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Greenhouse Gas Emissions Trend in Old Landfill, Malaysia

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According to Malaysia National Greenhouse Gas Inventory report, a total of 67,532 Gg CO_2eq of methane was emitted in year 2011. The highest methane emission was from the solid waste disposal sites, which accounted for about 46 % from the total which remained the largest source throughout the time series period. Proper gas monitoring was not done in most landfills which the emission trend, pattern and impact remains untold. Understanding methane and carbon dioxide concentration trends will positively help in spatial variation of landfill emissions in Malaysia. Therefore, this research highlighted two objectives. First, to test feasibility of prototype sampling tube to collect gas samples. Second, to analyze gas samples using micro gas chromatography and evaluate emission trend in Taman Beringin Closed Landfill. Using proper technique, the sampling tube was employed manually at the gas well which located at the highest point of the hill. Three samples collected everyday between 12 to 2 p.m. for 1 mth. Result shows an interesting trend recorded for methane and carbon dioxide. Though the concentrations vary for each day, it highlighted certain range in the graph. Methane ranging between 550,000 ppm to 850,000 ppm and carbon dioxide ranging between 400,000 ppm to 620,000 ppm. It is high concentration emitted everyday considering maximum recommended safe methane concentration for workers during an 8-h period is 1,000 ppm (0.1 %) as stated by National Institute for Occupational Safety and Health's (NIOSH) and Occupational Safety and Health Administration (OSHA) has set a Permissible Exposure Limit (PEL) for carbon dioxide of 5,000 ppm by volume (0.5 % concentration). In addition, T-test was done to statistically shows the significant different between samples collected and the permissible standard. Result shows significant high concentration emitted compared to the safe level allowable in ambient air. This study helps addressing gap in landfills greenhouse emission monitoring in Malaysia.

1. Introduction

Typically, landfill gas production begins within a year of waste placement and may continue for as long as 50 y after landfill closure therefore, highlighted landfill as a significant contributor to greenhouse gas (GHG) emissions through the decomposition processes and life-cycle activities. As methane constitutes about 50% of landfill biogas, reduction of methane emissions from municipal solid waste landfills results in climate change mitigation (Broun and Sattler, 2016). In Malaysia, landfilling remains the predominant approach to dispose municipal solid waste (MSW), regardless being the lowest preferences in the waste management hierarchy and an inverse approach to achieve sustainable environmental development (Othman et al., 2018). The sound handling of MSW is a high priority to minimize environmental degradation and pollution (Bong et al., 2018). The U.S. Environmental Protection Agency (USEPA) reported that greenhouse gas emissions from waste landfills amounted to 115.7 Mt of carbon dioxide equivalent (CO_2e) in 2015 (Hockstad and Hanel, 2018). Hence, it is also important to evaluate landfill gas emission in Malaysia. The regional specific emission factors and detailed inventory for methane emissions are essential to regional GHG inventories and climate change programs at provincial level (Bo-Feng et al., 2014). Therefore, highlighted the novelty of this research which is to provide a framework for detail inventory on greenhouse gas emission in Malaysia's landfills. The International Solid Waste Association (2009) has stressed the latter by stating that: ‘‘accurate measurements and quantification of greenhouse gas emissions is vital in order to set and monitor realistic reduction targets at all levels. This research aims to evaluate methane and carbon dioxide trend in landfills starting with the old landfill in Kuala Lumpur which assessable for this research and soon to other landfills in Malaysia using the ground surface

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enclosure technique. It is the most commonly used method for gas study on soil surface (Bogner et al., 1997) and methane oxidation processes (Scheutz et al., 2009). It involves positioning a static chamber on the surface of the landfill, where the methane concentration build-up allows for flux determination on that specific spot (Gonzalez-Valencia et al., 2016). This study is the first step in accomplishing the spatial variation of landfill emissions in Malaysia as plan in next stage of this study. This research has highlighted two objectives. First, to test feasibility of prototype sampling tube to collect gas samples. Second, to analyze gas samples using micro gas chromatography and evaluate emission trend in Taman Beringin Closed Landfill. Gas evaluation was never being done before at this landfill, resulting in no recorded data and remained unknown until now. It is therefore essential to design a sampling tube and test its feasibility for actual sampling on site and proper evaluation on emission trend.

2. Case study

2.1 Study area

Taman Beringin closed landfill was located in Kepong area near to MRR2 highway. It was hilly area full of aging waste underneath. The highest point was at 70-m elevation from sea level. Under the authority of DBKL, this 12-ha landfill was operated in 1996 and once closed in 2004. The closure was at C3 level which comprises of leachate treatment and gas management facility. This landfill has received a lot of attentions from media and residents nearby since its operation and until now. At present, new operator appointed by DBKL is doing well to address issues of leachate leakage into Sg. Jinjang which located next to this landfill. At the same time, this research commences and discover the installation of gas ventilation facilities provided here was not working well anymore due to blockage and thus resulting in prolong time for landfill stabilization. Figure 1 shows location map produce by GIS (Geographical Information System) software using google earth satellite image.

Figure 1: Location map of Taman Beringin Landfill (Google Earth, 2018)

3. Methodology

Figure 2 shows the overall workflow in this research. These steps were followed for each day sampling within a month.

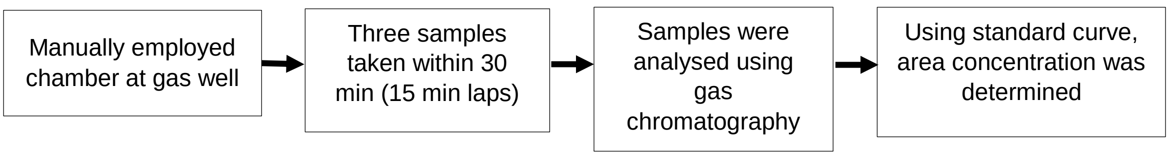

Figure 2: Overall workflow

3.1 Chamber design

This research starts with designing sampling tube for proper sampling on site. PVC was used as this material has lower reaction to gases. It is also steadfast and not easily rusting in acidic landfill environment. In this case, an opaque material was selected to prevent temperature increment inside the chamber.

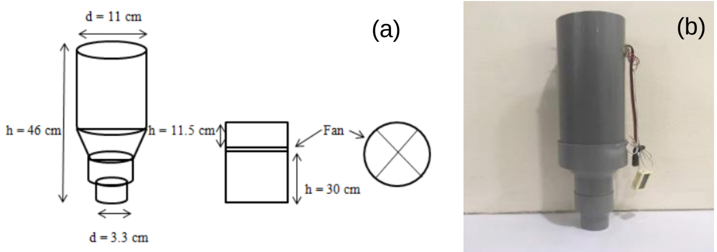

Figure 3: (a) Cross sectional area of sampling tube; (b) Sampling tube

3.2 Sampling

Sampling was done at noon time between 12 to 2 p.m. for 30 d. Sampling time was decided after pilot study was done for 24 h on site. Highest gas emission was recorded at noon time thus this time was selected for actual sampling. Pump was used to vacuum gas from sampling tube into the 1 L gas sampling bag (Tedlar® bag). While meteorological parameters were also recorded. Temperature probe in the chamber gives temperature reading inside the chamber, while hygrometer records ambient temperature and humidity.

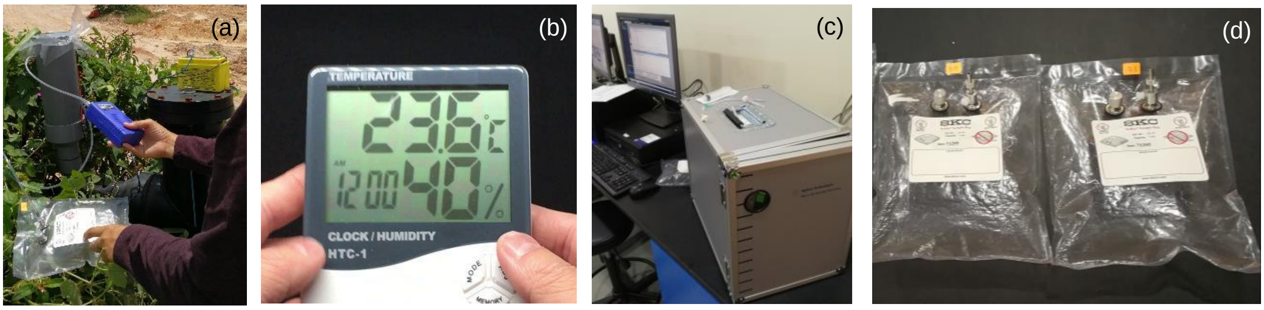

Figure 4: (a) Sampling at gas well; (b) Hygrometer; (c) Micro gas chromatoghraphy; (d) Gas sample in tedlar bags

3.3 Sample Analysis

Analyses was done using micro gas chromatography in laboratory. Samples collected from site will directly analysed within a same day. This is because the gas permeability of plastic materials is quite high, so a long storage more than 1 d in gas sampling bag should be avoided. Micro GC will produce result in graph showing the peak area for each composition. Area under these peaks can be used to quantify the concentration of each. Area result from micro GC was then compared to standard curve shown in Figure 5 below to determine the concentration in ppm for each samples collected. This standard curve was plotted from dilution process using pure gas for methane and carbon dioxide in lab.

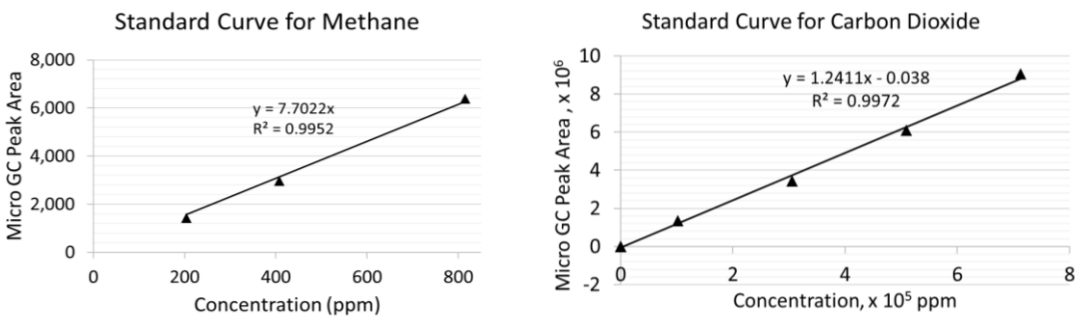

Figure 5: Standard curve for (a) methane; (b) carbon dioxide

4. Result and discussions

4.1 Trends

Result shows an interesting trend recorded for methane and carbon dioxide. Though the concentrations vary for each day, it highlighted certain range in the graph. Figure 6 shows methane range between 550,000 ppm to 850,000 ppm and carbon dioxide range between 400,000 ppm to 620,000 ppm. It is high concentration emitted everyday considering this landfill has been closed about 10-y already. Permissible limit in 8-h exposure period are 1,000 ppm (0.1 %) for methane and 5,000 ppm by volume (0.5 % concentration) for carbon dioxide.

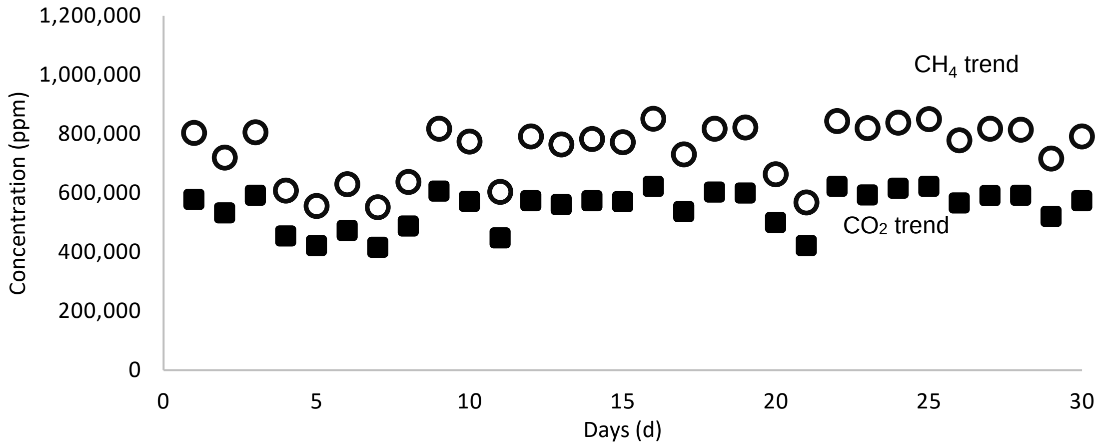

Figure 6: Methane and Carbon dioxide concentration trends during a month sampling.

Temperature recorded shows a stable range between 32 to 42 ºC without much fluctuate. However, humidity readings fluctuate every time after rainy events. Figure 7 below shows trend for humidity and temperature on site.

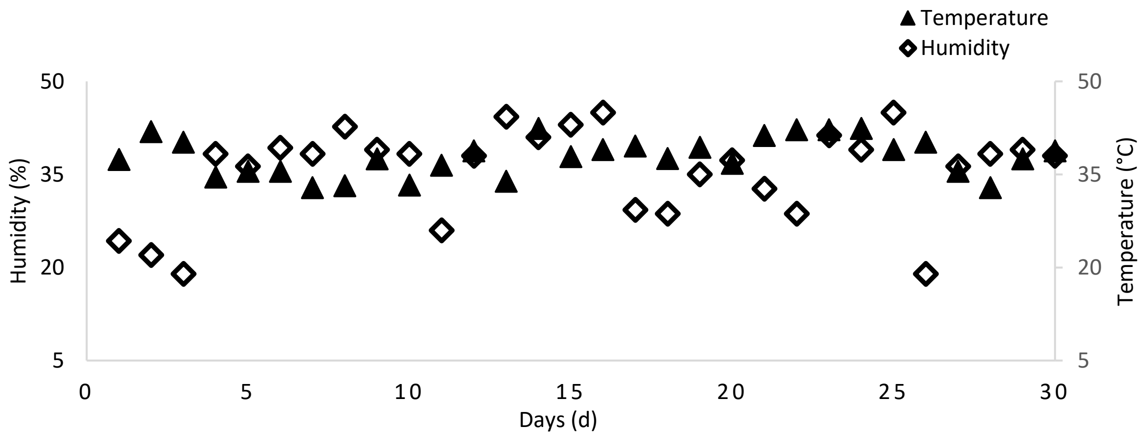

Figure 7: Humidity and temperature trends

4.2 T-Test (One-sample statistic)

The Occupational Safety and Health Administration (OSHA) has no permissible exposure limit for methane, but the National Institute for Occupational Safety and Health's (NIOSH) maximum recommended safe methane concentration for workers during an 8 h period is 1,000 ppm (0.1 %). While, OSHA has set a Permissible Exposure Limit (PEL) for carbon dioxide of 5,000 ppm by volume (0.5 % concentration). This limit is the recommended maximum concentration personnel can be exposed to in an eight-hour period. However, in normal ambient, carbon dioxide is about 350 ppm only. Therefore, t-test was done to statistically shows the significant different between samples collected and the permissible standard.

Table 1: T-Test for CH_4 and CO_2

One-Sample Statistic	N	Mean	Std. Deviation	Std. Error Mean	t	df	Sig.(2-tailed)	Mean Dif.	95 % confidence interval	
									Lower	Upper
CH_4 Test Value = 1,000	30	1,513.86	1,172.28311	214.02863	2.401	29	0.023	513.8604	76.1227	951.5981
CO_2 Test Value = 350	30	3,125.7	2,240.4092	409.04089	6.786	29	0	2,775.702	1,939.119	3,612.285

Based on the test result shows in Table 1 above; Mean methane score (M = 1,513.86, SD = 1,172.28) was significantly higher than the normal ppm methane level in ambient air of 1,000 ppm, a statistically significant mean different of 513.86, 95 % CI [76.12 to 951.59], t (29) = 2.401, p = 0.023.

p value < 0.05 which shows significantly high different in the test result. Therefore, methane emitted here was practically high compared to the safe methane level in ambient air.

While for carbon dioxide test, mean CO_2 score (M = 3,125.702, SD = 2,240.41) was significantly higher than the normal ppm carbon dioxide level in ambient air of 350 ppm, a statistically significant mean different of 2,775.702, 95% CI [1,939.12 to 3,612.28], t (29) = 6.786, p = 0.

p value < 0.05, equals to 0 which shows very significantly high different in the test result. Thus, carbon dioxide emitted here was practically very high compared to the safe carbon dioxide level in ambient air.

4.3 Significance of greenhouse effects from landfill

When greenhouse gases are emitted into the atmosphere, many remain there for long time periods ranging from a decade to many millennia. Over time, these gases are removed from the atmosphere by chemical reactions or by emissions sinks, such as the oceans and vegetation, which absorb greenhouse gases from the atmosphere. As a result of human activities however, these gases are entering the atmosphere more quickly than they are being removed, and thus their concentrations are increasing. The increasing trend in the waste sector was due mainly to an increase in solid waste generation arising from population growth. Based on this case study itself, it is worrying to know high emitting methane and carbon dioxide per second as we discussed. Table 2 shows the effect of common chemicals found in landfills towards ozone depletion and global warming (Agency, 2004).

Table 2: Effect of common chemicals in landfills towards ozone depletion and global warming

Chemical	CFC/HCFC No.	Ozone Depleting Potential	Global Warming Potential
Carbon Dioxide			1
Methane			21
Chloroform			4
Nitrous Oxide			310
Dichloromethane (methylene chloride)			9
1-Chloro-1, 1-difluoroethane	HCFC-142b	0.065	2,300
Chlorodifluoromethane	HCFC-22	0.055	1,900
Chlorofluoromethane	HCFC-31	0.02	
2-Chloro-1,1,1-trifluoroethane	HCFC-133a	0.06	
Chlorotrifluoromethane	CFC-13	1	14,000
Dichlorodifluoromethane	CFC-12	1	10,600
Dichlorofluoromethane	HCFC-21	0.04	
1,1,1,2-Tetrafluorochloroethane	HCFC-124	0.02-0.04	620
Trichlorofluoroethane (Freon 113)	HCFC-131	0.007-0.050	
Trichlorofluoromethane	CFC-11	1	4,600
Trichlorotrifluoroethane	CFC-113	0.8	6,000
1,1,1-Trichlorotrifluoroethane	CFC-113	0.8	6,000

5. Conclusion

Landfill gas emissions were often ignored due to its absent in physical form. It is crucial that personnel know the specific emission trends in which they can ensure safety of workers and people living at the surrounding area while taking into consideration of its contribution towards greenhouse effect. At present, gas management in this landfill was not properly done and this will lead to possibility of physical explosion, chemical substances in ambient and odors as well as public health concerns for close proximity residents live surround it. Thus, this study provides significant discovery to allow responsible parties to realize its importance and accordingly provide proper control in near future. Reducing greenhouse gas emission from landfills will help Malaysia government to achieved 40 % emission reduction target by year 2020. This research has highlighted the importance of monitoring landfill gas emission trend and sampling method which technique used here can be duplicate at any landfills in Malaysia. This effort is necessary for Malaysia to start the transition towards a climate-resilient development and low carbon economy.

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References

Bo-Feng C., Jian-Guo L., Qing-Xian G., Xiao-Qin N., Dong C., Lan-Cui L., Ying Z., Zhan-Sheng Z., 2014, Estimation of methane emissions from municipal solid waste landfills in China based on point emission sources, Advances in climate change research, 5(2), 81-91.

Bogner J., Meadows M., Czepiel P., 1997, Fluxes of methane between landfills and the atmosphere: natural and engineered controls, Soil Use and Management, 13, 268-277.

Bong C. P. C., Lim L. Y., Lee C. T., Ho W. S., Klemes J. J., 2018, Review on the characteristic and feasibility of leachate for biogas production by anaerobic digestion, Chemical Engineering Transactions, 63, 73-78.

Broun R., Sattler M., 2016, A comparison of greenhouse gas emissions and potential electricity recovery from conventional and bioreactor landfills, Journal of Cleaner Production, 112, 2664-2673.

Gonzalez-Valencia R., Magana-Rodriguez F., Cristóbal J., Thalasso F., 2016, Hotspot detection and spatial distribution of methane emissions from landfills by a surface probe method, Waste management, 55, 299-305.

Google Earth, 2018, <https://earth.google.com/web/@3.22723728,101.66109453,59.48195743a,1040.79937029d,35y,115.20039342h,44.99991176t,0r/data=ClMaURJJCiUweDMxY2M0N2IyMGE0NmMyNGY6MHgzNzYwODBmNTNmYjg2NjQyGWpI3GPpwwlAIeBFX0GaallAKg5UYW1hbiBCZXJpbmdpbhgBIAEoAg>accessed 02.10.2018.

Hockstad, L., Hanel, L., 2018, Inventory of US Greenhouse Gas Emissions and Sinks, Environmental Protection Agency, Washington D.C., United States

Othman K. I., Lim J. S., Ho W. S., Hashim H., Hafizan A. M., 2018, Carbon emission and landfill footprint constrained for waste management using cascade analysis, Chemical Engineering Transactions, 63, 145-150.

Scheutz C., Kjeldsen P., Bogner J. E., De Visscher A., Gebert J., Hilger H. A., Huber-Humer M., Spokas K, 2009, Microbial methane oxidation processes and technologies for mitigation of landfill gas emissions, Waste management and research, 27(5), 409-455.