mazzei, R. (2019). Membrane processes for microplastic removal. Molecules, 24(22), 4148.

Pronk, W., Ding, A., Morgenroth, E., Derlon, N., Desmond, P., Burkhardt, M., ... & Fane, A. G. (2019). Gravity-driven membrane filtration for water and wastewater treatment: a review. Water research, 149, 553-565.