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Treated leachate analysis of Tehran using membrane bioreactors (MBR)

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ABSTRACT

One of the most important concerns in Tehran municipal landfill is the production of leachate and its potential for water resources pollution. This study was undertaken to examine feasibility of biological and physico/chemical treating of high-strength landfill leachate that was collected from Tehran municipal landfill for roughly 50 years. The aim of this study was to estimate the optimal concentration of leachate in the reactor influent and process parameters on the base of aerobic digestion efficiency. An innovative method based on the membrane bioreactor (MBR) technology was developed to treat landfill leachate over 32 days. Water quality parameters, such as pH, dissolved oxygen, nitrate, nitrite, Biochemical Oxygen Demand (BOD_5) and chemical oxygen demand (COD) were measured daily. A decrease of more than 89% was achieved for a COD of 320 mg/L in the initial leachate. Ammonia was decreased from 2720 mg/L to 0.046 mg/L, while the nitrate concentration in the effluent decreased to 70.2 mg/L. The bacteria in the MBR system adjusted to the presence of the leachate, and increased 4 orders of magnitude. Heavy metals were removed by at least 82.7%. These successful results demonstrated the MBR technology is feasible, efficient method for the treatment of municipal landfill leachate.

Keywords: Leachate, Membrane Bioreactor, Tehran

INTRODUCTION

Leachate is an inevitable by-product from Municipal Solid Waste (MSW) landfills which contains a large amount of biodegradable organic matters and nitrogenous contents. Due to its harmful impacts and toxicity potential for surrounding environment like groundwater resources, soil, atmosphere and humankinds, it is obligatory to treat it effectively [1]. High loading of landfill leachate, divergent composition and different volume of leachate in particular seasons of the year make the treatment of such wastewater very complicated. Processes for landfill leachate treatment used today are often combined techniques; usually combinations of physical, chemical and biological methods are used. Among the biological methods used for leachate treatment aerobic, anaerobic and anoxic processes are the major ones [2–5]. While air stripping, adsorption and membrane filtration belong to the major physical methods applied to leachate treatment. Among the membrane processes, reverse osmosis has been one of the most widely used methods for the last 20 years [6]. There is growing interest in combining membranes with biological wastewater treatment - membrane bioreactor (MBR) - where membranes are the main solid–liquid devices [7]. The MBR-technology has become a standard technology for wastewater treatment. Actually MBRs have been used in more than 200 countries, approximately 5,000 cases [8]. Most of them are quite small plants but more and more big plants are under construction [9]. Since 1990, the number of MBR module products has grown exponentially until reaching over 50 different providers by the end of 2009 [7]. In regard to the largest MBRs, there are 8 plants in China, GA, Oman, AZ, Australia and Spain with a peak design capacity greater than 50 MLD (Megalitres per day), all of them constructed before 2007 [10]. MBR process has been one of the alternatives for both municipal and industrial wastewater treatment. MBRs use ultrafiltration and/or microfiltration membranes for the completion retention of sludge. This leads to increase microorganism's concentration in the reactor and improvement process efficiency with lower sludge production. The industrial applications of membrane bioreactors include i.e. oil wastewater treatment, nitrogen removal from food processing wastewater and complex compounds from pharmaceutical wastewaters [12]. There are two types of MBR reactors according to the location of membrane units i.e. submerged and external reactors. In recent years, submerged membrane reactors have attracted great attention due to more compact system and energy saving. The submerged MBR is an improvement on the conventional activated sludge process, where the traditional secondary clarifier is replaced by membrane unit of treated wastewater from the mixed solution in the bioreactor [11].

MBRs represent an important technical option for wastewater treatment and reuse, being very compact and efficient systems for separation of suspended and colloidal matter and enabling high quality, disinfected effluents to achieve the highest effluent quality standards for disinfection and clarification [13]. Among advanced biological treatment processes, MBR is the most important process, which consists of a membrane module and a bioreactor containing generally activated sludge with high mixed liquor suspended solids (MLSS) of greater than 10,000 mg/l. The application of MBR as a main treatment process after physico-chemical application seems to be promising due to the expected high effluent quality. However, ozonation and reverse osmosis could be used as a post-treatment following biological treatment to remove the residual organic matters [14]. The investment costs can be compared with conventional plants in case that the effluent requirements are the same. But MBR technology has further advantages. MBR is the prominent treatment method has been used in Tehran with the advantages like simplicity and ability to treat stabilized leachate. The MBR module consists of two compartments: a bioreactor for the biological treatment and a membrane filter for the solid–liquid separation. All particles, which are sent through the membrane filter, are returned to the bioreactor. However, there can be losses because of sludge removal and accumulation of solids on the membrane surface that will be removed during the membrane cleaning [15]. Tehran Leachate Treatment Plant (TLTP) is used for treating aged and stabilized leachate that has been dumped for approximately 50 years. In this paper some important parameters such as COD, BOD_5, TSS, pH, NO_2, NO_3, color, turbidity, conductivity, heavy metals and DO will be analyzed in each pond/lagoon of TLTP.

MATERIALS AND METHODS

Leachate Treatment plant and Landfill Leachate Characteristics

Tehran as the capital city of Iran covered roughly 8 million people in 2011 [23] and produces approximately 8,000 tons/day MSW [24]. Landfill leachate is generated during the decomposition of waste and the percolation of rain water through it and waste moisture from landfill body. In this case, leachate production will occur surely and its management will be vital for protecting environment. Therefore, the Municipality of Tehran has developed an integrated membrane system for treating mentioned leachate. The first leachate treatment plant in Iran has designed by the Environmental Department of University of Tehran and constructed by Tehran Waste Management Organization (TWMO). TLTP is capable of treating up to 1,400 cubic meters per day leachate. This plant is composed of several parts, which includes part of the following: Anaerobic tank, pH set up pond, mixing pools (fast and slow rate), coagulant pool, sedimentation reservoir, Aerobic tank, MBR system and Pools with chlorine and ozone disinfection. More important parts of TLTP include storage tank, aerobic and anaerobic tanks along with MBR modules within it. According to the design of this system, it can be mentioned that MBR system is the most important part. The characteristics of the landfill leachate used as TLTPs' fed are shown in Table 1. It is worth mentioning that the leachate has been used during this study was young because it contained readily biodegradable organic matter.

Table 1. Average quality of landfill leachate used as fed

Parameter	Unit	Values
Turbidity	mg/L	190±8.4
BOD_5	mg/L	44500±3000
COD	mg/L	68250±8000
pH	-	6.9±0.2
NO_2^--N	mg/L	150±50
NO_3^--N	mg/L	21 ± 2
Conductivity	µm/Cm	44150±4500

MBR System

In this process, we have used the MBR module 16. Each MBR filtration module has the capacity of 87 cubic meters per day for the purpose of leachate treatment. If all the 16 MBR modules have used, the system would be able to treat 1,420 cubic meters per day leachate.

Due to importance of timely stages control in MBR system as well as setting feeding, vacuuming, backwashing and measuring and recording of dissolve oxygen and temperature a PLC and computerized system with essential accessories, which includes control and relay boards, dissolved oxygen and temperature probes, electrical valves, feed pump were used. The Process Flow Diagram (PFD) of MBR system is shown in Fig. 2.

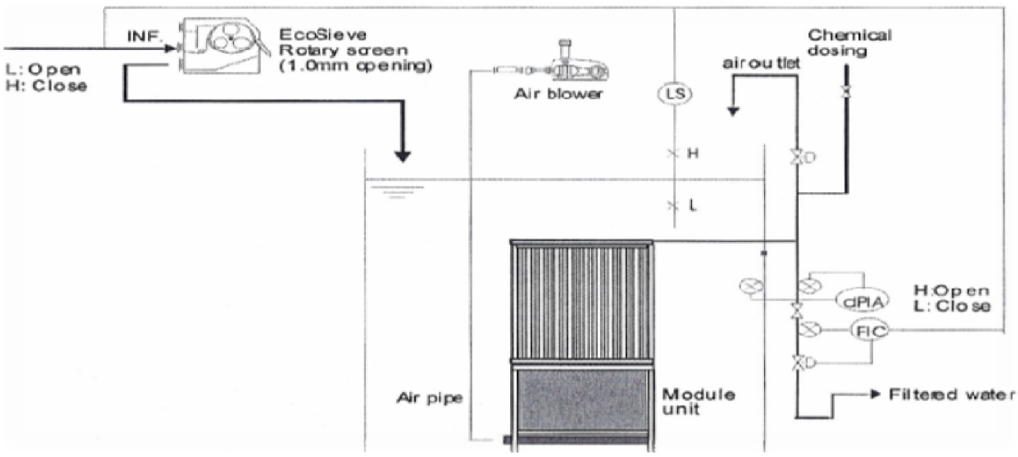

Fig. 2, Exemplified Natural Water Head Operation

For the purpose of treating leachate in TLTP, the dissolved oxygen (DO) concentration was maintained at 3.2 mg/L by adjusting the air flow to 4 m^3/h. Also he concentration of the mixed liquor suspended solids (MLSS) was 5000 mg/L and the sludge was withdrawn continuously with a pump set at different solid retention times (SRTs). HRT was controlled at 15 days by a rotary flow meter under the operational condition of invariable membrane flux. The effluent of the bioreactor was connected to an automatic vacuum effluent system directly by a rotary flow meter. When the vacuum pump operates, part of the gas in the MBR pump out to create a negative pressure and then the wastewater in the bioreactor drained out through the membrane module and enter into the treated wastewater tank. Backwash valve of the electrical gate (with the rate of 1 minute in 1 hour) and vacuum pump (with the rate of 3 minutes in 1 hour) periodically run in the automatic vacuum effluent system. However minimum vacuum level was kept by a floater, whether feeding or vacuum pumps were operating or not. Therefore, wastewater entered the bioreactor discontinuous through the flow into the submerged membrane module. Feeding pump operates discontinuous at operating time. Consider the disposal of excess sludge from the aeration tank mixed liquid, where sludge age According to reactor volume and flow of liquid mixtures were determined. In the first step to adjust the sludge age of 15 days, 12 L/day of MLSS were abstracted directly from the MBR, 30 days were exploited in this case due to excessive floor production and half of the volume of overflow to the reactor, in the second step 6 L/day of MLSS were abstracted and the sludge age was set at about 30 days, during 60 days of operation due to the production floor was no steady state, in the third step removing 4.5 L/day of MLSS the sludge age was set at about 40 days, in this mode of operation 80 days after the production floor in a relatively acceptable level of control relatively stable conditions were achieved, by adjusting the final step in the sludge age of about 55 days and 3.2 L/day disposal of MLSS after 100 days the conditions were quite stable in the MBR and the amount of MLSS inside the reactor, about 5000 mg/L remained stable at this time of vulnerability analysis, leachate treatment by the reactor was initiated.

Analytical methods

Measurements of COD, ammonium, nitrates, nitrites, total nitrogen and alkalinity were carried out according to standard methods (China, 2002). The COD values contributed by organics were corrected according to the fact that nitrite exerts a COD of 1.1 mg O_2/mg NO_2-N. nitrate (NO3−-N) and heavy metals concentrations were calculated according to Anthonisen et al. (1976). The pH and DO values were monitored by a pH probe (AD18-1000A, China) and an oxygen probe (CellOx 325, WTW, Germany), respectively. The pH and DO probes were regularly calibrated.

RESULTS AND DISCUSSION

The first step in the treatment process is pumping leachate into the pond. Secondly, leachate along with chemicals such as disodium hydrogen phosphate, sodium bicarbonate, and urea enters anaerobic tank. After injection of bacteria, the third phase would be retaining of after injection of bacteria, leachate for about 20 to 25 days in the mentioned tank. We measured the time required to put the necessary parameters. This measurement was repeated several times. As can be seen in Table 2, most of output parameters from anaerobic tank are listed. Also in Figure 3, the measurements of COD versus retention time for anaerobic bacteria in the tank has been shown. Most of the time the tank is anaerobic, the COD reduction is greater.

Table 1. Analysis of Anaerobic tank outlet

Parameter	Unit	Values
BOD_5	mg/L	782
COD	mg/L	1720
pH	-	5.6

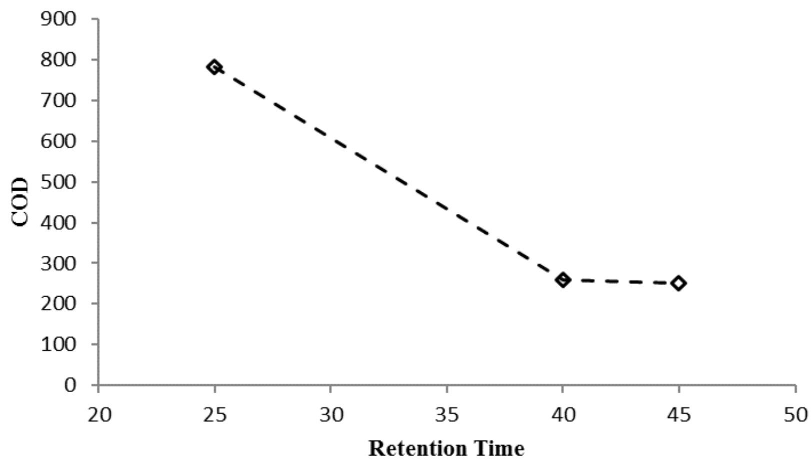

Fig.3. COD reduction in the retention time of chart

In the fourth stage, the injection of lime to adjust the pH and use of Poly Aluminum Chloride as a coagulant will be done and then the whole substrate will be mixed both slowly and fast. In the fifth phase of leachate treatment, the initial deposition or chemical treatment is introduced. In this stage sludge is separated from the effluent. The sixth step is aeration that will be occurred in the aerobic tank. By aeration, blowers and diffusers in the aerobic tank floor is built out. Aeration usually begins for about 8 hours per day and continues for a week. The secondary settling is carried out using the MBR system in the seventh stage of leachate treatment process. In this section, the MBR and how to work with it, and we discuss some of the necessary parameters.

MBR system was run for approximately 4 months. In this work, the attention was specifically focused on the mechanisms of nutrient removal held on MBR unit with high aeration ratio (4 m^3/h). Also in these study eight parameters (COD, BOD_5, NO3-N, NO2-N, heavy metals, TSS, TDS, pH, Conductivity and turbidity) were investigated. The analysis of these parameters is shown in Table 3. The removal of COD from wastewaters has been under investigations by many researchers in different methods [16]. COD discharge standard in Iran is 200 mg/L. In the work of Renou et al. [17], the removal percentage of TOC and COD were achieved up to 95–98% and 90%, respectively in a proper operation of MBRs. In this regards, Torabian et al. [18] and S. Kheradmand et al. [19] who examined anaerobic and aerobic reactors in COD removal, total systems and performance increased to 80% and 83-94%, respectively. In order to efficiently achieve discharge limit criteria, proper methods should be used. MBRs could be a suitable method for achieving this target. The average COD concentrations in the influent are 68000 mg/L. During the operation, removal efficiencies of COD were above 94.0% suggesting that it was irrespective of COD/N ratios. With high COD/N ratio of 45, the nutrient requirements decrease as the sludge age increases because net sludge production decreases as sludge age increases generally, for sludge ages greater than 10 days, the nitrogen removal attributable to net sludge production is less than 40 mg COD/mg N applied [20]. The maximum value for percent COD removal was obtained around COD/P-PO4 =160 and then dropped above 160 indicating phosphate limitation at high COD [21]. Increasing COD/N-NH4 ratios from 10 to 50 possibly resulted in decreases in COD steadily removal of efficiencies because of ammonium and PO4 limitations at high COD/N-NH4 and COD/P-PO4 ratio. in this study the sludge age (SRT) regulate at 55 days then the MLSS was stabilized at 6.3 g/L, Despite the fluctuations of average influent COD concentration ranging from 60000 mg/L to 75000 mg/L, the effluent COD concentrations were always lower than 1935 mg/L. as shown in Fig. 4, The average effluent COD concentrations was 1733 mg/L, with the average efficiency of 97.46%, under COD/N ratio of 46 and COD/PO4-P ratio of 455 and BOD/COD ratio of 0.65 These data indicated that the system could provide a consistent high efficiency of COD removal. The removal of NH4-N from leachate streams has also been a subject of research by many investigators. Typical discharge standard in Iran is 2.5 mg/L. removed 80% of TKN in a proper operation of MBRs. Using this method, removal Percentage of NH4-N was reached over 97% by N. Laitinen et al. [22] In other research which was performed by S. Kheradmand et al. in Iran, total system' NH4-N performance increased to 64.7% .Removal efficiency for ammonium-nitrogen increased with COD/NH4-N ratio between 10 and 40, because of high ammonium concentrations at low COD/NH4-N ratio, ammonium removal efficiencies were low. Increasing COD/PO4-P ratio resulted in steady increases in NH4-N removal efficiencies for COD/PO4- P values between 40 and 250 indicating adverse effects of high phosphate levels or COD limitations at low COD/PO4-P values.

Table 3. Full analysis of the output leachate treatment plant using MBR

Parameter	Unit	Values
Turbidity	mg/L	18.4
BOD_5	mg/L	59.7
COD	mg/L	89.6
pH		8.03
NO_2^--N	mg/L	0.05
NO_3^--N	mg/L	70.6
Conductivity	µs/Cm	3149.31
Cr	mg/L	0.06
Tss	mg/L	72
Cd	mg/L	0.05
Pb	mg/L	0.55
Co	mg/L	0.05
Ni	mg/L	0.72
Mn	mg/L	0.68
DO	mg/L	1.2

The last step of treating leachate is ozone disinfection and chlorination. The ozone disinfection chemical bonds are broken by the injection of ozone pollution and the amount of COD will be reduced. This process is applied till the purification process cycle ends. In Figure 4, treated leachate in TLTP has been demonstrated.

Fig.4. Treated leachate in TLTP

The present study contains results of landfill leachate treatability by MBR that is important for modeling, design and operation of landfill leachate treatment MBRs and determination of discharge limits. The output of the analysis indicates that the leachate treatment system using MBR Indicators of contamination is greatly reduced. By 16 MBR modules, leachate can be treated to the amount of 1420 cubic meters per day. By constructing and operating TLTP, Tehran will benefit from a landmark environmental goal.

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