Analysis of hydraulic retention time variation on the leachate treatment by using anaerobic fluidized bed reactor

T Tazkiaturrizki*, R Rahayu and P Purwaningrum

Environmental Engineering Department, Faculty of Landscape Architecture and Environmental Technology, Universitas Trisakti, Jakarta, Indonesia

*tazkiaturrizki13@trisakti.ac.id

Abstract. Sanitary landfill activities produce leachate that contain high pollutant wastewater of the solid waste. Anaerobic Fluidized Bed Reactor (AFBR) is one of the technologies that can treat wastewater with high pollutants. This study has the purpose to analyze the effect of hydraulic retention time (12, 24, 36, and 48 hours) on the leachate treatment using AFBR. The leachate was collected from TPA Rawa Kucing that has characteristics of COD 5200-5500 mg/L and BOD 2000-2500 mg/L. Seeding and acclimatization is the first method to get the biomass of anaerobic sludge without oxygen supply. During the process, nutrient for the biomass was maintained by giving additional nutrient of glucose 33%, sanitary landfill sludge filtrate 5% and 33% of leachate and 28.3% chlorine-free water at the first formula. The second formula is by mix the glucose 20%, sanitary landfill sludge filtrate 6% and 40% of leachate and 28.3% chlorine-free water, and it took 3 months. The results are optimum variations of hydraulic retention time is 48 hours, to remove BOD, COD, and TSS at 78%, 92% and 22% efficiency. The degradation rate of the substrate (k) in anaerobic fluidized bed reactor is 0.727/day for leachate which has load of 5229 mg/L.

1. Introduction
Sanitary Landfill is technology for waste final disposal in open area. If there is water contact the waste, it will release wastewater called “Leachate”. Leachate has high organic compound and need to be treated seriously due to can be pollute the environment. The variety of flowrate and leachate characteristic depend on landfill area, weather, and landfill age [1]. TPA Rawa Kucing at Neglasari District, Tangerang City has 37.7 hectare areas located close to settlement because of the uncontrolled growth of people who live in Tangerang City.

TPA Piyungan Yogyakarta has the leachate treatment by using coagulation-anaerobic biofilter process, the former of colloidal are from organic materials that combine become bigger particle and settled, the efficiency of COD removal is 88.3% [2]. Leachate treatment at TPA Galuga, Leuwiliang Bogor using the aerobic bioreactor and the efficiency of COD removal could reach 50% [3]. Leachate treatment at TPA Bantar Gebang, Bekasi using anaerobic-aerobic bio filter and denitrification process has COD removal efficiency at anaerobic process is 90.16%, and aerobic process 81.59% and denitrification process is 48.12% [4].

The technology of anaerobic digestion conduct with low energy requirement to treat the organic material become the lower of wastewater types, solid wastes and biomass into methane as final product [5]. The anaerobic process is proper process to treat high organic pollutant and it can be degradation.
well [6]. AFBR also efficient of the price and can be place on mesophilic and thermophilic condition of treatment for both low and high strength wastewaters quality [7].

There is several previous research that using reactor fixed film such as biofilter and fluidized bed show the efficiency removal is better that the conventional system [8]. The reactor is relatively small, porous and fluidized media support the treatment system to be proof of high biomass concentration and the operation can reduce the hydraulic retention time [9]. Fluidized Bed Reactor capable to keep the biomass inside the reactor to treat the wastewater and can remove organic pollution effectively. Others research show that anaerobic fluidized bed reactor is capable to remove BOD and COD until 94% removal efficiency [10]. The aims of this research are to remove the pollutant such as BOD, COD and TSS from leachate of TPA Rawa Kucing using Anaerobic Fluidized Bed Reactor by making the variety of hydraulic retention time.

2. Materials and methods
Biomass concentration retains in reactor by using the small, porous, and fluidized media, and it operate depends on hydraulic retention times (HRT) [9]. The HRT variation conduct this research are 12 hours, 24 hours, 36 hours and 48 hours. Sample of leachate is fresh leachate that the age of leachate is less than 10 years. So that the organic loading of the pollutant still high around 5229 mg/L with the ratio of BOD5/COD is 0.4 that indicate the organic compound of leachate is non degradable [11].

2.1. Anaerobic fluidized bed reactor
AFBR is a reactor with up flow system or down flow system that completed with support material such as the suspended sand with 0.3 mm of diameter. AFBR made from steel pipe with 16 cm of diameter, length 2.5 meter that connect with collection tank volume 120 liter. Leachate is pumping to the AFBR reactor so that the sand media where the biomass attached get the expansion and contact with leachate flow in anaerobic condition continuously.

2.2. Research steps
In this research there are three steps of analysis, analysis of leachate characteristic, seeding and acclimatization and main research of variation time. This research us multi-stage anaerobic reactor that was operated in continuous mode of operation with influent COD concentration of 5229 mg/L for a period 5 days as maximum.

2.2.1. Analysis of leachate characteristic. Initial analysis characteristic is measuring the quality of leachate TPA Rawa Kucing before doing the main research. There is analysis of BOD, COD and TSS.

2.2.2. Seeding and acclimatization. Seeding and acclimatization was done in one time and continuous in same reactor. Seeding process is mixing leachate, glucose and filtrate of sludge in landfill into the reactor as initial seed for metabolism and biomass growth that show by slime floc formed in sand media. Leachate will be us as a carbon and energy source for bioreactors [12]. Even though the leachate containing of biodegradable organics are good nutrients, the number of studies exploring their use is relatively limited [13]. To maintain the biomass growth, there will be additional nutrient of glucose 33%, sanitary landfill sludge filtrate 5% and leachate 33% and 28.3% chlorine-free water at the first step. Then for second formula will mix the glucose 20%, sanitary landfill sludge filtrate 6% and 40% of leachate and 28.3% chlorine-free water, and for 3 months.

Acclimatization is a process for microorganism adapting to live in the condition of leachate quality. During the acclimatization process, COD parameters was measured at least every 2 days (2 x 24 hours) to know the removal of soluble COD until the effluent of COD get the steady state condition and the removal of soluble COD has been reach 50% of initial concentration. Anaerobic Fluidized Bed Reactor was stated steady if the effluent of sample has COD concentration constant or steady.
2.2.3. Main research. The research using fresh leachate of TPA Rawa Kucing that has 5229 mg/L of COD. The consideration is that for lower HRTs than 20 days by adjusting the input of the fresh leachate to set the HRT [14].

2.3. Kinetics of substrate degradation
The kinetics of AFBR follows the Monod kinetics with the mass flux to simulate the rate of substrate uptake, as a result of changes in external substrate concentrations, and associated changes in the biofilm thickness in the biofilm that develop in a reactor [15]. The degradation rate of COD was calculating by using the first order [16], using Equation (1).

\[
\frac{dC}{dt} = -kC
\]

C is COD concentration (mg/L), t is time (days) and k is degradation constant of COD (h\(^{-1}\)). Co is the initial concentration of COD (mg/L). K is calculated by plotting \(\ln \frac{C}{Co}\) to t (days) by using the Equation (2).

\[
\ln \frac{C}{Co} = -kt
\]

3. Results and discussions
The leachate characteristic on table 1 and compare to standard of PerMenLHK No. P59/2016.

| Parameter | Units | Concentration | Standard Limits | Status        |
|-----------|-------|---------------|-----------------|---------------|
| pH        | -     | 8             | -               | -             |
| TSS       | mg/L  | 340           | 100             | Over standard |
| BOD\(_5\) | mg/L  | 2092          | 150             | Over standard |
| COD       | mg/L  | 5229          | 300             | Over standard |

3.1. The effect of HRT variation to BOD removal
BOD removal could be seen at figure 1. On the biological process more than 90% organic, 70–80% total nitrogen and 50–70% phosphorous removal were reported, at hydraulic retention times (HRT) of 2–3 h [17].

![Figure 1](image_url)

Figure 1. Effect of hydraulic retention times to BOD removal.

From figure 1 it can be seen that the HRT 12 hours, the BOD removal has 61% efficiency, then at 24 hours the removal efficiency of BOD is 66% and at 36 hours HRT the removal efficiency is also 61%. At the HRT is 48 hours the removal efficiency of BOD reach 78%. It supported by the literature that show the result of leachate treatment with anaerobic process using bio filter has 45% efficiency removal.
BOD from initial BOD 612 mg/L for HRT 25 hours [11]. The BOD removal of AFBR is better, at HRT 24 hours can reach the removal efficiency of BOD at 66%.

3.2. The effect of HRT variation to COD removal
The bioreactor started with high COD and sulfate removal efficiencies, indicating that the SRB inoculum obtained from the anaerobic baffled bioreactor was highly active [18]. From Figure 2, at the HRT 12 hours the removal efficiency of COD is 45% so that the effluent of COD. At 24 hours HRT, the COD removal is 57% efficiency. At HRT 36 hours the removal efficiency of COD is 76% and the last HRT of 48 hours the removal efficiency of COD become 82%.

![Figure 2. Effect of hydraulic retention times to COD removal.](image)

The efficiency of COD treatment on anaerobic reactor will increase to for 8 days can be reach 90% [4]. In others COD removals of 76.8% were achieved in fixed-film anaerobic reactors treating this same wastewater at an OLR of 10.5 g COD/l d and HRT of 4.04 days [9]. Generally, the AFBR and expanded granular sludge bed has retention time of 2–4 hours because of the growth of attach microorganism need a longer time to remove organic compound in leachate constantly [19].

3.3. The effect of HRT variation to TSS removal
Figure 3 shows that the HRT 12 hours, the TSS removal has 6% efficiency, then at 24 hours the removal efficiency of TSS is little bit increase to 10% and at 36 hours HRT the removal efficiency is 13%. At the HRT is 48 hours the removal efficiency of TSS was not so high 22%

From Figure 3 show the results that similar with the literature that TSS removal on leachate treatment with anaerobic process has the 25% removal efficiency for HRT 25 hours [11]. The TSS describes the sludge production on the reactor and it calculated to determine the appropriate SRT to obtain high concentration of methanogenic bacteria as the anaerobic process. The calculation must be considering the mass balance between the accumulated biomass and the amount of daily biomass washed out (VSS in effluent waters) [19].

![Figure 3. Effect of hydraulic retention times to TSS removal.](image)
3.4. Analysis of substrate degradation kinetics
The calculation of substrate degradation kinetics was done by using the first order of Monod kinetics and the kinetics of substrate degradation can be seen on Table 2.

**Table 2.** Kinetics of organic removal.

| HRT (days) | Initial Concentration [Co] | Effluent Concentration [Ct] | Ln [Ct]/[Co] | k   |
|------------|-----------------------------|-----------------------------|--------------|-----|
| 0.5        | 5229                        | 2720                        | 0.6535       | 1.3072 |
| 1          | 5229                        | 2400                        | 0.7787       | 0.7788 |
| 1.5        | 5229                        | 1440                        | 1.2895       | 0.8597 |
| 2          | 5229                        | 960                         | 1.6950       | 0.8475 |

From the Table 2, the k constant is 0.727 and this number show that the leachate removal for TPA Rawa Kucing is 0.727 less by the day before (1 day) [20].

4. Conclusion
The leachate characteristic of TPA Rawa Kucing over the standard limit of PerMenLHK No. P59 /2 2016. AFBR has good performance to treat leachate of TPA Rawa Kucing with the optimum efficiency of parameter COD (82%), BOD (78%), and TSS (22%) at HRT optimum is 48 hours. The kinetics of substrate degradation by using AFBR is 0.727/day. The effluent of AFBR still need the second stage treatment to remove pollutant and meet the standard of PerMenLHK No. P59 year of 2016.

**References**
[1] Gulsen H and Turan M 2004 Start-up of an Anaerobic Fluidized Bed Reactor for Landfill Leachate Treatment *J. Environmental Technology* 25(10) 1107-1114
[2] Susanto J P, Sri PG and Siti H I 2004 Leachate Treatment of Sanitary Landfill with Coagulation-Biofilter Anaerobic Yogyakarta *J. P3L-BPPT* 5(3) 167-173
[3] Romli M, Suprihatin and Dinna S Adjustment of Kinetics Parameter of Activated Sludge for Leachate Treatment (Bogor: IPB)
[4] Idaman S I 2015 The Treatment of Leachate by Anaerobic-aerobic Biofilter Process and Detitification Jakarta *JAL* 8(1)
[5] Ward A J, Hobbs P J, Holliman P J and Jones D L 2008 Optimization of the Anaerobic Digestion of Agricultural Resources *J. Bioresource Technology* 99(17) 7928-7940
[6] Indriyati 2003 *Seeding process and Aclimatization of Fixed Bed Reactor* (Jakarta: Badan Pengkajian dan Penerapan Teknologi)
[7] Turan M, Gulsen H, Mehmet S C 2005 Treatment of Landfill Leachate by Combined Anaerobic Fluidized Bed and Zeolite Column System *J.Environ Engg* 131 815-819
[8] Gulsen H and Turan M 2004 Anaerobic Treatability of Sanitary Landfill Leachate in a Fluidized Bed Reactor Turkish *J. Eng. Env. Sci*, 28 297-305
[9] Fernandez N, Montalvo S, Borja R, Guerrero L, Sanchez E, Cortes I, Colmenarejo M F, Travieso L and Raposo F 2008 Performance Evaluation of an Anaerobic Fluidized Bed Reactor with Natural Zeolite as Support Material when Treating High-Strength Distillery Wastewater *J. Renewable Energy* 33 2458-2466
[10] Sylvi and Diana 2001 *Treatment of Wastewater Tofu Industry in Anaerobic Fluidized Bed Reactor* (Bogor: IPB)
[11] Parasmita N B 2012 *Study of Hydraulic Retention Time to BOD, COD, TSS Removal of Leachate Treatment using Anaerobic-Aerobic Biofilter Treatment* (Universitas Diponegoro)
[12] Costa M C, Santos E S, Borros R J, Pires C and Martins M 2009 Wine wastes as carbon source
for biological treatment of acid mine drainage \textit{J.Chemosphere} \textbf{75} 831–836

[13] Liamleam W and Annachhatre A P 2007 Electron donors for biological sulfate reduction \textit{J. Biotecnology Advances} \textbf{25} 452–463.

[14] Prasetyo E, Sudibyo H and Budhijanto W 2017 Determination of the Optimum Hydraulic Retention Time in Two Stage Anaerobic Fluidized Bed Bioreactor for Landfill Leachate Treatment \textit{J. Eng. Technol. Sci.} \textbf{49}(3) 388-399

[15] Eddyasti A, Andalib M, Hafez H, Nakhla G and Zhu J 2011 Comparative modeling of biological nutrient removal from landfill leachate using a circulating fluidized bed bioreactor (CFBBR) \textit{J. Hazardous Materials} \textbf{187} 140-149

[16] Eckenfelder, W 2000 \textit{Industrial Water Pollution Control} (New York: McGraw Hills Companies)

[17] Andalib M, Nakhla G and Zhu J 2012 High rate biological nutrient removal from high strength wastewater using anaerobic-circulating fluidized bed bioreactor (A-CFBBR) \textit{J.Bioresource Technology} \textbf{118} 526-535

[18] Bekmezci O K, Ucar D, Kaksonen A H and Sahinkaya E 2011 Sulfidogenic biotreatment of synthetic acid mine drainage and sulfide oxidation in anaerobic baffled reactor \textit{Journal of Hazardous Materials} \textbf{189} 670–676

[19] Moharram M A, Abdelhalim H S and Rozaik E H 2016 Anaerobic up flow fluidized bed reactor performance as a primary treatment unit in domestic wastewater treatment \textit{J.HBRC} \textbf{12} 99-105

[20] Sahinkaya E, Dursun N, Ozkaya B and Kaksonen A H 2013 Use of landfill leachate as a carbon source in a sulfidogenic fluidized bed reactor for the treatment of synthetic acid mine drainage \textit{J. Minerals Engineering} \textbf{48} 56-60