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Pollution Impact of MSW Landfill Leachate

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ABSTRACT Improper disposal of Municipal Solid Waste (here after referred to MSW) into landfills not only creates a conducive environment for pests like flies, rats and others but also pollutes the ecosystem with the release of leachate. This study was conducted to analyze leachate characteristics and compare pollution intensity among three landfills of different level of urbanization namely urban landfill, sub-urban landfill and rural landfill. Leachate from Kundang landfill representing the urban type showed the highest COD value (6230 mg/l) among the three landfills. Both the rural type (Panchang Bedena landfill) and sub-urban type (Sungai Sedu landfill) have COD at 5060 mg/l and 170 mg/l, respectively. The pH ranged between 6.7 - 8 in all three landfills, whereas the TSS was 1.6 mg/l, 0.09 mg/L and 0.06 mg/l, at the rural, sub-urban and rural types, accordingly. In the urban landfill, the concentration of Cr, Cu, Pb, Zn, and Mg were 0.193 ppm, 0.003 ppm, 0.027 ppm, 0.06 ppm, and 4.25 ppm, respectively while Cr was not detected. The quantum of pollution from the released leachate to adjacent rivers was low with BOD value of 1 240 g/day, 670 g/day and 3 240 g/day from the urban, sub-urban and rural landfill, respectively. The concentration of metals, particularly Mg, was high which requires a proper wastewater treatment plant to be installed in order to prevent euthrophication in water bodies. Physical and chemical treatment would be the best option to reduce the pollution impact to the environment due to the low BOD to COD ratio (0.004 to 0.13) and the high metal content in the leachate.

ABSTRAK Pelupusan sisa munisipal yang tidak sempurna di tapak-tapak pelupusan bukan hanya menghasilkan persekitaran yang menggalakkan pembiakan haiwan perosak seperti lalat, tikus dan lain-lain tetapi juga mencemar ekosistem dengan pelepasan air larut resap atau *leachate*. Kajian ini dijalankan untuk menganalisa ciri-ciri *leachate* dan membandingkan tahap pencemaran di antara tiga tapak pelupusan yang berbeza dari segi klasifikasi pembangunan iaitu tapak pelupusan perbandaran, pinggir bandar dan luar bandar. *Leachate* dari tapak pelupusan Kundang mewakili jenis perbandaran menunjukkan nilai *COD* yang tertinggi (6230 mg/l) di antara ketiga-tiga tapak pelupusan. Tapak pelupusan luar bandar (tapak pelupusan Panchang Bedena) dan pinggir bandar (tapak pelupusan Sungai Sedu) masing-masing mempunyai *COD* sebanyak 5060 mg/l dan 170 mg/l. Nilai pH berada dalam julat 6.7 hingga 8.0 bagi ketiga-tiga tapak pelupusan, manakala jumlah pepejal terampai masing-masing adalah 0.06 mg/l, 0.09 mg/l dan 1.6 mg/l di tapak pelupusan perbandaran, pinggir bandar dan luar bandar. Di tapak pelupusan perbandaran, Kepekatan Cu, Pb, Zn dan Mg masing-masing adalah 0.193 ppm, 0.003 ppm, 0.027 ppm, 0.06 ppm dan 4.25 ppm, manakala Cr tidak dapat dikesan. Kuantum pencemaran akibat pembebasan *leachate* ke dalam sungai-sungai yang berdekatan adalah rendah dengan nilai *BOD* sebanyak 1240 g/hari, 670 g/hari dan 3240 g/hari masing-masing dari tapak pelupusan perbandaran, pinggir bandar dan luar bandar. Kepekatan logam terutamannya Mg adalah tinggi di mana ini memerlukan loji rawatan air kumbahan yang sempurna diadakan untuk menghalang eutrofikasi badan-badan air. Rawatan fizikal dan kimia mungkin adalah pilihan terbaik untuk mengurangkan impak pencemaran kepada alam sekitar akibat daripada nisbah *BOD/COD* yang rendah dan kandungan logam yang tinggi dalam *leachate.*

(Municipal solid waste, landfill, leachate, pollution impacts, rivers)

INTRODUCTION

Malaysia as a fast developing country has an average waste generation of 0.7 to 1.2 kg per capita where most of the solid wastes were disposed at 144 landfills throughout the country and the growing volume of municipal waste is due to its non-segregation and lack of recycling efforts [1]. Although land filling of municipal solid waste is not a well-liked alternative to most people, it is nonetheless the most preferred method particularly in developing countries like Malaysia [2] and it is an indispensable way of disposing waste cost-effectively [3]. In Malaysia, approximately 94% of the landfills operate as open dumping ground [4, 5 and 6]. Currently, landfills are the largest repository of both municipal and industrial wastes [1].

The impact of MSW landfill on the community is always negative, causing concern and fear not only about gas explosion and odour from such landfill [7] but the pollution of water resources due landfill leachate contamination [2, 4]. Purity of ground water is endangered by the uncontrolled or unmonitored leachate. As a finite resource that is essential for sustaining the existence of living being, good quality water is very crucial for the development.

The subsequent migration of leachate away from landfill boundaries and the release to the adjacent environment is a serious environmental concern and a threat to public health and safety. Leachate often contains high concentrations of various pollutants namely organic matter and inorganic ions including heavy metals [8]. Depending upon the nature of these formations and in the absence of a leachate treatment system, leachate has been associated with contamination of aquifers underlying landfills which prompted extensive investigations over the past four decades [9]. Leachate characteristics depend on the composition of the waste, the stage of stabilization, volume of the downpour and others [8]. Studies conducted indicate Malaysian landfill leachate has high COD of 1250 to 6660 mg/l and BOD readings of 120 to 1990 mg/l and exceptionally high concentrations of K, Na and Cl, that pretreatment is required prior to biological treatment [2, 8]. The concentration of heavy metals in leachate is higher during the acidogenic phase of waste due to the generation of acids in aerobic conditions [10, 11]. Leachate of municipal waste landfill were also found to contain dissolved organic matter which has high tendency to absorb phthalic acid esters, a 'priority pollutants' listed by U.S. EPA [12, 13].

This study aims to determine the waste characterization and leachate quality from landfills of different urbanization level namely the urban type, sub-urban and rural type. Subsequently, the quantitative impacts of the leachate disposal are determined.

MATERIALS AND METHOD

Three landfills in Selangor, one of the fast developing states in Malaysia, were selected for the study. The landfills were classified as urban landfill, sub-urban and rural landfill according to the socio-economic status of the area served. The urban landfill was represented by Kundang landfill, while Kampung Hang Tuah landfill and Panchang Bedena landfill were selected as the sub-urban and rural type, accordingly.

Waste Composition Studies

Waste composition studies were conducted for seven consecutive days at the selected landfills where randomly selected garbage trucks were identified for the studies. A quarter loads of the garbage trucks were separated and sorted to their respective waste groups. Waste separation was conducted manually into putrescible waste, plastics, paper, rubber, textile, metal, glass, wood and other wastes. The wastes were weighed and the percentages were determined based on the fresh weight.

Leachate Analysis

Leachate samples were collected in polyethelene bottles from leachate pond nearest to landfill sites. In landfills that lacked leachate collection pond, leachate samples were obtained from naturally-made 'pond' in the landfill. Samples collected were acid preserved and kept in containers at 4°C prior to analysis. Chemical and physical analysis, which include BOD_5, COD, pH, and heavy metal analysis (Cu, Fe, Zn and others) were performed to determine the leachate characteristics.

Biological Oxygen Demand (BOD_5)

BOD was determined using BOD bottles incubated for 5 days at 20°C. The dissolved oxygen (DO) before and after incubation was measured using DO meter YSI Model 57 and the BOD was computed from the difference in DO value.

Chemical Oxygen Demand (COD)

COD was obtained using dichromate reflux method using potassium dichromate, silver nitrate and sulphuric acid in a TECATOR COD digestion unit. The excess dichromate was titrated with 0.1M ferrous ammonium sulphate.

COD was calculated based on the difference in dichromate levels.

pH, TSS, TDS, Conductivity, Salinity and other Analysis

Appropriate probe was used to analyze diluted leachate samples to determine the value of each parameter. As for pH value, the analysis was conducted directly using pH probe (Hanna model No 8033).

Heavy Metal Analysis

The concentration of heavy metal was determined using the Inductivity Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) Model Baired 2000. The leachate samples were acid digested prior to the ICP-AES analysis.

RESULTS AND DISCUSSION

Waste composition

The urban landfill i.e. Kundang landfill in Rawang received approximately 300 tonnes of waste daily where major economic activities are industrial, commercial and a small portion of agricultural. The sub-urban landfill i.e. Sungai Sedu landfill in Banting received waste as much as 200 tonnes daily. The economic activities in this area are fairly mixed with agricultural sector and industrial activities that the wastes received by the landfill were of a very mixed composition (Table 1). The rural landfill i.e. Panchang Bedena landfill in Sabak Bernam, received waste at approximately 62 tonnes everyday. As the main economic activities in this area relates to agriculture, the major waste disposed into the landfill covered a very high portion of organic waste as indicated in Table 1.

The highest component is putrescible waste ranging from 42% to 59% as was observed in previous studies [1, 2 and 4]. The second highest percentage consisted of plastic waste at approximately 16% of the total waste weight at the rural landfill, 19% at the sub- urban landfill and 25% at urban landfill. This indicated that urban areas dispose higher quantity of plastics and it reduced slightly in the sub-urban and the rural landfills [14]. The three landfill types received approximately similar quantities of paper waste i.e. approximately 11%. The high content of putrescible waste would influence the characteristics of leachate generated by the landfills [8, 11] as these are the component that would be attacked by the microorganisms during the degradation process.

Analysis of Leachate Samples

Kundang Landfill (Urban Landfill)

Kundang landfill is situated in Rawang district and received waste from Rawang, Selayang, Kundang and Kuang areas since late 1996. Leachate samples were collected from 'leachate collection ponds' formed from depression of the geographical landscape. The characteristic of the leachate is indicated in Table 2.

The leachate collected from the urban landfill mainly originated from the older waste cell according to the distance to the leachate ponds. Leachate from older waste cells commonly display low BOD and neutral pH as the leachate was generated during the methanogenic phase [11, 15]. The leachate generated from more recently filled cell accumulates under the cell, while the leachate from older cells was released into the drainage system. The suspended solid was low as this leachate originated from methanogenic phase that most complex particles had undergone microbial degradation to form simple ionic and others particles.

Table 1. Municipal waste composition (% of fresh weight)

Component	(Panchang Bedena) Rural Landfill	(Sungai Sedu) Sub-urban Landfill	(Kundang) Urban Landfill
Age of landfill	9 years	13 years	12 years
Putrecible waste	58.67 ± 20.89	51.60 ± 11.89	42.02 ± 9.67
Paper	10.55 ± 2.52	10.90 ± 10.63	12.90 ± 5.32
Plastic	15.86 ± 1.89	18.60 ± 2.06	24.74 ± 4.11
Rubber	1.24 ± 1.07	3.00 ± 0.88	2.45 ± 1.27
Textile	3.59 ± 1.04	2.50 ± 1.39	2.48 ± 1.76
Metal	3.21 ± 0.33	3.90 ± 1.38	5.30 ± 3.18
Glass	2.18 ± 0.76	2.90 ± 1.0	1.84 ± 1.06
Wood	0.54 ± 0.36	2.00 ± 0.60	5.74 ± 0.64
Others, such as disposable diapers	4.16 ± 3.53	4.60 ± 0.70	2.53 ± 1.92

Table 2. Characteristics of Landfill Leachate

Parameter	Kundang landfill (Urban)	Sungai Sedu landfill (Semi-urban)	Panchang Bedena landfill (Rural)	EQA 1974	
				Std A	Std B
BOD_5 (mg/l)	27.5 ± 0.66	22.27 ± 0.46	348.7± 134.2	20	50
COD (mg/l)	6232 ± 1824.3	169.3 ± 76.95	5056.7 ± 867.4	50	100
pH	7.43 ± 0.04	6.72 ± 0.02	8.1 ± 0.1	6-9	5.5-9
TSS (mg/l)	0.06 ± 0.01	0.09 ± 0.001	1.6 ± 0.4	50	100
Hardness ($CaCO_3$) (ppm)	429.3 ± 240.0	135 573.3 ± 3144.9	30533.3 ± 957.3	-	-
Cd (ppm)	Not detected	0.002 ± 0.001	Not detected	0.01	0.02
Cr (ppm)	0.193 ± 0.02	0.006 ± 0.005	Not detected	-	0.05
Cu (ppm)	0.003 ± 0.002	0.005 ± 0.004	1.0 ± 0.3	0.2	1.0
Pb (ppm)	0.027 ± 0.012	0.147 ± 0.172	41.7 ± 39.2	0.1	0.5
Zn (ppm)	0.060 ± 0.044	0.153 ± 0.102	675.7 ± 548.7	0.2	1.0
Mg (ppm)	4.245 ± 0.420	7.480 ± 3.780	36533.3 ± 6671	-	-

Sungai Sedu Landfill (Sub-urban Landfill)

Sungai Sedu landfill is situated 2 km away from Banting town received waste since 1992. The landfill receives waste from Banting and Teluk Panglima Garang at approximately 200 tonnes daily. The landfill lacked proper leachate collection system, as well as, gas collection system. The COD of leachate from Sungai Sedu Landfill was 169.3 mg/l while the BOD_5 was 22.27 mg/l. The pH was found to be slightly acidic at pH 6.72 and this is probably due to the availability of readily biodegradable organics allowing indigenous microbes to conduct biodegradation actively and produce a considerable concentration of H^+ ion [15, 16]. TSS (0.09 mg/l) was considerably low probably due to the dilution factor influenced by the surface-runoff. However, the value of hardness was found to be very high at approximately 135 g/l most probably due to the present of high concentration of Ca leaching from the combination of putrescible, rubber, and wood wastes.

Panchang Bedena Landfill (Rural Landfill)

Panchang Bedena Landfill is located 5 km away from Sungai Besar town, and had been operating since 1993. The landfill is a class 3 landfill with the establishment of wastewater treatment plant, gas vent, leachate collection pond and other basic facilities including weigh-bridge. The leachate samples collected were from the leachate collection pond without any interference of surface run-off. The COD value of the leachate was approximately 5000 mg/L while the BOD was approximately 350 mg/L. The value of TSS was 1.6 mg/L and the pH was slightly basic at pH 8.1 indicating that the landfill had undergone the acid phase [15, 16] and most probably in the methane fermentation phase. The concentration of Zn was exceptionally high probably due to the high release of this ion into the leachate. This however was contradicting with previous studies implying higher pH allow lesser concentration of dissolved metallic ions [16].

The level of pollution parameters such as BOD, COD and metal concentration, differ from one landfill to the other with differences ranging from lower than -400% to higher than 500%. The value of BOD was much lower compared to the COD indicating that the leachate was from older waste cell, that BOD to COD ratio is approximately 4.4×10^{-3} for leachate from urban landfill. This low ratio indicates the decrement in the availability of biodegradable components in the leachate [17]. As for Sungai Sedu landfill, the BOD to COD ratio of the sub-urban landfill is 0.13 indicating that the landfill is a mature landfill with high concentration of humic and fulvic acids [15, 17]. Another possible explanation for the low BOD and COD value of leachate from both landfills is the dilution factor. This is so since the landfills lack proper lining and leachate treatment system that surface run-off can easily dilute the leachate. The BOD to COD ratio of the rural landfill namely at Panchang Bedena landfill was 0.069 which indicates that the leachate contained low concentration of biodegradable compound [17]. The leachate generated from both (urban and sub-urban) landfills was allowed to flow into the river adjacent to the landfill. As these landfills lacked leachate treatment system, the total concentration of pollutants that enters the river system is shown in Table 3.

Table 3. Impact on river pollution caused by leachate contamination

Parameter g/day	River adjacent to Kundang landfill	River adjacent to Sungai Sedu landfill	River adjacent to Panchang Bedena landfill	Actual pollution impact on the adjacent river (Panchang Bedena Landfill)
BOD_5	1 237.5	668.1	3 242.9	1 980.9 g/day
COD	280 440.0	5 079.0	47 027.3	13 187.4 g/day
TSS	2.7	2.7	15	1.40 g/day
Hardness ($CaCO_3$)	19 320	4 067 200	283 960	NA
Cd	Not detected	0.060	Not detected	NA
Cr	8.7	0.180	Not detected	NA
Cu	0.135	0.150	9.3	6.2 g/day
Pb	1.215	4.41	387.8	356.8 g/day
Zn	2.7	4.59	6 284.0	4 842.0 g/day
Mg	191.0	224.4	339 759.7	0.34 kg/day

The BOD values in both urban and sub-urban landfill leachates were generally low and Sungai Sedu landfill leachate was found to have approximately half the concentration of that of the Kundang landfill leachate. Therefore, the amount of dissolved oxygen available for the aquatic organisms in the river adjacent to Sungai Sedu landfill would be slightly higher than that of the Kundang landfill. This would affect the number of aquatic organisms that can sustain in the river environment [17]. The river ecosystem, polluted with leachate from Kundang landfill would suffer higher destruction rate as compared to that of the contamination from Sungai Sedu leachate with reference to oxygen demand factor. Besides Cr, heavy metal contamination was found to be higher in the river polluted with Sungai Sedu leachate than that of the Kundang landfill leachate. The river near Sungai Sedu landfill received higher concentration of Mg, Zn and Pb daily at approximately 224 g, 4.6 g and 4.4 g, respectively, while river adjacent to Kundang landfill received slightly lower concentration of Pb (1.2 g), Zn (2.7 g) and Mg (191 g). The pH of urban and sub-urban landfill leachates were near neutral indicating that the landfills are undergoing the methane fermentation phase [6, 15]. With the reduction in the generation of inorganic constituent, the concentration of heavy metal in the leachate will also decrease accordingly.

The impact of pollution which might be caused by leachate from Panchang Bedena landfill (Table 3) would prove to be detrimental to the aquatic ecosystem without proper treatment. Fortunately, the landfill operation involves the treatment process of leachate through activated carbon and aeration ponds before leachate is discharged into the public drainage. Table 3 indicates the actual pollution impact on the river adjacent to Panchang Bedena landfill. The BOD value was approximately 1 980 g/day where that much of oxygen will be in-available and loss from the aquatic organisms of the river adjacent to Panchang Bedena landfill and as much as 13 187 g of oxygen would be required to degrade the chemical compound released into the aquatic system. The river will have an increment of 1.4 g of TSS daily and tremendously high concentration of Mg ion (0.34 kg/day). The high supply of these nutrients would encourage eutrophication of the water body. However, due to the continuous flow of the river, the process was delayed and the ecosystem was able to recover.

The level of pollutants present in the river nearby Panchang Bedena landfill, Sungai Sedu landfill and Kundang landfill was low that these rivers are classified into Class IV of the proposed Interim National Water Quality Standards for Malaysia. The pollution intensity will increase uncontrollably once the river systems had exceeded the carrying capacity and eventually lead to the formation of eutrophication water body. The rivers will continuously get polluted as long as the adjacent landfill receives high waste volumes. With higher waste tonnage, larger volume of leachate would be generated which would lead to a more serious pollution impact to the rivers. Therefore, it is very essential that leachate treatment system should be implemented to reduce the pollutant intensity from contaminating the adjacent river system. Even though leachate treatment at the Panchang

Bedena landfill only reduced 8-91% of the pollution intensity, the process would prolong the sustainability of the rivers and its aquatic lives. Since both the urban and sub-urban landfills generate leachate of low BOD_5 and COD loads, biological treatment would be unsuitable [4] that appropriate physical and chemical treatment should be applied [4, 18]. Also, since the concentrations of heavy metal ions are low in the leachate, biodegradation could be carried out with less disruption due to heavy metal contamination.

CONCLUSIONS

Results indicated that the pollutant intensity caused by landfill leachate was still within the EQA standard. However without proper control and management, the pollution intensity would disrupt the aquatic ecosystem and destroy it totally. Therefore, proper leachate treatment system should be set up to avoid further risk of contamination to the water through pollution prevention technologies.

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REFERENCES

1. Agamuthu P., Fauziah S.H. and Lingesveeramani M. (2004). Evolution of MSW and its management in Malaysia- An overview. Paper presented in the World Congress ISWA 2004, 17- 21 October 2005, Rome, Italy.
2. Fauziah S. H. and Agamuthu P. (2003). Municipal solid waste management: A comparative study in selected landfills in Selangor. *In proceedings of Environment 2003: Environmental Management and Sustainable Development for Better Future Growth*. 434-437.
3. Roy, N.U. (1997). Recycling Realities and the Glass Container: New Technologies and Trends, In *Municipal Solid Wastes: Problems and Solution*, Landreth, R.E. and Rebers, P.A. (ed). Lewis Publisher, United State of America, pp. 2-5.
4. Agamuthu P. (2001). *Solid Waste: Principles and Management*. Kuala Lumpur: University of Malaya Press.
5. Fadil, O. and Mohd. Badruddin, M.Y. (2002). Factors Affecting Municipal Solid Waste Generation on Johor Bahru, Malaysia. Paper presented In *Solid Waste Seminar*, Kyoto University, 24-25 Oct 2002.
6. Tan, B.H., Jamaluddin M.J., Mohd Nasir, H., Abdul Aziz, B. (2002). Impact of Leachate from Open Dumping and Municipal Landfills on The Environment. A Perspective on Policies in Linggi Drainage Basin In *The Proceedings of International Conference on Environmental Management: Ten Years After Rio*, Universiti Kebangsaan Malaysia, Bangi, Selangor pp. 82-89.
7. Hassan, M.N. and Theng, L.C. (1999) Fundamental of sanitary landfill technology, In: *The Proceedings of the Workshop on Disposal of Solid Waste through Sanitary Landfill- Mechanisms, Processes Potential Impacts and Post-closure Management*, Universiti Putra Malaysia, 25-26 August 1999, pp 271-282.
8. Agamuthu, P. (1999). Characteristics of Municipal Solid Waste and Leachate from Selected Landfills in Malaysia, *Malaysian Journal of Science*, **18**: 99-103.
9. El-Fadel, M., Findikakis, A.N. and Leckie, J.O. (1997). Modelling Leachate Generation and Transport in Solid Waste Landfills: *Environmental Technology,* **18**:669- 686.
10. Mohf. Suffian, Y., Hamidi, A.A., Mohd. Nordin, A. and Nurul Hidayah, A. (2002). Removal of Iron from Landfill Leachate by Limestone: Determination of Removal Isoterm, In *Proceedings of National Science Fellowship Seminar 2002*, MOSTE, Putrajaya, Malaysia.
11. Reinhart, D.R., Grosh, C.J. (1998). Analysis of MSW Landfill Leachate Quality, In *Florida Center for Solid and Hazardous Waste Management*, Report # 97-3.
12. Keith, L.H. and Telliard, W.A. (1979). Priority Pollutants. *Environmental Science Technology*, **13**, 416-419.
13. Bauer, M.J., Herrmann, R., Martin, A. and Zellman, H. (1998). Chemodynamics, Transport Behaviour and Treatment of Phthalic Acid Esters in Municipal Landfill Leachates, *Water Science Technology*, **38**: 185-192.
14. Fauziah S.H., Simon C. and Agamuthu P. (2004). Municipal Solid Waste Management

in Malaysia- Possibility of improvement, *Malaysian Journal of Science*, **23**(2): 61-70.

15. Tchobanoglous G., Theisen H, Vigil S A. (1993). *Integrated Solid Waste Management: Engineering Principles and Management Issues*. Singapore. McGraw-Hill Inc.
16. Forstner U., Kersten M. and Wienberg R. (1988). Geochemical Processes in Landfill in *The Landfill as a Reactor* (Baccini P., ed) New York. Springer-Verlag.
17. Varshney, C.K. (1983). The aquatic environment In *Water Pollution and Management*, Edited by Varshney, C.K., Wiley Eastern Limited, India. pp. 6-12.
18. Amokrane, A., Comel, C. and Veron, J. (1997). Landfill Leachate Pretreatment by Coagulation-Flocculation, *Water Resource*, **31**: 2775-2782.