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Increasing of leachate quality using an integrated aerobic membrane bioreactor

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Original Article

Abstract

The aim of this study was the increasing of leachate quality using integrated membrane bioreactor (MBR). The reactor was fed with treated leachate with overall 70-1360 mg/l chemical oxygen demand (COD). The analysis of COD, biochemical oxygen demand (BOD_5), total suspended solids (TSS), and total dissolved solids (TDS) were performed in feed and filtrate, whenever the system reached steady state twice a week for 6 months. In all loading rate, BOD_5 concentration was less than the standard limit. The removal efficiency of COD in all experiments was up to 80%. Up to 99% of solids, which may mainly include colloidal solids, were removed with micropore membrane. There was no significant difference between TDS concentration in feed and filtrate. It was concluded that MBR is a versatile technology with high throughput and can treat compost leachate below standard limit if used after appropriate processes.

KEYWORDS: Leachate, Bioreactor, Waste Disposal, Membrane

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Introduction

With appropriate handling, composting is a sustainable, environmentally friendly, and feasible method for recycling and reducing organic waste volume in developing countries.[1] Approximately 60% of the municipal solid waste (MSW) produced in Isfahan, Iran, is converted to compost and about 50 m^3/day leachate is created from high moisture content in delivered organic waste.[2] Hence, the treatment of leachate is one of the key factors in solid waste management which should be performed with regard to its composition.[3] Because of the complexity of composting leachate pollutants, conventional treatments (biological or physicochemical) are no longer sufficient in order to reach the level of purification needed to fully reduce the negative impact of leachates on the environment.[4] Today, a combination of several processes is used for the treatment of these heavy polluted liquids.[5] Membrane separation coupling technology and sequencing batch bioreactors, most commonly called membrane sequencing bioreactor (MSBR), can replace the biomass settling and effluent withdrawing of the original SBR process.[6] Presently, many researchers have shown interest in leachate treatment.[7] Annual marketing growth rates of 10.5% indicate the widespread application (more than 5000 under operation) of

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this technology throughout the world.[8] Over 50 and 15 membrane bioreactor (MBR) plants for leachate treatment have been installed in Europe and China in the last 5 years, respectively.[9] Integrated bioreactors can attain carbon credit derived from the clean development mechanism (CDM) under the Kyoto protocol 1997, changing the paradigm of wastewater management from 'treatment and disposal' to 'useful utilization' as well as 'beneficial endeavor'.[10] MBR effluent has significantly high quality with minor fluctuation.[5] Sludge treatment cost, in MBR, is minimized when aeration cost is maximized. Economically optimum hydraulic retention time (HRT) and target mixed liquor suspended solids (MLSS) were found to be 16 hour and 11,000 mg/l, respectively.[8] Although it must be stressed that high investment costs, fouling, and high energy consumption (between 0.45 and 0.65 kWh/m^3 for the highest optimum operation) have been identified as the main limitations to faster commercialization and full scale operations of MBRs.[10] The addition of inorganic coagulants or powdered activated carbon (PAC) to the bioreactor can reduce fouling significantly.[6] Recently, semipermeable membrane, named osmotic membrane bioreactor (OsMBR), was suggested as a low fouling alternative to microporous membrane.[4] In comparison with side stream (sMBR) configuration, submerged or immersed (iMBR) is the most widely used due to lower associated costs of operation.[7] According to literature, separate application of MBR for raw leachate treatment leads to high fouling and increasing of costs. Hence, we decided to upgrade leachate quality using integrated aerobic MBR.

Materials and Methods

The experimental unit consisted of a cylindrical 2 l SBR equipped with an immerged membrane of 0.2 µm nominal pore size and 1 m^2/ea effective filtering surface area (ZeeWeed ZW10). The filtrate was extracted from the top header of the module under slight vacuum with maximum operating transmembrane pressure (TMP) of -0.6-0 Kgf/cm^2. Details of the MBR and membrane structure used in this study are illustrated in figure 1.

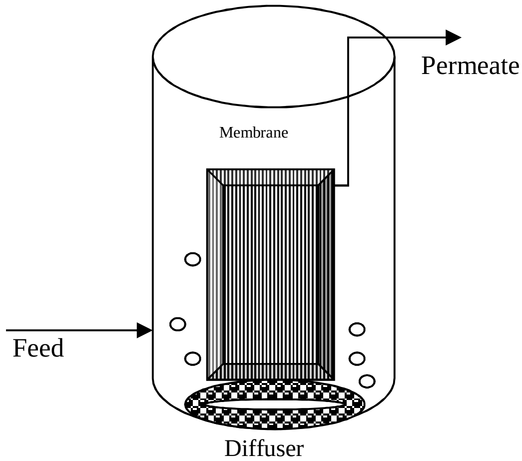

Figure 1. Details of membrane module used in this study

The bioreactor was acclimated by the addition of a sufficient quantity of activated sludge and diluted leachate. Biologically pretreated leachate was fed into the reactor which is continuously aerated using air compressor and diffusers to keep the dissolved oxygen (DO) concentration above 2 mg/l to supply oxygen for the biomass and to scour the membrane.

The process operation was divided into 5 phases; feeding (15 minutes), aeration (12-22 hours), settling (1 hour), filtration (30 minutes), and membrane relaxation (15 minutes). Dependence on the influent fluctuations, F/M ratio, was varied from 0.04 to 0.38 g chemical oxygen demand (COD) (e.g. mixed liquor solids)/d.

Relaxation is used to control the fouling of membrane at the end of run time.[8] The analysis of COD, biochemical oxygen demand (BOD_5), total suspended solids (TSS), and total dissolved solids (TDS) were performed in feed and filtrate twice a week according to the Standard Method for the Examination of Water and Wastewater .[11] One-sample t-test and paired sample t-test analyses were used for the statistical comparison of results.

Results and Discussion

Integrated process was fed with varied organic matter concentrations (85-5356 mg/l COD) and reaction time of 23 and 12 hours. Seasonal variations in leachate characteristics led to changes in the feed concentration. The results of biotreatment and filtration of leachate from compost facilities are presented in figures 2 to 5.

Figure 2 shows the feed and filtrate BOD_5 concentrations during bioreactor operation.

Figure 3 shows the variations of total COD during reactor operation time.

Figure 4 shows the typical trend of TSS evolution, during the start-up and steady state of a process. According to the one-sample t-test analysis, filtrate quality increased significantly below the standard (< 30 mg/l) limit ($P < 0.05$).

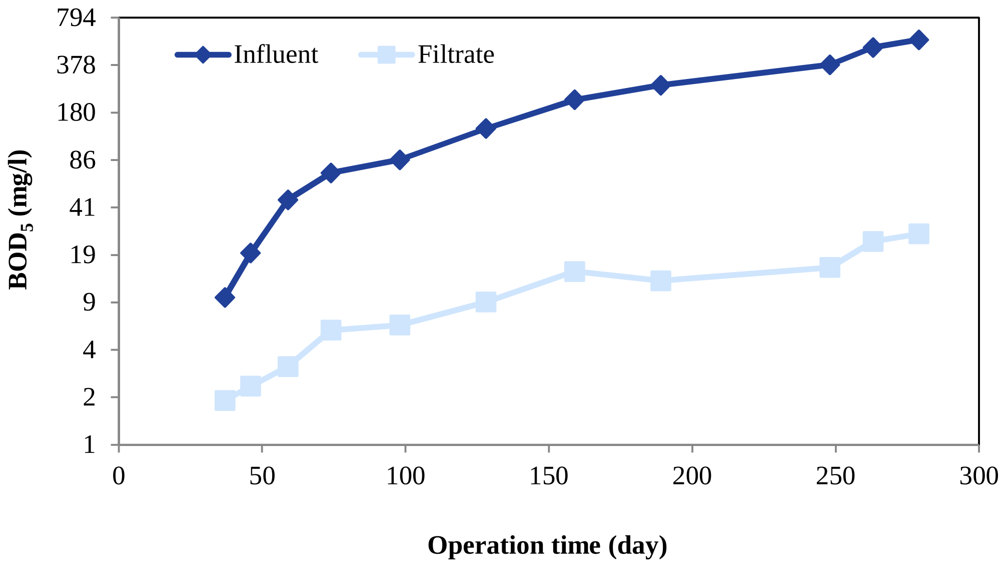

Figure 2. Feed and filtrate biochemical oxygen demand (BOD5) during bioreactor operation
BOD5 concentrations during bioreactor operation; BOD5: Biochemical oxygen demand

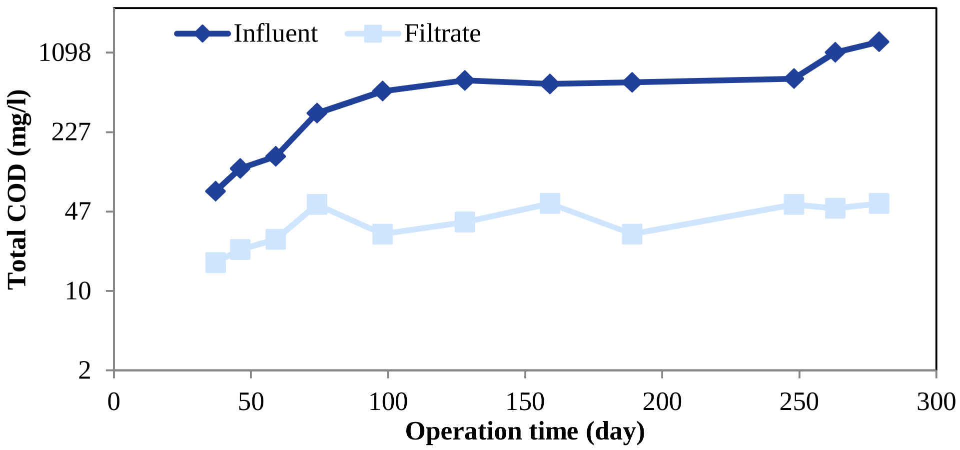

Figure 3. Variations of total chemical oxygen demand (COD) during reactor operation time
COD: Chemical oxygen demand

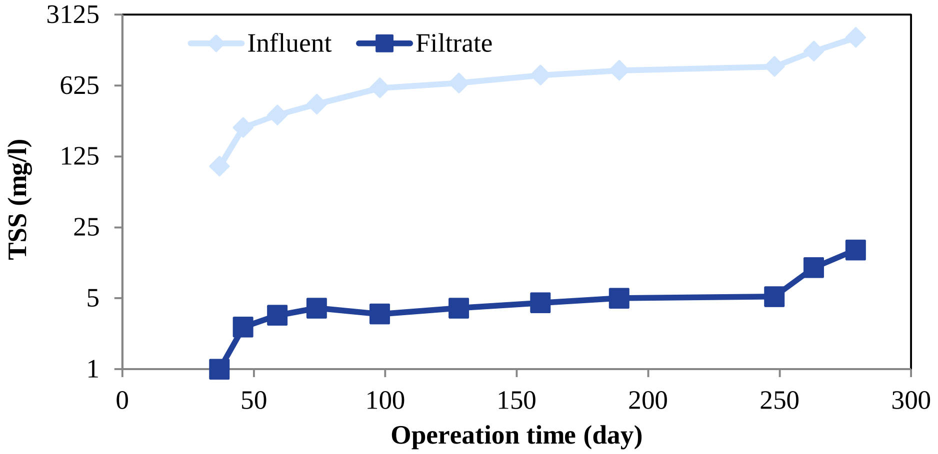

Figure 4. Changes in concentrations of total suspended solids (TSS) in different run times

TSS: Total suspended solids

Figure 4 shows that up to 99.9% of solids, which may mainly include colloidal solids, was removed with micropore membrane. Using ultrafiltration membrane, 5-10% additional efficiency was achieved.[12] As shown in figure 5, based on paired t-test analysis, there is no significant difference between TDS concentration in feed and filtrate ($P > 0.05$).

It seems that the membrane removed a considerable amount of mineral ions, but low weight molecules of organic acids passed through the membrane easily. In a similar study, TDS concentration in feed and filtrate was 15000 and 16633 mg/l, respectively.[9] Although TDS was not decreased significantly by membrane ($P > 0.05$), the permeate value was less than influent. In the study by Wilkinson, the permeate value was more than feed values.

In this study, after adaptation period, mixed liquor value was 4000 mg/l that increased up to 11000 mg/l within 280 days of operation. The pH values in the bioreactor increased slightly, but decreased in filtrate. The BOD_5 concentration in feed leachate ranged between 100 to 498 mg/l (Figure 2). The removal efficiency was 93%. As shown, in all loading rates, effluent concentration was less than the national standard limit (< 100 mg/l). In a similar study, the concentration of BOD_5 in MBR filtrate was recorded as less than 2 mg/l.[10] At BOD_5 loading rates below 1.71 kg/m^3/day, effluent concentration was less than 35 mg/l.[7] The main composition of COD in the membrane permeate is refractory organic matters.[11]

The study by Campagna et al. revealed that an important part of organic matter in landfill leachate can be removed by the primary clarifier and MBR. Furthermore, organic matter of one third percent is particulate or colloidal form and almost half of the organic fraction has a lower molecular weight (MW) than 500 Daltons (Da).[13] The average total COD concentration in the feed was 1332 mg/l. Insel et al. estimated readily and slowly biodegradable COD fractions of raw leachate to be 17% and 52%, respectively.[14]

As shown in figure 3, COD removal efficiency increased up to 70% in all experiments in the bioreactor with time. In spite of high BOD_5 removal in coupled process, overall COD reduction was not as satisfactory as that of BOD_5 degradation. This includes soluble COD portion; considerable soluble chemical oxygen demand (SCOD) values were analyzed (186 mg/l) in filtrate specially in loading more than 3500 mg/l COD. Large variations in feed COD (140-4200 mg/l) and operation conditions did not affect the MSBR effluent quality. This finding is in agreement with that of the study by Chen and

Liu.[3] In the study by Brown et al., The COD of the effluent was successfully reduced by more than 99% from an initial leachate COD of 116 g/l.[15]

Upgrading MBR with activated carbon removed a significant level of recalcitrant and bio-refractory compounds from leachate with reduced fouling. [16] The membrane process coupled with a SBR not only replaces the sedimentation period in the operation of a SBR, but also serves as an advanced treatment unit for suspended solids, which cannot be removed completely through conventional processes.[17]

The membrane used in this study is categorized as high flux anti-fouling microfiltration (MF) and separation via ion size exclusion was its main target based on pore size. In subsequent polishing of landfill leachate treatment, TSS removal was over 99%. In almost all the runs, filtrate TSS was stable. The coupling of membrane and sequencing batch reactor results in the purification of turbid SBR effluent.[18] Usually, the submerged membranes used in MBR are mostly MF or ultrafiltration (UF) membranes which can rarely remove dissolved material. Thus, as shown in figure 5, based on paired t-test analysis, there was no significant difference between TDS concentration in feed and filtrate ($P > 0.05$).

Conclusion

Complete treatment of leachate due to the omplexity of its composition is today's challenge. MBR is a versatile technology with high throughput and can treat compost leachate. Contrary to previous studies which had used MBR independently, in the application of MSBR process for advanced treatment of pre-anaerobic/aerobic treated compost leachate, a BOD_5 and total COD effluent concentration of below the Iranian standard were obtained. TDS values were higher than the permitted limit. There were no significant differences in MSBR filtrate quality in a varied range of feed concentration. Nevertheless, in high loading, membrane clogging led to filtrate flux loss and increase in the frequency of membrane cleaning and replacement. The acceptable performance of the MBR under different conditions suggests the promising capability of a full-scale, on-site MBR as an efficient and flexible treatment system in handling the fluctuating nature of both the quantity and quality of the leachate. Post-treatment processes, such as nanofiltration (NF), reverse osmosis (RO), or advanced oxidation processes (AOPs), can be used for low residual levels in MBR filtrate to even meet reusable quality.

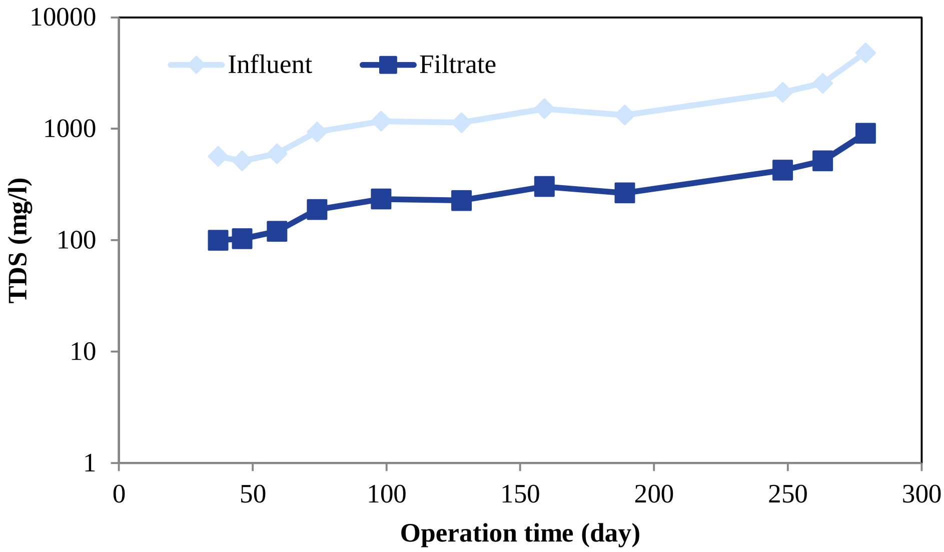

Figure 5. Total dissolved solids (TDS) concentrations during process operation
TDS: Total dissolved solids

Conflict of Interests

Authors have no conflict of interests.

Acknowledgements

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References

1. Taiwo AM. Composting as A Sustainable Waste Management Technique in Developing Countries. Journal of Environmental Science and Technology 2011; 4(2): 93-102.
2. Safari E, Jalili Ghazizade M, Shokouh A, Nabi Bidhendi GR. Anaerobic removal of COD from high strength fresh and partially stabilized leachates and application of multi stage kinetic model. International Journal of Environmental Research 2011; 5(2): 255-70.
3. Hashemi H, Ebrahimi A, Khodabakhshi A. Investigation of anaerobic biodegradability of real compost leachate emphasis on biogas harvesting. Int J Environ Sci Technol 2015; 12(9); 2841-6.
4. Castrillon L, Fernandez-Nava Y, Ulmanu M, Anger I, Maranon E. Physico-chemical and biological treatment of MSW landfill leachate. Waste Manag 2010; 30(2): 228-35.
5. Abbas AA, Jingsong G, Ping LZ, Ya PY, Al-Rekabi WS. Review on landfill leachate treatments. Journal of Applied Sciences Research 2009; 5(5): 534-45.
6. Neczaj E, Kacprzak M, Lach J, Okoniewska E. Effect of sonication on combined treatment of landfill leachate and domestic sewage in SBR reactor. Desalination 2007; 204(1-3): 227-33.
7. Hashemi H, Hajizadeh Y, Amin MM, Bina B, Ebrahimi A, Khodabakhshid A, et al. Macropollutants removal from compost leachate using membrane separation process. Desalination and Water Treatment 2015.
8. Kaewsuk J, Thorasampan W, Thanuttamavong M, Seo GT. Kinetic development and evaluation of membrane sequencing batch reactor (MSBR) with mixed cultures photosynthetic bacteria for dairy wastewater treatment. J Environ Manage 2010; 91(5): 1161-8.
9. Ahmed FN, Lan CQ. Treatment of landfill leachate using membrane bioreactors: A review. Desalination 2012; 287: 41-54.
10. Chan YJ, Chong MF, Law CL, Hassell DG. A review on anaerobic-aerobic treatment of industrial and municipal wastewater. Chemical Engineering Journal 2009; 155(1-2): 1-18.
11. Eaton AD, Franson MA. Standard methods for the examination of water and wastewater. Washington, DC: American Public Health Association; 2005.
12. Laitinen N, Luonsi A, Vilen J. Landfill leachate treatment with sequencing batch reactor and membrane bioreactor. Desalination 2006; 191(1-3): 86-91.
13. Campagna M, alCakmakci M, Busra Yaman F, Ozkaya B. Molecular weight distribution of a full-scale landfill leachate treatment by membrane bioreactor and nanofiltration membrane. Waste Management 2013; 33(4): 866-70.
14. Insel G, Dagdar M, Dogruel S, Dizge N, Ubay CE, Keskinler B. Biodegradation characteristics and size fractionation of landfill leachate for integrated membrane treatment. J Hazard Mater 2013; 260: 825-32.
15. Brown K, Ghoshdastidar AJ, Hanmore J, Frazee J, Tong AZ. Membrane bioreactor technology: A novel approach to the treatment of compost leachate. Waste Management 2013; 33(11): 2188-94.
16. Garces A, De Wilde W, Thoeye C, GueldreG. Operational cost optimization of MBR Schilde. Proceedings of the 4th IWA International Membranes Conference-Membranes for Water and Wastewater Treatment; 2007 May 15-17; Harrogate, UK.
17. Achilli A, Cath TY, Marchand EA, Childress AE. The forward osmosis membrane bioreactor: A low fouling alternative to MBR processes. Desalination 2009; 239(1-3): 10-21.
18. Le-Clech P, Jefferson B, Judd SJ. A comparison of submerged and sidestream tubular membrane bioreactor configurations. Desalination 2005; 173(2): 113-22.