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Reclamation of car washing wastewater by a hybrid system combining bio-carriers and non-woven membranes filtration

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ABSTRACT

Due to the considerable temporal and spatial variations in precipitation in Taiwan, water usage authorities often impose restrictions on car washing, plant watering, and swimming pool refilling in drought season. In response to these water restrictions, the commercial carwash industry has taken measures to install reclamation systems for recycling and reusing carwash wastewater. Dissolved air flotation (DAF), sand filtration (SF), or Multi-media filtration (MMF) units are common reclamation systems for removing suspended solids (SS) in car wash wastewater. However, these technologies are usually ineffective at removing organic contaminants and result in the accumulation of organic contaminants in reclaimed water system. Alternative technologies with higher efficiency to produce high quality reclaimed water must be developed to meet the water demands of car wash industry during drought season. This paper presents a hybrid system that combines bio-carriers and non-woven membranes filtration. When installed in a car washing reclamation facility, this system can remove both SS and organic pollutants. A large amount of microorganisms can grow on the surfaces of porous bio-carriers made of polyurethane resin. Higher organic removal can be achieved using a bio-carrier system for low organic loading wastewater, such as car washing wastewater. A non-woven membrane made of non-woven material serves as microfiltration system to separate suspended solids from wastewater at a lower operating pressure than other types of ultrafiltration membranes. During 6 months of operation in a car wash facility in northern Taiwan, the average influent COD and SS concentrations were 67 mg/l and 230 mg/l, respectively. After treatment with bio-carriers and non-woven membrane filtration, the COD and SS concentrations in reclaimed water were less than 20 mg/l and 10 mg/l, respectively. During this test period, fresh water was only added to make up the water loss from vaporization to atmosphere and sludge disposal. Compared to DAF and SF in typical car washing reclamation systems, the proposed hybrid system achieved better performance in producing high quality reclaimed water and maintaining stable operation.

Keywords: Car washing machine; Car washing wastewater; Wastewater reclamation; Water reuse; Microfiltration; Non-woven membrane; Bio-carrier

1. Introduction

Although the average annual precipitation in Taiwan is 2,500 mm, 2.6 times than the world average, the water supply is not always sufficient. Due to temporal and spatial variations in precipitation, rainfall occurs mostly in the summer in mountainous regions. During the rainy season, the rainfall drains straight to the sea through short rivers and rapid flows. Only a small percentage of the precipitation can be contained in reservoirs or recharged into groundwater. During the drought season, the water supply is usually insufficient. In this case, water usage authorities

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often restrict activities such as car washing, plant watering, and swimming pool refilling. In response, the carwash industry has taken measures to install reclamation systems for recycling and reusing carwash wastewater.

Sand and dust are the most common material in carwash wastewater. Alberto et al. [1] proposed removing these materials by coagulation. Al-Odwani et al. [2] used an oil-water separator, or multi-media filter, to treat carwash wastewater, and reclaimed 75% water after removing the oil and SS. Most of the reclamation systems installed in carwash stations in Taiwan use dissolved air flotation (DAF), sand filtration (SF) or multi-media filtration (MMF) to remove solids from car wash wastewater. However, those conventional technologies are ineffective in removing fine solids and dissolved organic contaminants. Fine solids can block the spray nozzles and dissolved organic contaminants encourage biofilm growth on the surface of pipes and tubes in carwash machines.

Tan et al. [3] suggested that an ultrafiltration (UF) membrane is a reliable technology for SS separation in carwash wastewater. However, membrane clogging must be addressed for long-term operation. They demonstrated that adding $KMnO_4$ into coagulant (PAC) enhanced the efficiency of coagulation and reduced the clogging of UF membrane. However, they did not solve the problem of organic contaminants accumulating in reclaimed water system.

The Industrial Technology Research Institute in Taiwan developed the BioMF system, which combines bio-carriers and non-woven membrane filtration [4]. This technology can treat low COD wastewater, and produce high quality effluent for reuse. Fig. 1 shows the schematic diagram of BioMF system. The first aerated reactor packs 70% of reactor volume with butterfly like bio-carriers. These carriers capture attached growth microorganisms and degrade the biodegradable matter

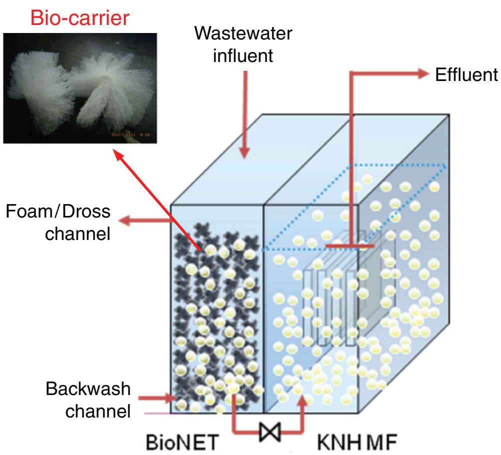

Fig. 1. The schematic diagram of the proposed BioMF system.

in carwash wastewater. Periodic backwash removes excess biofilm and SS trapped on and between carriers. Non-woven membranes are immersed in the second aerated reactor. Because few SS are removed from the carriers except by backwash conditions, the effluent from bio-carrier tank is introduced to the membrane tank for further SS removal. This paper proposes a BioMF system to eliminate the accumulation of organic contaminants and achieve a high removal efficiency in solid separation in carwash reclamation systems.

2. Material and methods

2.1. Bio-carriers and non-woven membranes

The commercialized bio-carriers and non-woven membranes were all made by KNH Enterprise Co., Ltd. The bio-carriers measured 1 cm in length and 0.5 cm in width. This carrier was hydrophilic and weighted 0.075 gram per carrier with 98% void ratio and 0.026 g/cm^3 bulk density. The characteristics of non-woven membrane were 2 µm in pore size, −16 mV @ pH 7 in surface zeta potential, and 113.7° in surface contact angle. The surface area of non-woven membranes for lab-scale feasibility study and full-scale case study were 20 cm^2 and 30 m^2, respectively.

2.2. Feasibility study for BioMF system reclaiming carwash wastewater

Fig. 2 shows the lab-scale BioMF system. The wastewater, or influent, of lab-scale BioMF system, was collected from a car washing station located in Hsinchu city. The key water quality characteristics were 7.3–10.0 in pH, 15–20 mg/l in COD concentration, 5.9–18.0 mg/l in TOC concentration, 4–108 mg/l in SS concentration, and 0–48 mg/l in VSS concentration. The HRT of bio-carrier reactor was 4.7 hours and the non-woven membrane flux was 0.7 m^3/m^{2}day.

2.3. Case study in wastewater reclamation of a car washing station

A full-scale BioMF wastewater reclamation system was installed at a carwash station located in Taipei in April, 2009. This system was designed to reclaim wastewater from at least 100 carwashes per day, or 24 CMD, per day. Fig. 3 depicts the KNH non-woven membrane module used in this case study. Fig. 4 shows the schematic diagram of the full-scale BioMF system in this case study. Fig. 5 shows the full-scale BioMF system for carwash wastewater reclamation. The volume of bio-carrier reactor and membrane tank were 1 m^3 and 1 m^3, respectively. The flux of non-woven membranes was 0.7 m^3/m^{2}day.

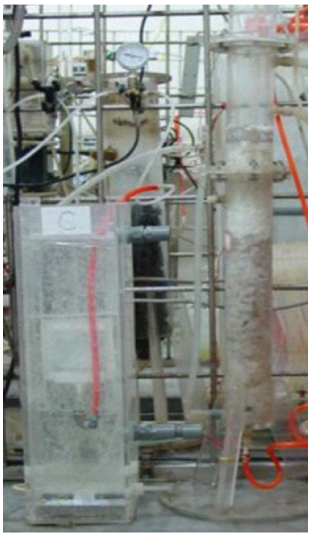

Fig. 2. The lab-scale BioMF system.

Fig. 3. Non-woven membrane module used in this case study.

The aeration rates in bio-carrier reactor and membrane tank were both 65 l/min. The membranes were backwashed with 12 wt% NaOCl once a day. The backwash time was 10 min and the flow rate was 15 l/min. The wastewater from the car washing machines was introduced to a primary sedimentation tank first, and then pumped into the BioMF system for reclamation.

2.4. Analytical methods

Water quality data was measured following Taiwan EPA's standard methods. The COD measurement was based on NIEA W515.54A, TOC was based on NIEA W531.51C, SS as based on NIEA W210.57A in this study.

3. Results and discussion

3.1. Performance and feasibility study

Figs. 6 and 7 show the COD and TOC concentrations at different stage in the lab-scale BioMF system, respectively. These figures show that the effluent COD and TOC concentrations of bio-carriers reactor were lower than 20 mg/l and 1 mg/l, respectively, as the COD loading rate of the bio-carriers reactor was 0.1–0.6 kg/m^3day. This implies that the bio-carrier reactor had a strong tolerance to fluctuations in the organic loading rate. The COD and TOC removal efficiency can be attributed to many microorganisms attached on the carrier surface and captured in the carrier void. The effluent TOC concentrations of the BioMF system were similar to tap-water, indicating that organic matter build-up was not a problem in this carwash reclamation system.

Fig. 8 shows the SS concentrations at different stages in the lab-scale BioMF system. The effluent of bio-carrier reactor was usually less than 10 mg/l.

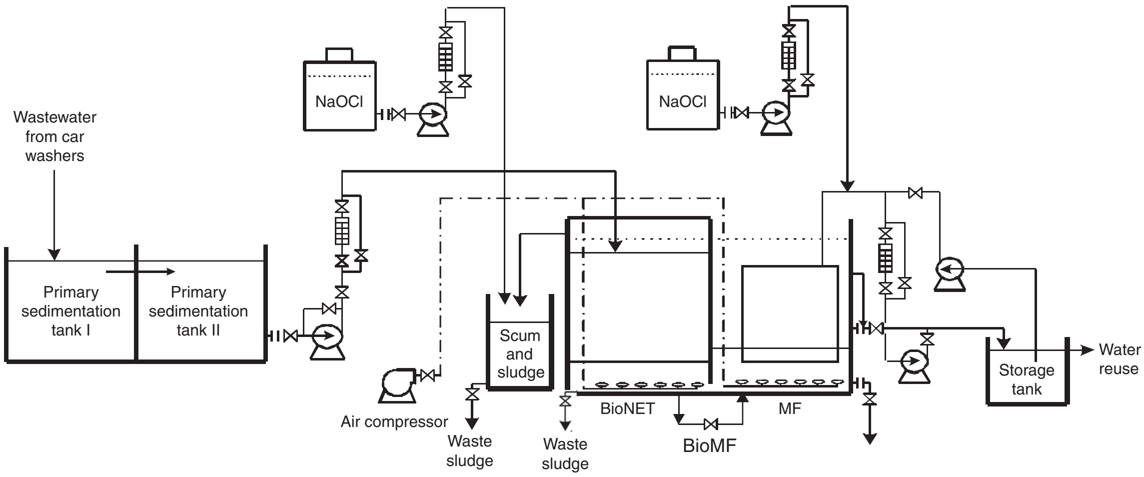

Fig. 4. The schematic diagram of full-scale BioMF system in this case study.

Fig. 5. Full-scale BioMF system for carwash wastewater reclamation.

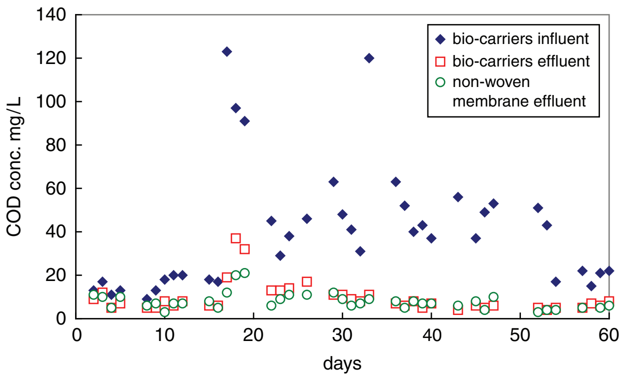

Fig. 6. The COD concentrations in the lab-scale BioMF system.

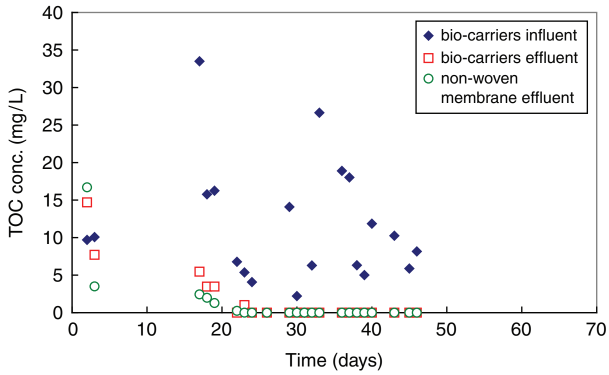

Fig. 7. The TOC concentrations in the lab-scale BioMF system.

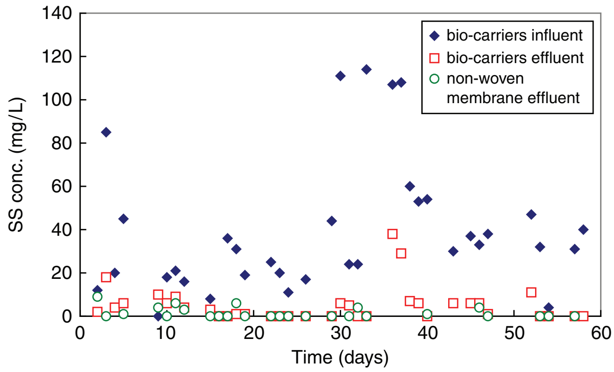

Fig. 8. The SS concentrations in the lab-scale BioMF system.

This result shows that bio-carriers not only retained most of the microorganisms, but also captured the SS in the carwash wastewater. The bio-carrier reactor also functioned as a pre-filtration unit for non-woven membrane filtration. Since the solid loading to membrane tank was reduced, the membranes could be operated in high flux conditions. During the feasibility study period, the flux of non-woven membrane exceeded 0.7 m^3/m^2 day, and no significant clogging problems appeared. This operating flux was higher than most commercial ultrafiltration and microfiltration membranes, which are usually 0.3–0.5 m^3/m^2 day.

The feasibility study results above show that the proposed system removed most of the COD, TOC, and SS from the carwash wastewater. The effluent quality of the BioMF system was close to that of tap-water. This indicates that the proposed BioMF system is suitable for reclaiming carwash wastewater.

3.2. Case study

A full-scale BioMF system has been successfully operated for more than 12 months in northern Taiwan. Table 1 shows the water quality data of this full-scale BioMF system. The range of influent COD and SS concentrations were 42–345 mg/l and 5.3–122 mg/l, respectively. After bio-carrier treatment and non-woven membrane filtration, the range of COD and SS concentrations in the reclaimed water were less than 50 mg/l and 2.8 mg/l, respectively. During this operation period, 6 to 8 CMD of fresh water was added to make up the water loss from vaporization to atmosphere, spatter in washing, membrane backwash, and sludge disposal, etc. The major sludge sources in the BioMF system included the deposit at the bottom of the bio-carrier reactor and membrane tank. To prevent the accumulated solids from influencing the carriers and membranes, they were discharged from the bottom pipes of reactor and tank every three months. The long-term performance of this full-scale BioMF system proves that the BioMF system is a suitable treatment system for reclaiming carwash wastewater.

Table 1
The water quality data of the full-scale BioMF system

Date	Bio-carriers influent		Bio-carriers effluent		Non-woven membrane effluent	
	COD, mg/l	SS, mg/l	COD, mg/l	SS, mg/l	COD, mg/l	SS, mg/l
May 14, 2009	72	6.2	—	—	20	0.8
May 21, 2009	56	5.3	—	—	50	0.4
June 3, 2009	48	5.8	—	—	40	0.3
June 10, 2009	48	10.8	—	—	36	0.1
June 20, 2009	345	122	—	—	38	1.1
February 15, 2010	68	45.6	16	12.0	17	2.8
March 15, 2010	42	18	42	12.8	12	0.6
April 15, 2010	54	30	37	43.6	17	0.2

4. Conclusions

The carwash industry in Taiwan often faces water use restrictions imposed by water usage authorities in drought season, and has taken measures to install reclamation systems for the recycling and reusing of carwash wastewater. Conventional reclamation systems for carwash wastewater are DAF, SF, MMF units. However, these units only remove suspended solids (SS) from car wash wastewater. These technologies are ineffective at removing organic contaminants, and result in the accumulation of organic contaminants in reclaimed water system. Alternative technologies with higher efficiency and high quality effluent must be developed to meet the water demands of the car wash industry during drought season. This paper proposes a BioMF system, which combines bio-carriers and non-woven membrane filtration, to reclaim carwash wastewater. This system can remove SS and organic matter simultaneously. The effluent quality of the BioMF system was similar to tap water. During the operation period, fresh water was only added to make up for the water loss from vaporization to atmosphere and sludge disposal. The performance of the BioMF system proves that it is a suitable treatment system for reclaiming carwash wastewater.

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References

[1] L. Alberto, C. Angel and M.B. Jose, Effect of a previous coagulation stage in the ultrafiltration of a metalworking emulsion using ceramic membranes, In: Desalination, 200 (2006) 330–332.
[2] A. Al-Odwani, M. Ahmed and S. Bou-Hamad, Carwash water reclamation in Kuwait, In: Desalination, 206 (2007) 17–28.
[3] X.J. Tan and L. Tan, Bioinformatics and Biomedical Engineering, 2008. ICBBE 2008. The 2nd International Conference on: Application of enhanced coagulation aided by UF (2008).
[4] W.K. Chang, W.Y. Chou, R.Y. Hong, M.J. Peng and S. Shao, BioNET technology for advanced biological treatment of water and wastewater, Asian-Pacific regional conference on practical environmental technologies, Taiwan (2003).