CLOSED LANDFILL HEAVY METAL CONTAMINATION DISTRIBUTION PROFILES AT DIFFERENT SOIL DEPTHS AND RADIUSES

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Abstract. Various types of wastes are the main sources of heavy metal within a landfill system including metal waste components such as food cans, scrap metal, household hazardous waste and electronic waste such as batteries and old computers. The procedure that occurs inside the waste cells quickens that procedure for substantial metal draining from the waste component. This study comparing soil samples taken from four different sites in Selangor of closed non-sanitary (Sungai Kembong) and sanitary (Ampar Tenang, Air Hitam and Kubang Badak) landfills at different depths (0-30 cm, 30-60 cm and 60-90 cm) and radiuses (5-10 m, 10-15 m and 15-20 m), for ten heavy metals (Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb) to find the risk of heavy metal movement from the upper layer cell into the deeper layer. The data were analysed using ICP-MS (Perkin Elmer NexION 300X). Al and Fe displayed higher concentration at most of the sites with different volume of concentration at different depth and radius. Most of the sites consistently showed higher contamination in deeper soil than the upper layer of the soil.
Keywords: *urban pollution, landfill, inorganic pollutant, laterite soil, leachate, municipal solid waste*

Introduction

It is estimated that approximately 0.5 to 4.5 kg of solid waste per person per day is produced at different regions of the world (Bakare et al., 2005; Swati et al., 2014). Land degradation, which caused by human activities, creates significant adverse effects on the environments and ecosystems worldwide (Thomaz and Luiz, 2012; Bai et al., 2013; Li et al., 2013; Chen et al., 2015). Thus, solid waste becomes an important and emerging environmental problem. The most common ways to manage such waste disposal are landfills and incinerators. At the time being, it is up to 95% total of municipal solid waste (MSW) collected is disposed of in landfills worldwide (El-Fadel, 1997; Swati, 2014). Landfilling is the major MSW disposal method used in modern cities (Wong, 2015).

Due to the problems of environmental pollution and the shortage of urban land, landfill becomes a major issue in any urban management in the world (Hoornweg and Bhada, 2012). As consequences, ex-landfills are turned into another beneficial alternative to the urban population. At present, there were 143 closed landfills in Malaysia

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(SWCorp, 2017). The number of the closed landfills had increased each year from 115 in 2003 to 131 in 2012 and it has been expected to become 296 when all the existing landfills closed their operation in 2020 (Simis et al., 2016). For the time being, there are about 160 operating landfills and 143 closed landfills, which make altogether 303 landfills in total that, are available in Malaysia. It has been expected more than 70.0% of the future ex-landfills to be located in urban areas and become the major concern of the local population within the ex-landfill areas (Chun-Yang and Talib, 2006).

Based on Act 672 under Solid Waste and Public Cleansing Management Act 2007, every ex-landfill must undergo waste recovery through new technology such as waste to energy facilities, construction and demolition recovery facilities, organic waste facilities, landfill closure, and integrated waste management. However, the existence of the ex-landfill within the neighbourhood reported creating issues of foul odours, leachate, and landfill gas pollution. The local communities have reported it and they claimed to have declined health and quality of life (Simis and Awang, 2015). These concerns probably have become more pragmatic when recent intensive studies demonstrated the increment of human health risk caused by exposure to toxic chemicals, such as dioxins and related compounds, and heavy metals in these dumping sites (Agusa et al., 2003; Minh et al., 2003).

Landfills containing hazardous materials are under critical observation today for potential hazards, resulting in the need for thorough risk analyses along with the soil and groundwater that have been contaminated with chemicals leaching from landfills. Several reports have been published which are documented on the leachate characterization and its effect on groundwater pollution (Boels and Fleming, 1993), but little information is available on the effect of landfills on soil contamination and its toxicological effects. Damaging human activities cause pollution. Thus, more information and assessment of land pollution are needed to overcome the problems occurred (Kardanpour et al., 2015; Mahmoud and El-Kader, 2015).

Based on the previous study, most organic chemical substances will eventually either be degraded through biochemical reactions in the landfill or be leached out of the landfill with water movement. However, the majority of heavy metals will remain in the landfill because heavy metal migration is very limited compared to the number of metals accumulated in the landfill (Oygard et al., 2004; Riber et al., 2005), especially in anaerobic processes. The slow movement of heavy metals is the result of heavy metals being subjected to strong sorption on soil particles, precipitation under anaerobic conditions, and chelation with inorganic and organic ligands in landfills (Bozkurt et al., 1999, 2000). Heavy metals occur naturally at low concentrations in soils. They are considered soil contaminants due to their widespread occurrence, as well as their acute and chronic toxicity (Youn-Joo, 2004).

High concentrations of heavy metal such as As, Cd, Cu, Pb, and Zn in soils have often been reported in a number of countries. It was reported by Bhattacharya (2012), that no significant adverse impacts of As upon human health in Bangladesh, India, and China. It is claimed that millions of people are potentially at risk from As poisoning. Similar to As, Cd accumulation in the offal of grazing animals in New Zealand and Australia made it unsuitable for human consumption. Besides, it affected access to meat products to overseas markets (Loganathan et al., 2008). There are also concerned about the urban development of horticultural sites which contained toxic levels of heavy metals in soils that resulting from excessive use of fungicides and herbicides (Pietrzak and Uren, 2011).

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Materials and methods

Study area description

Twelve points at 4 different sites of closed landfill located at Selangor, Malaysia namely; Ampar Tenang sanitary landfill (2°49'13.3"N 101°40'47.6"E), Sungai Kembong non-sanitary landfill (2°53'08.8"N 101°49'17.0"E), Air Hitam sanitary landfill (2°52'22.4"N 101°38'53.8"E) and Kubang Badak sanitary landfill (3°23'01.6"N 101°24'54.2"E) were selected for this study. The site selection was based on the types of the landfill and the size of the landfill located in Selangor state. *Table 1* indicates the landfill sites info with the area covered, wasted collected, total year of operation and the current status of the landfill studied.

Table 1. *Selected landfill sites with the area covered, waste collected per day, total year operation and current status*

LANDFILL SITES	AREA (ACRE)	WASTE COLLECTED (TONE/DAY)	TOTAL YEAR OPERATION	CURRENT STATUS	SOURCE
Air Hitam Sanitary Landfill	100	1500	16	Closed	Othman et al. (2016)
Kubang Badak Sanitary Landfill	30	400	10	Closed	Yahaya et al. (2016)
Ampar Tenang Sanitary Landfill	10	100	9	Closed	Yusoff et al. (2013)
Kampung Sungai Kembong Inert Waste	38.5	83	5	Closed	Yahaya et al. (2016)

Soil sampling

Soil samples were collected at different points (0-200 mm depth, approx. 1000 g) were taken by using soil auger (Eijkelkamp Agrisearch). The soil then was sealed in a polyethylene bag and labelled. The soil was dried in an oven for 70ºC for 3 days to a week depending on the moistness of the soil. Then samples were ground by using agate mortar until becoming small particles. Then it was sieved using a 2 mm mesh to remove stones and plant materials. Then samples were stored at room temperature before being digested using Microwave Digestion Ethos D (Milestone, 2001). Heavy metals, Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb were then analysed by using ICP-MS (Perkin Elmer NexION 300X).

Determination of Heavy Metals in Soils

0.5 g of soil samples were accurately weighed into a container made of PFA perfluoroalkoxy polymer and digested through a microwave digestion system using the digestion method as described by Zhao et al. (1994). Soil samples were air-dried and sieved. Soil samples were passed through a 2 mm sieve and ready for further analysis. Dried and the ground sample was mixed with 10 ml of concentrated nitric acid (HNO_3 65%) and digested. Acid was added for each soil samples and then the digestion tubes were placed in a rotor segment by using a torque wrench. The segments were inserted into the microwave cavity and connected with the temperature sensor. The mixture temperature was adjusted to ±175ºC and 1,200 Watt of power for 30 minutes using Microwave Digestion (Milestone Start D) as detailed in Method US EPA 3051. The digestion was completed after the last solution was clear and no brownish fumes

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were released from the digestion vessel tubes. When digestion was completed, samples were removed and diluted. The soil digests were adjusted to the final volume of 50 mL with deionized water. This solution is further 1:1 diluted for the analysis of components by ICP-MS and divided into triplicate each into 15 ml tubes.

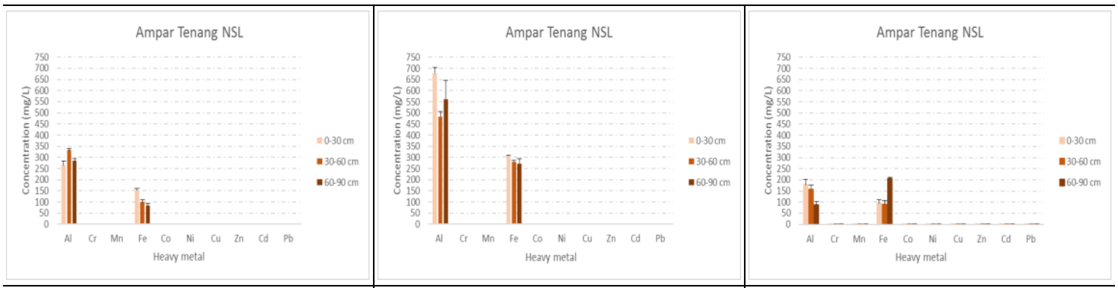
Data analysis

All the experiments were carried out in triplicates and data presented as mean values of three independent replicates. Data were further analysed using analysis of variance (ANOVA). Statistical analysis for all experiments was performed by using SAS through factorial analysis of variance followed by Tukey's test with significant different at P<0.0001.

Results and discussion

Ampar Tenang sanitary landfill

The results in *Fig. 1* showed heavy metal concentration in a closed sanitary landfill with a radius of 5 to 10 m, 10 to 15 m and 15 to 20 m at different depth 0 to 30 cm, 30 to 60 cm and 60 to 90 cm of Ampar Tenang sanitary landfill.



A | B | C

Figure 1. *The pattern of 10 heavy metal concentration depicted Ampar Tenang sanitary landfill at different soil depths (0-30 cm, 30-60 cm, and 60-90 cm) and radiuses (A: 5-10 m, B: 10-15 m and C: 15-20 m) of the closed landfill*

Results of heavy metal showed that Al and Fe concentration is higher at all point of Ampar Tenang landfill. Among the analysed heavy metals, Al and Fe concentration at radius 10 to 15 m had the highest concentrations. Each showed 679.088 mg/kg, 483.627 mg/kg and 560.437 mg/kg for Al while 306.678 mg/kg, 280.216 mg/kg and 272.183 mg/kg for Fe. Concentration for the radius 5 to 10 m and 15 to 20 m also almost equal within each depth. The heavy metal concentration at radius 15 to 20 m showed Al range between 87.711 mg/kg and 177.155 mg/kg while for Fe the concentration range between 90.317 mg/kg and 204.819 mg/kg. Meanwhile, radius 5 to 10 m showed Al concentration higher than Fe concentration. Each at 265.645 mg/kg, 332.441 mg/kg, and 284.904 mg/kg for Al and 152.911 mg/kg, 99.968 mg/kg and 84.924 mg/kg for Fe.

Sungai Kembong non-sanitary landfill

The results in *Fig. 2* showed heavy metal concentration in a closed non-sanitary landfill with a radius of 5 to 10 m, 10 to 15 m and 15 to 20 m at different depth 0 to

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30 cm, 30 to 60 cm and 60 to 90 cm of Sungai Kembong non-sanitary landfill. Results of heavy metal showed that Al and Fe concentration is higher at all point of Sungai Kembong landfill. Among the analysed heavy metals, Fe concentration at radius 15 to 20 m showed 364.243 mg/kg, 534.058 mg/kg and 559.114 mg/kg. Fe concentration at radius 15 to 20 m and 5 to 10 m also showed high concentrations. Each showed 170.397 mg/kg, 316.408 mg/kg and 436.530 mg/kg for radius 15 to 20 m while 337.625 mg/kg, 342.236 mg/kg and 289.030 mg/kg for radius 5 to 10 m. The Al concentration showed the highest reading for radius 5 to 10 m at 160.216 mg/kg, 185.739 mg/kg and 239.069 mg/kg compared to Al concentration at radius 10 to 15 m and radius 15 to 20 m. For radius 10 to 15 m, the concentration for Al range between 160.216 mg/kg, 185.739 mg/kg and 239.069 mg/kg. Meanwhile, for radius 15 to 20 m showed a range between 28.183 mg/kg and 43.081 mg/kg.

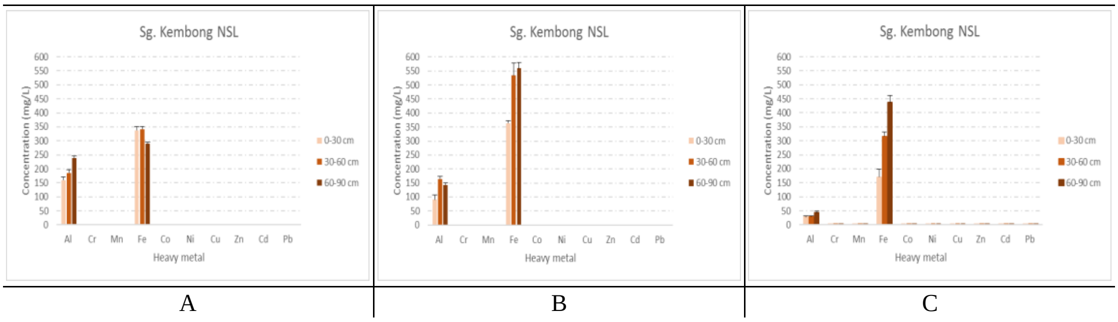

Figure 2. *The pattern of 10 heavy metal concentration depicted Sungai Kembong non-sanitary landfill at different soil depths (0-30 cm, 30-60 cm, and 60-90 cm) and radiuses (A: 5-10 m, B: 10-15 m and C: 15-20 m) of the closed landfill*

Air Hitam sanitary landfill

The results in *Fig. 3* showed heavy metal concentration in a closed non-sanitary landfill with a radius of 5 to 10 m, 10 to 15 m and 15 to 20 m at different depth 0 to 30 cm, 30 to 60 cm and 60 to 90 cm of Air Hitam sanitary landfill. Results of heavy metal showed that Al and Fe concentration is higher at all point of Air Hitam landfill. Among the analysed heavy metals, Al concentration at the radius 10 to 15 m showed the highest concentration. Each showed 235.604 mg/kg and 460.756 mg/kg and 422.434 mg/kg. Meanwhile, radius 5 to 15 m and 15 to 20 m showed 87.317 mg/kg, 75.733 mg/kg and 68.102 mg/kg for radius 5 to 10 m and 19.247 mg/kg, 42.861 mg/kg and 28.097 mg/kg for radius 15 to 20 m. For Fe concentration, the highest concentration depicted by radius 15 to 20 m; 523.195 mg/kg at 0 to 30 cm depth. Fe concentration at radius 10 to 15 m showed almost equal concentration at a different depth. Each showed 337.115 mg/kg, 270.938 mg/kg and 330.970 mg/kg. Meanwhile for radius 5 to 10 m, Fe concentration showed lower concentration at 107.231 mg/kg, 137.143 mg/kg and 136.536 mg/kg for each different depth.

Kubang Badak sanitary landfill

The results in *Fig. 4* showed heavy metal concentration in a closed sanitary landfill with a radius of 5 to 10 m, 10 to 15 m and 15 to 20 m at different depth 0 to 30 cm, 30 to 60 cm and 60 to 90 cm of Kubang Badak sanitary landfill. Results of heavy metal showed that Al and Fe concentration is higher at all point of Kubang Badak landfill.

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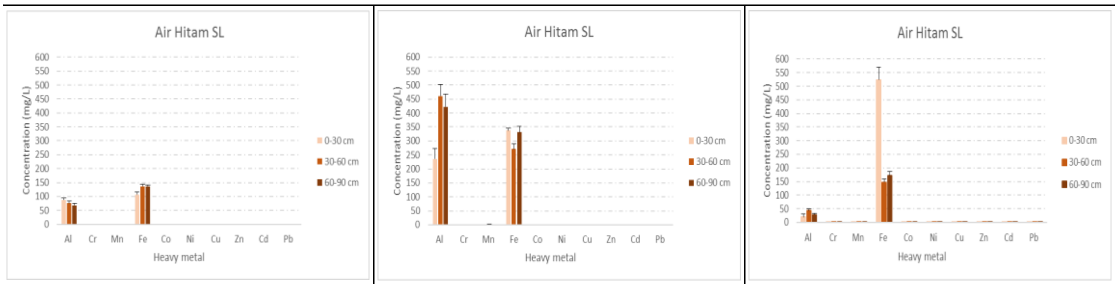
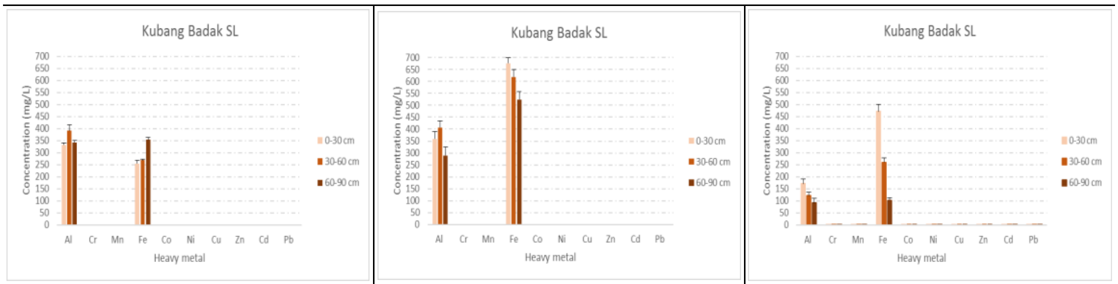
Among the analysed heavy metals, Fe concentration depicted the highest concentration at the radius 15 to 20 m, 10 to 15 m as well as radius 5 to 10 m of the radius. Each showed 471.797 mg/kg, 260.469 mg/kg and 103.413 mg/kg at radius 15 to 20 m; 676.043 mg/kg, 618.660 mg/kg and 524.594 mg/kg at radius 10 to 15 m and 255.221 mg/kg, 268.966 mg/kg and 353.415 mg/kg at radius 5 to 10 m. However, Al concentration showed the highest concentration depicted by radius 10 to 15 m and 5 to 10 m. Each showed 359.564 mg/kg, 407.121 mg/kg and 289.186 mg/kg at radius 10 to 15 m while 332.316 mg/kg, 391.556 mg/kg and 342.372 mg/kg at radius 5 to 10 m. Meanwhile, Al concentration at radius 15 to 20 m showed 172.183 mg/kg, 121.184 mg/kg and 91.807 mg/kg. Other heavy metal despite Al and Fe showed the lowest concentration at all radius and depth.



A B C

Figure 3. *The pattern of 10 heavy metal concentration depicted Air Hitam sanitary landfill at different soil depths (0-30 cm, 30-60 cm, and 60-90 cm) and radiuses (A: 5-10 m, B: 10-15 m and C: 15-20 m) of the closed landfill*



A B C

Figure 4. *The pattern of 10 heavy metal concentration depicted Kubang Badak sanitary landfill at different soil depths (0-30 cm, 30-60 cm, and 60-90 cm) and radiuses (A: 5-10 m, B: 10-15 m and C: 15-20 m) of the closed landfill*

Analysis of variance confirmed the findings by exhibiting highly significant differences ($P<0.0001$) between the radius, depth, and heavy metal concentration at three different radiuses, three different depths, and ten heavy metals concentration. This clearly demonstrates that environmental factors and landfill area background can have an important influence on the accumulation of certain heavy metal and its content. Al and Fe concentration showed the highest pattern on all 4 closed landfill sites. Research by Elwali et al. (2008), showed that the most common heavy metal contaminations at the landfill area vary from iron (Fe), cadmium (Cd), copper (Cu), zinc (Zn) and nickel (Ni). Furthermore, various studies reveal very high contaminants levels in the

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groundwater underneath the non-engineered waste disposal sites in Selangor (Bahaa-eldin et al., 2010; Suratman and Sefie, 2010; Taha et al., 2011). The subsurface soils were considerably polluted by heavy metals where wastes were dumped directly on top of the unlined natural formation (Mohd et al., 2013). This is probably the reason for the high concentration of the river alluvium soil beneath the landfill that has the highest metal concentrations of Cu, Zn and Pb (Elwali et al., 2008). Based on the shallow and fluctuation of the periodic water table, water infiltration during the rainy season, acidic soil environment and local groundwater flow direction were the main reasons that enhanced the contamination migration through the soil formation into the groundwater (Elwali et al., 2008). Although the contamination present in the solid waste applied a significant impact on the groundwater, it has to be stressed that different metals behaved differently. Heavy metal binding properties of these soil constituents differ with the charges of the soil material and the ionic valences. As a result, different depths of the sample soil from landfill depict different capability of heavy metal binding. In addition, the rate and amount of pollutant penetration through the soil is also influencing the concentration of heavy metal present in the landfill environment.

Conclusions

The effects of the heavy metals content and composition, radiuses, depths and localities interactions have not been studied in the landfill area. Despite significant results in our understanding of heavy metals contamination distribution profiles at different soil depths and radiuses at closed landfill area, type of soil, the control mechanisms regulating the type of heavy metals distribution and accumulation and soil chemical reaction still remain an enigma. Each factor had an effect on the heavy metals content and profile; however, the most influential factor appeared to be a type of soil. Recommendations for future researches are by identifying the key factors controlling heavy metals distribution and accumulation in a different type of soils a greater understanding of landfill pollution mechanism in response to interactions with environmental factors will emerge.

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