Landfill Use: A Potential Source of Toxicant to Aquatic Life

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EXECUTIVE SUMMARY

Regardless of the beneficial aspect of landfill use, its environmental impact becomes subject of concern to sustainability and development. Landfilling among other things lead to generation of leachate. Therefore this study was undertaken with a view to analyzing the detailed physical-chemical components of leachate from closed sanitary landfill and its associated impact on fish (*Clarias batrachus*). Whole effluent toxicity (WET) approach was used to evaluate the toxicological effect of leachate on fish. Five different concentrations of the leachate (3.13 – 5.63 % v/v) as observed during the range finding test were applied definitively to obtain the effluent's lethal concentration (LC50) on the named fish. BOD_5, COD, heavy metals and other components which included aromatic hydrocarbons were analyzed via standard methods (APHA, EPA, and AOAC). About 880 mg/L of ammonical nitrogen was a reflection of the leachate's stench ammoniac odour. The BOD_5 and COD analysis were recorded at 3,500 mg/L and 10, 234 mg/L respectively, whereas, benzene, toluene and ethyl benzene concentrations were 0.22 mg/L, 1.2 mg/L and 0.86 mg/L respectively, and above allowable/permissible discharge limit according to EPA standards. The acute toxicity test via static use of the leachate revealed an LC50 of 5.88% on *C.batrachus* as calculated using Finney's probit analysis from EPA. The study concluded that fish mortality observed in the research can be attributed to the physical-chemical constituents of the landfill leachate. Therefore it can be inferred that despite the use of landfills as waste management option, yet its negative impact on the immediate environment need to be investigated more.

INTRODUCTION

Waste is an indispensible part of anthropogenic activities. More than 95% of daily human activities generate waste and as such waste management is of significant concern to the society. Therefore waste has to be disposed sustainably, which is simply the transfer of waste from the society to nature (Lagerkvist, 2003). There is need for the disposal of these wastes in such a way that the ecosystem in general is not disrupted or the aquatic life compromised. Various waste disposal methods abound but the most common in the waste management hierarchy is landfilling.

Landfilling remains the dominant waste disposal method in most Asian and developing countries. All landfills produce leachate, which is the liquid formed as a result of the seepage of water through the landfilled waste or even any other permeable material. Though landfill is a significant waste disposal option in some places, yet regardless of the beneficial aspect of its use, its environmental impact becomes subject of concern to sustainability and development. To ascertain the degree at which leachate will pose any environmental threat depends on how the landfill is built, as well as, on characteristics of the waste disposed into the site.

Leachate composition varies with waste type (Christensen et al, 1994, Agamuthu et al, 2009). This variation arises from the presence of dissolved organic matters (alcohols, aldehydes, acids and short chain sugars), inorganic macro components (basic anions and cations including ammonium, chloride, and sulphate), heavy metals and polychlorinated biphenyl (Ludwig et al, 2003). Landfill leachate is characterized by high levels of salts and NH_x-N as well as high organic loading. Higher organic loading yields greater substrate availability for planktonic and epiphytic bacteria, and may induce inhibitory effect on sedimentary bacteria (Wendong et al, 2007).

In terms of solid waste management, many uncontrolled landfills without appropriate bottom liners and leachate collection systems exist in different sizes and ages, as some are more or less illegal dumps. At the exception of a few, most of the landfills are devoid of sanitary status as they are characterized of none or inadequate leachate collection and/or treatment facilities and also lack infrastructure to exploit landfill gas (Fauziah and Agamuthu, 2010).

Toxicological evaluations of the landfill leachate are in great demand, to ensure safe discharge of leachate from landfills. Now, it is gradually being incorporated into the environmental legislations in some countries (Enu-ah et al, 2009). Most by-products that are difficult to detect by chemical analysis can be compensated by toxicological evaluation. Therefore, toxicity tests have become useful tools for detecting the changes of leachate quality to complement the chemical oxidation method (Enu-ah et al, 2009). Some leachate toxicity studies (Wong, 1989; Sisinno et al, 2000; Osaki et al, 2006, Jaffar et al, 2009) have been carried out on fish and other aquatic organisms like zebra fish, *Cyprinus caprio,* tilapia, Japanese Medeka and Artemia but not much of the studies had investigated the leachate impact on pollution-resistant fish like *Clarias batrachus*. Therefore this study was undertaken with a view to analyzing the detailed physic-chemical components of leachate from closed sanitary landfill and its associated impact on fish (*Clarias batrachus*).

MATERIALS AND METHODS

Whole effluent toxicity (WET) approach was used to evaluate the toxicological effect of leachate on fish. A landfill (Air Hitam Sanitary Landfill) in Malaysia was chosen to represent closed/inactive landfills as deposition of waste to this landfill was terminated since 2006 till date. Raw leachate samples were collected on different days from the landfill and duly replicated to ensure coherence in analysis. The leachate was analyzed of physical-chemical parameters such as pH, dissolved oxygen, total dissolved solids etc using appropriate measuring instruments. Also APHA (2008) standard methods were utilized to analyze for BOD_5 and COD while inductively-coupled plasma mass spectrometry (ICP-MS), and, gas chromatography and mass spectrometry (GC-MS) were used to analyze other components of the leachate like metals, monocyclic aromatic hydrocarbons, chlorinated hydrocarbons, alcohols, pesticides, semivolatile organic carbons and volatile fatty acids.

Clarias batrachus was chosen for the effluent test due to its resistive potential and economic importance. Procured from fish farm, it was acclimatized for 14 days in fish aquarium. The average fish wet weight was 1.3 ± 0.2 g with mean length 5.00 ± 0.1 cm. Proper measures were taken to ensure that mortality of less than 5% was maintained 5 days prior to toxicity testing. Acute toxicity test based on APHA (2008), OECD (1993) and US EPA (2000) recommendations; hence laboratory static test was carried out to determine the median lethal concentration (LC50) of the raw leachate sample on the test organism. A group of 10 fish (in triplicates) of similar size were selected randomly and transferred from the acclimation tank using small hand net into suitable test aquarium of 25 L capacity. This was to avoid any occurrence of mechanical injury to the test fish. Five different concentrations of the leachate (3.13, 3.75, 4.38, 5 and 5.63 % v/v) as observed during the range finding test were applied definitively to obtain the effluent's lethal concentration (LC50) on the named fish. A control group of equal number of fish was set up without addition of leachate sample. The 96 hours LC50 for the test organism and the 95% confidence limits were generated using an EPA program, Finneys' Probit Analysis Version 1.5.

RESULTS & DISCUSSION

Based on visual observation, apparent colour of the raw leachate was bright brown with strong ammoniac odour (Table 1). The pH, conductivity and dissolved oxygen values were 8.2±0.3, 20±2.3 mS/cm and 5.8±0.2 mg/l respectively. The value of pH is an important parameter in wastewater quality and effluent discharge. This is a measure of the aggressiveness of leachate and biochemical conditions in solid waste. The pH of the leachate is expected because mature landfills show pH values greater than 7 while more neutral pH values are expected in the leachates that have already undergone some stabilization (Chian & Dewelle, 1976; Jaffer et al, 2009). COD and BOD values were 10,234±175 mg/L and 3,500±125 mg/L respectively; hence a BOD/COD ratio of 0.34 was obtained. Though landfills in Malaysia are characterized of high BOD and COD, this leachate recorded less due to its non-operational status but it still exceeded the allowable limit for effluent discharge. High concentration of ammonia was recorded (880±74 mg/L) and its presence may be due to biodegradation of amino acids and other nitrogenous organic matter in the deposited waste. Its presence also helps to determine the pollution potential in a landfill. Heavy metals such as Pb and Cd were not detected in the raw leachate though 0.12±0.08 mg/L of Hg was obtained. The concentrations of other metal components such as Cr (0.11±0.03) mg/L and Zn (0.1±0.02) mg/L were also obtained in the leachate analysis. Despite the absence of most heavy metals in the leachate sample, Hg value was significant. It is possible that some waste substances that had mercuric compound in their formulation such as cosmetics containers, battery components, gasoline, paints, rubber and plastics were discarded in a mixture with other waste forms and sent to landfill.

Table 1 Physical-chemical properties of raw leachate from Air Hitam Sanitary landfill

Component	Unit	Quantity	Standard Limits
Apparent colour	-	Bright Brown	-
Odour	-	Stench ammoniac	-
pH	-	8.2	5.5-9.0 (EQA B)
Dissolved Oxygen	mg/L	5.8	40 (EQA B)
BOD	mg/L	3 500	50 (EQA B)
COD	mg/L	10 234	100 (EQA B)
Chloride	mg/L	4 150	
Ammonical Nitrogen	mg/L	880	1 (EPA)
Mercury	mg/L	0.12	0.001
Chromium	mg/L	0.11	0.005
Zinc	mg/L	0.1	1 (EQA B)
BOD/COD	-	0.34	-
Benzene	µg/L	0.22	0.005 (EPA)
Toluene	µg/L	1.2	1 (EPA)
Ethyl benzene	µg/L	0.86	0.7 (EPA)
Cation Exchange Capacity	meq/100ml	10.3	-
Oil &Grease	mg/L	7	10 (EQA B)

- means not available EQA B is for Malaysian Environmental Quality Act Standard B

The analysis showed very low concentrations of some chemical parameters like volatile fatty acids, alcohols, chlorinated hydrocarbons etc which were even below machine detection limit. However, benzene (0.22±0.14 mg/L), toluene (1.2±0.06 mg/L) and ethyl benzene (0.86±0.01 mg/L) were detected. Such monocyclic aromatic hydrocarbons might have been dumped in the landfill during its operational stage; hence they were reflected in the leachate composition. Definitely, improper waste disposal option might have led to presence of such components in the MSW stream. Therefore leachate characterization gives an idea of the possible toxicants associated with the leachate from landfill.

The acute toxicity testing of the leachate on the fish showed some degree of mortality unlike the control group which did not record any mortality. Figure 1 showed that the mortality of *C.batrachus increased* with increased leachate concentration. After 96 hours of exposure, total of 50% mortality was recorded in the highest leachate concentration (5.63%). However, the mortality peaks were at 12th and 36th hour of exposure. The least mortality was 3.3% along the various exposure intervals. This implied that the leachate is toxic to the fish and may be associated with the concentration of parameters of dissolved organic matters like BOD and COD.

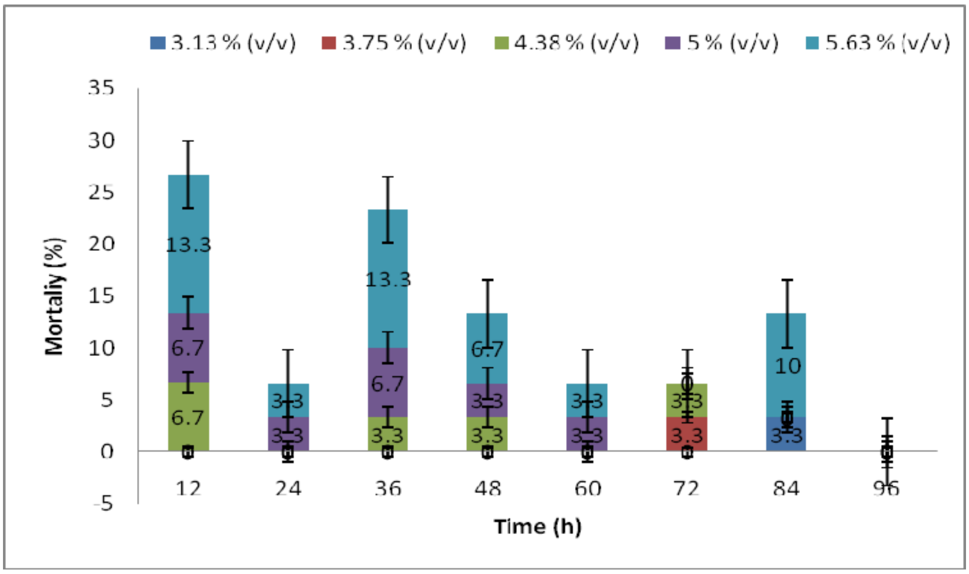

Figure 1 The mortality effect of different concentrations (% v/v) of the raw leachate on *C. batrachus* exposed for 96 hours

Finney's Probit Analysis method was utilized to generate LC50 value of the leachate on *C.batrachus* which gave 5.9% v/v (Table 2). The corresponding 95% confidence limits to the LC50 value were 5.3 and 7.2% v/v for the lower and upper limits respectively. This result varied from some other studies due to fish species (Jaffer et al, 2009; Osaki, 2006), size (Benli & Koksal, 2005) and even sampling period (Wong, 1989) yet it showed that leachate from a closed landfill is still toxic.

Table 2. Probit Analysis of raw leachate on *C. batrachus*

X=Log(d)	d	r	p	Y=probit of p	nW
0.4949	3.13	1	0.0333	3.2379	5.7070
0.5740	3.75	1	0.0333	3.2425	5.7446
0.6410	4.38	5	0.1667	4.0333	13.4914
0.6990	5.00	7	0.2333	4.2789	15.7707
0.7501	5.63	15	0.5000	5.0028	19.0985

The Probit line is Y = 7.5265X + -0.7927	
Number of Iterations	6
Chi-Square value	1.9045
The Estimate of Log(LC50) is	0.7696
The Estimate of LC50 is	5.8836 %(v/v)

The Standard Error of Log(LC50) is	0.0275
The 95% c.l. for Log(LC50) are	0.7281, 0.8550
The 95% c.l. for LC50 are	5.3467, 7.1611

The mortality effect might be associated to the ammonia (NH_3-N) content of the leachate. Ammonia is a strong indicator of toxicity in aquatic environment. In fact of all the toxic pollutants that can be found in landfill leachate, NH_3-N which results from the decomposition process of organic nitrogen has not be identified only as a major long term pollutant (Kurniawan et al, 2006) but also as the primary cause of toxicity (Kurniawan, 2009). Though ammonia ion (NH_4^+) cannot penetrate cell wall of organisms, yet it can be potentially toxic to fish because at molecular form (NH_3), it can easily permeate the tissue especially when concentration gradient exists (Svobodva et al. 1993).

The level of oxygen uptake by the fish might have been impaired by the presence of the monocyclic aromatic hydrocarbon; benzene, toluene and ethyl benzene which are potential toxicants to fish. Benzene could have easily induced toxicity in the experiment because it is a highly volatile organic chemical with high mobility in aquifer (Matsuto, 2006). Unlike the control group in the experiment that showed normal behavioural pattern, there were some behavioural abnormalities shown by the exposed group which were evidence of toxicity situation; such as leaping out of water, loss of balance and muscular spasms, increased activity and irritability.

CONCLUSION

This study infers that leachate from a closed sanitary landfill is characterized of toxic components via accumulation of different waste types. Ammonia, BOD, COD and some monocyclic aromatic hydrocarbons have the potential to cause leachate induced toxicity to aquatic life. The leachate was very toxic to *C.batrachus* and this might be a bioindicator to assess Whole Effluent Toxicity (WET) for landfill leachate.

REFERENCES

Agamuthu, P., Fauziah, S.H & Khidzir, K (2009). Evolution of Solid Waste Management in Malaysia: Impacts and implications of the Solid waste bill, 2007. *Journal of Material Cycles of Waste Management*, **11**:96-103.

American Public Health Association (APHA) (2008). *Standard methods for the Examination of Water and Wastewater*, 20th edition, American Public Health Association, Washington D.C.

Benli & Koksal, G (2005). The Acute Toxicity of Ammonia on Tilapia (Oreochromis niloticus L) lannae and Fingerlings. *Turkish Journal of Veterinary and Animal Sciences*. **29**: 339-344

Chian, E., & Dewelle, F. (1976). Sanitary landfill leachate and their treatment. *Journal Environmental Engineering* Divis., **102**: 411-431.

Christensen, T., Kjeldsen, P., Albrechtsen, H., Heron, G., Nielsen, P., Bjerg, P.L & Holm, P.E. (1994). Attenuation of Landfill Leachate Pollutants in Aquifers. *Critical Reviews in Environmental Science and Technology*, **24**, no 2, pp. 119-202

Eun-ah, C., Kazuo, T., Masataka, H., Tatsuyoshi, Y & Sotaro, H (2009). Toxicological evaluation of the chemical oxidation methods for landfill stabilization. *Journal of Wastse Management*, **9**(3):1006-1011.

Fauziah, S. & Agamuthu, P (2010). Landfills in Malaysia: Past, Present and Future. From Sanitary to Sustainable landfilling- why, how and when? 1st International Conference on Final Sinks 23rd – 25th September, **2010**, Vienna.

Jaffar, Y., Heng, L. & Salmijah, S (2009). Toxicity Testing and the effect of landfill leachate in Malaysia on Behaviour of Common Carp (*Cyprinus carpio L*., 1758; Pisces, Cyprinidae). *American Journal of Environmental Sciences*, **5** (3): 209-217.

Kurniawan, T. (2009). Landfill Leachate: Persistent Threats to Aquatic Environment. *SciTopics*. Retrieved May 5, 2010, from http://www.scitopics.com/Landfill_Leachate_Persistent_Threats_to_Aquatic_Environment.html

Kurniawan, T., Wai-hung, L & Chan, G (2006). Physico-chemical treatments for removal of recalcitrant contaminants from landfill leachate. *Journal of Hazardous Material* **129**(1-3): 80-100.

Lagerkvist, A. Ed (2003). Landfill Technology, Division of Waste Science and Technology, Lulea University of Technology, Lulea, Sweden.

Ludwig, C., Hellwed, S., & Stucki S. (2003). *Municipal Solid Waste Management. Strategies and Technologies for Sustainable Solutions*. Springer-Verlag Berlin Heidelberg, New York.

Matsuto, T (2006). Risk assessment of landfill: evaluation of human health risk, In Abstract Proceedings of the 4th Intercontinental Landfill Research Symposium, Lagerkvist, A (Ed) Technical report, Division of Waste Science and Technology, Lulea University of Technology, Lulea, Sweden.

OECD, Organization of Economic Co-operation and Development, OECD, Paris. **1993**.

Osaki, K., Shosaku,K., Norihisa, T. & Yoshiro,O (2006). Toxicity testing of leachate from waste landfills using Medaka (*oryzias latipes*) for monitoring environmental safety. *Environmental Monitoring and Assessment*, **117**: 73-84. Doi: 10.1007/s10661-006-7670-x.

Sisinno, C., Oliveira-Filho, E., Dufrayer, E., Moreira, J & Paumgartten, F (2000). Toxicity evaluation of a municipal dump leachate using zebrafish acute tests. Bulletin *Environmental Contamination Toxicology*, **64**: 107-113.Doi: 10.1007/s001289910017.

Svobodova, Z., Lloyd, R., Machova, J. & Vykusova, B (1993). Water Quality and Fish Health. *EIFAC Technical Paper. N0 54*.Rome FAO.

United States Environmental Protection Agency (USEPA) (2000). *Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards for the Landfills Point Source Category,* **65**, no 12. pp 3007 – 3051.

Wendong T., Hen J. & Sheldon, J (2007) Microbial biomass and heterotrophic production of surface flow mesocosm wetlands treating woodwaste leachate: Response to hydraulic and organic loading and relations with mass reduction. Ecological Engineering, **31**(2): 132-139

Wong, M. (1989). Toxicity test of landfill leachate using *Sarotherodon mossambicus* (freshwater fish). *Ecotoxicology and Environmental Safety,* **17**: 149-156. Doi: 10.1016/0147-6513(89)90033-X.