Original Article

Evaluate the effects of organic loading rate from windrow composting leachate on the performance of an anaerobic migrating blanket reactor

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ABSTRACT

Aims: Feasibility of the anaerobic migrating blanket reactor (AMBR) was investigated for the treatment of composting leachate.
Materials and Methods: The AMBR consisted of a rectangular, plexiglas reactor (inside dimensions: length = 43 cm, height = 23.5 cm, width = 10 cm) with an active volume of 10 L. which divided reactor into four identical compartments (2.5 L). Composting leachate was used as a feed. Start-up of a reactor with diluted feed of approximately 10.43 g/L. Chemical oxygen demand (COD) was accomplished in about 44 weeks using seed sludge from the anaerobic digester of municipal wastewater treatment plant and operated continuously at mesophilic phase. The organic loading rates (OLRs) applied to the system was gradually increased from 1 to 19.65 g COD/L.d.
Results: The reactor with hydraulic retention time of 10 day at 35°C and initial OLR of 1 g COD/L.d showed 82.3% COD removal efficiency. The best performance of the reactor was observed with an OLR of 3.79 g COD/L.d. In influent of reactor, BOD_5/COD ratio, TSS, VSS and TDS were ranged from 0.47 to 0.69, 1650 to 16,830, 990 to 12,622 and 2630 to 31,240 mg/L and in effluent of reactor were reached to 0.28 to 0.38, 660 to 7452, 346.5 to 4597 and 1860 to 19,490 mg/L, respectively.
Conclusion: The AMBR could be an appealing option for pretreatment of organic load in composting leachate and improving the efficiency of the next biological reactors.

Key words: Anaerobic migrating blanket reactor, composting leachate, organic loading rate, readily biodegradable chemical oxygen demand

Access this article online	
Quick Response Code:	Website: www.ijehe.org
	DOI: 10.4103/2277-9183.163973

INTRODUCTION

Recently, composting is increasingly used worldwide as a means of solid waste management to change organic wastes to organic fertilizer identify as compost.[1] Windrow composting of organic waste are the most commonly used in the large cities of Iran, in this process, leachate is produced that significant effects on the environment.[2-4] Composting

This article may be cited as:
Ebrahimi A, Amin MM, Bina B, Ebrahimi A, Pourzamani H, Hajizadeh Y, *et al*. Evaluate the effects of organic loading rate from windrow composting leachate on the performance of an anaerobic migrating blanket reactor. Int J Env Health Eng 2015;4:30.

leachate constitutes a very complex composition, which may contain a large number of xenobiotic organic compounds faced in the solid waste disposal site or formed as a result of biological and chemical processes.[5,6]

The treatment of composting leachate is very complicated and generally requires various and combined process applications.[7] Biological treatment of composting leachate is a suitable process because The persistent substances of composting leachate is less than landfill leachate and have a relatively high 5-day biochemical oxygen demand (BOD_5)/ chemical oxygen demand (COD) ratio.[8] Therefore, these process are hardly efficient for removal of bioresistant organics.[9] It is better that leachate was treated by anaerobic method due to its high organic load.[10-13] Many of studies were done on the treatment of landfill and composting leachate by anaerobic migrating blanket reactor (AMBR), anaerobic baffled reactor and upflow anaerobic sludge blanket (UASB) reactor in a pilot and full scale and obtained COD removal efficiency more than 70%.[13-17]

In this study, an AMBR was applied to treat a composting leachate. Because of the AMBR process is an appropriate process for treatment of high organic compounds and this process resistance to hydraulic shock loads and presence of toxic substances.[18,19] The most advantage of the AMBR is its ability to separate acidogenesis and methanogensis longitudinally down reactor, allowing the reactor to behave as a two-phase system without the associated control problems and high costs.[20] The separation of two phases causes an increase in protection against toxic material and higher resistance to changes in environmental parameters such as pH, temperature, and organic loading.[21,22] Innovation of this research is that, biological pretreatment of composting leachate produced from mixed municipal solid waste. The aim of this study was to evaluate of the effects of organic loading rate (OLR) from composting leachate on the performance of an AMBR.

MATERIALS AND METHODS

Experimental set-up, sampling and operation

The rectangular section dimensions of the AMBR reactor used in this study were inside dimensions, length = 43 cm, height = 23.5 cm and width = 10 cm, with an active volume of 10 L [Figure 1]. The AMBR reactor contained vertical mixers and standing baffles which divided reactor into four identical compartments (2.5 L). Each compartment has down comer and riser regions created by a further vertical baffle. The width of up comer was 2.6 times of the width of down comer.

Biomass sampling valves was installed at a height of approximately 8 cm from the top of each chamber. The temperature of the reactor was maintained at 35 ± 1°C, by an internal heater supported by thermocouple. All pumps were injection diaphragm pumps of Etatron Co, Italy. Programmable logic controller system was used to control the reactor operation (Omron, Japan).

The AMBR reactor was inoculated with 5 L sludge from an anaerobic digester (North Isfahan, IR) that operated at 35°C. Total suspended solid (TSS) and volatile suspended solid (VSS) concentration of the seed sludge were 35.5 and 26.65 g/L. It was first sieved (<2 mm) to remove any debris and large particles.

The samples were taken from the Isfahan composting factory [Figure 2]. The leachate samples have taken from composting factory of Isfahan city in Iran. That is located 8 km west of Isfahan with altitude of about 1550 m above mean sea level. This factory is received 1200 tons/day of solid waste generated from the Isfahan area and its surroundings. The organic waste constitutes about 70% of the waste stream resulting in relatively high moisture (60-70%).[23] Samples were taken from an influent evaporative lagoon and in standard condition were transferred to the laboratory of Isfahan University of medical science of Iran. Table 1 represents the characteristics of the

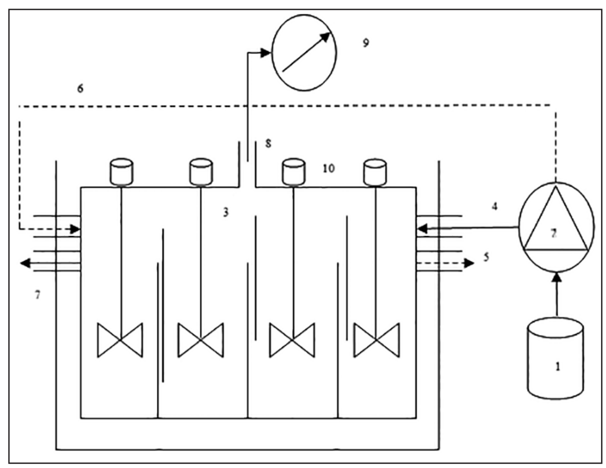

Figure 1: Schematic diagram of the anaerobic migrating blanket reactor (AMBR) (1 - Feed Tank, 2 - Injection Pump Diaphragm, 3 - AMBR reactor, 4 and 6 - Influents, 5 and 7 - Effluents, 8 - Biogas output, 9 - Gas meter, 10 - Mixers)

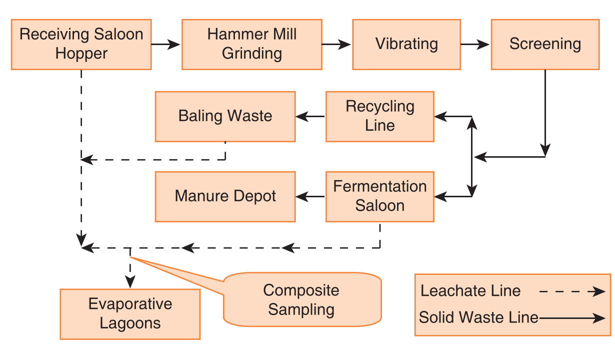

Figure 2: Processing of municipal solid waste in Isfahan composting factory

Table 1: Characteristics of raw composting leachate

Raw leachate	Range	Average
COD (g/L)	80-120	95.5
BOD_5 (g/L)	49-69.5	55.2
TSS (g/L)	14-17	15.5
TDS (g/L)	28-31.5	29.6
TKN (g/L)	1.8-2.8	2.3
Orthophosphate as P (g/L)	0.25-0.35	0.28
EC (ms/cm)	30-37.5	33.5
pH	3.5-5.5	4.4

COD: Chemical oxygen demand, BOD: Biochemical oxygen demand, TSS: Total suspended solid, TDS: Total dissolved solid, TKN: Total kjeldahl nitrogen, EC: Electrical conductivity

leachate used in this study. The COD concentration of raw leachate was in the range of 80-110 g/L. Thus, it was diluted with tap water to optimum concentration with the volume of 1 L and continuously fed into the AMBR reactor using a peristaltic pump. It was made up freshly every 7 days and stored in a refrigerator at 4°C.

The initial COD loading rate of the reactor was 1 g COD/L.d after the startup period, which corresponded to 10 days of hydraulic retention time (HRT). The loading rate was increased by decreasing the dilution of inflow leachate of the reactor, and steady-state condition was identified when the COD removal efficiency exceeded 75%, and the biogas production rate was consistent in the three consecutive analyses. OLRs gradually increased to 19.65 g COD/L.d. In the period of the adaptation phase, the raw leachate with pH between 3.5 and 5 was neutralized using NaOH.

Operating time of AMBR reactor for all OLRs was 280 days in 11 runs. Initially, in order to prevent the washout of biomass floc, the final compartment was not mixed. After 2 months of operation, all four compartments were mixed equally for 10 s every 15 min at 80 rotations min to ensure gentle mixing (Mixers: Model Landa). Monitoring included the analysis of samples from the influent and each compartment of the AMBR system for COD, TSS, VSS, and pH. Temperature and pH were monitored daily.

Analyzes

The pH and electrical conductivity (EC) was measured with a calibrated pH and EC meter (Schott Model). COD measurement was conducted based on Dichromate method (closed reflux, 5220 C, colorimetric method, Spectrophotometer Milton Roy Company 2OD), and BOD_5 in accordance to Winkler's method (5210 B) (APHA, 2005).[24] The floc/filtration method was used for measurement of the readily biodegradable COD (rbCOD) concentration.[25] For SS analysis, 100 ml, filtered and weighted samples were heated in a plate till dry and then kept in an oven for 1 h, at 110°C. The SS was calculated from the difference between the wet and dry weight of the filtered samples. The VSS analysis was performed by burning the samples in a furnace at a temperature of 550°C.[24] Each experiment was performed in duplicate to determine experimental errors.

RESULTS

Reactor start-up

In order to reactor start-up, the batch operation of AMBR was started using an initial sludge concentration of 26,650 mg VSS/L. The system was run on a batch for 2 weeks. During this time, the content of the reactor was recycled for homogeneity. After these time the AMBR was run continuously and observation were made for 40 days with first and second OLR of 0.53 and 0.78 g COD/L.d with influent COD in the range of 5-8 g/L. When there was no more fluctuation in COD, then OLR was increased up to 1 g COD/L.d in run 1. Removal efficiency of COD in start-up time was achieved to more than 75% and is shown in Figure 3.

Chemical oxygen demand, soluble chemical oxygen demand and readily biodegradable chemical oxygen demand removal efficiency

The average influent of COD, soluble COD (sCOD), rbCOD, BOD_5 were in the ranges of 10.43-100.77, 3.34-40.31, 1.56-29.22, 4.93-69.53 and effluent concentration of theirs are 1.85-25, 0.42-7.25, 0.07-2.3 and 0.52-8.56 g/L, respectively. Furthermore, influent and effluent ranges of BOD_5/COD ratio are 0.47-0.69 and 0.28-0.38. The effects of increasing COD concentrations in influent flow on the COD removal efficiency were examined, under steady-state conditions and are shown in Figures 4 and 5. It also indicates the reactor effectiveness as percent COD removal. After each increase in OLR the COD, sCOD, and rbCOD concentrations in effluents increased. Average removal efficiency of COD, sCOD, rbCOD and BOD_5 in HRT = 10 days were 80.88%, 85.70%, 94.43% and 89% and the best removal efficiency was at an OLR of 3.8 g COD/L.d (HRT of 10 days) and the COD, sCOD, rbCOD and BOD_5 conversion of 82.8%, 85.7%, 96.48% and 90.65% were achieved. The removal efficiency of COD, sCOD, rbCOD and BOD_5 in HRT = 5 day were decreased to 74.6%, 79.3%, 87.7% and 83.8%, respectively [Figures 4 and 5]. The variations of COD in the reactor are illustrated in Figure 6. The most removal efficiency of COD was done in compartment 1 (52%).

pH

pH variation profile is show in Figure 7. The results of pH variations along with the reactor showed that the pH decrease in compartment 1, 2-3% during the reactor operation. However, the pH in next compartments returned to near neutrality.

Sludge characterization

The influent and effluent of TSS and VSS concentration also VSS/TSS ratios in AMBR reactor at different OLRs are presented in Figure 8. The influent concentration of TSS and VSS were in the ranges of 1.65-16.74 and 0.99-12.56 g/L. The effluent concentration of TSS and VSS were in the ranges of 0.66-7.45 and 0.34-4.59 g/L, respectively. At the time of

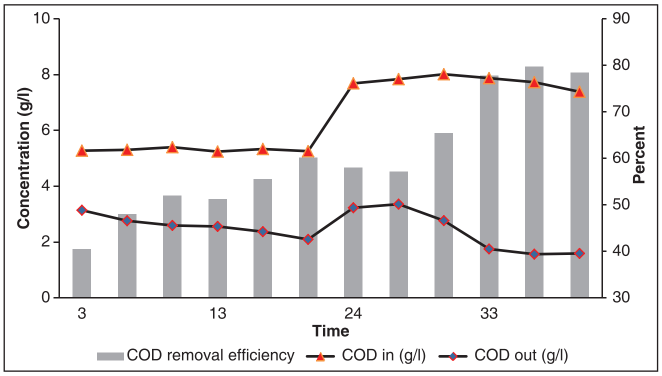

Figure 3: Variation of influent and effluent chemical oxygen demand concentration in start-up time in anaerobic migrating blanket reactor

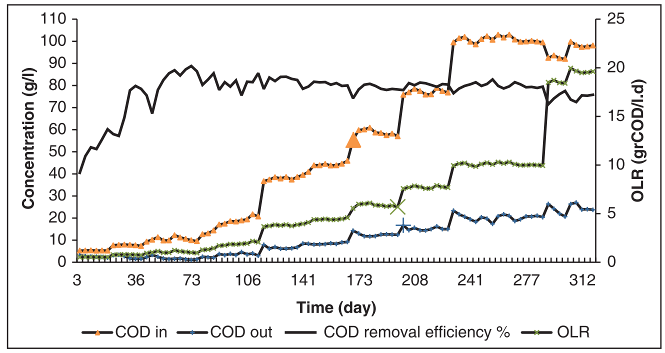

Figure 4: Variation of influent and effluent of chemical oxygen demand (COD) concentration, organic loading rates and removal efficiency of COD in operation time in anaerobic migrating blanket reactor

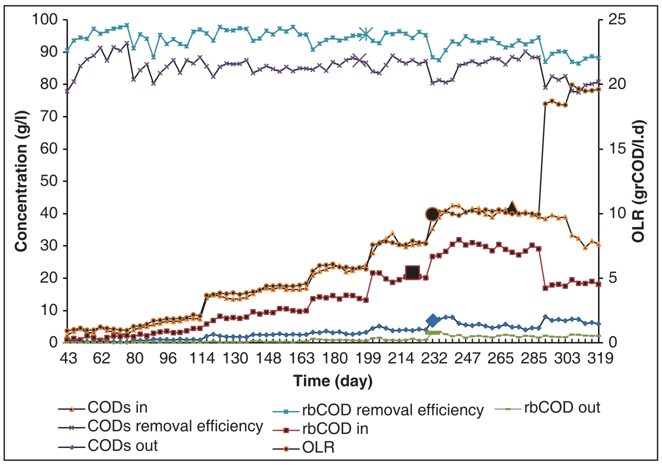

Figure 5: Variation of influent and effluent of soluble chemical oxygen demand (sCOD) and readily biodegradable chemical oxygen demand (rbCOD) concentration, organic loading rates and removal efficiency of sCOD and rbCOD in operation time in anaerobic migrating blanket reactor

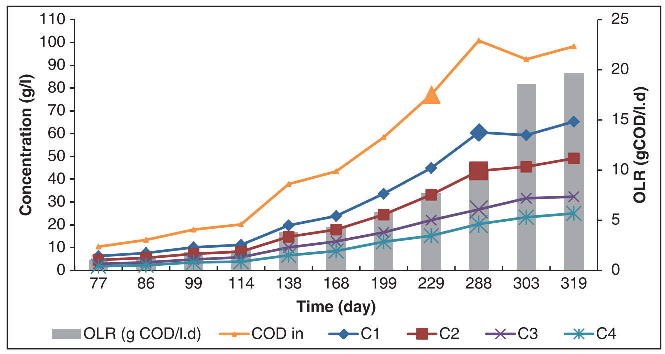

Figure 6: Chemical oxygen demand variation at different compartments of anaerobic migrating blanket reactor (C_i = compartment)

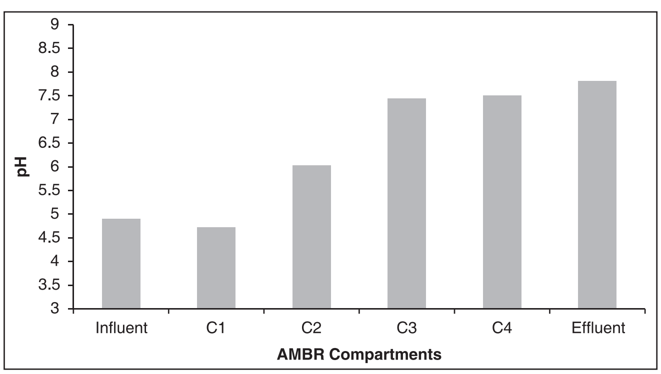

Figure 7: pH variation profile during anaerobic migrating blanket reactor operation period

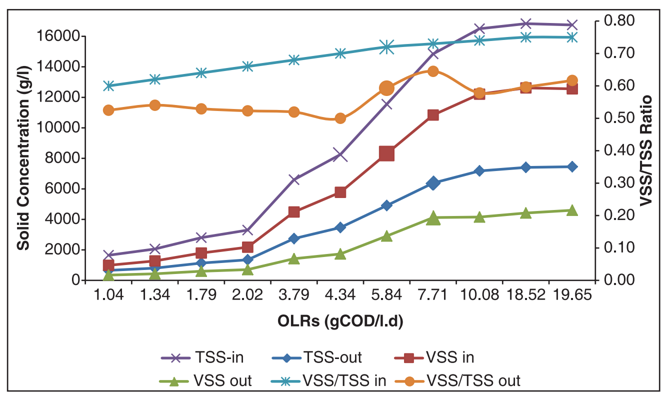

Figure 8: Total suspended solid (TSS), volatile suspended solid (VSS) and VSS/TSS ratio in anaerobic migrating blanket reactor during operation period

reactor start-up, influent and effluent of VSS/TSS ratio were 0.6 and 0.53. The influent of VSS/TSS increased up to 0.75 at an OLR of 19.65 g COD/L.d. The effluent of this ratio decreased to 0.5 at an OLR of 4.34 g COD/L.d, then increased up to 0.65 at an OLR of 7.71 g COD/L.d next decreased to 0.62 at an OLR of 19.65 g COD/L.d.

DISCUSSION

In this experiment, the maximum removal efficiency of COD, sCOD, rbCOD and BOD_5 was 82.8%, 87.42%, 96.48%, and 90.65% at OLRs of 4 g COD/L.d and lower. Furthermore, the removal efficiency of rbCOD and BOD_5 were higher than COD and sCOD. High removal efficiencies were achieved for COD, sCOD, rbCOD and BOD_5 by the AMBR system due to the relatively high biodegradability of leachate.

The other studies are exhibited similar results, the study of Shooshtari *et al*. is show that 87% sCOD removal efficiency, at an OLR of 12 g COD/L.d, While maximum influent COD concentration was 35 g/L in treatment of landfill leachate by UASB reactor.[13] The result survey of Ndon and Dague indicate on the effect of HRT on anaerobic sequencing batch reactor and achieved 80-90% sCOD removal efficiency at different dilute substrate concentrations.[26] The result study of Angenent and *et al*. is show, the AMBR reactor is very efficient with sCOD removals of 94.9% for loading rates up to 25 g COD/L.d at an HRT of 12 h.[16]

The raw composting leachate had an average BOD_5/COD ratio of 0.58, which suggested that the leachate was biodegradable by biological treatment process. The study of Xu *et al*. is shown that landfill leachate have a BOD_5/COD ratio of 0.71.[27]

When increasing the OLR to 19.65 g COD/L.d and HRT = 5 day [Figures 4 and 5] removal efficiency of COD, sCOD, rbCOD and BOD_5 decreased. The slope of the curve decreases because while the loading rate increases and HRT decreases, the COD removal rate efficiency cannot be maintained. The result study of Chang (1989) is show also treated municipal leachate at a concentration of 58,400 mg COD/L using of continuous UASB type reactor.[28] COD removal efficiencies are 81.7-92.8% for OLR lower than 13 kg COD/m^3.day but decreased to 67.9% when the OLR is increase to 22 kg COD/m^3.day.[28] Toprak is discover that the COD removal efficiency correlates inversely with the organic loading.[15] The results are achieve by Agdag and Sponza is show, when the OLR increased from 4.3 to 16 kg/m^3/day, the COD removal efficiency decreased.[29] Increasing of flow rate was effecting on poor substrate with the biomass contact and least degradation of the incoming COD. Channeling in parts of the reactor could have happened over short time periods. Although enough biomass was present in the reactor to degrade the organic load, the high flow rate made it infeasible for the biomass inside the reactor to decay the substrate completely.[18,30] In addition, when AMBR treating leachate at a 5 day HRT showed signs of stress characterized by a marked decrease in both the sCOD removal efficiency and accumulation of volatile fatty acid (VFA) in the reactor.[31]

Using performance data from Table 2 and the BOD_5: COD ratio, the AMBR treating 100% leachate produced effluent that would exceed regulations. For this particular case, it would seem that anaerobic treatment is best suited as a pretreatment method. The factors resulting in the COD removal stabilization could be the high chloride concentration along with low nitrate and phosphate concentrations. However, further research is required to quantify the effect of inhibiting factors such as ammonia nitrogen, chloride, and low concentrations of phosphate and nitrate.

The variation in the COD profile in AMBR was shown in Figure 6. As it can be seen, most of COD was removed in compartment 1 (50%), increasing the initial OLR enhanced the biological oxidation up to a certain point at which OLR started to inhibit the degradation rate. As a result of, in strong wastewater containing high organic load, significant amounts of fatty acids can develop from partial degradation of the substrate and these can inhibit the methanogenic population in the reactor.[22]

According to Figure 7, the effluent pH was always more than the feed pH. The pH decrease in compartment 1 can be attributed to the fact that high concentrations of VFAs were present in this compartment, while in next compartments due to conversion and stabilization of intermediate product, that is, VFAs to methane ratio and activity of methanogenic bacteria the pH value increased to neutral range.[22]

The result [Figure 8] shows that the reactor was stable to severe shocks loads. This is according to the study of Nachaiyasit and Stuckey, which indicates that this process

Table 2: Influent and effluent concentration and ratio of COD, SCOD, rbCOD, BOD_5 and BOD_5/COD in AMBR

Time (day)	Run	HRT(d)	OLR (gCOD/l.d)	COD (g/l)		SCOD (g/l)		rbCOD (g/l)		BOD_5 (g/l)		BOD_5/COD	
				in	out	in	out	in	out	in	out	in	out
1-37	1	10	1.04	10.43	1.85	3.34	0.42	1.56	0.07	4.90	0.52	0.47	0.28
38-46	2	10	1.34	13.38	2.30	4.55	0.73	2.21	0.14	6.76	0.75	0.51	0.33
47-59	3	10	1.79	17.89	3.52	6.26	0.99	3.22	0.24	9.48	1.28	0.53	0.36
60-74	4	10	2.02	20.19	3.82	7.27	0.98	3.94	0.22	11.20	1.12	0.56	0.29
75-98	5	10	3.79	37.87	6.63	14.01	2.00	7.39	0.26	21.40	2.00	0.57	0.30
99-128	6	10	4.34	43.43	8.50	16.50	2.53	9.77	0.41	26.28	3.25	0.61	0.38
129-159	7	10	5.84	58.38	12.56	22.77	3.10	14.01	0.85	36.78	4.32	0.63	0.34
160-189	8	10	7.71	77.09	15.23	30.84	4.20	20.43	1.00	51.26	4.85	0.67	0.32
190-248	9	10	10.08	100.77	20.33	40.31	5.65	29.22	2.21	69.53	7.54	0.69	0.37
249-263	10	5	18.52	92.61	23.33	38.90	7.25	17.60	1.90	56.49	8.56	0.61	0.37
264-279	11	5	19.65	98.26	25.00	31.44	6.52	18.67	2.30	50.11	8.15	0.51	0.33
Minimum			1.04	10.43	1.85	3.34	0.42	1.56	0.07	4.90	0.52	0.47	0.28
Maximum			19.65	100.77	25.00	40.31	7.25	29.22	2.30	69.53	8.56	0.69	0.38

is stable to large unstable shock loads.[32] Determination of VSS/TSS ratio gives correlation to the biomass growth and its quality. At the time of reactor start-up, influent and effluent of VSS/TSS ratio were 0.6 and 0.53. The effluent of this ratio decreased to 0.5 at an OLR of 4.34 g COD/L.d and then increased up to 0.65 at an OLR of 7.71 g COD/L.d next decreased to 0.62 at an OLR of 19.65 g COD/L.d. This provides further support to the earlier hypothesis that biomass growth rate is limited in high OLR.[25]

CONCLUSION

The AMBR reactor has potential in treating composting leachate that varies in both flow and concentration. Because of these characteristics, AMBR reactor could be a suitable system as pretreatment for anaerobic or aerobic wastewater treatment processes. The maximum removal efficiency of COD, sCOD, rbCOD and BOD_5 was 82.8%, 87.42%, 96.48%, and 90.65% at OLRs of 4 g COD/L.d and lower and the COD removal efficiency correlates inversely with the organic loading. Further research is required to quantify the effect of inhibiting factors such as ammonia nitrogen, chloride, and low concentrations of phosphate and nitrate. The effluent sCOD concentration of the AMBR reactor in this study was 5.65 g/L, which did not pass the effluent standards (Act of the Iran Department of Environment) so, it was necessary to use an anaerobic and aerobic process after the AMBR reactor.

ACKNOWLEDGMENTS

This work was financially supported by the Department of Environment Health Engineering, Isfahan University of Medical sciences, Isfahan, Iran.

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Source of Support: Isfahan University of Medical Sciences, **Conflict of Interest:** None declared.