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Landfill Leachate Treatment Using Hybrid Up-Flow Anaerobic Sludge Blanket (HUASB) Reactor

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Abstract: The effect of development of a country would lead to vast amount of solid wastes being produced. Malaysia as a developing country also facing a solid waste management issue particularly due to the production of landfill leachate. Leachate contains dangerous substances such as organic matters, heavy metals, nitrogen ammonia and other materials that could pollute underground water resource. In conjunction to this issue, this study was conducted to investigate the efficiency of the lab-scale Hybrid Upflow Sludge Blanket (HUASB) in treating landfill leachate. The parameters studied in this research include Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solid (SS), Total Nitrogen (TN), and Total Phosphorus (TP). The lab-scale HUASB has been run for 30 days with sampling and analyzed for every 3 days. Results from this study show that the HUASB has a great potential in removing TP and SS as their removal efficiencies achieved were 90.60% and 80.70%, respectively. The removal of COD and BOD were slightly lower with an average of 73.70% and 64%, and the removal of TN was relatively low at only 50.32%. From the results, it was shown that the HUASB reactor has a promising capability in treating landfill leachate in particular for organic pollutants and phosphorus removal.

Keywords: Landfill Leachate, HUASB Reactor, Organic Pollutants Removal

1. Introduction

Sanitary landfilling is the most common way to eliminate solid urban wastes. An important problem associated with landfills is the production of leachates. The landfill has been the most economical and environmentally acceptable method for the disposal of solid waste throughout the world. Up to 95% of solid waste generated worldwide is currently disposed in landfills [1]. Leachate is defined as water that has percolated through the wastes (rainwater or groundwater seepage), a source of soil and groundwater contamination and biogas produced by the fermentation of organic matter, a source of air pollution [2]. The leachates are very dangerous to the environment because it contains organic materials, heavy metals, Nitrogen Ammonia and other materials that could pollute underground water source. The characteristics of the landfill leachate can usually be represented by the basic parameters COD, BOD, pH, Suspended Solids (SS), Total Nitrogen (TN) and Total Phosphorus (TP).

Hybrid Up flow Anaerobic Sludge Blanket (HUASB) reactor is an anaerobic digester that combines a UASB reactor with an anaerobic filter. This combination is an advanced form that enables improved solid retention time in the treatment of waste water. Up-flow Anaerobic Sludge Blanket (UASB) is a form of anaerobic digester that is used in the treatment of wastewater. UASB reactor uses an anaerobic process to form a blanket of granular sludge which suspends in the tank. The process is a modern anaerobic treatment that can have high treatment efficiency and a short hydraulic retention time [3]. The anaerobic filter is a high rating system that gathers the advantages of other anaerobic systems and that minimizes the disadvantages. In an up-flow anaerobic filter, biomass are retained as biofilms on support material, such as plastic rings. Anaerobic treatment methods are more suitable for concentrated leachate streams as they are offering lower operating costs, the emission of biogas, and low sludge production [4]. Anaerobic processes of landfill leachate in UASB reactor allow complete removal of COD from 65 to 76% and BOD removal beyond 90% [5]. The aim of this study is to determine landfill leachate treatment efficiency and ability using Hybrid Up flow Anaerobic Sludge Blanket (HUASB) reactor in lab-scale. HUASB reactor will act as a filter to remove leachate pollutant contents such as organic substances, heavy metal and Nitrogen Ammonia. The process to determine HUASB reactor's capacity is tested for parameter Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solid (SS), Total Nitrogen (TN), and Total Phosphorus (TP).

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2. Methodology

Materials used in this experimental study where landfill leachate, leachate sludge, fine grained clay, zeolite and HUASB model from high performance polyethylene. Leachate used for this study was taken from Simpang Renggam Landfill, Johor. The samples were collected in plastic containers. Upon collection, the leachate was stored at 4°C to minimize microbial activities and degradation of pollutants until experiments analyses were carried out. Fine grained clay used to be up to 0.45 mm size. While Zeolite was crushed into small pieces and sieved into 5mm size.

The experiment was carried out in a lab scaled constructed reactor. This reactor was constructed from Perspex material (20 cm x 20 cm x 70 cm) which gave the total volume for HUASB reactor is 28000 cm^3 ≈ 28 litres. On this reactor contains leachate sludge as a blanket with 30 cm height, fine grained with 30 cm height and 3 cm zeolite at the top of the media. The flow of the pump was 0.1 ml/min.

3. Results and Discussion

3.1 pH value

Results show the changes in pH values which were taken during the period of detention time. The pH value of the original water sample is 7.17 and increased till 8.73 end of the month as shown in the Table 1 and Fig. 1.

Table 1: Result for pH Test

Retention Time (days)	pH
0	7.17
3	7.89
6	8.00
9	8.03
12	8.07
15	8.16
18	8.19
21	8.51
24	8.67
27	8.71
30	8.73

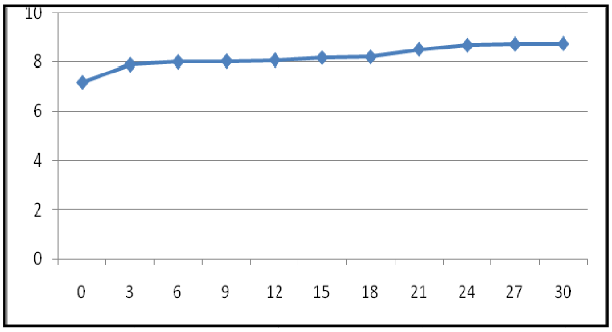

Fig. 1 Results change in pH value during the period of detention

Solak et al. [6] stated that pH will influence the removal effectiveness of suspended particles. While Suzuki and Maruyama [7] has stated that suspended solid will removed effectively at pH 5-6 to 98% of the removal percentage by using coagulant method.

This study anyhow remained the existing pH at a merely natural range of pH level. However from day-21 until end of experiment, pH is in the alkaline range of 8.51 to 8.73. pH in water samples of the original leachate was low because of the production of organic acid by bacterial metabolism. Most microorganisms grow best under neutral pH conditions, since other pH values may adversely affect metabolism by altering the chemical equilibrium of enzymatic reactions, or by actually destroying the enzymes.

3.2 BOD removal

BOD_5 is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at a certain temperature over a specific time period. Table 2 shows the result of BOD_5 for 30 days retention time. The result showed that percentage of BOD removal increased up to 79.08 %. The BOD concentration for 30 days and BOD percentage removal can be seen in Fig. 2 and Fig. 3.

Table 2 Result of BOD Test

Retention Time (days)	BOD (mg/L)	BOD removal percentage (%)
0	153	0.00
3	99	35.30
6	64	58.17
9	63	58.82
12	62	59.48
15	61	60.13
18	60	60.78
21	36	76.47
24	35	77.12
27	34	77.78
30	32	79.08

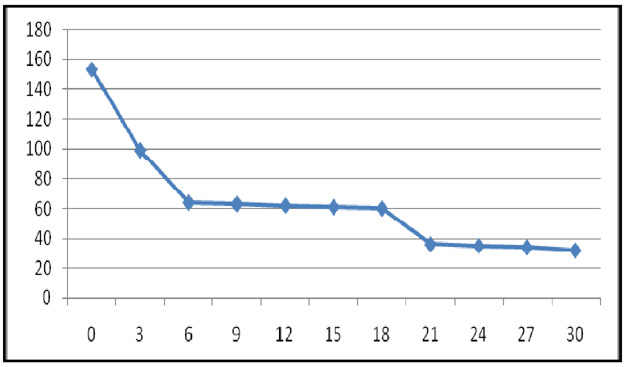

Fig. 2 BOD concentration for 30 days

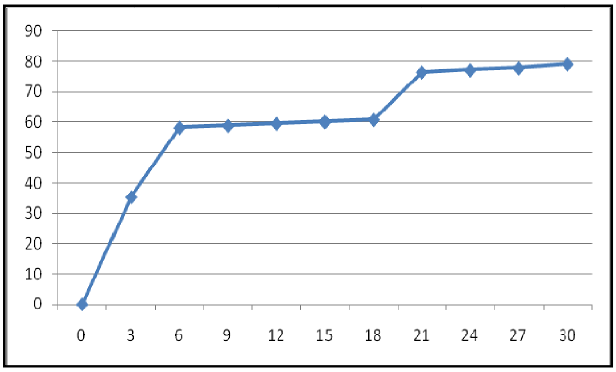

Fig. 3 BOD percentage removal

Ghasimi et al. [8] has stated that an anaerobic process in the leachate treatment will remove 80% of BOD at day-53, and it will increase gradually till 85% at day-91. However, this study showed that more than 60% of BOD removed at 6hr of contact time and gradually increases up to 80% of BOD removal. It shows that an anaerobic process in the HUASB system could enhance the removal percentage of organic loading in the leachate treatment process since the hybrid media would provide ample spaces for bacterial growth before turn to biofilms.

3.3 COD removal

The chemical oxygen demand test (COD) is the standard method for indirect measurement of the amount of pollution (that cannot be oxidized biologically) in a sample of water. Table 3 shows the graph of COD concentrations for 30 days. The COD percentage removal rate was quite good in the first week, on day-3 and day-6. On the day-9 and further, the rate was still increasing although the rates are quite constant. COD removal efficiencies in the range of 60-95% was achieved depend on the process condition. Therefore we assume that this experiment has succeeded in removing average 73.70% COD where the raw concentrations is 4640 mg/L and decrease to 739 mg/L at the end of the experiment as illustrated in the Fig. 4 and Fig. 5.

Table 3 COD concentrations for 30 days.

Retention Time (days)	COD (mg/L)	COD percentage removal (%)
0	4640	0.00
3	2628	43.36
6	1474	68.23
9	1334	71.25
12	1258	72.89
15	1154	75.13
18	1052	77.33
21	1043	77.52
24	761	83.60
27	760	83.62
30	739	84.07

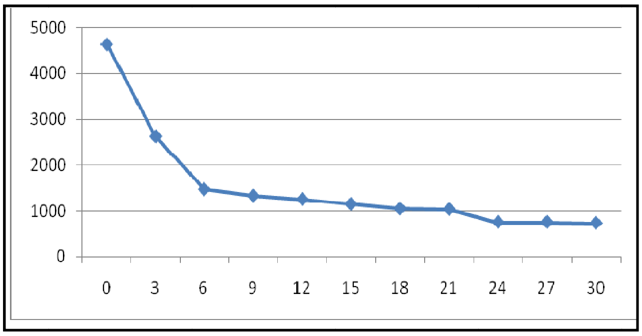

Fig. 4 COD concentrations for 30 days

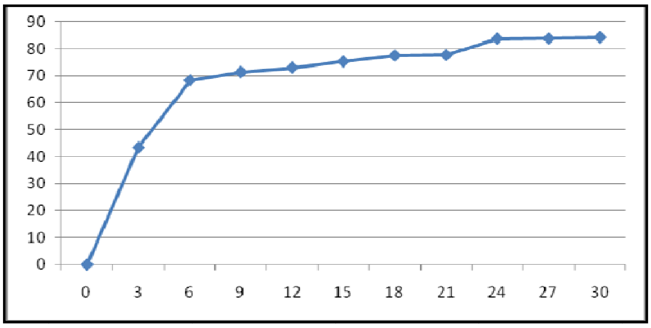

Fig. 5 COD percentage removal

Abdul et al. [9] has stated that the COD removal is parallel to contact time duration until the optimum level. The percentage removal of COD is also influenced by pH changes. Yilmaz et al. [10] has stated that the removal of COD was higher in the acidic state. By using a combination of zeolite and clay as a filter medium such as this study showed that more than 60% of BOD removed at 6 hr of contact time and gradually increase up to 80% of BOD removal. It shows that the combination process of anaerobic and filtering medium would increase the removal percentage of COD in the leachate treatment system.

3.4 Suspended Solid Removal

Suspended Solids is a water quality measurement usually abbreviated SS. This parameter was at one time called non-filterable residue (NFR), a term that refers to the identical measurement: the dry-weight of particles trapped by a filter, typically of a specified pore size. Table 4 shows from 1010 mg/L of SS on leachate, this reactor can remove that SS up to 116 mg/L. Therefore, the average percentage of SS removal is 80.70%. However, on day-18 and day-21, the SS concentration increased from 151 mg/L to 191 mg/L. The SS concentration for 30 days and SS percentage removal can be seen in Fig. 6 and Fig. 7.

Table 4 Result of SS test

Retention Time (days)	SS (mg/L)	SS percentage removal (%)
0	1010	0.00
3	377	62.67
6	236	76.63
9	210	79.21
12	186	81.58
15	166	83.56
18	151	85.05
21	191	81.09
24	176	82.58
27	140	86.14
30	116	88.51

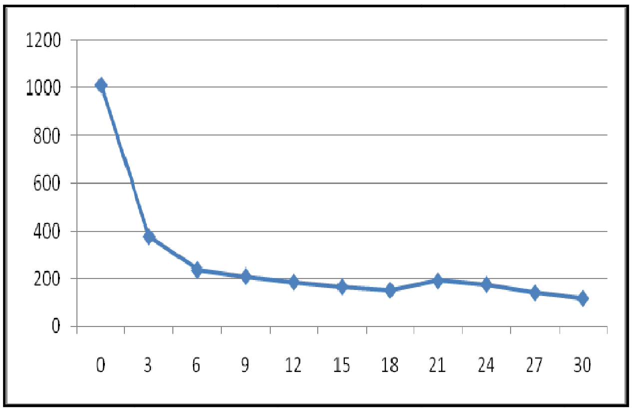

Fig. 6 SS concentration for 30 days

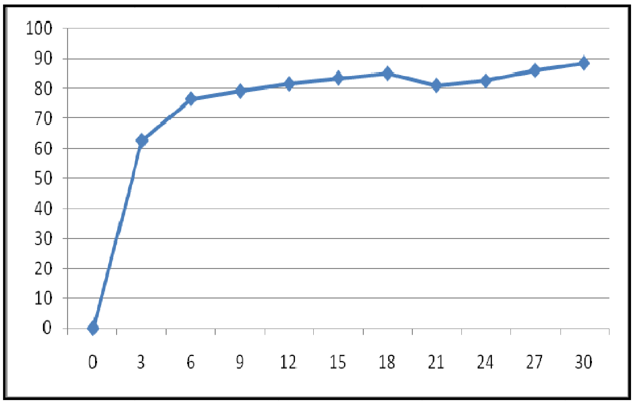

Fig. 7 SS percentage removal

Solak et al. [6] has stated that pH will influence the removal efficiency of suspended solids. . Suzuki and Maruyama [7] in their research found that the removal of suspended solids using a coagulation process was about 98% at pH 5-6. While this study showed that the removal of suspended solids was 88.51% at day-30 of retention time.

3.5 Total Ammonical-Nitrogen, NH_3 Removal

Widiastuti et al. [11] has stated that natural zeolite would react positively to removal of ammonical-nitrogen depends to contact time, amount of zeolite, initial concentration and pH. Based on their study on wastewater treatment, the removal of ammonia was about 97% and the optimum removal was at pH 5. Rozie et al. [12] in their research on removal of ammonia using zeolite and clay showed that the removal of ammonia by combination of zeolite and clay was only taken 5 minutes compared to natural zeolite alone which need about 60 minutes to remove the ammonia. Through a modification study on initial concentration by using zeolite, Fulya and Ayse [13], found that the removal of ammonia was very fast at the first 30 minutes and become stable after reaching the optimum contact time.

Table 5 shows that generally TN removal was in low efficiency. The average percentage of total nitrogen removal is 50.32%. At first TN can be removed up to 730 mg/L from raw leachate which was 3200 mg/L in value of concentration with 77.19% of TN removal. After that the graph becomes fluctuated and at day-30 there is still 1930 mg/L concentration, only 39.77% removal as shown in the Fig. 8 and Fig. 9.

Table 5 Result of TNH_3 test

Retention Time (days)	TN (mg/L)	TN percentage removal (%)
0	3200	0.00
3	730	77.19
6	1180	63.13
9	1070	66.56
12	1310	59.06
15	1560	51.40
18	1790	44.06
21	2810	12.18
24	1970	38.44
27	1560	51.40
30	1930	39.77

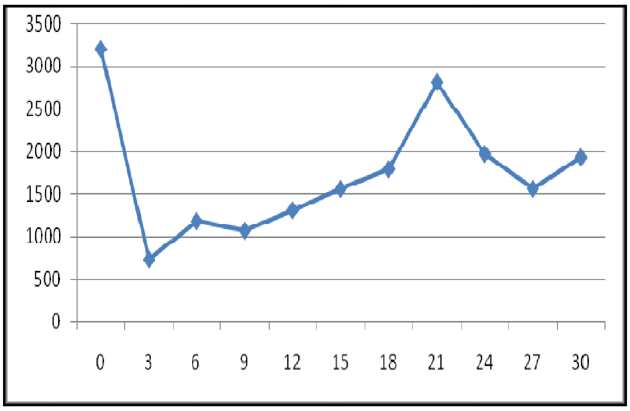

Fig. 8 TNH_3 concentration for 30 days

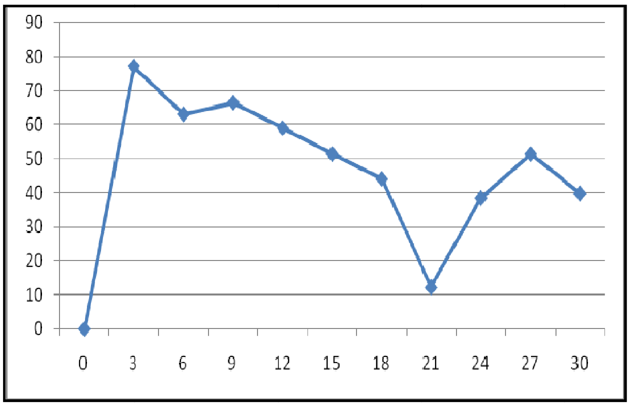

Fig. 9 TNH_3 percentage removal

3.6 Total Phosphorous Removal

Phosphorus is a nutrient used by organisms for growth. It occurs in natural water and wastewater bound to oxygen to form phosphates. Phosphates come from a variety of sources including agricultural fertilizers, domestic wastewater, detergents, industrial process wastes and geological formations.

Table 6 shows the removal of phosphorus in 30 days contact time continuously in the HUASB system. The initial concentration of phosphorous in the raw sample was 259 mg/L. The graph shows that the concentration of phosphorous dropped drastically within 3 days with 99.22% of removal. The graph then becomes stable until day-30. From the result of this study, the optimum contact time of phosphorous in the HUASB system is 3 days as shown in the Fig. 10 and Fig. 11. Meanwhile, Fig. 12 shows that the average removal percentage.

Table 6 Result of TP test

Retention Time (days)	TP (mg/L)	TP percentage removal (%)
0	259	0.00
3	2	99.22
6	10	96.13
9	12	95.37
12	13	94.98
15	16	93.82
18	17	93.44
21	44	83.01
24	49	81.08
27	49	89.58
30	53	79.54

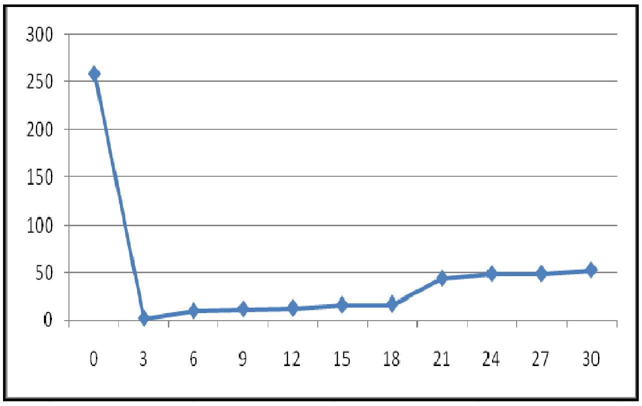

Fig. 10 TP concentration for 30 days

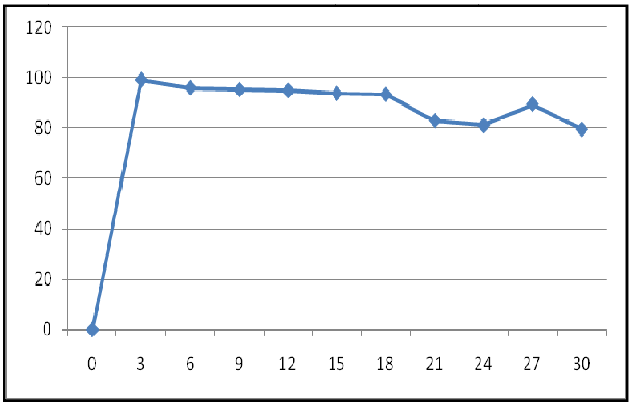

Fig. 11 TP percentage removal

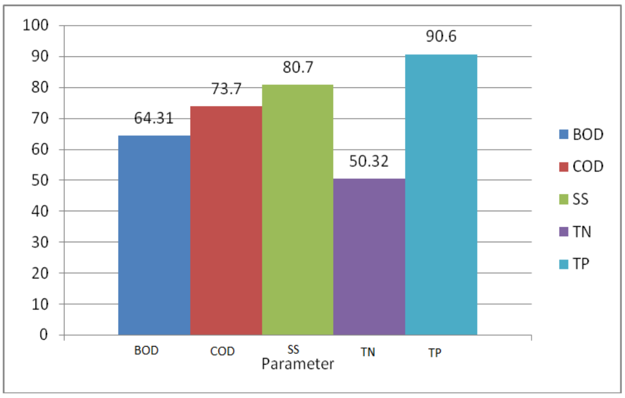

Fig. 12 Average removal percentage for parameter BOD, COD, SS, TN and TP

4.0 Conclusion

From this research, the performance of the HUASB system was good after 30 days retention time especially for total phosphorous and total suspended solids which were 90.60% and 80.70% respectively as shown in Figure 6. As a conclusion, the HUASB system has performed well in removing organic pollutants. Based on the value of all parameters in this experiment, it is recommended that the time is further extended especially for BOD removal.

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