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LEACHATE CHARACTERIZATION FROM A CLOSED LANDFILL IN AIR HITAM, PUCHONG, MALAYSIA

(Pencirian Air Larut Resap dari Tapak Pelupusan Ditutup Air Hitam, Puchong, Malaysia)

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Abstract

Leachate, wastewater that was collected from landfill is known to have pungent smell and may impose serious harm to human health and the environment. Air Hitam, Puchong Sanitary Landfill has stopped its land filling operation since December 2006 and is under post-closure maintenance stages. After several years of stopping its operation, a landfill will still produce leachate hence it needs constant monitoring and maintenance. The main aim of this paper was to characterize leachate produced from Air Hitam, Puchong Closed Landfill, according to several important parameters: pH, temperature, chemical oxygen demand (COD), ammoniacal nitrogen (NH_4-N), total organic carbon (TOC), total solids, volatile organic acids (VOA) and heavy metals content, to determine its suitability in producing methane by identifying its phase. Leachate samples were drawn weekly for a period of 3 months from three different ponds, untreated raw leachate pond 1 and treated leachate pond 2 and 3. Results obtained showed that the average values were around 25°C, average pH 8, highest COD reading was 5,248 mg/L, TOC highest at 6,797 mg/L, VOA highest at 1,424 mg/L and ammoniacal content of 3.10 mg/L the highest.

Keywords: Leachate, characterization, closed landfill, COD, Air Hitam sanitary landfill

Abstrak

Air larut resap adalah air buangan yang diperoleh dari tapak pelupusan sisa pepejal yang mempunyai bau yang tajam dan boleh mengakibatkan kemudaratan kepada kesihatan manusia dan keselamatan alam sekitar. Tapak pelupusan sanitari Air Hitam, Puchong telah dihentikan operasinya pada bulan Disember 2006 dan di bawah aktiviti penyelenggaraan selepas penutupan. Selepas bertahun-tahun beroperasi, tapak pelupusan masih akan mengeluarkan air larut resap, dan oleh itu ia memerlukan pemantauan berterusan dan penyelenggaraan. Artikel ini memberi tumpuan kepada pencirian air larut resap dari tapak pelupusan sisa pepejal yang telah ditutup menurut parameter ini: pH, suhu, parameter oksigen kimia (COD), nitrogen ammonia (NH_4-N), jumlah karbon organik (TOC), jumlah pepejal, pepejal meruap dan kandungan logam berat untuk menentukan kesesuaian air larut resap ini menghasilkan gas methana, dengan menentukan fasa air larut resap. Sample air larut resap diambil setiap minggu bagi tempoh 3 bulan daripada tiga kolam berbeza, kolam air larut resap tidak dirawat 1 dan kolam air larut resap dirawat 2 dan 3. Keputusan yang diperolehi menunjukkan bahawa suhu purata 25°C, purata pH 8, nilai -nilai tertinggi yang direkod ialah; COD 5248 mg/L, TOC 6797 mg/L, VOC 1424 mg/L dan kandungan ammonia 3.10 mg/L.

Kata kunci: Air larut resap, pencirian, tapak pelupusan sisa pepejal, COD, tapak pelupusan sisa pepejal sanitari Air Hitam.

Introduction

As the population of an area grows, the amount of wastes generated is greatly increased. Vast product innovation and as the power of buying and spending gains popularity among humans, wastes are uncontrollably produced day by day. Sanitary landfill method is widely accepted as the ultimate approach to dispose of solid waste material due to its economic advantage [1]. Outcome from this waste management is leachate and generated by excess rainwater percolating through the waste layers in a landfill [2], and is of dark colored, it could be yellow, brown or black, due to decomposition of organic matter [3].

A sanitary landfill receives domestic waste; that are wastes from residential and offices. Hence, leachate content has a variety of chemicals as many types of wastes dumped in landfills. Landfill operators are bounded by regulations that leachate must be treated and its contents concentration comply with the limits stated in the regulation set by Malaysian government, before leachate is released to nearby river. In addition, leachate collection system is equipped with underground pipes which allow leachate to flow out of the landfill to a pond where treatment is applied. Surroundings of the underground pipes must also be monitored to avoid groundwater pollution that may impose health effects to humans. In order to apply an effective treatment to treat leachate, a thorough characterization of leachate is crucial to determine its content and their concentrations.

Landfill leachate is a potentially polluting liquid and could cause harmful effects to the surrounding surface water and groundwater due to its high concentration of toxic contents. Run-off arising from a landfill containing only soil and rubble may contain suspended solids, be turbid, and threaten fish and other aquatic organisms. Monitoring of landfill leachate provides assurance that the landfill operation will not cause harm to human as well as the environment [4].

Age of landfill is one of the important effects on leachate characteristics. As landfill age increases biological decomposition of deposited wastes altered from a relatively shorter decomposition period to a longer decomposition period, which has two sub phases; acidic and methanogenic. It is reported that leachate from these two stages has different constituents, with younger leachate having high concentration of volatile fatty acids; hence it is more likely to be in the acidic phase [5]. Younger leachate in acidic phase with age converts into methanogenic phase where fatty acids in acidic or acidogenic phase is converted into methane and carbon dioxide [6], also conversion between two phases requires a long time as organic matter needs to be decomposed into gaseous and liquid fermentation products. In this study, landfill leachate samples were taken from a closed landfill with an age of more than 10 years. Main purpose of this paper was to characterize leachate according to chosen parameters, from Air Hitam closed landfill to determine its suitability to produce methane, by identifying its phase.

Experimental

Sampling

Study area selected is a 100 acre closed landfill that is located in Air Hitam, Puchong, Malaysia and is surrounded by residential areas. This sanitary landfill received domestic wastes from 1st April 1995 and stopped its waste collection on 31st December 2006. Throughout the years, the operator, Worldwide Landfills Sdn. Bhd.[7] reported to have received a total of 6,207,684.59 ton of wastes. As of now, the landfill is undergoing post closure maintenance activity. The most crucial maintenance is the leachate collection and monitoring.

Observed in the landfill site that there are several ponds containing leachate, raw untreated leachate and treated leachate. This paper focuses on the characterization of leachate from three different ponds; first pond contains raw untreated leachate and the other two ponds contain mechanically treated leachate where Figure 1 describes the leachate flow from its generation in landfill to final discharge. Leachate samples were collected from all three ponds weekly for a period of 12 weeks, from September to December 2010. Leachate samples were stored at temperature -4°C and all analyses performed within one week.

Sample Analysis

Samples collected were analyzed and tested according to these parameters: pH, temperature, chemical oxygen demand (COD), total solids (TS), and concentration of heavy metals, ammoniacal nitrogen (NH_4-N), total organic carbon (TOC), and volatile organic acid (VOA). Tests were conducted according to the Standard Methods for the Examination of Water and Wastewater [8]. COD was measured using a HACH HR COD digestion vial and HACH DR2010 spectrophotometer was used to read the measurements. Ammoniacal nitrogen, total organic and volatile organic acid were prepared using Merck's Spectroquant test kits and measured using Spectroquant Nova 60 spectrophotometer. Heavy metals concentrations determined were As, Ca, Cd, Cr, Fe, Co, Cu, Li, Mg, Mn, Mo, Ni, Pb, Sb, V, Zn, Al, Ba and Hg. These metals' concentrations were measured using Inductively Coupled Plasma of Optical Emission Spectrometry (ICP-OES) model Thermo Scientific iCAP 6000 series with ASX-520 auto sampler and multi-elements and Hg standard solution. Diluted leachate samples were preserved with the addition of few drops of nitric acid, for the heavy metals analysis [9]. All analyses were performed within one week of sampling to avoid the possibility of sample degradation.

Results and Discussion

Following Figure 1, it illustrates that leachate generated in landfill was collected and channeled to Pond 1, where no treatment was applied, raw untreated leachate which then channeled to Pond 2 where aeration was applied and transferred to Pond 3 for further aeration and finally, leachate was tested according to selected parameters to ensure that the concentration of leachate compositions comply to the Environmental Quality Act 1974 Second Schedule (Regulation 13) for discharge of leachate before it is discharged to nearby river.

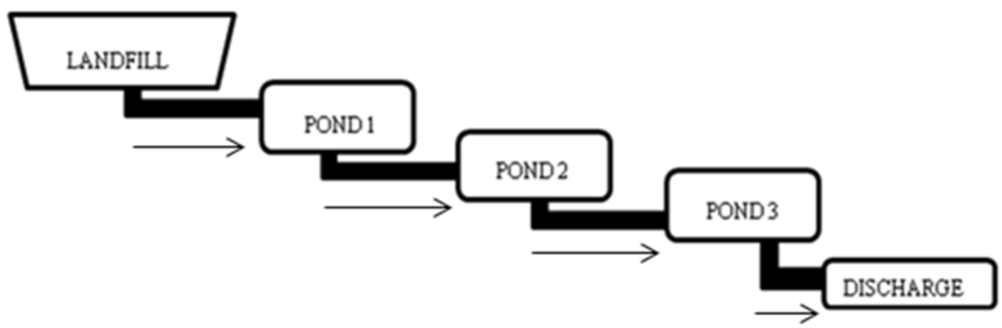

Figure 1. Schematic diagram of leachate flow

Parameter analysis for a 12 week period of leachate samples drawn from three different ponds (Pond 1, Pond 2 and Pond 3) is summarized in Table 1, which also showed significant variations of respective parameters in all three ponds. pH change from 8.49 to 6.96 was due to the high alkalinity in samples, which is typical for old landfill leachate. Occurrence of pH changes was contributed by the decomposition in the readily biodegradable organics and gas production [10]. This pH values obtained in this study offset and does not agree to the values reported by Aziz *et. al.* in 2010, which stated that mature landfills possess pH of 6.6 to 7.5 [5]. Justification for the decreased pH value after aeration process is due to the ammonification process that releases H^+ ions [11].

Ammonification is a step in the nitrogen cycle, which ammonium ion is formed by either nitrogen fixation or nitrite ammonification. Nitrogen fixation occurs in aerobic condition, due to its need for oxygen presence while nitrite ammonification is typically an anaerobic process [12]. Hence, increasing value of NH_4-N from Pond 1 to 3 was contributed by the ammonification process by nitrogen fixation, where oxygen was supplied during aeration in Pond 2 and 3.

Aeration in leachate ponds observed to have reduced COD values from 3607 mg/L to 1239 mg/L, which is about 65.7% reduction. Aeration facilitates in COD reduction due to the aerobic microorganisms consumption of the organic matter in landfill leachate, when oxygen in supplied and transformed it into new microbial biomass and partly carbon dioxide, by means of aerobic metabolism [13]. Further aeration of leachate can further reduce the COD value hence it depends on the aeration and holding time of leachate in the aeration pond. Other parameters changed as well with the application of aeration, which improves the quality of leachate and observed that %TS is also reduced from 1.15 to 0.98 %. Reduction of %TS is due to aeration also contributed by the transition from acidogenic to methanogenic phase in landfill leachate [14].

Table 1. Leachate characterization of Air Hitam Landfill

Parameter	Pond 1	Pond 2	Pond 3
pH	8.49	7.51	6.96
Temp (°C)	26.68	26.47	26.44
COD (mg/L)	3607	1461	1239
TOC (mg/L0	5337	2874	2118
VOA (as Acetic Acid, mg/L)	555	262	216
NH4-N (mg/L)	0.28	0.45	1.50
%TS	1.15	1.09	0.98
Aluminum (mg/L)	0.021	0.007	0.020
Calcium (mg/L)	0.949	1.059	1.053
Magnesium (mg/L)	0.314	0.403	0.416
Barium (mg/L)	<0.2	<0.2	<0.2
Cadmium (mg/L)	0.006	0.007	0.374
Chromium (mg/L)	0.003	0.004	0.002
Copper (mg/L)	0.013	0.011	0.011
Zinc (mg/L)	0.013	0.032	0.019
Lead (mg/L)	0.017	0.004	0.00025
Iron (mg/L)	0.080	0.159	0.045
Nickel (mg/L)	<0.2	<0.2	<0.2
Manganese (mg/L)	0.005	0.011	0.007
Molybdenum (mg/L)	0.058	0.029	0.013
Vanadium (mg/L)	<0.2	<0.2	<0.2
Antimony (mg/L)	0.020	0.012	0.012
Arsenic (mg/L)	0.011	0.016	0.232
Mercury (mg/L)	0.063	0.026	0.018

Heavy metals were observed to be of low concentrations. It was reported by [15] that heavy metals concentrations are significantly high in younger leachate, and in an acidic phase, where it could possibly be a threat. Therefore, low concentration of heavy metals is possible for older, aged leachate in methanogenic phase. However, values of heavy metals in Table 1 do not seem to have a significant pattern or trend. Cr, Cu, Pb, Fe, Hg Mo and V ions were reduced with aeration but other metals remain unchanged or slightly increased. In my opinion, it could be due to the accumulation of these metals in the aeration pond and was collected together upon sampling.

Concentration of VOA should be increasing as TOC reduced but findings in this study found that value of VOA decreased from Pond 1 to 3; 555 mg/L to 216 mg/L where it should be increasing as aerobic microorganism degraded organic matter into acetic acids. However, aeration pond at sampling location was an exposed to rain and flushing effect occurred to dilute to acetic acids that was produced [16] hence, leachate from Pond 2 and 3 is less favorable for methane production. Another reason for VOA reduction as leachate progressed from Pond 1 through 3 is possibly to temperature change that affects microbial population and consequently changes VFA production [17].

Leachate generation was also influenced by the amount of precipitation received in the landfill site and COD and TOC values were compared to amount of precipitation received during sampling period. Precipitation data was obtained from Department of Meteorological, Malaysia [18]. Figure 2 illustrates the trend in COD reading over the 12 weeks for all three ponds compared to precipitation received one day before sampling, to allow precipitation that falls and trapped in landfill stays up to one day before it was completely discharged onto Pond 1. Note that in Figure 2, on the first week COD is high at value of ~3000mg/L, corresponds to no precipitation. Same is observed on 3rd, 4th and 5th week, no precipitation received and the COD value is at the highest of 5248 mg/L. Figure 3 shows the TOC trend over precipitation received, and the trend is dissimilar to COD, however at 7th, 8th and 9th week, no precipitation received and the TOC is at its highest at 6797 mg/L. Value of COD is significantly lower with high precipitation as water assists the redistribution of nutrients and microorganisms in within the landfill [19]. Precipitation received throughout the sampling period affects the flow of leachate.

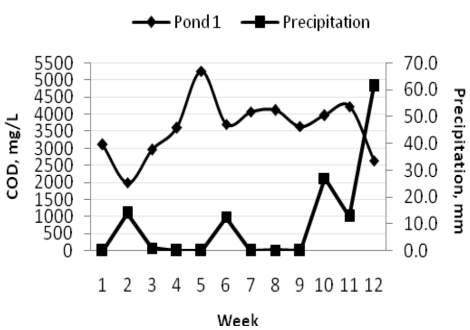

Figure 2. Relation between COD and precipitation

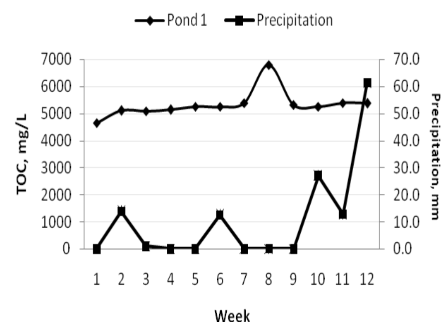

Figure 3. Relation between TOC and precipitation

Reported by B. Rincón, there are three principal digestions that occur and they are: hydrolytics, acetogenics and methanogenics [20]. In a landfill, there are two distinguished phases with the early phase called the acidogenic phase which contributes to volatile acids production. Later on, as a landfill matures, it transformed to methanogenic phase where volatile acids present are converted into biogas, methane and carbon dioxide by means of methanogenic microorganisms or methanogens [1]. Values of pH, and COD presented propose that leachate samples are in methanogenic phase and additionally, in this study Pond 1 reported to have 555 mg/L of volatile acids. It was described that methanogenic phase leachate has pH value of 7.5 to 9.0 and COD value of 500 to 4500 [21].

Conclusion

Aged leachate from a closed landfill in Air Hitam has been characterized as reported and it is found that the landfill leachate is in methanogenic phase. High content of VFA in raw untreated leachate recommended that VFA contained in leachate to be converted in methane via methanogenesis. Furthermore, parameter values differences from Pond 1 through 3 was due to the application of aeration as well as the precipitation received throughout the year considering Malaysia’s tropical climate. Hence, high moisture content of the incoming waste stream at Air Hitam has a significant impact on the leachate generation and the chemical composition.

Acknowledgement

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