



RESEARCH ARTICLE

Treatment of landfill leachate by anaerobic baffled reactor (ABR)

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ABSTRACT

Anaerobic baffled reactor (ABR) is one of the widely used wastewater treatment systems in industrial and domestic applications. In this study, the effect of dilution rates (5%, 10%, 20%, 50%) on the landfill leachate (LFL) with regard to chemical oxygen demand (COD), color, nitrogen compounds, and organic matter was investigated. The maximum removals were observed when the dilution rate was 20% (v:v,1:5). COD, dissolved organic carbon (DOC), total nitrogen (TN), color, nitrate (NO₃⁻) and ammonium (NH₄⁺) removal efficiency was approximately 81%, 61%, 15%, 17%, 1% and 5%, respectively. The results indicated that the adverse effects of the dilution rate on the removal of contaminants are high when it is higher than 1:5 (v:v). The study suggests that the dilution of leachate presents a significant effect on the treatment performance.

Keywords: Anaerobic baffled reactor, landfill leachate, dilution rate

1. INTRODUCTION

The sanitary landfill method has been commonly used for garbage treatment and disposal as it is cheaper and has easy maintenance when compared to other technologies [1, 2]. However, the major environmental concern of this method is the generation of large amounts of landfill leachate (LFL), which may cause serious pollution to groundwater and surface waters. Landfill leachate is highly toxic wastewater that is formed as a result of the decomposition of wastes in wild or landfill sites and has a highly toxic effect on the environment and aquatic life [3, 4]. The components of landfill leachate vary from region to region depending on the solid waste composition, storage method, hydrology of the landfills, climate, and storage age [5]. The age of solid waste has important impacts on the compounds of LFL. Age of LFL; depending on factors the characteristics of solid waste, components of waste, moisture content, rainwater, temperature, etc. [6]. Therefore, the accumulation and treatment of LFL are known as major problems. Many treatment technologies are used for LFL treatment. Biological

treatment methods are preferred due to the high organic compounds of LFL [7]. Anaerobic treatment processes are widely used for LFL treatment. The anaerobic baffled reactor (ABR) first developed by Bachmann et al. [8] can be described as a series of up-flow anaerobic sludge blanket reactors (UASB). The ABR can provide favorable environmental conditions for the development of different microbial populations in each a compartment due to baffles in their structure. This property of ABR indicates that it can occur in the single reactor of sequential anaerobic and anoxic steps [9]. Compared with the high-rate anaerobic reactors, the ABR is one of the most favorable anaerobic treatment systems. ABRs were commonly applied to treat various wastewater such as domestic wastewater, palm oil mill effluent, swine wastes, pulp, and paper mill black liquors, azo dyes containing wastewater, landfill leachate, synthetic tannery wastewater containing sulfate and chromium (III), whisky distillery wastewater, nitrogen-containing wastewaters, textile dye wastewater, and brewery wastewater [10]. Compared with other anaerobic reactors, ABR has many advantages such as a low energy consumption, low sludge production, longer sludge retention time, high strength to organic

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and hydraulic shock loading, efficient removal of soluble microbial products [11]. The ABR has several advantages due to its circulation pattern that approaches up-flow sludge blanket reactor. The difference from other studies, its design simplicity, use of easy equipment, low sludge production, high treatment efficiency, and low capital and operating costs are among its attractive features.

This study aims to investigate the treatability of LFL using an anaerobic baffled reactor. The influence of several dilution rates on the efficiency of LFL treatment performance was determined with regard to COD, color, nitrogen compounds, and organic matter.

2. MATERIALS AND METHOD

2.1. Anaerobic baffled reactor (ABR) operation

A schematic of the laboratory-scale ABR is demonstrated in Fig 1. ABR used in this study has a

working volume of 19 L (wide: 20 cm, long: 80 cm, deep: 20 cm), and a continuous flow four-compartment system. The working temperature of ABR was kept at 30°C by a heater. A peristaltic pump was used for feeding LFL to the ABR reactor. The anaerobic baffled reactor (ABR) was seeded with sludge collected from the anaerobic reactor at the wastewater treatment plant (WWTP) (Kahramanmaraş, Turkey). The four-compartments of the ABR were filled with anaerobic sludge (1:4,v:v) from anaerobic sewage sludge. Initially, the mixed liquor suspended solids (MLSS) concentration of ABR was adjusted to 17000 mg L⁻¹. The ABR system was operated at a 24-h hydraulic retention time (HRT). The experimental plan used in this study is given in Table 1 below. This landfill leachate was diluted rate in proportions 1:2, 1:5, 1:10, and 1:50 with tap water to increase the biodegradability of landfill leachate. A four-compartment ABR was adopted in the experiment plan (Table 1) and the system performance of the ABR was determined for 105 days over 4 different dilution rates.

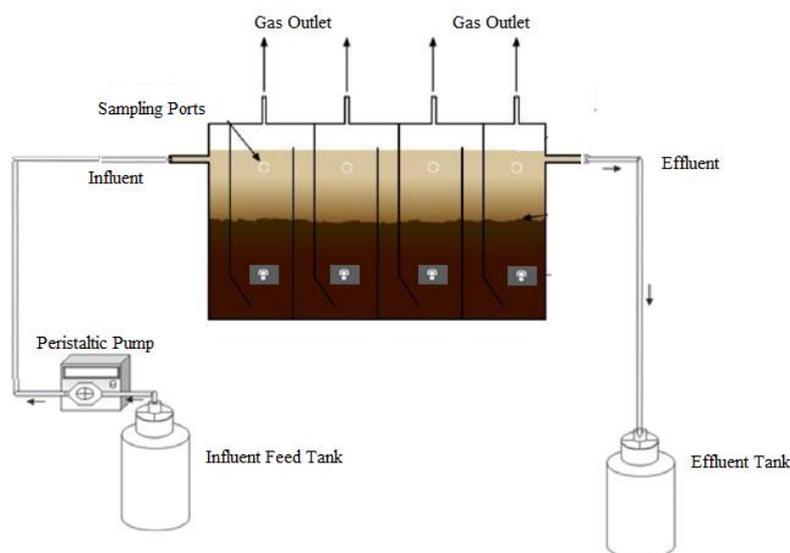


Fig 1. Anaerobic baffled reactor (ABR)

Table 1. Experimental Plan

PARTS	Dilution Rate % (v:v)
Part I	5% (1:20)
Part II	10% (1:10)
Part III	20% (1:5)
Part IV	50% (1:2)

2.2. Landfill leachate characterizations

LFL was gathered from Kahramanmaraş (Turkey) sanitary landfill on-site. LFL generated in this landfill site was about 815-830 tons day⁻¹. The LFL is collected in pools before it is discharged and treated. LFL was regularly taken from the pools and stored

under laboratory conditions (4°C). These leachate samples were collected four times per month. The characteristic of LFL was given in Table 2.

2.3. Analyses

The ABR influent, the four compartment effluent, and the ABR effluents were sampled once every two days. All samples were centrifuged at 4000 rpm for 5 min (Eppendorf Centrifuge 5415R, Hamburg, Germany) and then, were filtered using a sterile syringe 0.45µm filter (Sartorius AG, Gottingen, Germany). The influent, each-compartment, and effluent DOC, TN concentrations were analyzed using a TOC instrument coupled with TN (Shimadzu TOC-VCPN, Kyoto, Japan). The pH was measured by a pH meter (Thermo, Orion 4 Star, Indonesia). The color was analyzed as Pt-Co units. Pt-Co color measurements were performed

spectrophotometrically at 465 nm during lab-scale studies. Ionic composition of influent, each-compartment and effluent samples (ammonium, nitrate) was measured by ion chromatography (Dionex ICS-3000, Sunnyvale, CA, USA). The COD

measurements were carried out according to the dichromate-closed reflux Colorimetric Method described in Standard Methods (Standard Methods, 5220 D).

Table 2. LFL Characterization

Parameters	Concentration (mg L ⁻¹)	Parameters	Concentration (mg L ⁻¹)
Dissolved Organic Carbon (DOC)	7058±400	NO ₂ ⁻	320±20
COD	16000±1500	NO ₃ ⁻	670±40
Biochemical oxygen demand (BOD)	1500±300	Color	6380±300 Pt-Co (Color unit)
NH ₄ ⁺ -N	2120±200	PO ₄ ³⁻ -P	78±10

3. RESULTS & DISCUSSION

3.1. COD removal performance

ABR performance with LFL addition with a ratio of 5, 10, 20, and 50% (v/v) was studied to determine the biodegradability of LFL (Table 1). Initially (part I, Table 1.) the minimum dilution rate of LFL in the influent was determined. COD removal performance was shown in Fig 2. COD removal efficiency was 26, 57, 80, and 70% at dilution rates of 5, 10, 20, and 50%, respectively. A gradual increase in COD removal was observed in the first three dilutions in the ABR. Then, a decrease in COD removal efficiency was observed at 50% dilution rate. It has been determined that COD removal efficiency was above 80% and 70% at dilution rates of 20% and 50%, respectively. According to COD removal efficiency, the optimum dilution rate was determined as 20%. A gradual increase in COD removal efficiency was investigated in the first three compartments of the ABR process. Therefore, anaerobic biological degradation has occurred at this stage. In a study performed by Krishna et al. [12] the ABR process was evaluated different HRTs for the treatment of complex wastewater. They obtained the COD removal efficiency above 88% for 0.6 to 2 kg COD m⁻³d⁻¹ of

organic loading rate (OLR). Mohtashami et al. [13] investigated that treatment of the landfill leachate using an ABR system of four compartments (total reactor volume of 64L and HRT of 4 days). COD removal efficiencies over 80% were achieved in different OLR (1.2-7.75 kg COD m⁻³d⁻¹).

In another study, the performance of ABR was evaluated with diluted wastewater (500 mg COD L⁻¹). The ABR was operated with an HRT of 80 h at 35°C, resulted in more than 80% COD removal [14]. Arvin et al. [15] the performance of an ABR treating LFL was evaluated in their study. They observed that the change in HRT and the concentration of LFL increased the COD removal efficiency (>86%). Similarly, in our study COD removal efficiency was approximately 80%, the corresponding dilution rate was 20%. Wang and Shen [16] used an ABR unit for co-treatment of landfill leachate and municipal sewage. They investigated the effect on ABR performance of different mixed rates of landfill leachate and municipal sewage. The results showed that the biological treatment performance in ABR increased when BOD₅/COD ratio was increased from 0.15–0.3 to 0.4–0.6. To investigate the effect of OLR and sulfate loading rate (SLR) on landfill leachate treatment, Burbano-Figueroa et al. [17] was used an ABR.

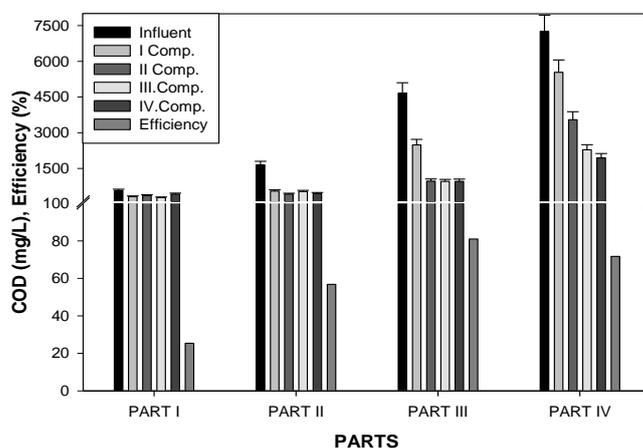


Fig 2. COD removal performance

3.2. Color removal performance

Biological treatment of LFL is very difficult due to the high amount of pollutant parameters [18,19]. In our study, color removal efficiency was observed using the ABR system. In recent years, color removal from LFL has been much attention. In this context, the color removal performance of ABR during LFL treatment

was shown in Fig 3. In the ABR, the color removal efficiency was 16, 31, 16, and 36% at dilution rates of 5, 10, 20, and 50%, respectively. The highest color removal efficiency was observed at a dilution rate of 50% and the corresponding removal efficiency was 36%. According to color removal efficiency, the optimum dilution rate was determined to be 50% (Fig 3).

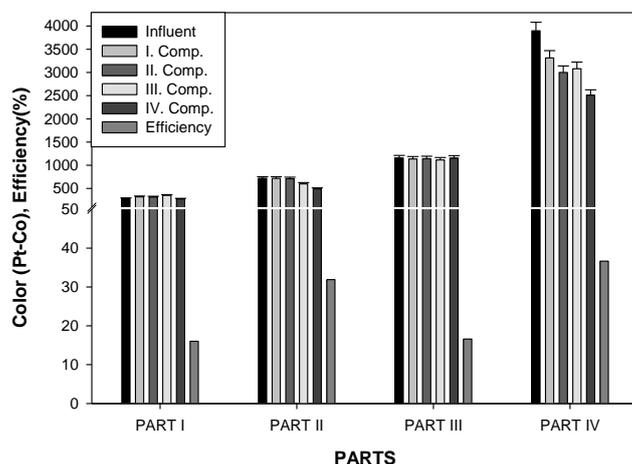


Fig 3. Color (Pt-Co) removal performance

3.3. OC and TN removal performance

DOC removal efficiency was 12%, 45%, 61%, and 30% at dilution rates of 5, 10, 20, and 50%, respectively (Fig 4A). The DOC removal efficiency reached over 60% when increasing the dilution rate from 5% to 20%. Also, DOC removal efficiency was reached 30% when the dilution rate was increased to 50%. In the lowest dilution rate (5%), the TN removal efficiency was 1% as a result of the removed TN concentration to 54mg L⁻¹ (Fig 4B). At an increasing dilution rate from 5% to 50% the TN removal efficiency was increased from 1% to %28. The highest DOC removal efficiency was observed at a dilution rate of 20% and

the corresponding removal efficiency was 61% (Fig 4A). The highest TN removal efficiency was observed at a dilution rate of 20% and the corresponding removal efficiency was 28%. According to TN removal efficiency, the optimum dilution rate was determined to be 20% (Fig 4B). To treat palm oil mill wastewater, Faisal and Unno [20] used A modified anaerobic baffled bioreactor (MABR) under steady-state conditions. They showed that the organic matter removal efficiency in terms of COD and total organic carbon was achieved as 72.1–95.9% and 44.2–91.3% under steady-state conditions (HRT from 3 to 10 days), respectively.

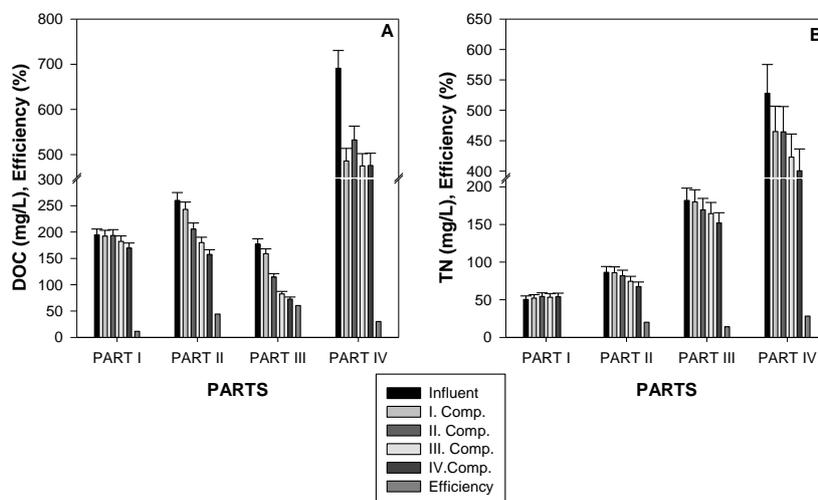


Fig 4. DOC removal performance (A); TN removal performance (B)

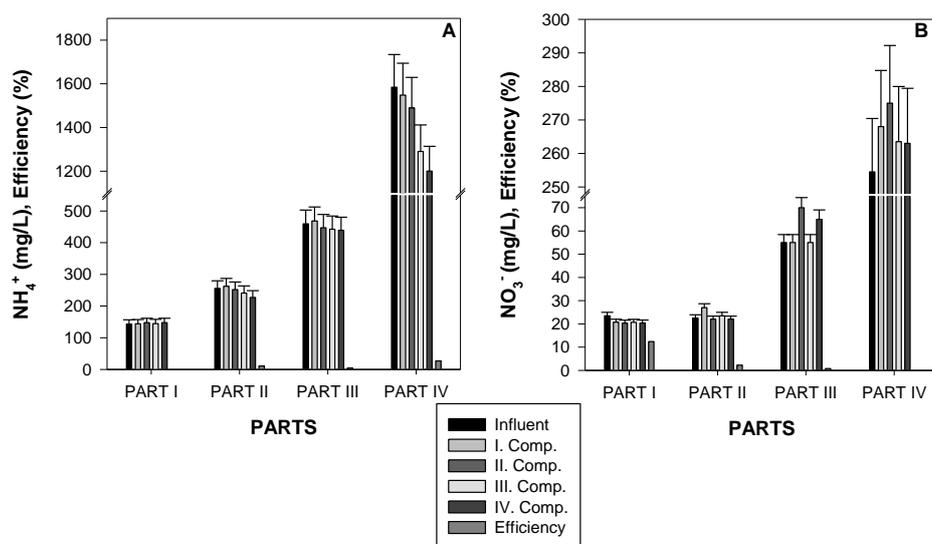


Fig 5. NH₄⁺ removal performance (A); NO₃⁻ removal performance (B)

3.4. NO₃⁻ and NH₄⁺ removal performance

Biological treatment of LFL is very difficult due to high ammonium and other pollutant parameters [21]. Increase in dilution rate to 5% and 50% increased NH₄⁺ removal from 1% to 27% and decreased NO₃⁻ removal efficiency from 12% to 1% (Fig 5A-B). However, a further increase in dilution rate to 50%, positively affected the NH₄⁺ removal, which was slightly increased to 1% and 26% at 5% and 20% dilution rate, respectively (Fig 5A). The maximum NH₄⁺ removal efficiency of 26% was obtained at a 50% dilution rate. An increase in dilution rate to 50%, negatively affected the NO₃⁻ removal, which was significantly decreased to 12% and 1% at 5% and 50% dilution rate, respectively (Fig 5B).

4. CONCLUSIONS

In this paper, dilution rates of landfill leachate were investigated to evaluate the ABR performance. The effects of different dilution rates on LFL treatment using ABR was evaluated with regard to the removal performance of COD, color, NO₃⁻, NH₄⁺, and organic matter.

The most important results obtained in this study are as follows:

- High COD removal efficiency was observed in the ABR process, optimum conditions were determined as a dilution rate of 20% (v:v,1:5), corresponding to removal efficiency above 80%.
- The efficiency of organic and inorganic material removal increased significantly with the increase in the dilution rate of the landfill leachate.
- COD, DOC, TN, Color, NO₃⁻ and NH₄⁺ removal efficiencies were approximately 81, 61, 15, 17, 1, and 5%, at dilution rate of 20%.

This study showed that the ABR could offer an attractive alternative for COD removal from LFL. However, air stripping as pre-treatment or aerobic reactor as post-treatment may be used added in order to

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