Characteristic of leachate at Alor Pongsu Landfill Site, Perak, Malaysia: A comparative study

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Abstract. Leachate is a harmful by product generated from the landfill site. Leachate contains a high concentration of pollutant which can cause serious pollution to environmental. In this study, characteristics of leachate in Alor Pongsu Landfill Site (APLS) were monitored and analyzed according to the Standard Methods for the Examination of Water and Wastewater (2005). Composition in leachate at APLS was monitored for one year starting from January 2015 until January 2016. Nine parameters were monitored including color, chemical oxygen demand (COD), biological oxygen demand (BOD_5), ammoniacal nitrogen (NH_3-N), biodegradability ratio (BOD_5/COD), temperature, dissolved oxygen (DO), total dissolved solid (TDS) and pH. Based on the analysis, Alor Pongsu Landfill leachate was categorized as stabilized landfill leachate by referring to the $BOD_5/COD < 0.1$. Comparison with allowable discharge limits for leachate shows that most of parameters exceeded the standard discharge limitation. Thus, proper treatment is needed before leachate can be discharged to the environment.

1. Introduction

Municipal solid waste (MSW) disposal has become an ever-increasing problem in many parts of the world, especially in developing countries such as Malaysia. For the disposal of MSW, the sanitary landfill is considered as the most widely practiced method due to its economic advantage and up to 95% of total MSW was collected worldwide [1]. In Malaysia, municipal solid waste has been estimated to increase from 23000 tons/day in 2010 to 30000 tons/day in 2020 [2]. Variety sources of MSW make wastewater generated from the landfill are complex and difficult to be remediated. There are 296 landfills reported in Malaysia and about 166 are still operating. It was also noted that, out of the 166 operating landfills, only 11 are sanitary and capable of preventing environmental from landfill gas and leachate escape to the environment [2].

The discharge coming from a sanitary landfill mainly consists of leachate with a strongly polluted wastewater and biogas [3-4]. Leachate contains excessive concentrations of biodegradable and non-biodegradable products, which include organic matter, phenols, ammonia nitrogen, phosphate, heavy metals, and sulphide as well as a strong color and bad odor [5][6]. The production of leachate mostly depends on the solid waste composition, particle size, the degree of compaction, hydrology of the site, the age of the landfill, moisture and temperature conditions, and available oxygen [7]. Meanwhile, the quality of leachate is related to the phase of degradation process which occurs in landfill sites. There are three stages of anaerobic degradation process which are acid fermentation, intermediate anaerobic phase and anaerobic degradation. Acid fermentation phase present in young or new landfill site and aerobic activities dominant the process with a large production of volatile fatty acid, but occurs in the short period. Whilst, the intermediate anaerobic phase is a stage where methanogenic bacteria start to grow, volatile fatty acid is decreased and ammonia is released [8]. Finally is the anaerobic degradation or known as stabilized leachate which is recognized in the old landfill (age > 10 years) [8]. Old leachate is even more complex as they are stable and difficult to be treated biologically. The main purpose of this study is to characterize leachate at Alor Pongsu Landfill side. The comparison APLS leachate with nearby old landfill leachate and leachate in South East Asia country were also done. Moreover, the characterization of leachate directly served as a reference for the implementation of the most suitable technique for reducing the negative environmental effects of discharged leachate.

2. Material and Method

Alor Pongsu Landfill Site (APLS), Malaysia is classified as an anaerobic stabilized landfill. It is located in Alor Pongsu, Perak, Malaysia, at coordinates of 5°04' N, 100°35' E. APLS has started its operation more than 16 years since 2000. The site also receives an average of 660,000 metric tons of solid waste per year, which represent the daily average of domestic waste. Solid waste recycling activities were done here. This site also provided detention pond for leachate collection and also function as biological treatment (natural anaerobic process) before effluent being discharge to the environment. APLS is also categorized as improved anaerobic sanitary landfill leachate (class III).

2.1. Leachate Sampling

During monitoring, leachate samples were manually collected from January 2015 to January 2016. The sample was taken by grab sampling from the artificial pond (detention pond) and fully filled 20 L plastic containers to avoid space for aeration. The sample was analyzed within 24 hours from the time of sampling. The shorter the time taken between sampling and analysis, the more reliable result will be. Sample collection and preservation were performed in accordance with the Standard Methods for the Examination of Water and Wastewater (2005) [9].

2.2 Leachate Characterization.

In this study, temperature, dissolved oxygen (DO), total dissolved solid (TDS) and pH were examined using multi-parameter probe while color was measured using a DR 2800 HACH spectrophotometer. COD concentration was determined by a closed reflux colorimetric method using a DR 2800 HACH spectrophotometer with a high range (HR) limit. NH_3–N concentration was measured by Nessler Method. Biological oxygen demand (BOD_5) was tested by following the standard method procedure and five days of incubated period required to stabilize the non-seeded dilution sample. The analysis was analyzed at Environmental Laboratory of School of Civil Engineering, Universiti Sains Malaysia. The measurements of samples were conducted in triplicates according to the standard methods for the examination of water and wastewater [10]. Then the obtained data were compared with data published by previous researchers and MEQA (1974). The analysis data for maximum, minimum, mean and standard deviation were carried out by using IBM SPSS statistic software, version 22.

3. Result and Discussion

3.1 Leachate characteristic

Table 1. Characteristics of leachate landfill at Alor Pongsu Landfill from January 2015 until January 2016

Bil	Parameter	Unit	Min	Max	Value (Mean)	Standard Deviation	MEQA*
1	Temperature	◦C	25.9	31.6	29.8	1.51	40
2	pH		7.85	8.64	8.13	0.20	6.0-9.0
3	Color	PtCo	10, 650	20, 300	14, 984	2281	-
4	COD	mg/L	2950	4675	3852	582	400
5	NH_3-N	mg/L	1040	1690	1241	214	5
6	BOD_5	mg/L	113	343	196	63	20
7	BOD_5/COD		0.03	0.08	0.05	0.02	-
8	DO	mg/L	0.09	3.00	0.85	0.84	-
9	TDS	mg/L	1800	9257	6237	2803	-

*Environmental Quality (control of pollution from solid waste transfer station and landfill) Regulation 2009 under the Laws of Malaysia Environmental Quality Act (MEQA) 1974 (MDC, 1997) [10]

Table 1 summarizes the characteristic value of leachate at APLS. There were nine parameters that have been monitored during the sampling period. The data were presented according to minimum, maximum and average value. Limitation discharge leachate effluent from MEQA was also listed and compared. Whilst, collected data from previous researcher for leachate characteristic from nearby landfill site such as Pulau Burung landfill site (PBLS), Matang landfill site (MLS) and Kulim landfill site (KLS) from 2010 until 2015 was summarized in table 2.

Table 2. Summary of leachate landfill characteristics at nearby landfill site (Pulau Burung, Matang and Kulim landfill site) from 2010 until 2015

Parameter	Unit	Value	Location	Type	Citation
Temperature	°C	29-33.5	MLS	anaerobic	[11][12]
		30.5-34.7	PBLS	semi-aerobic	[13][12]
pH		8.1-8.5	PBLS	semi-aerobic	[13][14][15][12]
		8.05 - 8.66	MLS	anaerobic	[11][16][12]
		7.59 - 8.25	KLS	anaerobic	[16][17][12]
Color	PtCo	2933-3615	PBLS	semi-aerobic	[13][14][18][15][12]
		2220-6398	MLS	anaerobic	[16][12]
		279-3029	KLS	anaerobic	[16][17][12]
COD	mg/L	1123-3180	PBLS	semi-aerobic	[13][14][18][15][12]
		770 - 1456	MLS	anaerobic	[11][16][12]
		110-1295	KLS	anaerobic	[17][16][12]
BOD_5	mg/L	60-243	PBLS	semi-aerobic	[13][14][18][15][12]
		100 - 257	MLS	anaerobic	[11][16][1][12]
		29-285	KLS	anaerobic	[16][12]
NH_3-N	mg/L	620 - 2050	PBLS	semi-aerobic	[13][14][18][15][12]
		500 -857	MLS	anaerobic	[11][16][12]
		210 - 720	KLS	anaerobic	[17][16][12]
BOD_5/COD		0.05-0.10	PBLS	semi-aerobic	[13][12]
		0.14 - 0.39	MLS	anaerobic	[11][16][1][12]
		0.20-0.24	KLS	anaerobic	[16][12]
DO	mg/L	0.14	PBLS	semi-aerobic	[13]
TDS	mg/L	5306	PBLS	semi-aerobic	[13]

3.2 Temperature

The average temperature of leachate was recorded as 29.8 ◦C. Temperature was also influenced by the weather at landfill site [11]. During sampling in a rainy day, the sample temperature were noticed to drop until 25.9◦C while in sunny days, it can achieve up to 31.6◦C. According to Zawawi [19], the climate for APLS area is classified as typical Peninsular Malaysia with temperature daily range between 30◦C – 40◦C. The nearby landfill sites also recorded the temperature between 29.0◦C – 33.5◦C at MLS and 30.5◦C – 34.7◦C at PBLS (table 2). High humidity (80%-90%) and high average annual rainfall count (1800mm) were recorded in this area [19]. Comparison with MEQA (40◦C) shows that temperature for leachate at APLS still acceptable and within the limitation (table 1). Therefore, treatment for temperature adjustment is not required.

3.3 pH

The second parameter is pH. The average pH sample was noted as pH 8.13 while the minimum and maximum value was pH 7.85 and 8.64. The data agrees with pH range for mature leachate (landfill age > 10 years) that it should be more than 7.5 [4][20][21][13]. pH value increased with the age of the landfill. Based on pH data, leachate in APLS can be classified as in methanogenic phase. In this phase, the volatile fatty acid in leachate was depleted and lead to the increasing of pH values as well as alkalinity

[8][4]. Comparison of APLS with local mature leachate landfill as presented in table 2 (PBLS, MLS, KLS) was also congruent with pH observed i. e. pH 8.1 – 8.5 at PBLS, pH 8.05-8.66 at MLS and pH 7.59-8.25 at KLS. The average pH value obtained from APLS still under MEQA (pH 6 – 9) limitation.

3.4 Color

Color is one of the emerging parameters in determining water quality. The average value of color was recorded as 14,984 PtCo (table 1) while the minimum and maximum were 10,650 and 20,300 PtCo. Color is highly dependent on pH and organic matter in the sample. Increased in the pH number consequently increased the color concentration [9]. The previous result in table 2 also congruent that old leachate produces more number of color concentration. The range recorded by previous researcher for PBLS, MLS and KLS were 2933-3615 PtCo, 2220-6398 PtCo and 279-3029 PtCo respectively. Comparison with nearby landfill shows that APLS recorded higher color concentration. According to Aziz [23], the presence of high organic substance also contributes to the color concentration. Abundance of organic matter that non-degraded such as humic and fulvic compound was detected in the stabilized (old) leachate sample [24].

3.5 Chemical Oxygen Demand

COD is a test to measure the pollutant strength (organic and inorganic matter) inside the sample. As presented in table 1, the average COD value was 3852 mg/L while the minimum and maximum were 2950 mg/L and 4675 mg/L. The average COD value indicated that APLS was classified as in methanogenic phase. In this phase, the COD value ranges between 500 and 5000 mg/L [21][25][4]. Moreover, previous pH data and comparison was also supported this classification. Nearby landfill leachate gave COD value in the range of 1123 – 3180 g/l for semi-aerobic and 110 – 2180 mg/l for anaerobic leachate. COD decreased with the aged of the landfill [21]. According to MEQA [10], the value for COD of leachate should be less than 400 mg/L before it can be discharged safely into the environment. Thus, treatment of leachate must be conducted in order to reduce risk of contamination.

3.6 Ammoniacal Nitrogen

The average NH_3-N obtained from this monitoring was 1241 mg/L while minimum and the maximum value were 1040 and 1690 mg/L respectively. This data was consistent with nearby stabilized leachate characteristic at Pulau Burung which was recorded in range between 620 – 2050 mg/L (table 2). Whilst, NH_3-N at Matang landfill site and Kulim landfill side were also shown higher result (table 2) such as 500 -857 mg/L and 210 – 720 mg/L respectively. Leachate is rich with ammonia nitrogen as a result of the hydrolysis and fermentation of the nitrogenous fractions of the biodegradable substrates [26]. Decomposition of organic matter is stable in an anaerobic condition and enhances production of NH_3-N and nitrogen compound [27]. According to Bhalla [27], the amount of organic matter is reduced by the age of landfill sites. Although APLS is categorized as old landfill, NH_3-N value still higher compared to MEQA limitation (5 mg/L).

3.7 Biological Oxygen Demand

BOD_5 is functional as an indicator to measure the amount of organic pollution, which can be oxidized biologically in a sample of water or wastewater. Normally, a standard of five days BOD test was applied to measure the oxygen demand in evaluating the organic pollutant in water and wastewater. Monitoring at APLS give an average BOD_5 reading 196 mg/L minimum and maximum value was 113 mg/L and 343 mg/L respectively (table 1). BOD_5 is also dependently to the age of the landfill. The range of BOD_5 for landfill age >10 years were between 100-200 mg/L while young landfill between 200 – 30,000 mg/L [18]. The average data was congruent with the stated range. Moreover, comparison with other landfill which is Pulau Burung, Matang and Kulim landfill also in the same range with APLS such as 60-243 mg/L, 100-257 mg/L and 29-285 mg/l respectively. According to Malaysian standards, the permissible level of BOD_5 is 20 mg/L and APLS was over the limitation as well as reported in other studies (table 2).

3.8 BOD_5/COD

Biodegradation ratio (BOD_5/COD) is the crucial indicator to determine the period phase of leachate which directly described the condition of the sample. There are three period phases, which were acid phase (young leachate), intermediate phase (partially stabilized leachate) and methanogenic phase (stabilized leachate). According to Kurniawan [28], BOD_5/COD > 0.5 is categorized as young leachate, while BOD_5/COD between 0.1 – 0.5 is categorized as partially stabilized leachate and BOD_5/COD less than 0.1 is stabilized leachate. Referring to table 1, the average BOD_5/COD for Alor Pongsu landfill leachate was 0.05 while the maximum and minimum were 0.03 and 0.08 respectively. The data recorded shows that the leachate is classified as stabilized landfill leachate. Summarize data in table 2 also shows that, two nearby landfill which is MLS and KLS can be group as partially stabilized leachate while PBLS can be categorized as stabilized landfill leachate similar to APLS. The low BOD_5/COD ratio indicates that the leachate is stable and difficult to be biologically degraded further [18].

3.9 Dissolved Oxygen

Dissolved oxygen levels in wastewater depend on the physical, chemical and biochemical activities in the water body. Measuring DO is a key test for determine water pollution and waste treatment process. Table 1 presents that DO range between 0.09 to 3.00 mg/L. For nearby mature leachate at PBLS (table 2), the DO value of 0.14 was recorded [13]. The same range of 0.12 to 0.18 mg/L was published by Yusoff [7] for landfill leachate in Selangor, Malaysia. The composition of DO in landfill leachate is normally lower due to aerobic decomposition of waste which microbes use dissolved oxygen as energy to transform organic materials to inorganic material.

3.10 Total Dissolved Solid

Total dissolved solid is generally affected by the total number of dissolved organic and inorganic materials obtained in the solution [8]. As presented in table 1, the average, maximum and minimum amount of TDS recorded as 6237 mg/L, 9257 mg/L and 1800 mg/L respectively. The same TDS range of 5348 mg/L to 6563 mg/L was published by Bhalla [27]. Comparison with previous data recorded in table 2 also shows high numbers for TDS which is 5306 mg/L. High TDS in leachate may reflect the overall pollutant load as a consequence of degradation of organic matter.

3.11 Comparison the quality of stabilized landfill leachate in South East Asia (Malaysia, Indonesia and Thailand)

Landfill leachate quality were influenced from the waste composition, the age of landfill, waste amount, rain intensity as well as the category of municipal landfill solid waste. Each country and city has different composition of waste which depending on the local life culture. In Indonesia, organic waste is dominant by 55.5%, followed with plastic waste of 19.1% and the rest are paper, textiles, glass, wood, metal, rubber, bones, and others [29]. While in Thailand with MSW generated 9930 tons per day, organic waste is 49.9%, plastic 28.5%, paper 8.5%, textile/leather 5.2%, glass/ ceramic 4.4%, metal 1.4%, bond and shell 1.9%, hazardous waste 0.2% and other 49.9% [30]. In Malaysia, food waste monopoly the composition with 39.70% followed by paper 22.79%, paper 13.95%, textile/leather 3.66%, glass/ceramic 3.22%, waste yard/wood 6.4%, rubber 1.54%, metal 1.45% and others 7.29% [3]. Referring to the data above, generally organic biodegradable matter dominant the composition of waste in landfill and the rest are non-biodegradable matter. Variety composition of solid waste make waste water contains recalcitrant pollutant and difficult to be remediate.

Table 3 shows the summary of landfill leachate characteristic in South East Asia countries. The data were collected and selected from old landfill leachate site in each country. Concentrations of each parameter were different. It may be caused by different waste composition, rain intensity and waste amount. The pH value for these three countries have the tendency to be present as alkaline (methanogenic phase) while COD, BOD_5, NH_3-N and TDS recorded high concentrations. The Southern East Asian countries faced a similar problem which is hazardous leachate effluents from landfill site tend to have different waste composition due to rainfall intensity. High concentration of those parameter indicated that leachate need to be treated before it can be release to the water body.

Table 3. Summary of landfill leachate characteristic in Southern East Asia (Malaysia, Indonesia and Thailand)

Parameter	Unit	Malaysia	Indonesia	Thailand
pH		8.13	7.42 - 7.45	8.00
COD	mg/L	3852	291.1- 585	4300
BOD_5	mg/L	196	62 - 218.10	418
NH_3-N	mg/L	1241	62 - 125	1934
TDS	mg/L	6237	1.2-1.263	18, 900

3.12 Leachate phase and treatment for leachate at APLS

Generally, APLS is classified as old and anaerobic landfill leachate since it has been operated for more than 10 years and there is no additional treatment provided on site except detention pond. Consequently, comparison in table 4 also shows that, leachate at APLS fitted well with stabilized characteristic. Leachate at APLS is in methanogenic conditions as it has a high value of pH, ammonia and lower range of COD, TDS and BOD_5/COD. Methanogenic phase is the third phase in anaerobic degradation where accelerated by methanogenic bacteria and produce high methane gas concentration. In this stage, the concentration of volatile fatty acid is low, thus explains the increment of pH and lower COD, BOD_5/COD value. The presence of ammonia in leachate can give negative impact on environmental. Ammonia is generated from hydrolysis and fermentation of nitrogen occur in stabilized landfill leachate (methanogenic phase). This element is extremely toxic toward aquatic life. As the volatile fatty acids fraction decreases with landfill age, the biological treatments become ineffective in organic matter disposal from stabilised landfill leachates. Therefore, conventional physico-chemical treatment technology or chemical treatment may suitable to be applied on site. Currently, advanced oxidation process (AOPs) catch researcher attention in leachate treatment industry. AOP is a powerful method to decomposed organic and inorganic matter (including heavy matter) by using hydroxyl radical. This powerful hydroxyl radical with the potential of E = 2.80 V able to oxidize complex molecular structure into simpler element or mineralization (water, corbon dioxide and inorganic salt). Thus, application of AOPs as treatment method onto recalcitrant leachate is suitable and relevant.

Table 4. Comparison between leachate at APLS with leachate classification at different landfill age and type [18][16][22]

Constituent	Leachate characteristic at APLS	Landfill age and leachate type		
		Young (<5 years)	Intermediate (5-10 years)	Stabilized (>10 years)
pH	8.13	<6.5	6.5-7.5	>7.5
COD (mg/L)	3852	500-22,00	1500-71,000	150-10,000
BOD_5/COD	0.05	>0.3	0.1-0.3	<0.1
NH_3-N (mg/L)	1241	0-190	30-3000	6-430
TDS (mg/L)	6237	2500-14,000	4000-55,000	1100-6400

3. Conclusion

Nine parameters of landfill leachate at Alor Pongsu, Perak were investigated in this study and compared. The results are necessary to formulate a suitable technique for treatment. In this study, the strength of leachate is higher compared to nearby landfill leachate possibly due to the landfill's age and source of solid waste. Moreover, Alor Pongsu leachate demonstrates low biodegradability (BOD_5/COD) 0.05 and it is classified as stabilized landfill leachate. Due to its characteristics, the studied leachate requires treatment to minimize the pollutants to a desirable level prior to discharge into water courses. Suggested, apply a chemical process (AOPs) or a combination of treatment processes for APLS leachate.

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References

[1] Ms N N, Subramaniam K and Hazilia H. 2016 Characterization of leachate from Panchang bedena landfill, Btang Padang landfill and Matang Landfill: A comparative study. Malaysia *Journal of Science*, **34** 69
[2] Johari A, Alkali H, Hashim H, Ahmed S I and Mat R 2014 Municipal solid waste management and potential revenue from recycling in Malaysia. *Modern Applied Science*, **8**, 37
[3] Aziz H A Municipal Solid Waste Management Challenges In Malaysia, Key paper at *the Waste Management Asia, 2016*, 27-28 January, 2016, Kuala Lumpur, Fleming Gulf
[4] Renou S, Givaudan G, Poulain S, Dirassouyan F and Moulin P 2008 Landfill leachate treatment: Review and opportunity, *Journal of hazardous material*, **150**, 468
[5] Kamaruddin M A, Yusoff M S, Aziz H A and Hung Y T 2015 Sustainable treatment of landfill leachate. *Applied Water Science*, **5**), 113
[6] Raghab S M, El Meguid A M A and Hegazi H A 2013 Treatment of leachate from municipal solid waste landfill. *HBRC Journal*, **9**, 187
[7] Yusoff I, Alias Y, Yusof M, and Ashraf M A. 2013 Assessment of pollutants migration at Ampar Tenang landfill site, Selangor, Malaysia. *Sci Asia*, **39**, 392
[8] Naveen B P, Sivapullaiah P V and Sitharam T G 2014 Characteristic of a municipal solid waste landfill leachate. Proceedings of *Indian Geotechnical Conference IGC-2014*, December 18-20, 2014, Kakinada, India
[9] Standard Methods for the Examination of Water and Wastewater, APHA, WPCF, AWWA, 21st ed., American Public Health Association (APHA) 2005, Washington, DC.
[10] MDC S B Laws of Malaysia-Environmental Quality Act 1974 and Regulation. 4th ed. Kuala Lumpur, Malaysia, 1997.
[11] Zin M N S, Aziz A H, M Adlan and A Ariffin 2012 Characterization of leachate at Matang Landfill site, Perak, Malaysia', *Academic Journal of Science*, **1**, 317
[12] Aziz S Q, Aziz H A, Bashir M J K and Mojirin A 2015 Assessment of various tropical municipal landfill leachate characteristics and treatment opportunities, *Global NEST Journal*, **17** 439
[13] Zakaria S N F, Aziz A H, Amr A and Salem S 2015 Performance of Ozone/$ZrCl_4$ oxidation in stabilized landfill leachate treatment. *In Applied Mechanics and Materials*, **802** 501
[14] Salem S A, Aziz H A and Adlan M N 2013 Optimization of stabilized leachate treatment using ozone/persulfate in the advanced oxidation process, *Journal waste management*, **33** 1434
[15] Othman E, Yusoff M S, Aziz H A, Adlan M N, Bashir M J and Hung Y T 2010 The effectiveness of Silica Sand in semi-aerobic stabilized landfill leachate treatment. *Water Journal*, **2** 904
[16] Zainol N A, Aziz H A and Yusoff M S 2012 Characterization of leachate from Kuala Sepetang and Kulim landfills: a comparative study. *Energy and Environment Research*, **2** 45
[17] Zainol N A, Aziz H A and Yusoff M S 2011 The use of polyaluminum chloride for the treatment of landfill leachate via coagulation and flocculation processes, *Journal of chemical sciences*, **1** 34
[18] Aziz S Q, Aziz H A, Yusoff M S, Bashir M J and Umar M 2010 Leachate characterization in semi-aerobic and anaerobic sanitary landfills: A comparative study. *Journal of Environmental Management*, **91** 2608

[19] Zawawi M H, Syafalni and Abustan I 2011 Detection of groundwater aquifer using resistivity imaging profiling at Beriah Landfill Site, Perak, Malaysia. *Journal of advanced material research*, **250-253**, 1852
[20] Kulikowska D and Klimiuk E 2008 The effect of landfill age on municipal leachate composition. *Bioresource Technology*, **99**, 5981
[21] Poznyak T, Bautista G L, Chaírez I, Córdova R I, and Ríos L E 2008 Decomposition of toxic pollutants in landfill leachate by ozone after coagulation treatment. *Journal of Hazardous Materials*, **152**, 1108
[22] Heyer K U, Stegmann R and für Abfallwirtschaft I 2001 Leachate management: leachate generation, collection, treatment and costs. Ingenieurbüro für Abfallwirtschaft. On line at: http://www. ifashamburg. de/pdf/leachate. pdf.
[23] Aziz H A, Alias S, Adlan M N, Asaari A H and Zahari M S 2007 Colour removal from landfill leachate by coagulation and flocculation processes. *Bioresource Technology*, **98** 218
[24] Shouliang H, Beidou X, Haichan Y U, Liansheng H E, Shilei F A N and Hongliang L I U 2008 Characteristics of dissolved organic matter (DOM) in leachate with different landfill ages. *Journal of Environmental Sciences*, **20** 492
[25] Christensen, T. H., Kjeldsen, P., Bjerg, P. L., Jensen, D. L., Christensen, J. B., Baun, A., Albrechtsen, H. & Heron, G. (2001). Biogeochemistry of landfill leachate plumes. *Applied geochemistry*, **16** 659
[26] Kamaruddin M A, Yusoff M S, Aziz H A and Basri N K 2013 Removal of COD, ammoniacal nitrogen and colour from stabilized landfill leachate by anaerobic organism, *Applied Water Science*, **3** 359
[27] Bhalla B, Saini M S and Jha M K 2012 Characterization of leachate from Municipal Solid Waste (MSW) Landfilling Sites of Ludhiana, India: A Comparative Study. *International Journal of Engineering Research and Applications*, **2** 732
[28] Kurniawan T A, Lo W H and Chan G Y 2006 Physico-chemical treatments for removal of recalcitrant contaminants from landfill leachate, *Journal of hazardous materials*, **129** 80
[29] Yanuwiadi B 2016 Landfills Leachates Quality and Quantity in Tidal Area in Banjarmasin Landfills, Indonesia. *Resources and Environment*, **6** 23
[30] Laohalidanond K, Chaiyawong P and Kerdsuwan S 2015 Municipal Solid Waste Characteristics and Green and Clean Energy Recovery in Asian Megacities. *Energy Procedia*, **79** 391