Complete Treatment of Compost Leachate Using Integrated Biological and Membrane Filtration Processes

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ABSTRACT: *A lab-scale SBR equipped with a flat sheet membrane in submerged configuration that is named MSBR was used for treatment of composting leachate. It was fed by biologically treated leachate with overall 70-1360 mg/L Chemical Oxygen Demand (COD). The values of pH, Electrical Conductivity (EC), and Dissolved Oxygen (DO) were monitored routinely. However, analysis of total COD, Soluble COD (SCOD), Biological Oxygen Demand (BOD_5), Total Suspended Solids (TSS) and Volatile Suspended Solids (VSS) were done in feed and filtrate, whenever the system reached steady state twice a week for about 6 months. In all loading rate, BOD_5 concentration was less than standard limit. The removal efficiency of total COD increased in bioreactor with time in all experiments was up to 80%. Influent SCOD varied spectacularly (50-1050 mg/L) due to the leachate collection during different seasons but in the effluent it remained relatively stable. About 60% of the feed SCOD was non biodegradable type that was separated by the membrane. Up to 99 % further solids was removed with micro pore membrane which might be mainly included in colloidal solids. The value of EC for the leachate sample was 0.86-4 mS/cm in 22 °C which decreased by membrane significantly. It was concluded that, MSBR as a versatile technology with high throughput could treat composting leachate below the standard limit if used after proper processes.*

KEYWORDS: *Treatment; Composting leachate; MSBR; Standard*.

INTRODUCTION

One of the major concerns associated with the treatment of organic wastes in composting facilities is the management and treatment of leachates, which present a high organic load [1]. High values of COD in the composting leachate will deplete the dissolved oxygen in receiving waters. The resulting anoxic environments cause fatalities of plants, fish and other aquatic organisms. Many toxic organic compounds exist in the leachate, i.e. if it is not treated properly, surface and groundwater may become contaminated placing the

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public and local ecosystems at risk [2, 3]. In comparison with landfill leachate, composting leachate is a strong wastewater with a complex composition containing potential pathogens, dissolved organic matters, inorganic macrocomponents, heavy metals, and xenobiotic organic compounds that should be treated properly [4]. Typical research focuses on biological and physiochemical treatment of leachate such as anaerobic digestion, reverse osmosis, fenton reagent, etc [5]. Physical or chemical treatment methods for leachate treatment have focused on one particular water quality parameter or showed low efficiency. Further, the lack of flexibility, need high maintenance and may introduce new contaminants [2]. Raw leachate may be treated anaerobically, saving the environment and converting the organic material partially to biogas energy [6]. However, because of the complex chemical composition of leachate resulting from composting operations, conventional aerobic processes (activated sludge or SBR) are not sufficient anymore to reach the level of purification needed to fully reduce the negative impact of leachates on the environment [7]. Nowadays, the combination of several processes is used for treatment of these heavily polluted wastewaters [8]. Coupling of membrane separation technology and sequencing batch bioreactors, most commonly called Membrane Sequencing Batch Reactor (MSBR) can replace the biomass settling and effluent withdrawal from the original SBR process [9]. Annual marketing growth rate of 10.5% indicate the widespread application (more than 5000 under operation) of membrane technology throughout the world. Over 50 and 15 MBR plants for leachate treatment have been installed in Europe and China in the last 5 years respectively [10]. Integrated bioreactors can attain carbon credit derived from Clean Development Mechanism (CDM) under Kyoto protocol 1997, changing the paradigm of wastewater management from ‘treatment and disposal’ to ‘useful utilization’ as well as ‘beneficial endeavor’[11]. With integration of SBR and membrane, bulking is no problem and the quality of produced water is much more stable [12] because; MSBR technology provides biological treatment with membrane separation [2]. The MSBR system consists of an aerated water-filled tank containing activated sludge and multiple capillary- form membrane tubes. The pores of the membranes effectively retain the microorganisms, macromolecules and suspended solids. It has many advantages over conventional activated sludge treatment processes. The overall retention time of the activated sludge is longer in the MSBR, which increases contact opportunities of bacteria with contaminants, and subsequently leads to high efficiency [13]. MSBR system is very compact, particularly compared to the space required by engineered wetlands. Also, it is not affected by freezing caused by sub-zero temperatures, thus it can be used during all times of year [2]. Membrane sequencing batch reactor effluent has a high quality with less fluctuation [14]. Sludge treatment cost in MSBR is minimized when aeration cost is maximized. Economically optimum HRT and target MLSS were turned out to be 16 h and 11,000 mg/L respectively [15]. However 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 [11]. Inorganic coagulants or Powdered Activated Carbon (PAC) addition to the bioreactor can reduce fouling significantly [16]. Recently, a semi permeable membrane called Osmotic Membrane BioReactor (OsMBR) has been suggested instead of microporous membrane as a low fouling alternative [17]. In comparison with side stream (sMBR) configuration, submerged or immersed (iMBR) is most widely used due to lower associated costs of operation [18]. MSBR can also be operated as an anaerobic system. The anaerobic MSBR treating dairy wastewater (at HRT of 1.5 d) could achieve BOD removal around 97–98% [9]. Staged anaerobic–aerobic MBR has been employed successfully in treatment of high strength synthetic wastewater containing high concentrations of ammonium with COD up to 10500 mg/L and NH^{4+}-N up to 1220 mg/L. The reported COD removals have exceeded 99% for OLR up to 10.08 kgCOD m^3/day [19]. The removal efficiencies of total organic constituents were in the order of BOD (99%) > COD (89%) > TOC (87%), whereas the removal efficiencies of investigated organic micro pollutants were as follows: organochlorinated pesticides (OCPs) (94%) > 4-nonylphenol (4-NP) (77%) > PAHs (59%) [20]. According to literature, separate application of membrane bioreactor for raw leachate treatment leads to the high fouling and increasing of costs [21]. Hence, we decided to use this process as a complementary unit in composting leachate treatment after anaerobic-aerobic processes.

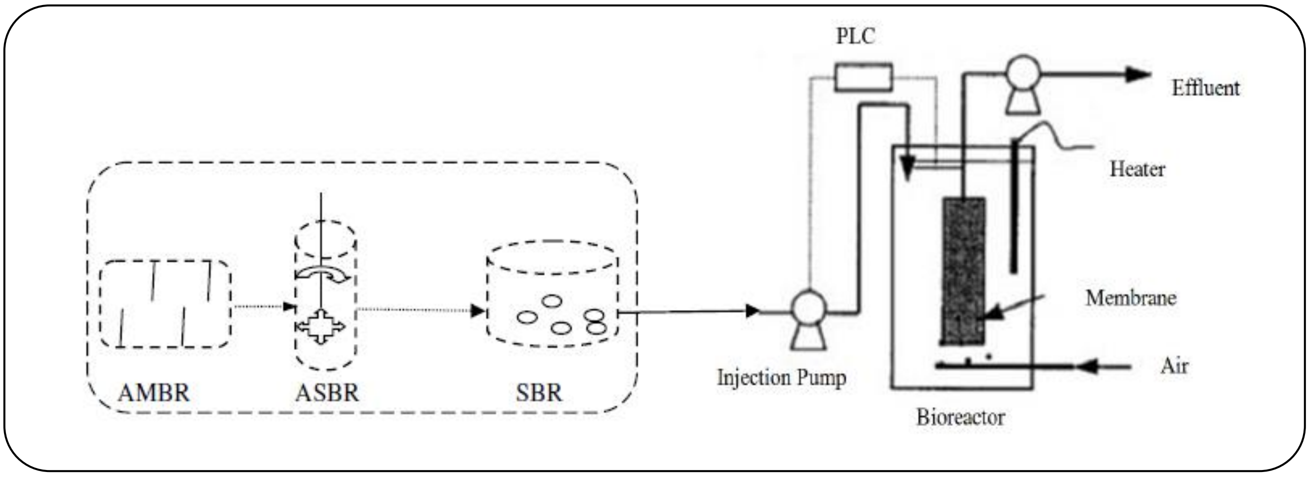

Fig. 1: Schematic of processes used in this study

EXPERIMENTAL SECTION

The experimental unit consisted of a cylindrical 2 L SBR equipped with polyethersulfone membrane, nominal pore size of 0.4 µm 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 max operating TransMembrane Pressure (TMP) of -0.6-0 kgf/cm^2. Details of the MSBR reactor used in this study are presented in Fig. 1.

Composting leachate samples were taken grab method and stored in 4ºC in laboratory. After reaching MSBR efficiency more than 80%, biologically pretreated leachate was fed into a reactor which was continuously aerated using air compressor and diffusers to keep DO concentration above 2 mg/L to supply oxygen for the biomass and to scour the membrane. MSBR worked under different process conditions obtained by HRT= 23-12 h, SRT= 14 days, VER = 0.5, and cycle time (tc), including (feeding = 15 min, aeration= 12-23 hrs, settling = 0.5h and withdrawal = 15 min). The bioreactor was adapted by the addition of sufficient quantity of activated sludge and diluted leachate. Relaxation is used to control the fouling of the membrane at the end of the run time. At the beginning of all the experiments, the membrane was backwashed with permeate flow until the permeate flux stabilized. In addition, before loading the membrane into the bioreactor, it was rinsed thoroughly with permeate and then immersed in 200 ppm sodium hypochlorite as a cleaning solution, for 30 min [22]. The values of pH (Metrohm Herisau-E520), TDS (HACH Sension5), and DO (Oxi 330i, WTW, Germany) were monitored routinely. However, analyses of total COD, SCOD (spectrophotometer DR-5000, Model 8452A, Hatch-Lange), BOD_5 (Oxitop bottles, WTW IS 6, Germany), and MLSS (Gravimetery) were done in feed and filtrate, whenever the system reached a steady state according to the Standard Method of Water and Wastewater [23]. TOC was measured using total organic carbon analyzer (Shimatsu TOC 500).

RESULTS AND DISCUSSION

Integrated MSBR process was fed in varied organic matter concentration (85- 5356 mg/L COD) and reaction time of 23 and 12 h. Seasonal variations in leachate characteristics led to changes in the MSBR feed concentrations. The results of biotreatment and filtration of composting facilities leachate are presented in Figs. 2 to 5.

In this study after adaptation period, MLSS values were around 4000 mg/L and increased around 11000 mg/L after 280 days operation. The pH values in the bioreactor reached 8 but they decreased in filtrate around 7.5. The BOD_5 concentration in biological treated leachate ranged between 100 to 498 mg/L (Fig. 2). The removal efficiency was 93±10 % during the operational time. As shown, at all loading rates, effluent concentration was less than the national standard limit for discharge to the river (<100 mg/L) [22].

In general, COD in membrane filtrates was composed of high molecular weight, refractory compounds, Soluble Microbial Products (SMP), partly due to the presence of dispersed biomass or recalcitrant bacterial debrises [*21*]. Total COD concentration in the feed ranged 140-4200 mg/L.

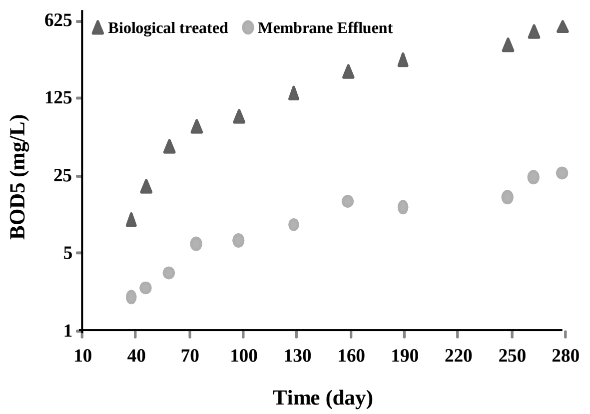

Fig. 2: Trend of BOD_5 concentration in biological and membrane effluent.

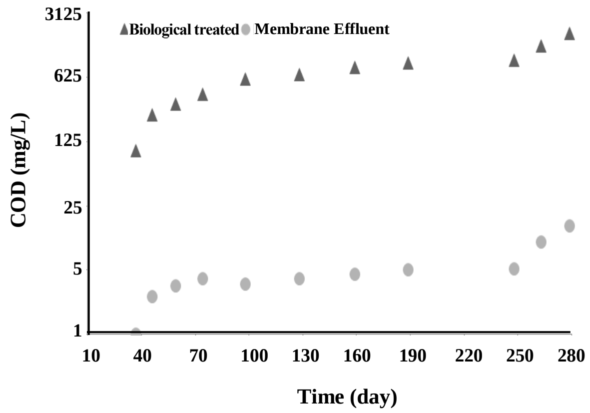

Fig. 3: Trend of COD concentration in biological and membrane effluent.

Variations of COD concentrations with time are shown in Fig. 3. COD removal efficiency increased in bioreactor with time in all experiments up to 70%. In spite of high BOD_5 removal in coupled process, overall COD reduction was not as adequate as that of BOD_5 degradation. This includes soluble COD portion so that the considerable SCOD values were analyzed (186 mg/L) in filtrate specially in loading more than 3500 mg/L COD. Large variations in feed COD and operation conditions were not affecting the MSBR effluent quality.

SCOD in the bioreactor influent varied spectacularly (66-3664 mg/L) due to the leachate collection during different seasons but in effluent remained relatively stable. This circumstance allows us to operate the MSBR system under different loading conditions. SCOD determination by 0.2 μm filters using spectrophotometer revealed that about 60% of the feed COD is of the nonbiodegradable type that was separated by the flat sheet membrane. Variation of SCOD values in MSBR filtrate agreed with another study result that was between 72.3% and 96.2% [24]. The range of TOC concentration in MSBR filtrates was 0.2-8 mg/L using TOC analyzer. The total permeation fluxes of MFI zeolite membrane in separation of BTX from water were found to increase with increasing of the temperature and feed concentration. The separation factors increased with increasing feed concentration and decreased with increasing of temperature [25].

Upgrading MBR with activated carbon removed the significance level of recalcitrant and bio-refractory compounds from leachate with reduced fouling [26]. The membrane process coupled with a SBR not only replaces the sedimentation period in the operation of a SBR but also serves as an complementary treatment unit for suspended solids, which cannot be removed completely by conventional processes [27]. Fig. 4 shows the typical trend of TSS evolution, during the start-up and steady-state of an MSBR operated. In the operation time, filtrate quality increased significantly below the standard limit.

Fig. 4 shows that up to 99.9 % further solids was removed with micro pore membrane, which mainly includes colloidal solids. 5-10% additional efficiency has been obtained using ultra filtration membrane in comparison with no application of the membrane [28]. In subsequent polishing of landfill leachate treatment, TSS removal was over 99%. Approximately in all the runs, filtrate TSS was stable. Membrane coupled sequencing batch reactor results in purification of turbid effluent that could be disinfected by ultraviolet radiation [14]. Usually, the submerged membranes used in MBR are mostly micro or ultra filters which can rarely remove dissolved materials [22]. As shown in Fig. 5, there was no significant difference between EC values in the feed and filtrate.

In *Le-Clech et al.* (2005) study, TDS concentration in the feed and filtrate was 15000 and 16633 mg/L respectively [29].

CONCLUSIONS

Although the previous studies used MBR single-handedly, in application of MSBR process for complementary treatment of pre anaerobic-aerobic treated

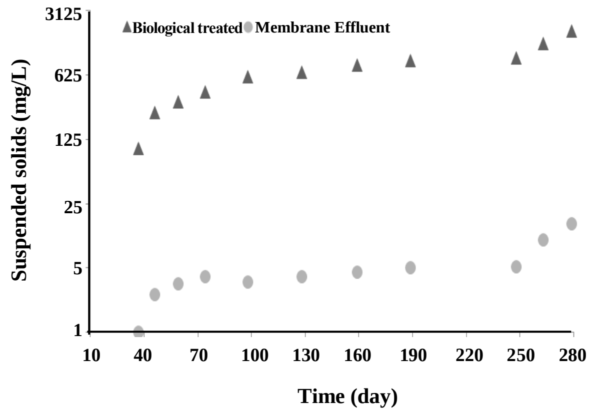

Fig. 4: Trend of suspended solids in biological and membrane effluent.

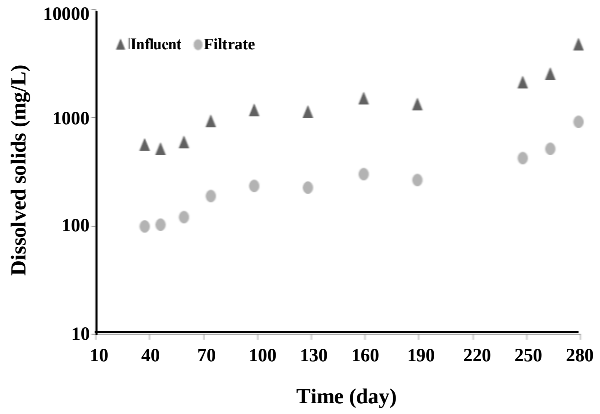

Fig. 5: Trend of Dissolved Solids in influent and filtrate of the membrane bioreactor.

composting leachate, BOD_5 and total COD effluent concentration reached below the Iranian standard. TDS values were higher than the permitted limit. There were no significant differences in MSBR filtrate quality in various ranges of feed concentration. But in the high loading membrane, clogging led to filtrate flux loss and increased the frequency of the 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 efficient and versatile treatment system in handling the fluctuating nature of both the quantity and quality of composting leachate. Post treatment processes such as NF, RO or AOPs can be used for low level of residual in MBR filtrate to meet strict discharge standards.

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