Geological Society of Malaysia Bulletin 51
June 2005 p.41-46

Characteristics of Leachate at the Air Hitam Sanitary Landfill in Puchong, Selangor

Norlailatul Zuraidah Mohd Radzuan, W.Z.W. Yaacob, Abdul Rahim Samsudin & A. Ghani Rafek

Environmental Program, Department of Environmental Science and Earth Resources, School of Science & Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor Darul Ehsan

Abstract: The Air Hitam sanitary landfill in Puchong, Selangor currently receives 3000 ton/day of solid waste. The landfill has been in operation since November 1995, in what was formerly a valley area. The purpose of this study is to determine the characteristics for leachate from lined landfill in helping to develop more useful quality leachate database for other landfills where leachate treatment must be designed in advance. The composition of leachate varied depending mainly upon their sampling points. It was found that the leachates possessed a typical characteristic; that is young leachate (AH3) at Air Hitam sanitary landfill was generally characterized by higher values of leachate characteristics. The concentrations of Na^+ and K^+ were exceptionally high, 8160 ~ 20166.7 mg/l for Na^+ and 3416.333 to 7916.667 mg/l for K^+. Heavy metal concentrations were found to be relatively low for Mn (0.001 ~ 0.005 mg/l), Cd (0.002 ~ 0.006 mg/l), Cu (0.046 ~ 0.095 mg/l) and Cr (0.046 ~ 0.175 mg/l) while those of Fe (1.447 ~ 3.627 mg/l), Zn (0.110 ~ 0.242 mg/l), Pb (0.050 ~ 0.217 mg/l) and Ni (0.085 ~ 0.167 mg/l) were relatively higher. The values of sulfate also varied for leachate samples with values between 218.75 to 993.75mg/l. The concentrations of ammoniacal nitrogen in leachate samples were 107.5 up to 419.17 mg/l. Although heavy metals determined were comparatively low and heterogeneously distributed in and around the landfill, the site is a source of contaminants to the monsoon drains and directly to the river. Low COD value was found in ground water sample indicating that the groundwater was not polluted by leachate at the Air Hitam sanitary landfill.

Abstrak: Tapak pelupusan sisa pepejal (TPSP) bersih Air Hitam di Puchong, Selangor menerima sisa pepejal sebanyak 3000 tan per hari. TPSP yang dahulunya merupakan kawasan lembah telah beroperasi sejak November 1995. Objektif kajian ini adalah menentukan ciri-ciri cecair larut lesap di TPSP yang mempunyai sistem alas untuk membantu membina lebih banyak lagi data kualiti cecair larut lesap yang berguna supaya dapat membina sistem rawatan cecair larutlesap yang lebih berkesan. Hasilnya, komposisi sampel cecair larut lesap yang diperolehi adalah pelbagai bergantung kepada titik persampelan. Kepekatan Na^+ dan K^+ adalah sangat tinggi iaitu, 8160 ~ 20166.7 mg/l untuk Na^+ dan 3416.333 ~ 7916.667 mg/l untuk K^+. Kepekatan logam berat-logam berat yang dikaji adalah agak rendah iaitu Mn (0.001 ~ 0.005 mg/l), Cd (0.002 ~ 0.006 mg/l), Cu (0.046 ~ 0.095 mg/l) dan Cr (0.046 ~ 0.175 mg/l) manakala untuk Fe (1.447 ~ 3.627 mg/l), Zn (0.110 ~ 0.242 mg/l), Pb (0.050 ~ 0.217 mg/l) dan Ni (0.085 ~ 0.167 mg/l) nilai yang diperolehi agak tinggi. Kepekatan total sulfat dalam sampel cecair larutlesap ialah 218.75 sehingga 993.75mg/l. Kepekatan ammonia nitrogen dalam sampel cecair larut lesap pula ialah 107.5 sehingga 419.17 mg/l. Walaupun kepekatan logam-logam berat adalah rendah dan tidak homogenus kelimpahannya sama ada di dalam atau di sekitar TPSP, tetapi kawasan kajian merupakan sumber logam berat yang masuk ke dalam sistem saliran dan masuk secara terus ke dalam sungai berhampiran. Nilai COD yang rendah (3.0 mg/l) di dalam sampel air bawah tanah menunjukkan air bawah tanah tidak tercemar dengan cecair larut lesap dan sistem alas TPSP Air Hitam adalah berkesan.

INTRODUCTION

The Air Hitam sanitary landfill in Selangor which currently receives 3000 ton/day of solid waste is to be managed by Worldwide Landfill Sdn. Bhd for 20 years. The landfill has been in operation since November 1995, in what was formerly a valley area where the underlaying soil cover has a permeability (K) of 10^{-6} ms^{-1}. The landfill has a total capacity of 5.2 million tons with 52 hectares in total surface area and the site is equipped with proper leachate and gas collection systems. The landfill is lined with high density of polyethylene (HDPE) of 2 millimeters thick.

Sanitary land filling is currently most widely employed due to its economic advantages. Unfortunately, leachate from the sanitary landfill can be a major source of contamination to both surface and ground water. Leachate can be a source of pollution as it can leave the landfill site if it is unlined or if the lining fails (Kennedy and Everett, 2000 ; Baker and Curry, 2004).

Leachate is the contaminated liquid that builds up in the landfill site, produced during the decomposition or biodegradation process, when water seeps through the ground cover and flows out of the landfill (Agamuthu 1999; Baker and Curry, 2004; Rodriguez et al., 2004). A large number of hazardous compounds posing an environmental threat have previously been identified in landfill leachates (Oman, 1993; Chiras, 2001). A study on the composition of leachates from 58 landfills in Texas showed 113 different toxic chemicals in leachates from municipal landfills and 72 toxic chemicals in leachates from hazardous waste landfills (Brown and Donnelly, 1988).

The composition or quality of a leachate is dependent on the refuse composition, age, site conditions such as precipitation, infiltration and runoff, the degree of compaction, the particle size, depth of waste, available oxygen, temperature, co-disposal with sludge from municipal wastewater treatment plant and co-disposal with incinerator ash (Reinhart and Grosh, 1998; Li and Zhao 1999; Al-Yaqut and Hamoda, 2003; Rodriguez et al., 2004). At some locations in the landfill, the leachate strength is greater than others. The leachate in a pond represents an average composition of the leachate being generated at different locations in the landfill. A similar comment could be made about any landfill facility; leachate composition, concentration and volume vary between and within sites. It has been demonstrated that large variations in leachate quality exist for different landfills but also at different locations within the same landfill (Tatsi and Zouboulis, 2002).

A high quality leachate database is a valuable management tool for predicting the future pattern of leachate composition. This type of prediction is important, especially for landfills where leachate treatment must be designed in advance (Lo, 1996). Effective pollution control through the proper design of landfill and leachate management facilities requires an understanding of leachate quality (Reinhart and Grosh, 1998). The great variety of leachate constituents prevents evaluation of the fate and the role played by each component in the environment impact (Calace et al., 2000). Because of the varying reactor conditions and varying compositions in the produced leachate, there is a need to characterize the specific leachate to be dealt with. Landfills characterized prior to the late 1980's were generally unlined (Reinhart and Grosh, 1998). Leachate samples collected from unlined landfills can be erroneously low in concentration due to dilution from groundwater and other sampling errors. These same factors may lead to the variability associated with leachate quality data. With the recent advent of lined landfills, leachate quality data are now more meaningful and useful and perhaps less variable. Analysis of data from lined landfills was needed to provide useful information for the design and management of landfill leachates.

The main objective of this study was to characterize leachates in Air Hitam landfill in order to develop a more useful quality leachate database for other landfills where leachate treatment must be designed in advance. A second objective was to compare the data with the characteristics of both surface water and ground water samples at the landfill in order to determine the presence of a pollution.

MATERIALS AND METHODS

Ten samples each with replicates each were collected in polyethylene bottles. The *in situ* parameters such pH, dissolved oxygen (DO), conductivity, total dissolved solids (TDS) and temperature were measured immediately using a meter probe. The samples were then transported to the laboratory and acidified for heavy metals analysis and stored at 4°C according to the respective standard method (APHA, 1992). A brief description of the samples

Table 1. Samples collected from Air Hitam Sanitary Landfill site

Sample No.	Sample description
AH1	Water sample from upper monsoon drain before meeting the sanitary landfill
AH2	Water sample from upper monsoon drain that is directly contact with leachate from seepage
AH3	Young leachate from seepage at new phase of landfill area after six months' operation
AH4	Treated leachate from treatment pond
AH5	Raw leachate from collecting pond
AH6	Effluent from treatment pond that flows into the monsoon drain
AH7	Water sample from monsoon drain after the treatment pond at the boundary of landfill site
AH8	Water sample from outside the boundary of landfill site
AH9	Water sample from lower monsoon drain after meeting the sanitary landfill
AH10	Ground water from borehole next to collecting pond

Table 2. Physical and chemical characteristics of water samples at the Air Hitam sanitary landfill

	Temperature (°C)	pH	DO	BOD	COD	TSS	TDS	Conductivity, (μs/cm)	NH_3-N	SO_4^{2-}
AH1	31.4	6.65	6.17	3.1	5.05	51.000	164.6	232.8	0.05	28.00
AH2	31.5	6.84	1.10	83.6	157.0	72.500	293.1	444.5	12.44	13.50
AH3	32.4	6.46	0.41	1532.6	4443.2	1542.000	11000.0	22780.0	419.17	218.75
AH4	30.8	7.42	3.23	563.4	1212.3	18.092	693.7	1127.4	7.50	257.50
AH5	35.4	7.82	0.82	745.8	1929.3	172.000	4397.0	8650.0	141.50	993.75
AH6	31.4	6.51	0.77	136.0	500.0	293.000	2539.0	5030.0	79.38	55.00
AH7	31.9	7.16	2.65	18.8	38.72	17.023	655.0	1007.0	63.44	25.75
AH8	31.8	6.91	2.99	32.5	69.44	19.064	708.0	1164.5	16.69	26.75
AH9	32.0	6.86	2.84	27.8	60.61	18.024	691.0	1062.6	59.05	25.25
AH10	29 2	5 90	6 80	1 0	3 0	0 033	15 3	46 2	0 04	36 00

collected, along with the sample numbers are summarized in Table 1, (see Figure 1). Chemical oxygen demand (COD), ammonia-N (NH_3-N) and total sulphate (SO_4^{2-}) were determined using spectrophotometer DR 2000. Biochemical oxygen demand (BOD) was determined using BOD bottles incubated for 5 days at room temperature. The dissolved oxygen (DO) before and after incubation was measured using a DO

meter (Hach model) and the BOD was computed from the difference in DO value. Total suspended solid (TSS) was determined with filtering the leachate using glass fiber filter and weighing the filter paper before and after filtration. The heavy metals lead (Pb), nickel (Ni), copper (Cu), zinc (Zn), cadmium (Cd), chromium (Cr), iron (Fe), manganese (Mn), and cations potassium (K^+), sodium (Na^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined using the Inductivity Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). The leachate was filtered through 0.45 μm Milipore filter before ICP analysis.

RESULTS AND DISCUSSION

Leachate Characterictics

The results obtained are shown in Tables 2 and 3. The data reported are mean values of five replicates. From the results of the water quality analysis, it was found that the leachates possessed typical characteristics (Table 2); that is, pH increases with leachate age while organic concentrations (measured as COD and BOD) decreased as similarly mentioned by Tatsi and Zouboulis (2002) that fresh or young leachate is generally characterized by higher values of characteristics.

The parameters of COD varied from 4443.2 mg/l with a pH value 6.46 in AH3 down to 1929.3 mg/l in AH5 with a pH value 7.82. The COD in AH2 (157 mg/l) was very low because of dilution factor. However, it was still higher than the limit stipulated in the Environmental Quality Act (EQA) (1974) for industrial effluents where 50 mg/l for Standard A and 100 mg/l for Standard B (Agamuthu 2001). Compared with AH4 and AH5, higher concentration of NH_3-N was found in AH3. Ammonia nitrogen was present in high concentrations probably owing to the deamination of amino acids during destruction of original organic compounds (Tatsi and Zouboulis 2002). High concentrations of ammonia assisted in the dissolution of other components in the waste. High values of conductivity indicate the presence of dissolved inorganic materials in the samplesHence, the measure of conductivity could represent the TDS contents (Chen, 1995; Al-Yaqout and Hamoda, 2003). The highest conductivity was found to be 22780 μs/cm and 8650 μs/cm in AH3 and AH5 respectively. The highest TDS concentrations were found to be 11000 mg/l and 8650 mg/l in AH3 and AH5 respectively.

High conductivity values indicate the presence of dissolved inorganic materials in the samples. Conductivity is sensitive to variations in dissolved solids with which it has almost direct relationship, and mineral content, both of which are elevated in the leachate due to contact with the refuse. Therefore, the high values of leachate conductivity reflected a large content of soluble inorganic materials. From the Table 3, it was observed that AH5 which is old leachate, showed high values of heavy metals compared with the young leachate, AH3. The reason is that sample AH5 was taken from collecting pond, which contains almost all leachates from the landfill, while AH3 was located at a small quantity of leachate has just been produced. The variation in leachate composition can be attributed to many factors such as the composition and depth of waste and waste age (Reinhart and Grosh, 1998). The results showed that the Air Hitam sanitary landfill leachate contains high quantities of Na^+ and K^+. According to Agamuthu (1999), Malaysian landfill leachates generally contain high quantities of Na^+ and K^+. The concentrations of Na^+, K^+, Ca^{2+} and Mg^{2+} in the leachates were found to be of the following order: $Na^+ > K^+ > Mg^{2+} > Ca^{2+}$ (Figure 2). The highest iron concentrations were found to be 3.627 mg/l and 3.614 mg/l for AH3 and AH5, respectively. Fe was the highest in concentration compared with other heavy metals element in this study. Therefore, leachate colors at Air Hitam sanitary landfill varied from dark yellow to dark brown were attributed mainly to the oxidation of ferrous ions to ferric form and the formation of ferric hydroxide colloids and complexes with fulvic/humic substances (Chu et al., 1994). The concentrations of trace elements (Mn, Cd, Cu and Cr) were found to be low, while those of Fe, Zn, Pb, Ni, were relatively higher in leachate samples. From Figure 3, the concentrations of heavy metals in AH3 are Fe > Zn > Pb > Ni > Cu > Cr > Cd > Mn. While in AH5, Cr was found higher than Ni in concentration, where

Table 3. Cations and heavy metals concentrations of all samples in Air Hitam sanitary landfill in mg/l of unit.

	Na	K	Mg	Ca	Zn	Pb	Ni	Cu	Cd	Cr	Fe	Mn
AH1	14.790	0.408	3.350	1.752	0.021	0.058	0.001	0.007	0.000	0.000	0.096	0.003
AH2	180.800	0.869	3.580	1.816	0.015	0.009	0.002	0.006	0.000	0.000	0.084	0.013
AH3	9250.000	4133.333	380.280	4.290	0.203	0.145	0.100	0.089	0.003	0.052	3.627	0.005
AH4	8160.000	3416.333	134.600	5.460	0.110	0.050	0.085	0.046	0.002	0.046	1.447	0.001
AH5	20166.700	7916.667	330.689	3.690	0.242	0.217	0.167	0.095	0.006	0.175	3.614	0.004
AH6	2520.000	946.667	39.210	3.380	0.026	0.036	0.019	0.019	0.003	0.010	0.687	0.029
AH7	526.000	248.000	6.861	2.130	0.026	0.005	0.005	0.006	0.000	0.001	0.189	0.055
AH8	514.000	200.000	7.800	0.904	0.010	0.006	0.008	0.007	0.000	0.002	0.224	0.025
AH9	593.600	211.200	6.503	1.898	0.009	0.009	0.004	0.006	0.000	0.001	0.586	0.052

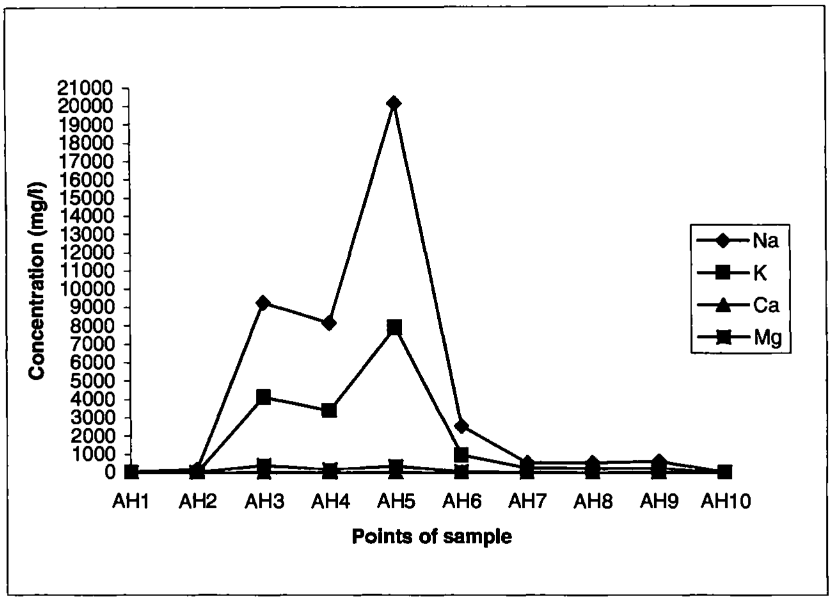

Figure 2. Concentrations (mg/l) of major cations Na, K, Mg and Ca in sample points at Air Hitam sanitary landfill.

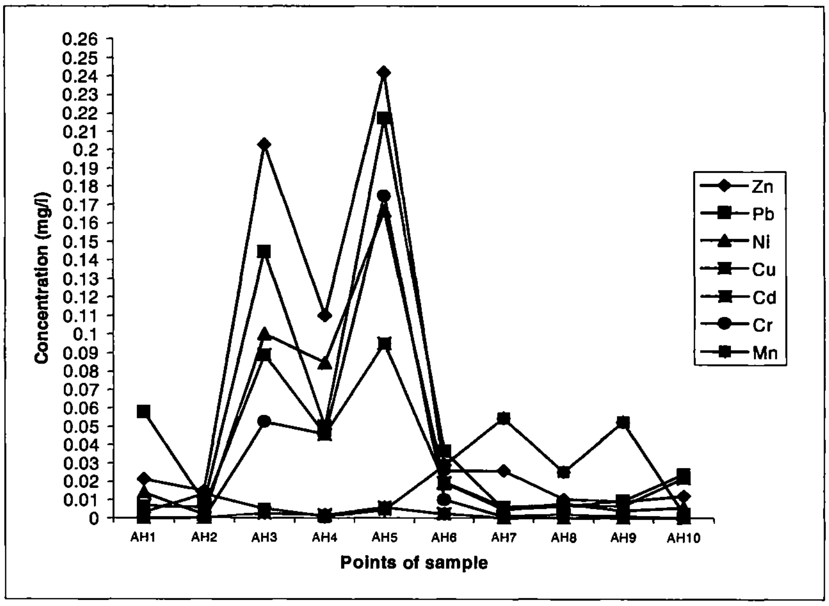

Figure 3. Concentrations (mg/l) of heavy metals Zn, Pb, Ni, Cu, Cd, Cr and Mn in sample points at Air Hitam sanitary landfill.

Table 4. National Water Quality Standard for Malaysia (NWQS) by DOE

Parameters	Unit	Classes I	IIA/IIB	III#	IV	V
Cd	mg/l	Natural levels	0.01	0.01*(0.001)	0.01	Levels above IV
Cr (IV)	mg/l		0.05	1.4 (0.05)	0.1	
Cr (III)	mg/l		-	2.5	-	
Cu	mg/l		0.02	-	0.2	
Ca	mg/l		-	-	-	
Mg	mg/l		-	-	-	
Na	mg/l		-	-	3 SAR	
K	mg/l		-	-	-	
Fe	mg/l		1	1	1 (Leaf) 5 (Others)	
Pb	mg/l		0.05	0.02* (0.01)	5	
Mn	mg/l		0.1	0.1	0.2	
Ni	mg/l		0.05	0.9*	0.2	
Zn	mg/l		5	0.4*	2	
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.9	2.7	>2.7
BOD	mg/l	1	3	6	12	>12
COD	mg/l	10	25	50	100	>100
DO	mg/l	7	5-7	3-5	<3	<1
pH		6.5-8.5	6-9	5-9	5-9	-
TDS	mg/l	500	1000/-	-	4000	-
TSS	mg/l	25	50	150	300	300
Temperature	°C	-	Normal + 2°C/-	Normal + 2°C	-	-

Fe > Zn > Pb > Cr > Ni > Cu > Cd > Mn. In AH4, Ni was found higher than Pb, where Fe > Zn > Ni > Pb > Cu > Cr > Cd > Mn.

Characteristic of effluent (AH6)

The data indicates that the concentrations of TSS (293 mg/l) correspondents to the requirements of Class IV (300 mg/l) of National Water Quality Standard for Malaysia (NWQS) (Table 4), but it fails to meet the needs of Class I (25 mg/l) (DOE, 2002). The COD effluent varied from 262 to 397 mg/l can reach 500 mg/l of current discharge standard. However, more efforts are needed to meet the requirements of 200 mg/l. The ammonium nitrogen concentration in the effluent has already exceeded the limits of discharge standard. The concentrations of heavy metals in AH6 are all below the discharge standards.

Characteristics of water samples

From the Table 2, water from the monsoon drain was polluted when it reached point AH2 where it was in contact with the leachate. Water samples of AH7, AH8 and AH9, which were taken lower down beyond the treatment pond, did not meet even the needs of Class IIA and IIB of NWQS for wastewater release into environment. However, the groundwater sample (AH10) at Air Hitam sanitary landfill was not polluted by the leachates

CONCLUSION

From the results of the water quality analysis, it was found that the leachates possessed typical characteristics; that is young leachate (AH3) at the Air Hitam sanitary landfill was generally characterized by higher values of leachate characteristics. However, concentrations of heavy metals in the old leachate (AH5) were higher than AH3. The concentrations of heavy metals Fe, Zn, Pb and Ni were relatively higher, while those of Mn, Cd, Cr, Cu were found to be relatively low in all leachate samples. As such, it would not cause much concern for leachate management or disposal into monsoon drain because no significant values were observed for the removal efficiencies of heavy metals with biological and chemical treatment. However, while heavy metals determined were comparatively low and heterogeneously distributed in and around the landfill, the site is still a source of heavy metals to the monsoon drains and directly to the river. Except for the heavy metals, the effluent characteristics did not meet the Department of Environment standard guidelines for wastewater release. Low COD value was found in AH10 indicating that the groundwater was not polluted by the leachates. Thus, lining system that has been practiced in the landfill was effective to reduce the concentration of certain pollutants.

REFERENCES

Agamuthu, P. 1999. Characteristics of Municipal Solid Waste and Leachate from Selected Landfills in Malaysia. *Malaysian Journal of Science*. 18: 99-103.

Agamuthu, P. 2001. *Solid waste: principles and management: with Malaysian case studies*. Kuala Lumpur: Universiti of Malaya Press.

Al-Yaqut, A. F. & hamoda, M. F. 2003. Evaluation of Landfill Leachate in Arid Climate – a Case Study. *Environment International*. 29: 593-600.

APHA. 1992. *Standard Methods for the Examination of Water and Wastewater.* 18th ed. American Public Health Association, American Water Work Association and Water Environment Federation, Washington.

Baker, A. & Curry, M. 2004. Fluorescence of Leachates from Three Contrasting Landfills. *Water Research*. 38: 2605-2613.

Brown, K. & Donnelly, K. C. 1988. An Estimation of the Risk Associted with the Organic Contituents of Hazardous and Municipal Waste Landfill Leachate. *Hazardous Waste and Hazardous Materials.* 5: 1-30.

Calace, N., Liberatori, A., Petronio, B. M. & Pietroletti, M. 2001. Characteristic of Different Molecular Weight Fractions of Organic Matter in Landfill Leachate and Their Role in Soil Sorption of Heavy Metals. *Environmental Pollution.* 113: 331-339.

Chen, P. H. 1995. Assessment of Leachates from Sanitary Landfills: Impact of Age, Rainfall and Treatment. *Environmental International.* 22: 225-237.

Chiras, D. D. 2001. *Environmental Science: Creating a Sustainable Future.* United State: Jones and Bartlett Publishers Inc.

Chu, L.M., Cheung, K.C., Wong, M.H. 1994. Variations in the chemical properties of landfill leachate. *Environmental Management.* 18: 105-117.

Kennedy, L. G. & Everett, J. W. 2000. Microbial Degredation of Simulated Landfill Leachate: Solid Iron/Sulfur Interactions. *Advances In Environmental Research.* 5: 103-116.

Li, X. Z. & Zhao, Q. L. 1999. Inhibition of Microbial Activity of Activated Sludge by Ammonia in Leachate. *Environmental International.* 25:961-968.

Lo, I. M. C. 1996. Characteristics and Treatment of Leachates From domestic Landfills. *Environment International.* 22: 433-442.

DOE. 2002. Environmental Quality Report 2001. *Department of Environment*, Malaysia.

Oman, C. 1993. Identification of Organic Compounds in Municipal Landfill Leachates. *Environmental Pollution.* 20: 265-271.

Reinhart, D. R. & Grosh, C. J. 1998. Analysis of Florida MSW Landfill Leachate Quality. Final Report. University of Central Florida.

Rodriguez, J., Castrillon, L., Maranon, E., Sastre, H. & Fernandez, E. Removal of Non-biodegredable Organic Matter from Landfill Leachates by Adsorption. *Water Research.* 38: 3297-3303.

Tatsi, A. A & Zouboulis, A. I. 2002. A Field Investigation of the Quantity and Quality of Leachate from a Municipal Solid Waste Landfill in a Mediterranean Climate (Thessaloniki, Greece). *Advances In Environmental Research.* 6: 207-219

Manuscript received 31 March 2005