RESEARCH ARTICLE

Volatile organic compounds (VOCs) release from different type of wastes and potential health risk to waste collectors

Siti Rohana Mohd Yatim*, Famira Othman, Muhammad Afiq Zaki

Centre of Environmental Health and Safety, Faculty of Health Sciences, Universiti Teknologi MARA Cawangan Selangor, Kampus Puncak Alam, 42300 Bandar Puncak Alam, Selangor, Malaysia

***Corresponding Author**

Siti Rohana Mohd Yatim
Email: sitirohana@uitm.edu.my

Abstract:

Among air pollutants, emission of VOCs will lead to various short-term and long-term diseases based on their concentration level in the air. In this study, waste samples were prepared by collecting 15kg for each type of waste (food waste and mixed waste) and were stored in modified waste storage bins. The experiment was conducted by mimicking outdoor environmental setting for 21 days to stimulate the decomposition of the waste during extended storage period. The type of VOCs tested in this study are benzene, toluene, ethylbenzene, m-xylene, limonene and dimethyl disulphide. It was found that type of waste influenced the level of VOCs emitted with, p-value <0.05. Meanwhile, the time for waste collection does not influence the level of VOC emitted from the modified waste storage bin. Health risk assessment was also determined by calculating the Hazard Quotient, Hazard Index and Cancer Risk. For non-carcinogenic effects in this study have higher values of hazard index (HI > 1) for food waste and mixed waste which signify the occurrence of non-carcinogenic effects while the carcinogenic risk which is benzene in this study was found below the acceptable range. As a result, the determination of VOCs in a waste disposal bin and conducting health risk assessment is necessary to assess the impact on collection workers health as well as to the environment.

Keywords: Health risk, waste collector, waste storage

1. INTRODUCTION

Solid waste management has become a common problem in the urban area throughout the world, especially in the fast-growing cities and townships of the developing nations such as Malaysia. In almost everything we do, there will be left behind some kind of waste. In Malaysia, the solid waste produced containing a very high concentration of organic waste and therefore contain a high moisture and a bulk density above 200 kg/m3 [1]. This is due to the fact that Malaysia experiencing tropical climates with heavy rainfall throughout the year. Besides attracting pests such as rodents, flies and cockroaches, these household wastes released unpleasant odour which was contributing by the emission of several types of hazardous gases such as VOCs and could be detrimental to health. VOCs are known as a biogas produced from the decomposition of biodegradable materials through the action of bacteria, fungi and other living microorganisms.

Long-time exposure to polluted air even contain a small number of parts per million (ppm) of VOCs may cause long-term diseases. Many studies have been conducted for VOCs emission and exposure to workers in landfill, transfer station, composting and other site which focus during the transportation of the municipal solid waste (MSW). In contrary, there are limited study was conducted for MSW site storage and collection and its impact towards household waste collecter. Aromatic compounds used in this study are benzene, toluene, ethylbenzene and m-xylene (BTEX) which also classified as hazardous air pollutants [2].

2. MATERIALS AND METHODS

2.1 Sample Preparation

The experiment was conducted by using a modified waste storage bin. The modified storage bin is a normal 45 liter household waste disposal bin, made from plastic and has a pipe on the lid for VOCs sampling. The lid of the waste bin was kept close all the time during the period of study in order to ensure less or no changes as possible in term of oxygen contents and VOCs fugitive emission. The simulated food waste was used for the decomposition process in this study and was established according to the pilot study of household food waste collection conducted in Puncak Alam. The percentage of each components found in Puncak Alam residential area was also similar to MSW data composition generated in Balakong Selangor [3].

2.2 Sample Collection

In this study, the real waste collection was carried out in students cafeteria and residential area in Puncak Alam, There are 2 types of waste were collected from this study area which are the mixed and food waste respectively. Sum amount of 15 kg of waste were collected for each type of waste. Fraction of percentage for each type of waste were weight thoroughly so as to achieve waste fraction according to Samah et al. [1]. All of them were collected in the plastic bag and later transferred into modified waste bin in order to obtain VOCs generated from decomposition process.

2.3 Data Collection and Analysis of VOCs

The waste storage bin was set to outdoor setting in order to mimic the real condition of surrounding environment. The waste were left outside for 21 days based on a study conducted by Påledal, Hellman, & Moestedt [4]. Photoionization detector which is ppbRAE 3000 were used to measure volatile organic compound as this instrument will give a direct reading to selected type of VOCs use in this study. Different storage time were also identified to know the trend level of VOCs release upon the time that waste collectors performing the job which is in the morning, afternoon and evening.

2.4 Health Risk Assessment

Health risk assessment (HRA) is defined as a tool for human health risk estimation due to exposure to VOCs recommended by USEPA 2009 [5]. Equation below were used to calculate health risk index among waste collectors who exposed to the VOCs using Exposure Concentration Inhalation (EC_i) based on study Nadal et al.; Mustafa et al. and US Environmental Protection Agency [5-7].

$$EC_i = \frac{C \text{ x } ET \text{ x } EF \text{ x } ED}{AT \text{ x } 365 \text{ x } 24}$$

Where C is concentration of VOCs in air (mg/m³); ET is exposure time which is 8 hours/24 hours; EF is exposure frequency which is 350 days per year; ED is exposure duration about 25 years and AT is average time which 25 years (non-carcinogenic substances) and 70 years (carcinogenic chemicals). Next, after obtaining the EC_i is to calculate the hazard quotient (HQ), Hazard Index (HI) and cancer risk (CR). Equation 2 shows the carcinogenic risk calculated by multiplying the exposure by the US EPA Inhalation Unit Risk (IUR). In this study, the carcinogenic risk was benzene and ethylbenzene. Meanwhile the other VOCs in study is known as non-carcinogenic risk and was estimated using HQ by comparing the exposure concentration and the inhalation reference concentration (RfC) in equation 3. Lastly, value of HI is calculated for non-carcinogenic risk in Equation 4. The value of HI below or equal to 1 is known to be safe and permissible limit exposure [8].

$$\text{Cancer Risk (CR)} = EC_i \text{ x } IUR$$

$$\text{Hazard Quotient (HQ)} = \frac{EC_i \text{ x } 1{,}000\mu g/mg}{RfC}$$

$$\text{Hazard Index (HI)} = \sum_{1}^{n} \text{HQ non} - \text{carcinogenic}$$

3. RESULTS AND DISCUSSION

3.1 The Mean Concentration Level of VOCs Release from Different Type of Waste; Food Waste and Mixed Waste.

Figure 1 shows overall results that food waste has a higher VOCs than mixed waste. Aromatic hydrocarbons presented by benzene, toluene, xylene and ethylbenzene were basically related to the presence of municipal solid waste of synthetic materials such as plastic, solvents and others [9]. This factor can be signify based on the origin of the food properties and flavours that promotes the growth of microorganisms, the oxidation of lipids and also the waste decomposition. Basically, food waste usually contribute to the biological volatiles such as aromatic compounds, terpenes and also acetic acid [10].

Table 1 shows the result of the 6 types of selected VOCs has a significance value for different type of waste. This is because the p-value in this study is less than 0.05, showing that there is a relationship in the composition type of waste and the level of VOCs produced. This signifies that the test is statistically significant and the null hypothesis fails to be rejected. Benzene shows the highest reading in food waste. According to a study conducted by Fleming-Jones and Smith [11] all food tested contain benzene in the experiment except for American cheese and vanilla ice cream. Other than that, the same study also identified that cooked beef contained highest benzene. This explains the reason for benzene detection because most of our food we consume today contain a trace of benzene and increasing over time. Besides that, benzene was found to be the most abundant compound followed by toluene in an emission from a dumpsite [12-14].

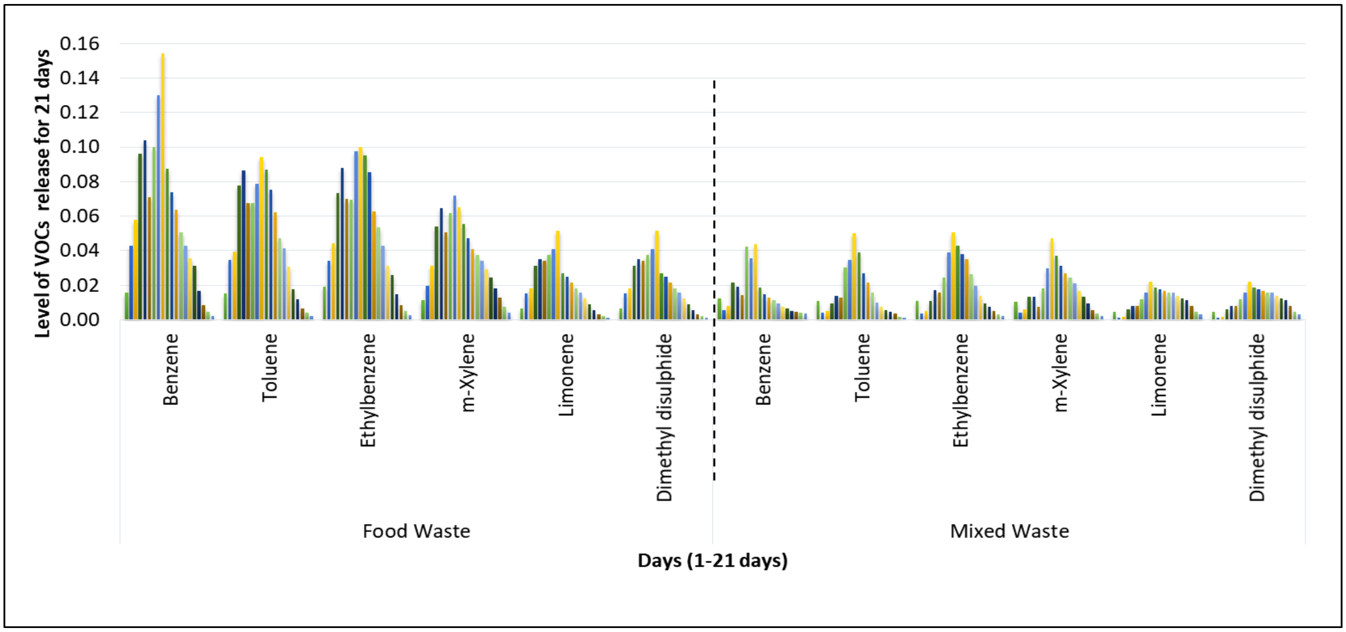

Figure 1: Average concentration level of VOCs in food waste and mixed waste for 21 days

Table 1: Mean concentration level of VOCs release from different type of waste

VOCs	Food Waste	Mixed Waste	Mean Diff. (95% CI)	t-stats (df)	*p*-value[a]
Benzene	0.5695	0.1561	0.041 (0.030, 0.052)	7.24 (124)	
Toluene	0.4544	0.1594	0.029 (0.029, 0.038)	6.83 (124)	
Ethylbenzene	0.4917	0.0194	0.029 (0.026, 0.038)	6.52 (124)	
m-Xylene	0.3563	0.0172	0.018 (0.012, 0.024)	5.82 (124)	$p<0.05$
Limonene	0.0197	0.0109	0.008 (0.004, 0.012)	4.38 (124)	
Dimethyl disulphide	0.0090	0.0062	0.002 (0.001, 0.004)	3.07 (124)	

Note: [a] indicate Independent T-test test

3.2 The Concentration Level of VOCs Release from Food Waste and Mixed Waste at Different Time

Conversely, in Table 2 shows the result for concentration level of VOCs release from food waste and mixed waste with three different times of collection (9.00am, 1.00pm, 5.00pm). Different time of waste collection was chosen to identify the level of VOCs yield different time. The level of VOCs likely to be slightly higher in the morning at 9.00am. The observed variation might be attributed to the difference in composition of waste as well as the stage of decomposition. As for the weather condition in this study does not take place since the temperature does not have significant difference almost 30˚C to 33˚C.

For this result shows the p-value greater than 0.05. Since there are few study conducted by [4, 15] found that different season does influence the level of VOCs release in their study. Therefore, to apply in Malaysian condition, three working hours' time (9.00am, 1.00pm, 5.00pm) was selected for identifying whether time could be one of the factor. In conclusion, in this study the time of waste collection shows that there is no statistically significant difference to the level of VOCs emitted.

Table 2: Concentration level of VOCs release from food waste and mixed waste with three different time of collection

VOCs	Food Waste			Mixed Waste	
	Time	Mean ± (SD)	*p*-value[a]	Mean ± (SD)	*p*-value[a]
Benzene	9.00 am	0.015 ± 0.012	0.990	0.057 ± 0.046	0.927
	1.00 pm	0.017 ± 0.015		0.058 ± 0.044	
	5.00 pm	0.015 ± 0.013		0.056 ± 0.042	
Toluene	9.00 am	0.015 ± 0.013	0.999	0.045 ± 0.031	0.943
	1.00 pm	0.016 ± 0.015		0.046 ± 0.032	
	5.00 pm	0.016 ± 0.015		0.045 ± 0.032	
Ethylbenzene	9.00 am	0.019 ± 0.014	0.996	0.050 ± 0.034	0.988
	1.00 pm	0.020 ± 0.015		0.049 ± 0.033	
	5.00 pm	0.019 ± 0.015		0.049 ± 0.033	
m-Xylene	9.00 am	0.017 ± 0.013	0.992	0.036 ± 0.021	0.983
	1.00 pm	0.017 ± 0.012		0.035 ± 0.023	
	5.00 pm	0.017 ± 0.012		0.036 ± 0.022	
Limonene	9.00 am	0.011 ± 0.064	0.956	0.020 ± 0.016	0.950
	1.00 pm	0.011 ± 0.060		0.020 ± 0.015	
	5.00 pm	0.010 ± 0.059		0.019 ± 0.013	
Dimethyl disulphide	9.00 am	0.006 ± 0.004	0.982	0.009 ± 0.006	0.990
	1.00 pm	0.006 ± 0.004		0.009 ± 0.006	
	5.00 pm	0.006 ± 0.004		0.009 ± 0.006	

3.3 Health Risk Assessment

Table 3 shows the summary of Cancer Risk (CR), Hazard Quotient (HQ) and Hazard Index (HI) of food waste and mixed waste via inhalation route exposure for 21 days. Based on the outcome of the CR calculated found that the CR for benzene for both food waste and mixed waste are lower than the acceptable range (10^{-6} – 10^{-4}). The non-carcinogenic VOCs in this study were toluene, ethylbenzene, m-xylene, limonene and dimethyl disulphide. The HQ values for food waste follows the following order m-xylene > ethylbenzene > toluene > dimethyl disulphide Meanwhile for mixed waste, the order from m-xylene > ethylbenzene > dimethyl disulphide > toluene.

Limonene was not subjected to HI and HQ calculation as its Reference Inhalation Unit classified as 'Not Applicable'. The HI value for food waste is greater than the value for mixed waste. However, as the result shows that the hazard index (HI = ΣHQs) exceed that value for both type of waste. This shown that there need concern for the potential for non-carcinogenic effects of VOCs towards waste collectors.

Table 3: Summary of cancer risk (CR), hazard quotient (HQ) and hazard index (HI) of food waste and mixed waste via inhalation route exposure

VOCs	CR		HQ		HI		USEPA (2001)
	FW	MW	FW	MW	FW	MW	
Benzene	6.68×10^{-9}	1.90×10^{-9}	NA		NA		Range (10^{-6} – 10^{-4})
Toluene	NA		0.169	0.059	10.40	7.49	HI value > 1
Ethylbenzene			0.998	0.394			
m-Xylene			7.61	3.52			
Limonene			-	-			
Dimethyl Disuphide			0.133	0.077			

4. CONCLUSION

The VOCs selected in this study were all detected in food waste and mixed waste with the mean values ranging from 0.0090 to 0.5695 mg/m^3 and 0.062 to 0.1594 mg/m^3 relevel in food waste while toluene showed a highest reading in mixed waste. Basically, it can be concluded that the VOCs emission was mainly affected by the different composition of waste. Food waste was known for its characteristic which was easily decomposed by microbes to give off various VOCs [16]. In this study, it is clearly in line with this finding as the significant value (p-value < 0.05) by comparing the level of VOCs from these two types of waste. On the other hand, there was no significant difference (p-value > 0.05) when the amount of VOCs released compared for different time of waste collection. Thus it can be concluded different time of waste collection does not affecting the VOCs emission in both type of waste. In this study, it was also notable that the workers were at risk for non-carcinogenic health effect as the Hazard Index (HI> 1) for both food and mixed wastes. Therefore, it is vital to protect the waste collectors from over exposure to the VOCs.

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REFERENCES

[1] Manaf, L. A., *et al*., "Municipal solid waste management in Malaysia: Practices and challenges." *Waste Management*, *29*(11), 2902–2906, 2009.

[2] USEPA., National Emissions Standards for Hazardous Air Pollutants: Municipal Solid Waste Landfills, U.S. Environmental Protection Agency (US EPA)." *Office of Air Quality Planning and Standards, Report* 68/FR/2227, 2003.

[3] Samah, M. A., *et al*, "Real data composition of municipal solid waste (MSW) generated in Balakong, Selangor, Malaysia." *Life Science Journal*, *10*(4), 1687–1694, 2013.

[4] Påledal, S., Hellman, E., & Moestedt, J. "The effect of temperature, storage time and collection method on biomethane potential of source separated household food waste." *Waste Management*, 69, 2017.

[5] USEPA., "Risk assessment guidance for superfund volume I: human health evaluation manual (part F, supplemental guidance for inhalation risk assessment). United States Environmental Protection Agency." *Office of Superfund Remediation and Technology Innovation*, EPA-540-R-070-002, 2009.

[6] Nadal, M., *et al*., "Health risks of the occupational exposure to microbiological and chemical pollutants in a municipal waste organic fraction treatment plant." *International Journal of Hygiene and Environmental Health,* 212(6), 661–669, 2009.

[7] Mustafa, M. F., *et al*., "Volatile compounds emission and health risk assessment during composting of organic fraction of municipal solid waste." *Journal of Hazardous Materials*, 327, 35–43, 2017.

[8] USEPA, "Risk Assessment Guidance for Superfund (RAGS) Volume III - Part A: Process for Conducting Probabilistic Risk Assessment, Appendix B." *Office of Emergency and Remedial Response U.S. Environmental Protection Agency*, *III*(December), 1–385, 2001.

[9] Pierucci, P., *et al*., "Volatile organic compounds produced during the aerobic biological processing of municipal solid waste in a pilot plant." *Chemosphere*, 59, 423–430, 2005.
[10] Statheropoulos, M., Agapiou, A., & Pallis, G. A study of volatile organic compounds evolved in urban waste disposal bins. *Atmospheric Environment*, *39*(26), 4639–4645.,2005.
[11] Fleming-Jones, M. E., & Smith, R. E. "Volatile organic compounds in foods: a five year study." *Journal of Agricultural and Food Chemistry*, *51*(27), 8120–8127, 3003.
[12] Majumdar, D., & Srivastava, A., "Volatile organic compound emissions from municipal solid waste disposal sites: A case study of Mumbai, India." *Journal of the Air & Waste Management Association*, *62*(4), 398–407, 2012.
[13] Duan, Z., *et al.*, "Temporal variation of trace compound emission on the working surface of a landfill in Beijing, China." *Atmospheric Environment*, *88*, 230-238, 2014.
[14] Chiemchaisri, C., Chiemchaisri, W., & Boocha, M. "Emissions of Volatile Organic Compounds from Solid Wastes and Leachate at a Municipal Solid Waste Dumpsite in Thailand. In Water and Wastewater Treatment Technologies."Springer, Singapore, 2019.
[15] Vilavert, L., *et al*., "Volatile organic compounds and bioaerosols in the vicinity of a municipal waste organic fraction treatment plant. Human health risks." *Environmental Science and Pollution Research*, *19*(1), 96–104, 2012.
[16] Kim, K.H., *et al*., "Food decay and offensive odorants: a comparative analysis among three types of food." *Waste Management* , 29, 1265-1273, 2009.