Contamination Composition of Fe, Mn and Al at 8 Different Profiles of Solid Waste Disposal Areas in Malaysia

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Abstract—**Solid waste is a major issue in environmental management as it was generated by almost every single person in the world. In Malaysia, it is estimated 0.8 kg solid waste dumped by one person in rural area and 1.5 kg by person in urban area in a day. Landfill as a final waste disposal point is currently in critical number where it keeps on increasing every year. The most serious issues is landfill may cause air, water and soil pollution as waste disposed at landfill may produce leachate through water runoff at the area. Hence, this research aimed to assess the contamination level of three types of heavy metal which are Iron, Manganese and Aluminum (Fe, Mn, Al) at 8 selected contaminated landfill areas in Selangor, Perak and Melaka. As a result, Fe exhibited highly contamination level ranged from 0.15 mg/L to 0.77 mg/L followed by Mn ranged from 0.06 mg/L to 0.57 mg/L and the lowest is Al ranged from 0.04 mg/L to 0.08 mg/L. Interestingly Perak solid waste disposal area was found to have the highest Fe content (0.77 mg/L), substantially higher than all other areas tested. In contrast Mn was detected highest (0.57 mg/L) in Selangor landfill area. There was positive relationship between type and total content of heavy metals and location of landfill area. Therefore, collaboration and concern from authority and public in managing solid waste may help to reduce the pollution as these types of heavy metal may cause bad impact to the environment and surely human health.**

Index Terms—**Solid waste, landfill, leachate, heavy metal.**

I. Introduction

Solid waste is resulting from after used and unwanted solid materials from commercial, institutional, residences and city buildings. This waste consists of materials such as glass, metal, paper, plastics, wood, yard waste, food scraps and others but the sources can vary from one country to another. Some of solid wastes that are harmful to human health and also environment are classified as hazardous wastes. Saundry [1] defined hazardous wastes as materials which are highly flammable, explosive and highly toxic which may cause cancer, DNA mutations, and birth defects to human and other living things. Generation of solid wastes in Malaysia has recently increased by 3% each year to a critical stage in term of the amount and composition due to the impact of rapid development, urban migration, and affluence among the community [2]. Moreover, Lau [3] reported that, solid waste in Malaysia is predicted to increase from 292 kg/capita to 511 kg/capita in 25 year starting from year 2000. This study is supported by Ministry of Housing and Local Government which also reported that, waste generation in Peninsular Malaysia frequently increased since 2000 [4]. Therefore, it is important to manage the solid waste in order to mitigate bad environmental effects. Failure to manage this problem may lead to the huge waste increasing which is by 2025, the amount of waste is estimated to rise up to 1.8 million tons per day because ASEAN countries are among the highest contributor of solid waste [5]. However, as a developed country, Malaysia has faced problems of inadequate manpower, technology, land scarcity, and also other facilities to handle the increasing rate of waste generation [6]. Current approaches applied to mitigate the problems are the 3R (Reuse, Reduce, Recycle) campaign and other intermediate process such as incineration and composted only help to reduce the waste by 15% to 20% in 2020 [7]. The main method of disposing the solid waste in Malaysia are still landfill where currently 80% in usage and estimated to contribute another 65% of waste by 2020. Nevertheless, the condition of most landfills in the country are very bad as it lack of proper management and maintenance system such as lining systems, leachate treatment system and gas venting system [7].

Landfill as final disposal area for solid waste is the most efficient and easy way to settle up the abundance of collected waste. However, improper management of the landfills have directed to environmental and social problems such as air, soil, water and groundwater contamination surrounding of landfill area, flooding, noise from the collection vehicles, scavenging activities at the landfills and most critical, it affects the public health, ecosystem and surrounding environment [8]. According to [9] the report from Ministry of Housing and Local Government for Malaysia in 2012, mentioned that there are 183 landfills that still in operation out of 292 landfills but unfortunately this figure already exceed the capacity. This is due to very cost-effective alternatives to dispose the waste [10]. Ref. [9] also mentioned that out of 183 landfill sites, 12 are classified under level III and level IV sanitary landfills whereas the other 171 sites are categorised in level 0 and level II. Level II is also categorised as semi-sanitary landfill because it lacks of leachate control system. Table I described the classes of landfill sites in Malaysia [9].

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TABLE I: CLASSES OF LANDFILL SITES IN MALAYSIA

Level	Type of Landfill
0	Open Dumping
I	Controlled tipping
II	Sanitary landfill with bund and daily cover
III	Sanitary landfill with leachate recirculation system
IV	Sanitary landfill with leachate treatment facilities

On top of that both level 0 and level II landfills are currently main contributor to the contamination as landfills need to have a system to prevent leachate from getting into the underground water [11]. Leachate produced from water run off at landfill frequently has major caused to pollute soil, groundwater and surface water. It transfers to the environment from the bottom of the landfill which is through the unsaturated soil layers flow to the groundwater and continuously to surface water through hydraulic connections. The discharge of leachate from treatment plant or untreated leachate also may results to contaminate the environment and also public health [12]. Therefore this study was implemented to investigate this in greater depth whether environmental factors and landfill area background such as year of operation and waste collected per day can exert some influences on type and total content of leachate.

II. MATERIAL AND METHODS

A. Site Sampling

Eight landfill areas located in three states in Malaysia which are Sungai Wangi at Perak; Sungai Sabai landfill, Sungai Kertas dumpsite, Taman Beringin landfill, Air Hitam Sanitary landfill, Dengkil Inert Waste landfill and Jeram Sanitary landfill at Selangor and Krubong landfill located at Melaka were selected for this study. The selections of the sites were based on scales which are below 50 acres and more than 50 acres. Table II listed the selected sites with the level, area, waste collected and total of year operated.

TABLE II: EIGHT SELECTED LANDFILL AREAS WITH THEIR CLASSES OF LEVEL, SCALE, CAPACITY AND OPERATION PERIOD OF TIME

Site	Level	Area (acre)	Waste collected (tone/day)	Total year operation
Sungai Sabai Landfill	0	20	170	20
Sungai Wangi Landfill	0	25	140	30
Sungai Kertas Dumpsite	0	27	130	12
Taman Beringin Landfill	0	40	2000	37
Krubong Landfill	0	54	700	20
Air Hitam Sanitary Landfill	IV	100	2500	20
Dengkil Inert Waste Landfill	0	145	400	11
Jeram Sanitary Landfill	IV	160	2500	8

B. Soil Sampling

Soil samples were collected from 10 different points (0 to 200mm depth) at the landfill site and homogenized in one container. Samples were then dried in oven at 70℃ for three days. After that samples were grinded until become small particle and sieved using 2 mm sieve for further analysis.

C. Microwave Extraction

0.5 g of sample was accurately weighed into a container made of PFA perfluoroalkoxy polymer, which was then placed in a in TFM Teflon tubes. All samples were digested through microwave digestion system (Milestone Start D) as detailed in Method US EPA 3051. 10ml of Nitric Acid (HNO_3) 65% was added for each soil samples and then the digestion vessel tubes were placed in rotor segment by using torque wrench. The segments were inserted into microwave cavity and connected with the temperature sensor. Rate of change in temperature was adjusted to ±175℃ and 1,200 Watt of power was provided for 30 minutes. The digestion was completed after the last solution was clear and no brownish fumes were released from the digestion vessel tubes. Digested samples were cooled down, diluted up to 50 ml with deionised water and filtered through Vacuum pump (Model GCD-136Xn) and Whatman filter paper no. 42. Lastly, the solution was transferred to conical flask tube before being tested for specific heavy metals analysis.

D. Analysis of Heavy Metal

Analysis of aluminum (Al), iron (Fe) and manganese(Mn) in landfill area soil samples were carried out by adopting standard USEPA 3051 method (USEPA, 1995) using Hach Spectrophotometer (Model DR5000). Al, Fe and Mn were chosen based on the study which indicate that Al usually contained in recycle products such as cans, pots, and other waste generated but rarely recorded [13] whereas Fe and Mn are metals that usually found as one of the highest source that contributed to soil and water contamination [14]. Therefore, this research may demonstrate the significance of all three heavy metals and how they reflect to the landfill soil.

1) FerroZine method (Fe)

FerroZine Method (0.009-1.400 mg/L) was based on Method 8147 (Stookey, 1970). In stored program, [260 Iron, FerroZine] was selected as referred in manual procedure. 25 ml of sample was filled in graduated mixing cylinder and was added with 0.5 ml of FerroZine Iron reagent solution then inverted to mix. After the solution dissolved, purple colour was developed as indication of iron existing in sample solution. Then, 10 ml of prepared sample was poured into the square sample cell after the timer expired. For the blank preparation, 10 ml of deionised water was filled in another square sample cell. Then, both sample cells were wiped using Kimwipes (Kimtech Science). Next, the blank sample cell was inserted into cell holder and zeroing [0.000 mg/L Fe]. Lastly, the prepared sample cell was wiped using Kimwipes (Kimtech Science) then inserted into the cell holder and the result was displayed in screen.

2) Periodate oxidation method (Mn)

Periodate Oxidation Method (0.1-20.00 mg/L) was adapted on Method 8034 (Federal register, 1979). In stored program, [295 Manganese, HR] was selected as referred in manual procedure. For the sample preparation, 10 ml of sample was filled into square sample and one Buffer Powder Pillow was added then inverted until the solution dissolved. Next, one content of Sodium Periodate Powder Pillow was added into sample solution and was inverted until the solution dissolved completely. After the solution dissolved, violet colour was developed as indication of manganese existing in sample solution. For the blank preparation, the second sample cell was added with sample. Then, both sample cells were wiped using Kimwipes (Kimtech Science). Next, the blank sample cell was inserted into cell holder and zeroing [0.0 mg/L Mn]. Lastly, the prepared sample was inserted into the cell holder and the result was displayed in screen.

3) Aluminon method (Al)

Aluminon method (0.008-0.800 mg/L) was based on Method 8012. In stored program, [10 Aluminon, Aluminum Alumin] was selected as referred in manual procedure. 50 ml of sample was filled in a graduated mixing cylinder and added with one Ascorbic Acid Powder Pillow then inverted until the solution dissolved. Next, add one AluVer 3 Aluminum reagent then invert several time until orange-red colour developed as indication of aluminum existing in the sample solution. After the solution dissolved, 10ml of the mixture solution was filled in square sample cell. After that one sachet bleaching 3 reagent was added to the blank and mixed well. The second sample cell was added with 10ml of the solution from cylinder. Then, both sample cells were wiped using Kimwipes (Kimtech Science). Next, the blank sample cell was inserted into cell holder and zeroing [0.000 mg/L Al^3]. Lastly, the prepared sample was inserted into the cell holder and the result was displayed in screen.

E. Data Analysis

Statistical analysis for all experiments was performed by using SAS through factorial analysis of variance followed by Tukey's test with significant different at $p<0.0001$.

III. Result and Discussion

Analysis of variance confirmed the findings by exhibiting highly significant differences ($P<0.0001$) between the heavy metal concentration, type of contaminant, scale, class, year of operation, capacity, location and all combinations of interactions. 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. Assessment of the summarized data (Table III) revealed that, of all 8 landfill areas analyzed, only one site contaminated with high content of Fe and Mn, whereas the rest exhibit merely high Fe content. The site that detected with high Fe and Mn was classified under open dumping site (class 0), with 20 year operation, loading capacity 170 tonne/day and 20 acre scale. In comparison the landfill area with the highest content of Fe also portrayed the similar pattern which also classified under open dumping site (class 0) with 20 year operation but different loading capacity and scale of 700 tonne/day and 54 acre respectively.

Fig. 1 presented the average result of heavy metals concentration at every sites with Fe is verified to be the major contributor to the soil contaminants ranging from 0.15mg/L to 0.77mg/L followed by Mn (0.06mg/L to 0.57mg/L) and the lowest is Al range from 0.04mg/L to 0.08mg/L. The possibility of Krubong landfill projected the highest concentration of Fe is due to the background of the site which is a small scale unsanitary landfill but collected huge number of waste. Taman Beringin landfill showed the lowest result for all heavy metals even though the background of the landfill similar with Krubong. This is because Taman Beringin landfill actually is a waste transfer station that has incinerator and furthermore some of the wastes were transferred to Bukit Tagar sanitary landfill [15]. Air Hitam Sanitary landfill and Jeram Sanitary landfill showed lower result because both landfill sites are classified under level IV which is sanitary landfill with leachate treatment facilities. The facilities provided helps to decrease the contamination even though both sites collected the highest waste every day. Whereas Dengkil Inert Waste landfill also indicated low result for all heavy metals probably because the area is 145 acre but collected wastes only 400 tone/day and just operated for 11 years. The other two sites which are Sungai Wangi and Sungai Kertas presented quite similar results as the size of landfill and waste collected are within a same range. Sungai Sabai landfill is the only site that obtained quite high and similar concentration of both Fe and Mn. This probably because of the site location where it has no nearest location for water intake and the distance of this landfill to the nearest water bodies are about 2km which may lead to higher heavy metals deposited in soil [16]. To sum up, there are several relations between classes of landfill, area of sites, total of waste dumped and total of year the landfill has been operated. The observation for classes of landfill showed that, sanitary classes (level II, III, and IV) may produce low concentration of contaminants. However, wide landfill area with low total of waste collected also showed low concentration of contaminants but still, the concentration may increase if the areas are not in sanitary stage. As for the other sites with high concentration of contaminants, the sites need to be treated with some alternatives such as upgrade them into sanitary landfill. Hence, proper management of landfill may help to decrease the amount of contamination and increase the quality of environment for the future.

TABLE III: Concentration of Heavy Metals at Selected Landfill

Site	Fe (mg/L)	Mn (mg/L)	Al (mg/L)
Sungai Sabai Landfill	0.631	0.567	0.079
Sungai Wangi Landfill	0.397	0.077	0.053
Sungai Kertas Dumpsite	0.443	0.09	0.068
Taman Beringin Landfill	0.194	0.06	0.058
Krubong Landfill	0.770	0.190	0.060
Air Hitam Sanitary Landfill	0.251	0.12	0.038
Dengkil Inert Waste Landfill	0.154	0.09	0.043
Jeram Sanitary Landfill	0.323	0.07	0.061

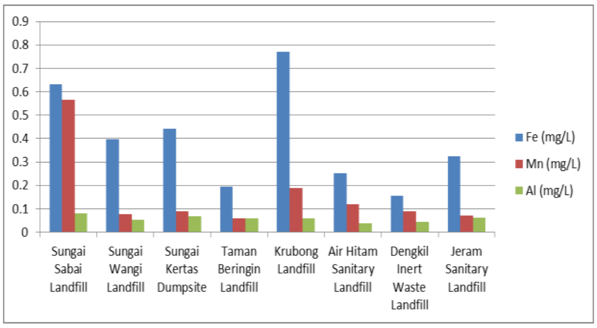

Fig. 1. Pattern of heavy metals concentration at 8 different landfill areas in Malaysia.

IV. Conclusion

In general the highest content of solid waste area contaminants, either in total or individual heavy metals were detected in open dumping site landfill area. It can be concluded that the background of the site such as area, loading capacity, type of landfill area as well as year of operation are strongly associated with the type and content of heavy metals contaminant. However the relative distributions of heavy metals within each site did not necessary correlate to the levels of total content of heavy metals contaminant. Given these results, it can be hypothesized that there was a strong possibility of landfill area profile x environment interactions influencing contaminant composition of landfill area.

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