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CHARACTERIZATION OF LEACHATE FROM PANCHANG BEDENA LANDFILL, BATANG PADANG LANDFILL AND MATANG LANDFILL: A COMPARATIVE STUDY

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ABSTRACT A Landfill is the main disposal method of solid waste in Malaysia but this creates issues due to its leachate generation. Improper leachate treatment pollutes the environment and is harmful to human health. This study aims to determine the characteristics of landfill leachate from three landfills sites that differs in age and types; Panchang Bedena Landfill (PBL), Batang Padang Landfill (BPL) and Matang Landfill (ML). The parameters tested in this study include pH, temperature, suspended solid (SS), chromium hexavalent, BOD_5, COD, copper, lead and cadmium. Analysis was carried out with standard methods using HANNA HI 9828 Portable Multiparameter, atomic absorption spectrophotometer and portable spectrophotometer, HACH DR2800. The mean values of the parameters from PBL, BPL and ML are pH (8.60, 7.67 and 6.76), temperature (29.30, 33.02 and 29.47 ^{o}C), chromium hexavalent (0.030, 0.007 and 0.020 mg/L), SS (101.7, 127.3 and 45.0 mg/L), BOD_5 (106.70, 144.07 and 100.30 mg/L), COD (153.7, 1418.0 and 257.5 mg/L), BOD_5/COD (0.69, 0.09 and 0.39 mg/L), copper (0.24, 1.52 and 0.10 mg/L), lead (1.95, 0.75 and 0.13 mg/L) and cadmium (0.03, 0.001 and 0.003 mg/L), were recorded, respectively. The obtained results were compared to the standard limit under the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulation 2009. The leachate quality from PBL has the highest range of heavy metals, followed by BPL and ML which is due to landfill age. However, BPL shows greater organic contaminants such as SS, BOD_5 and COD which may be due to the absence of leachate aeration facilities at the landfill site compared to PBL and ML. A proper treatment strategy is crucial to reduce the pollutants before being discharged into the water bodies.

ABSTRAK Tapak pelupusan adalah kaedah pelupusan utama sisa pepejal di Malaysia tetapi ini mewujudkan isu penghasilan air larut resap. Rawatan air larut resap yang tidak cekap akan mencemarkan alam sekitar dan membahayakan kesihatan manusia. Kajian ini bertujuan untuk menentukan ciri-ciri air larut resap dari tiga tapak pelupusan sampah yang berbeza tempoh operasi dan kategori; tapak pelupusan Panchang Bedena (PBL), tapak pelupusan Batang Padang (BPL) dan tapak pelupusan Matang (ML). Parameter yang diuji dalam kajian ini termasuk pH, suhu, pepejal terampai (SS), kromium heksavalen, permintaan oksigen biokimia (BOD5), permintaan oksigen kimia (COD), kuprum, plumbum dan kadmium. Analisis telah dijalankan dengan menggunakan HANNA HI 9828 Multiparameter mudah alih, spektrofotometer penyerapan atom dan spektrofotometer mudah alih, HACH DR2800. Nilai purata parameter dari PBL, BPL dan ML adalah pH (8.60, 7.67 dan 6.76), suhu (29.30, 33.02 dan 29.47 ^{o}C), kromium heksavalen (0.030, 0.007 dan 0.020 mg/L), SS (101.7, 127,3 dan 45.0 mg/L), BOD_5 (106.70, 144.07 dan 100.30 mg/L), COD (153.7, 1418.0 dan 257.5 mg/L), BOD5/COD (0.69, 0.09 dan 0.39 mg/L), kuprum (0.24, 1.52 dan 0.10 mg/L), plumbum (1.95, 0.75 dan 0.13 mg/L) dan cadmium (0.03, 0.001 dan 0.003 mg/L), masing-masing dicatatkan. Keputusan yang diperolehi dibandingkan dengan had piawaian Peraturan Kualiti Alam Sekeliling (Kawalan Pencemaran daripada Stesen Pemindahan Sisa Pepejal dan Kambus Tanah) Peraturan 2009. Kualiti air larut resap dari PBL mencatatkan julat tertinggi untuk logam berat, diikuti oleh BPL dan ML yang disebabkan oleh usia tapak pelupusan. Walau bagaimanapun, BPL menunjukkan bahan cemar organik yang lebih tinggi seperti SS, BOD5 dan COD yang mungkin disebabkan oleh ketiadaan kemudahan fasiliti pengudaraan di kolam air larut resap berbanding dengan PBL dan ML. Strategi rawatan yang betul adalah penting untuk mengurangkan bahan pencemar sebelum dilepaskan ke dalam sumber air.

(**Keywords**: *Leachate, Characteristics, Parameters*)

INTRODUCTION

The generation of wastes is increasing each year. As a country that's focusing more towards industrialization, Malaysia cannot escape from population expansion that changes consumption pattern which will then lead to higher waste generation [1]. In order to manage its wastes, Malaysia opted for the landfill method which has been the primary disposal method in various countries [2] including Malaysia [3-5]. Landfills are considered the most widely practiced method for disposal of Municipal Solid Waste (MSW), taking in up to 95 % total MSW collected worldwide [6, 7]. At present, landfilling is the only method used for MSW disposal in Malaysia, most of which practices the open dumping method that can pose serious environmental and social threats. This is due to the production of leachate that had become a major environmental problem [8]. Chronic production of toxic leachate can contain high concentrations of organic compounds as well as pathogens. Coupled with the slow degradation of waste mass, this two factors posed a long-term environmental and health risk which are a major concern when discussing conventional landfill method [9]. The leachates are discharged directly into water courses without any treatment, thus threatening the surrounding ecosystem, particularly in cases where landfills are located upstream from water intakes [5]. Regadio [10] mention that the potential pollution caused by leachates is the result of several factors, including the release of ammonia, chlorinated and non-chlorinated organic compounds and heavy metal ions into the environment, all of which are toxic to living organisms. Therefore, the main purpose of this research is to study the characteristics of landfill leachate in three landfills in Peninsular Malaysia, namely, Panchang Bedena Landfill (PBL), Batang Padang Landfill (BPL) and Matang Landfill (ML). The identification of environmental risks of these sites was performedvia comparison with Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009 under the Laws of Malaysia Environmental Quality Act (EQA) 1974. This study attempts to provide baseline data on the characteristics of landfill leachate and the level of the pollutants.

MATERIALS AND METHOD

Site Characteristics

The three different sites were chosen based on the different age of landfill sites and also types of landfill and the available facilities. The age of landfill is characterized by the duration of time the landfills were actively utilized. The characterizations of leachate from these three sites were compared. Summary of landfill site characteristics is indicated in Table 1.

Table 1. Site characteristics

Panchang Badena landfill (PBL)	Batang Padang Landfill (BPL)	Matang Landfill (MT)
Lot 280, 281, Mukim Panchang Badena, 45300 Sungai Besar, Selangor	Kampung Panderas Slim Village, Perak	Near Taiping Town, Perak
10 acres	7.59 acres	29.65 acres
Unsanitary landfill (with leachate aeration)	Unsanitary landfill (without leachate aeration)	Sanitary landfill (Improved anaerobic landfill)
Class III non sanitary landfill	Class I non sanitary landfill	Level 3 for sanitary lanfill
Have been operated more than 10 years	Have been operated more than 30 years	Have been operated more than 14 years
	120-150 tons of waste received daily	300 tons of waste received daily

a.Panchang Bedena Landfill.

The study site for this project was conducted at Lot 280, 281, Mukim Panchang Bedena, 45300 Sungai Besar, Selangor which is an active 10 acres landfill located in Sabak Bernam, Malaysia. The coordination of this landfill is 3°41’23.97”N, 100°57’46.60”E. This is an improved anaerobic unsanitary landfill with leachate retention pond facilities with forced aeration. This landfill has been in operation for more than 10 years. According to classification on non sanitary landfill in Malaysia by Fauziah [11], this landfill is classified as class III, with Class II facilities, in addition to leachate recirculation system that allows the collection, recirculation and monitoring of landfill leachate (Table 2).

b.Batang Padang Landfill.

Batang Padang Municipal Solid Waste Landfill is located in Kampung Panderas Slim Village, Perak. Distance from the town of Slim River and Tanjong Malim is approximately 23 km and 28 km, respectively. This site occupies an area of 7.59 of acres. An estimated 120-150 tons of municipal solid wastes were disposed at Batang Padang MSW landfill per day. The landfill is fully maintained by the local authority and who their operation more than 30 years ago without the provision of any leachate treatment. This landfill is classified as unsanitary landfill, also known as open dumping. Based on Table 2, this is a class I non sanitary landfill, with minimal infrastructure.

c.Matang Landfill.

ML is located at 4^{o} 49'20.08"N and 100^{o} 40'44.08"E near Taiping in Perak, Malaysia. ML has been operated for more than 14 years with the total landfill area of 12 ha, approximately 29.65 acres. The landfill receives about 300 tons of solid waste daily. Matang landfill has been upgraded to a new aerobic sanitary landfill. ML is equipped with a leachate collection pond, however, there is no further treatment for the leachate except for forced aeration. This landfill is classified as an improved aerobic landfill and falls under level 3 for sanitary landfill (Table 3).

The Malaysian Government by the Department of Local Government under the Ministry of Housing and Local Government has published a guideline with an updated version on August 2006 which is "The Technical Guideline for Sanitary Landfill, Design and Operation", (MHLG, 2006). The purpose of this guideline is to develop a better landfill site in Malaysia with proposed countermeasures that merge local and foreign innovation and technologies.

However, at present, there are 330 solid waste disposal facilities in Malaysia, of which 291 are municipal solid waste controlled dumps, also known as non sanitary landfill. There are only 12 sanitary landfills recorded, including the Air Hitam sanitary landfill which has already been closed [11]. The summary of municipal solid waste disposal sites in Malaysia is presented in Table 4.

Table 2. Classification of non-sanitary landfills in Malaysia [11].

Non sanitary landfill class	Facilities
I	Minimum infrastructure such as fencing and perimeter drains
II	Class I facilities, in addition to gas removal system, separate unloading and working area, daily cover and enclosing bund (divider constructed as the embankment of different waste cells), elimination of informal scavenging and provision of environmental protection facilities
III	Class II facilities, in addition to leachate recirculation system allowing the collection,recirculation and monitoring of landfill leachate
IV	Class III facilities, in addition to a leachate treatment system

Table 3. Levels of sanitary landfills (MHLG, 2006)

Level	Description
Level 1	Controlled tipping
Level 2	Sanitary landfill with a bound and daily cover
Level 3	Sanitary landfill with leachate recirculation system
Level 4	Sanitary landfill with leachate treatment facilities

Table 4. Estimated number of MSW disposal sites in Malaysia in 2011 [11]

Status of disposal facilities	Current number
Operating controlled dumps	155
Closed controlled dumps	136
Sanitary landfills	12
Total	**303**

Leachate Sampling

The landfill leachate samples used in this study were collected from PBL, BPL and ML. The samples were collected in 1 Liter amber bottles and stored at 4 ^{o}C in laboratory prior to analysis to minimize the biological and chemical reactions. The collection and preservation of samples were done accordance with the Standard Method for the Examination of Water and Wastewater [12]. However, this study is limited by the frequency of samples taken, which was carried out only once for each site. While this may limit the quality of data obtained, this baseline data can be used to estimate or generate hypotheses for future research.

Analysis of Leachate

Temperature and pH were analyzed insitu using HANNA HI 9828 Portable Multiparameter, while Atomic Absorption Spectrophotometer was used to analyze lead and cadmium. The concentrations of other chemicals (suspended solid (SS), copper and chromium hexavalent) were identified using portable spectrophotometer, HACH DR2800. Biological oxygen demand (BOD_5) and chemical oxygen demand (COD) were analyzed using the standard method [13]. The values of the parameters obtained were then compared with Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009.

RESULT AND DISCUSSIONS

The characteristics of landfill leachate at PBL, BPL and ML, and the values for the measured parameters are shown in Table 5.

Table 5. Characteristic of landfill leachate at PBL, BPL and ML

Bil	Parameters	PBL Mean (n=3)	BPL Mean (n=3)	ML Mean (n=3)	Standards
1	pH	8.60	7.67	6.76	6.0- 9.0*
2	Temperature (oC)	29.30	33.02	29.47	40*
3	Suspended Solid (mg/L)	101.70	127.33	45.00	50*
4	BOD5 (mg/L)	106.70	144.07	100.29	20*
5	COD (mg/L)	153.70	1481.00	257.45	400*
6	BOD5/COD	0.69	0.09	0.39	**
7	Lead (mg/L)	1.953	0.745	0.130	0.1*
8	Copper (mg/L)	0.24	1.52	0.10	0.2*
9	Chromium Hexavalent	0.030	0.007	0.020	0.05*
10	Cadmium	0.030	0.001	0.003	0.01*

Notes :

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

** As stated in Table 6

Physical Characteristics (pH, Temperature and Suspended Solid)

The pH values of PBL, BPL and ML are 8.60, 7.67 and 6.76, respectively. The results are consistent with those published by previous authors [4, 14-18]. The pH values remain within the permissible limit (6.0-9.0) stated in the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009. pH is an essential quality parameter as it influences many biological and chemical processes of the media. Decaying activities of the waste in the landfill site also affect the value of pH in leachate. In addition, the range of pH is also affected by the age of the landfill from which it originated from. [8]. During the early phase of landfill reaction, the available oxygen will be consumed by aerobic bacteria. Once the oxygen has been depleted, the anaerobic bacteria will then convert compounds created by aerobic bacteria into acetic, lactic and formic acids and alcohols causing the landfill to become highly acidic. Late acidic phase and early methanogenic phase will increase the value of pH [17, 19]. Generally, the pH of a stabilized leachate is higher than that of a young leachate [5]. The difference could be due to the stabilized leachate that is produced after or during the fermentation of methane; hence the pH is higher than 7.5 which indicates the short acidic phase and early methanogenic phase [20-22]. The generalized and the changes in leachate is shown in Figure 1.

Temperatures of the leachate during sampling were 29.30, 33.02 and 29.47 ^{o}C for PBL, BPL and ML, respectively. The temperatures aligned with results stated in various other research [14, 16, 23]. These values are within the limit (40^{o}C) stated in the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009. As the characteristic feature of the climate of Malaysia is uniform temperature, therefore, the temperatures of the samples did not show much variation (Malaysian Meteorological Department, 2012).

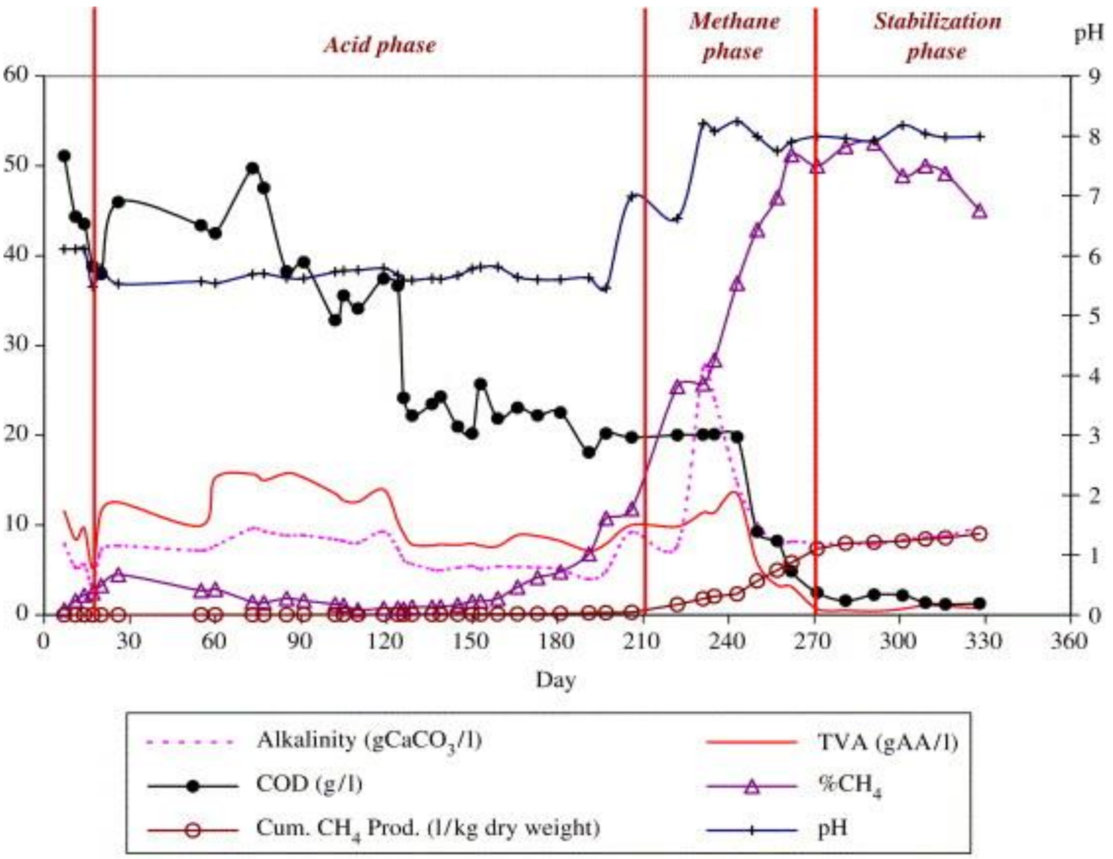

Figure 1. Generalized phases and the changes in leachate, methane composition and production with time of the simulated landfill reactor without leachate recirculation (RC) [19]

The average values of SS at PBL, BPL and ML were 101.70, 127.33 and 45.00 mg/L, respectively. Results showed that samples from PBL and BPL were higher than the permissible limit (50 mg/L) set in the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009. Previous research have also found high SS value in leachate sample [14, 15]. The high turbidity and SS value is mostly associated by the presence of high organic matter with some insoluble form [24]. In addition, there was no treatment carried out for the leachate such as coagulation or flocculation process. In fact, only PBL and ML have the leachate pond with forced aeration. Aeration has an effect of decreasing SS in leachate [5].

BOD_5

In this study, the value of BOD_5recorded for each sample of leachate at PBL, BPL and ML were 106.70, 144.07 and 100.29 mg/L, respectively. The measured BOD_5 from all sites exceeded the limit (20 mg/L) set in the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009. High value of BOD_5 was also recorded from Kuala Sepetang Landfill as studied by Zainol [14] and in several other research [5, 25]. It has been reported that the age of the landfill will affect the value of $BOD_5$with new landfills usually record a range of BOD_5 between 2000-30000 mg/L. Conversely, BOD_5 for mature landfills usually varies from 100-200 mg/L [5, 8, 26]. This is an indication that the landfills are in the methanogenic phase where almost all of the organic compound have been dissolved in the leachate but have yet to complete the stabilization process[27]. Therefore, we made the assumption that the lower value of BOD_5 for these landfill sites is due to the operational age of all three landfills that is more than 10 years.

COD

While the BOD_5 value recorded higher than the limit, the COD value, however, was lower than stated in the regulation, with the exception of BPL. Both PBL and ML showed COD values of 153.70 and 257.45 mg/L, respectively while leachate at BPL showed an extremely high COD value of 1481.00 mg/L. The value is at least three times higher than the limit (400 mg/L) by Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009. This staggering difference between BPL and the other two landfills is due to the fact that there is no leachate facilities provided at the BPL landfill site as opposed to the forced aeration carried out at PBL and ML. The higher value of leachate is also contributed by the decomposition process which continuously produce new leachate even though the landfill sites have been in operation for more than 10 years [28]. COD that range between 500 to 4500 mg/L can be classified as in the methnogenic phase [29-31]. Stabilized leachates are rich with organic matter [32] such as humic substance (measured as COD intensity) and fulvic like fraction [8, 14]. The greater values COD were also recorded from Pulau Burung Landfill Site as studied by Bashir [23] and Kuala Sepetang Landfill Site by Zainol [14].

BOD_5/COD Ratio

The values of organic compounds in leachate depend on the different levels of biodegradability of the landfill. The BOD_5/COD ratio can be considered as a measure of the biodegradability of the organic matter, and hence of the maturity of the leachate and the landfill, which typically decreases with time [6]. The characteristics of landfill stability as a function of BOD_5/COD ratio are shown in Table 6. In this study, the BOD_5/COD ratio for the collected samples were 0.69 (PBL), 0.09 (BPL) and 0.39 (ML). The ratio values indicated that PBL falls within the category of young and unstable landfill while BPL is categorized as an old stable landfill. ML, on the other hand, was categorize as a moderate stable landfill. However, according to the BOD_5/COD ratio in Table 6, the COD values recorded by Zainol [14], KLS and KSLS leachates showed higher biodegradability (0.19 and 0.24) indicating that both leachates are partially stabilized leachates ($0.1<BOD_5/COD<0.3$) rather than stabilized leachate ($BOD_5<0.1$), even though the age of both landfills are already more than 10 years old. This study also showed the same pattern as recorded by Zainol [14]. The higher BOD_5/COD ratio is probably occurred because the landfills are still operating and producing young leachates which are mixed together with old leachates thus increasing its biodegradability [28]. Therefore, biological degradation is still occurring in these landfills [33]. SS, turbidity, colour and COD leachates are possibly related to the landfill age since the characteristics and constituents of leachates depend on this factor.

Leachates undergo four phases of change according to the age of the landfill, including transition (0-5 years), acid formation (5-10 years), methanogenic phase (15-20 years), and final maturation (> than 20 years) [5]. The variation of the values could also be due to climate condition, landfill design, site characteristics, solid waste composition and landfill age [34].

Heavy Metals (Lead, Copper, Chromium Hexavalent and Cadmium)

The values of lead from all samples exceeded the standard limit (0.1 mg/L) as stated in Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009. The values of copper were 0.24, 1.52 and 0.10 mg/L for PBL, BPL and ML, respectively. Based on the regulation, the values of copper from PBL and BPL were higher than the standard limit (0.2 mg/L). For cadmium, however, only PBL exceeded the limit stated in regulation. Apart from that, the values of chromium hexavalent for all three landfills fell below the standard limit (0.05 mg/L). In general, PBL showed the highest reading of heavy metals compared to BPL and ML since the value of lead, copper and cadmium at PBL exceeded the standard limit. The presence of heavy metals in leachate is strongly related to the composition of waste, such as metal based material waste from construction materials, electrical appliances and many more, which releases the heavy metals into the leachate [35]. Heavy metals are also common toxic constituents in some household and office items that are disposed in landfills [36]. Since pH values increase with the age of the landfill, it reduces metal solubility. With that, the oxidation-reduction process and dissociation of acid will be affected. The heavy metals will react with the hydrogen ion and precipitate in metal hydroxides. At this stage, the stabilized leachate contains less concentration of heavy metal (less than 2 mg/L) due to the high pH value [8].

Table 6. Landfill stability as a function of BOD5/ COD ratio (SWANA, 1997)

BOD5/COD ratio	Significance
> 0.5	Young, unstable
0.1 – 0.5	Moderately stable landfill
< 0.1	Old stable landfill

CONCLUSIONS

Ten parameters of landfill leachate were investigated in this study for three different landfill sites in Peninsular Malaysia to compare its differences based on landfill type and age. In this study, type of landfill such as non sanitary with and without leachate aeration facilities and sanitary landfill has a significant effect on the quality of leachate. Other than that, age of the landfill site also plays an important factor in the quality of leachate production. The older the landfill age, the more stabilize and less pollutant it has. The characteristics of the waste itself very much affect the presence of contaminants in the leachate and can be distributed by physical, chemical and biological processes. The measured parameters also seemed to be affected by climate such as rainfall; and the technology and waste management applied to the landfill. In general, the leachate quality from PBL has the highest range of heavy metals, followed by BPL and ML. This is may due to landfill age, since BPL and ML has been operating longer than PBL. However, BPL shows greater organic contaminants such as SS, BOD_5 and COD due to the absence of leachate aeration facilities compared to PBL and ML. Therefore, the implementation of the better and suitable technology for the treatment of landfill leachate should be considered in order to lessen the pollutants before being discharged into our water body system.

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