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Original Research

Leachate Treatment Using Aged Refuse (AR) as a Biofilter Medium

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Abstract

The uncontrolled formation of leachate during a waste-disposal process has become a serious issue in landfill management. An innovative filtration process for treating leachate by using aged refuse as a medium in biofilter has been studied recently. The aim of this study is to treat leachate by using aged refuse varied by years (4, 8, and 11 years) as a biofilter medium. To achieve the target, a few objectives were listed: i) to construct the biofilter system in a laboratory scale, ii) to explore the use of aged refuse (AR) as a biofilter medium to treat leachate from the selected landfill in Malaysia, and iii) to assess the quality of leachate treated with different aged refuse regarding physical properties, chemical properties, and microbe activity. Results showed that the initial concentration of leachate parameters is: i) chemical oxygen demand (COD) was 981.47 mg/L, ii) biochemical oxygen demand (BOD) was 527.16 mg/L, and iii) ammonia-nitrogen (NH_3-N) was 2,815.56 mg/L and iv) bacterial count is 3.3×10^6 CFUs. After treating with aged refuse, the quality of leachate is increased based on the concentration reduction of COD, BOD, and N H_3-N in the range of 30% to 49%, 17% to 48%, and 68% to 92%, respectively.

Keywords: landfill, leachate, aged refuse, biofilter system, treatment

Introduction

There are 296 landfills in Malaysia and 166 are still in operation, including 9 sanitary landfills [1]. A sanitary landfill is considered to be the most common way of disposing of urban solid wastes. However, landfill wastes cause two types of pollutant:

i) Leachates
ii) Biogas, which corresponds to migration into the natural environment

Landfill leachate extracts dissolved or suspended material and a significant quantity of chemical constituents enters into leachate when water passes through solid wastes undergoing decomposition in the landfill compartment [2]. Landfill leachate is an important source of pollution that is damaging to the environment [3], due to the complex mixture of pollutants, high chemical oxygen demand (COD), and high ammonium nitrogen (NH_4^+-N) content, among other factors. The quantity of leachates depends on rainwater percolation through wastes, biochemical processes in waste cells, the inherent water content of wastes, and its degree of compaction into the landfill tip [4]. The quality of leachates is affected by age, precipitation, seasonal weather variation, waste type, and composition of landfill leachates, which varies greatly depending on the age of the landfill [5].

Currently, many treatment methods for leachate decontamination, including biological, physical, and chemical methods, land treatments and various combinations thereof

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Table 1. Details of study sanitary landfill sites in Selangor, Malaysia.

Details	Air Hitam Landfill	Jeram Landfill
Location	Mukim Petaling, Daerah Petaling, Puchong, Selangor	Mukim Jeram, Klang
Area	42 hectares [11]	Over 64.7 hectares
Phases	8	6
Opened and closed year	Opened in November 1997 and prematurely closed in December 2006 (Worldwide Landfill, 2007)	Opened in January 2007 and expected to be closed in 2018
Municipal collecting coverage	Klang Valley with an annual capacity of 550,000 tons [12]	1,000 to 1,500 tons of waste per day around Shah Alam, Petaling Jaya, Subang Jaya, Ampang Jaya, Klang and Kuala Selangor area.

have been used. However the suitable treatment strategy depends on the leachate characteristics and the final requirements given by local discharge water standards [6]. An innovative process for leachate treatment using a biofilter consisting of 8-10-year old aged refuse was initiated by [7]. The refuse in landfills becomes stabilized or aged after years of placement, and the resultant partly or fully stabilized refuse thus obtained is referred to as 'aged refuse' or AR [7]. The aged refuse contains a wide spectrum and large quantity of micro-organisms that can effectively decompose refractory organic matter present in wastewaters [8]. The AR biofilter was found to be very effective for the treatment of landfill leachate [7, 9, 10], sewage [7], and feedlot wastewater [8].

The aim of this study is to treat leachate by using aged refuse varied by age. To achieve the target, a few objectives were listed:

i) To construct the biofilter system in a laboratory scale
ii) To explore the use of AR as a biofilter medium to treat leachate from the selected landfill in Malaysia
iii) To assess the quality of leachate treated with different AR regarding the physical properties (pH values, total suspended solids – TSS, total dissolved solids – TDS), chemical properties (chemical oxygen demand – COD, biochemical oxygen demand – BOD and ammonia-nitrogen – NH_3-N content) and microbe activity

Organic material was the primary contribution in solid waste in Malaysia (RMK9, 2005). Thus it is believed that the refuse contains huge quantities of microbes suitable for leachate treatment.

Materials and Methods

Samples Location

Two sanitary landfills in Malaysia were chosen for AR and leachate sampling. The details of site are tabulated in Table 1. The landfills are operated by Worldwide Landfills Sdn Bhd. The type of waste is domestic waste (95%) and other (5%).

Sampling Procedures and Preparation

The AR sample of two different sites was chosen in order to investigate the properties and efficiencies of AR classified as young (4 years old – Jeram Landfill), middle (8 years old – Air Hitam Landfill) and old (11 years old – Air Hitam Landfill) age for treating the leachate. The leachate sample was collected at the Jeram Sanitary Landfill (JSL) equalization lagoon with fresh leachate flow from the landfill cell. The leachate was kept in clean plastic

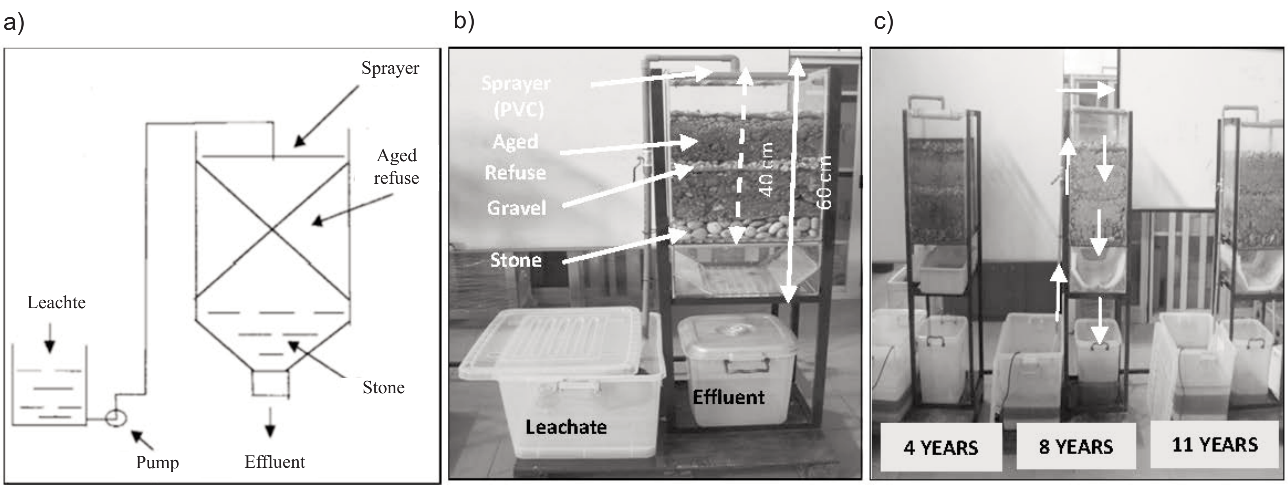

Fig. 1. (a) General experimental setup of aged-refuse-based biofilter [7], (b) single unit of biofiltration system for leachate treatment, and (c) arrows depict the leachate flow through the aged refuse biofilters for 4, 8, and 11 years of age.

Table 2. Acceptable conditions of discharged leachate and initial value of untreated leachate samples collected from the equalization lagoon.

Parameter	Unit	Discharged Leachate Standard Value	Untreated Leachate
Temperature	ºC	40*	27.2
pH	-	6.0-9.0*	7.9
Total suspended solids (TSS)	mg/L	300[a]	41.12
Total dissolved solids (TDS)	mg/L	3,700[a]	686.58
Chemical oxygen demand (COD)	mg/L	400*	981.47
Biochemical oxygen demand (BOD)	mg/L	20*	527.16
Ammonia nitrogen (NH_3-N)	mg/L	5*	2,815.56
Microbial count	CFUs	10^7 ~10^{10} [a]	3.3×10^6

*Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009.

[a] Data from standard discharge of sewage in Malaysia has been used for TSS, TDS, and microbial count.

bottles and immediately transported to the laboratory for proper storage. The samples were kept in a cold room for the future use.

Aged Refuse Biofilter Set-up

The intention of these experiments was to redesign the basic biofilter system [7] to adapt with the formation of refuse and test it with different aged refuse for the leachate treatment purposely to use in Malaysia condition. The biofilter is a lab-scale model consistig of aged refuse as the media and the leachate was distributed over the surface of refuse by spraying. The setup of the biofilter is shown in Fig. 1b.

The biofilter shape was square in cross-section with effective width and length of 40 cm while the height of the column is 60 cm. The AR was divided into two layers and slight thin layer of gravel at the top and bottom, where each AR layer was placed. Larger stones with average size 5 cm were installed until 5 cm height from bottom to top.

Three leaching columns consisting of AR medium (differed by age) are prepared to assess initial and final leachate parameters such as physical, chemical, and biological properties. The distilled water was first introduced to the biofilter media in order to get the similar value of the initial moisture content of the sample with the existing sample on landfill sites. Followed by the introduction of leachate for the stabilization (1st cycle) stage in the treatment process and to make sure the refuse and leachate mixed thoroughly. The leachate sprayed over the refuse surface with duration time of 10 minutes, 3 times a day with the flow rate applied was 0.5 L/min. Finally, the effluent was collected in the effluent collection box. The effluent will be reused for another cycle (2nd and 3rd cycle) until the leachate reached the wastewater discharge standard. The purpose of this cycle is to determine the effectiveness and the suitability stage for the treatment. Fig. 1c showed the flow process of the leachate in the biofilter. The analysis included chemical, physical, and biological analysis for leachate and aged refuse samples. All experiment procedures were referred by Water and Wastewater Standard Methods (2005).

Results and Discussion

The parameters for untreated leachate were measured and the results were tabulated in Table 2. The results were compared with [13] and other reference. The initial pH was moderately alkaline with pH 7.9 at temperature 27.2ºC. The chemical oxygen demand (COD) and biochemical oxygen (BOD) demand content were quite high with a value of 981.47 mg/L and 527.16 mg/L compared with the standard discharge value which is 400 mg/L and 20 mg/L, respectively. Meanwhile, for total suspended solids and total dissolved solids, both values were 41.12 mg/L and 686.58 mg/L, which are below the standard values; 300 mg/L and 3,700 mg/L but there still needs to be treatment before discharging the leachate into the water.

The ammonia nitrogen concentration was detected very high with a value of 2,815.56 mg/L compared to a standard discharge value which is only 5 mg/L. It is attributable to the source of solid waste at the site. The presence of ammonia because the dissolved oxygen reduced and increased in food to mass (F:M) ratio for both aerobic and anaerobic conditions. Malaysian solid waste contains a very high concentration of organic waste such as food, paper and plastic [14]. The biodegradable portion of organic contaminants in leachate decreases, as landfill age increases, because of anaerobic decomposition happening in a landfill site [15]. The number of the microbe presence less than standard with value of 3.3×10^6 CFUs.

As shown in Fig. 2(a), when the leachate contacts with the AR in the biofilter, the COD concentration slowly decreases by cycle around 30% to 50% of removal. Even though the COD concentration in the 2nd cycle at each AR slightly increase, the COD value still remains below the initial value of influent leachate. Overall results showed the COD removal by the AR biofilter increased gradually to 50%, indicating low pollutant content in the effluent.

Fig. 2(b) shows that there is a decrease in BOD concentration from the initial phase to the stabilization phase, and there is a slight increase from stabilization phase to 2^{nd} cycle followed by decreasing again in the 3^{rd} cycle. The BOD concentration in leachate effluent is considered to be high but slightly reduced below its initial value. The highest value in BOD indicates that the leachate contains a high amount of organic matter and pollutants. Approximately 20% to 50% of the biochemical oxygen demand can be reduced at each cycle by varying AR in the biofilter.

As shown in Fig. 2(c), the removal of NH_3-N in leachate by using AR biofilter is much more effective than the other biodegradable organic matter found in the landfill leachate. There is a drastic decrease in ammonia nitrogen concentration from the initial phase to stabilization phase. Over 65% to 92% of NH_3-N can be reduced within this cycle. According to [16], the changes in ammonia-nitrogen concentrations due to the existence of microorganisms in the AR, which have a strong capability for nitrification and a weak ability for denitrification.

Meanwhile, the pH values in Fig. 2(d) for the influent are about 7.9, but after the treatment process the pH of effluent decreased and maintains the values around 7.5 to 7.75. The pH value for effluent has complied with the standard. The fluctuated pH values may be related to the growth of microbes, which gives a greater effect to the change in leachate composition.

Fig. 2(e) shows the amount of total suspended solids reduced during the treatment process. At the stage of stabilization phase, the total suspended solids decrease (for 4, 8 and 11 years) compared to the initial phase value. Then the value drastically increased during the 2^{nd} cycle and decreased again in the 3^{rd} cycle.

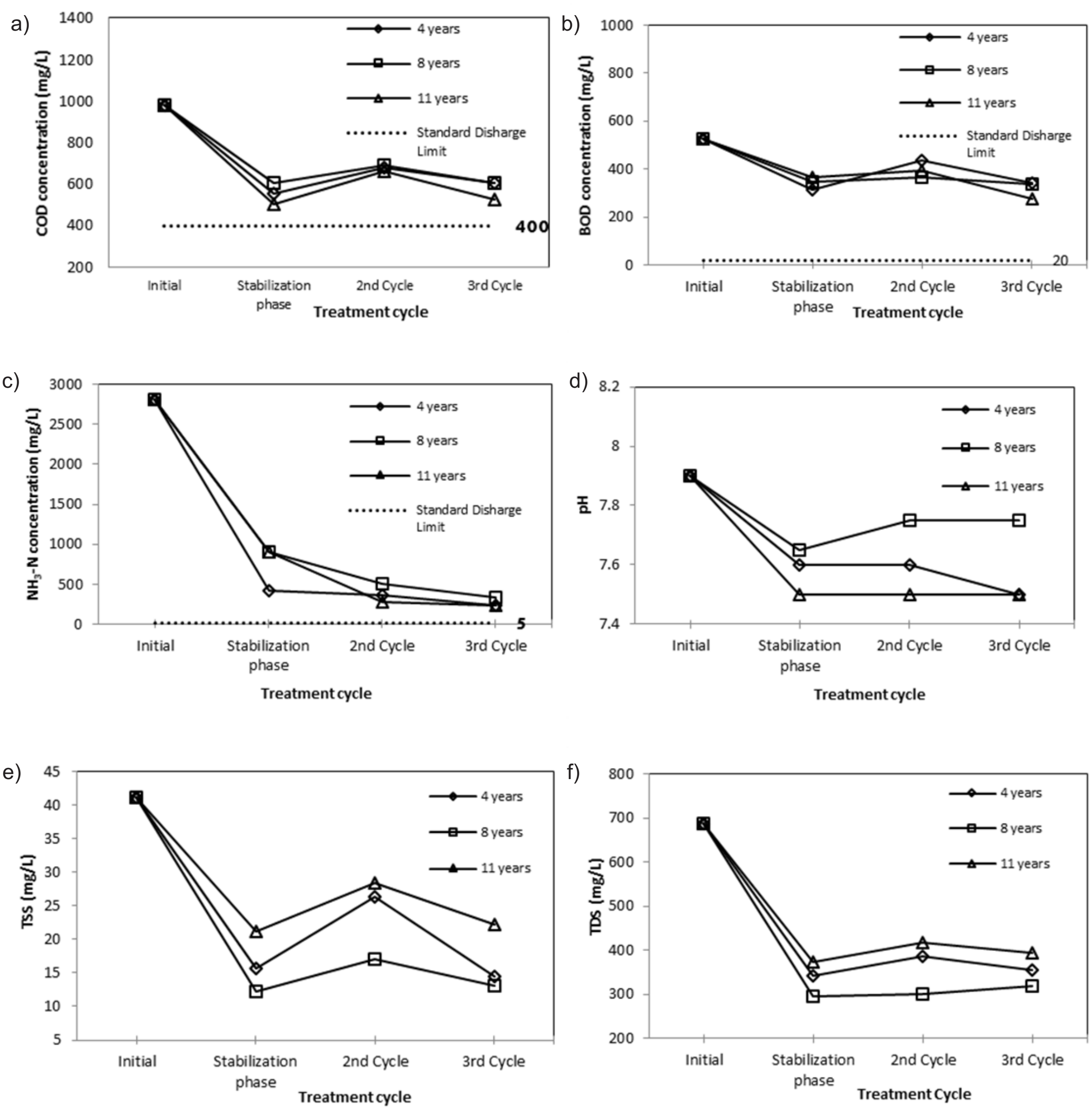

Fig. 2. The concentration of select parameters during the treatment cycle a) chemical oxygen demand – COD, b) biochemical oxygen demand – BOD, (c) Ammonia nitrogen, (d) pH value, (e) total suspended solids, and (f) total dissolved solids

Meanwhile, Fig. 2(f) shows total dissolved solids present during the treatment process. At the initial phase, the value for the total dissolved solids was 686.58 mg/L but slightly decrease at the stabilization phase, (for 4, 8, and 11 years). During 2nd cycle total dissolved solids slightly increased, but after the 3rd cycle its value remains decreased, ranging from 310 to 393 mg/L. The effluent quality for both total suspended solids and total dissolved solids were high as referred to standard discharge. This could happen because of the AR used in the biofilter considered to be dissolved substances and fine particles taken away and washed during the leachate passing through [7].

Microbial quantities of both influent and effluent were determined by using the standard plate count method. From the results, the microbes in the influent contain 3.3×10^6 CFUs/mL and the counts decrease at the stabilization phase for 4, 8, and 11 years AR. While after 2nd cycle, the numbers of the microbes in the effluent actively increase about 2.4 to 6.5×10^6 CFUs/mL of microbe counted on the plate. Indicating that the microbes in leachate were rapidly growing during the 2nd cycle after passing through the AR which is rich with organic matter and acts as a suitable medium for microbe growth. At the 3rd cycle, again the numbers of microbes in effluent slowly decrease, ranging from 2.1 to 3.1×10^6 CFUs/mL showing that the microbial growth has been stopped and probably died because of a lack in food supply.

Conclusions

The biofilter system in a laboratory scale has been constructed and the AR by different age (4, 8, and 11 years) were used as a medium to study its effectiveness of filtration treatment for landfill leachate. There were several conclusions that can be drawn from this paper.

After treatment, the AR showed great potential in removing COD, BOD, NH_3-N, TSS, and TDS in leachate. From overall data observation, a biofilter of 8-year old AR as a filtration medium shows a significant result for a certain leachate parameter (BOD, TSS, TDS) compared to others.

It was observed that the value of COD in leachate was decreased for all ages of AR. For overall treatment using AR, the highest percentages of removal are the TSS and NH_3-N concentration in leachate, which were 70% and 92%, respectively. The lowest percentage of removal in this treatment was pH and BOD, which are 2% to 5% of pH and around 17% to 40% of the BOD in leachate. The number of microbes in the biofilter also increased as the leachate seeping through the refuse. The final effluent from the biofilter is clear.

Overall, the analysis data have managed to answer the objectives of this study. Considering the treatment efficiencies, it can be concluded that biological degradation and filtration mechanisms are the major process in treatment.

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