Journal of Agriculture Science & Technology ISSN 1561-7645 JAGST 20 (3) 2021, 102 -108
https://ojs.jkuat.ac.ke/index.php/JAGST/index (15th JKUAT Conference – Special Issue)

ORIGINAL RESEARCH ARTICLE

OCCUPATIONAL EXPOSURE TO FUGITIVE GASES (CO AND H_2S) AND ALTERED OXYGEN LEVELS AMONG WASTE HANDLERS IN SELECTED DUMPSITES IN KENYA

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ABSTRACT
Solid wastes disposal sites provide a livelihood to many waste pickers. Sporadic fires within the dumpsites and waste decomposition lead to the emission of fugitive gases such as carbon monoxide (CO) and Hydrogen Sulphide (H_2S). Increased CO and H_2S in ambient air also reduce oxygen (O_2) gas levels which can cause negative health effects to the dumpsite workers. This study assessed the levels of CO, O_2 and H_2S in selected dumpsites. The sites assessed were in Thika (Kiambu County), Ngong (Kajiado County), and Kawangware (Nairobi County) while control sites for the three dumpsites were located within a radius of 300 metres from the edge of each dumpsite. Levels of CO, O2 and H_2S were determined using a Multi-gas monitor (model GX2012) during working time at the dumpsites and control sites away from the active dumps. Data was entered into SPSS version 20.1 for analysis. The ANOVA and student t-test were done at a 95% confidence interval. The active dumpsite CO gas mean values were 14.5 ±0.42ppm in Thika, 10 ±0.43ppm in Ngong and 14.5 ±0.34ppm in Kawangware, hence were higher compared to control sites (0ppm). The dumpsite H_2S gas levels in Thika and Ngong were both 0.5 ±0.1 ppm, while Kawangware levels were 0.25 ±0.1 ppm. These readings were higher compared to control sites (0.0ppm). The mean dumpsite O_2 levels were 20.53% ±0.08 hence significantly lower than from the control sites (20.90± 0.10%). The study revealed that workers in the three sites were exposed to fluctuating O_2 levels which should not fall below 18% by volume, elevated levels of CO (13.00± 2.60) ppm and H_2S (0.042 ±0.14ppm). These were higher compared to the control sites (0±0.1ppm). This calls for an effective dumpsite gas monitoring and control design to prevent increases beyond regulatory levels.

Key words: Dumpsite, workers, Exposure, O_2, CO, H_2S

1.0 INTRODUCTION
The high rate of urbanization in Kenya has resulted in increased solid and liquid waste generation and management besides other environmental impacts (World Health Organization, 2014). Landfills are options employed by many countries in waste management and disposal although there is no sanitary landfill in Kenya (Panyako, 2016). Clean air for the ever-growing number of residents within the Nairobi Metropolis is being negatively impacted by various sources such as industrial and vehicular emissions, dust generation, increased waste generation, poor waste management and general environmental pollution resulting in negative environmental impacts (Karak et al, 2012) Well managed waste in a city reduces environmental pollution and can be a source of income. Operation of open dumpsites has many adverse effects including emission of hydrogen sulphide (H_2S) and carbon monoxide (CO) gases which are generated by decaying organic waste, pollution of the local environment arising from contamination of groundwater and/or aquifers by leachates (Tampa, 2011). It also injures wildlife through nuisance problems

such as unpleasant smell, excess heat, dust and noise pollution to dumpsite workers, damage of access roads by heavy trucks to the site and harbouring of disease-carrying vectors such as rats and flies (Tsuma et al., 2016)

Almost all the activities in solid waste management involve working in hazardous conditions whose likelihood of causing harm either to the worker directly, to the residents around the dumpsite or the environment is relatively high with substantial consequences. Waste pickers handling solid waste worldwide are exposed to occupational health and safety hazards related to the physical nature of the waste being handled, emissions, working methods employed at the dumpsites and equipment used (Ramos et al., 2013). People living and working in the vicinity of solid waste processing and disposal facilities are also exposed to both environmental, health and safety hazards. These give rise to risks connected to emissions from the decay of organic solid wastes, pollution control measures used to manage these wastes such as open-air burning, and the overall safety of the facility. As with other occupational risks, these risks are better managed in high-income countries but are still largely unmanaged in most developing countries including Kenya (Cointreau, 2006). In Kenya, the poor and needy are increasingly turning to scavenging/waste picking despite the associated socioeconomic impacts and dangers involved. Therefore, this study aimed at assessing and quantifying amounts of CO, O_2 and H_2S in selected dumpsites in Nairobi Metropolis, Kenya.

2.0 MATERIALS AND METHODS

2.1 Study area

The study was undertaken in three dumpsites situated in Kiambu, Kajiado and Nairobi Counties. In Kiambu, it is located in Thika at an area known as Kang'oki, located at 1.0500°S, 37.0833°E. In Kajiado County, it is located in Ngong at 1.3667°S, 36.6333°E while in Nairobi the study was conducted at Kawangware dumpsite which is a waste transfer station located at 1.1656°S, 36.450°E. Fig 1 is the map of Nairobi Metropolitan showing the waste catchment areas.

Fig 1: Map of Nairobi metropolitan showing the study areas

2.2 Study design

The research utilized a cross-sectional study design.

2.3 Measurement of gases

Data on carbon monoxide gas, hydrogen sulphide gas and oxygen was measured using a multi-gas monitor model GX2012 which was calibrated for measuring CO, H_2S and O_2 with an accuracy level of ± 5%, ± 5% and ±-0.5% respectively.

The dumpsites were divided into 4 quadrants and in each, measurements were taken at random in each quadrant within a height of 2 meters from the ground. These measurements were taken in triplicates from every quadrat twice a week during working hours within a month. Control sites about 250 meters away from the edge of dumpsites were also subjected to these measurements. The control sites did not have the characteristics of a dumpsite and waste pickers were not present in those sites.

2.4 Data processing and analysis

Data was recorded in field notebooks and transferred to an MS Excel spreadsheet on a computer. Before analysis, the data was cleaned, checked for discrepancies and missing values before transferring to Statistical Package for Social Scientists (SPSS) version 21.0 for analysis. Statistical analysis done included measurement of dispersion and central tendency like mean and standard deviations. The following gases; CO, H_2S and O_2 were analyzed using ANOVA to determine their association in the dumpsites while a student t-test was used to determine the association of gases in different dumpsites. The level of significance was considered at a 95% (0.05) confidence interval.

3.0 RESULTS

3.1. Levels of CO, H_2S and O_2 in the dumpsites

3.1.1 Oxygen Levels

The CO and H_2S are end-products of the decomposition of biodegradable wastes and are legally considered to be waste products while and O_2 is utilized during aerobic decomposition. The results (Table 1) reveal that O_2 levels in Thika dumpsite was 20.53 ±0.21%, 20.6± 0.23 % in Ngong dumpsite and 20.45 ±0.15% in Kawangware dumpsite while control sites recorded 21.00%, 20.90% and 20.8% in Thika, Ngong and Kawangware, respectively with ±0.1 standard deviations.

3.1.2 CO Levels

The CO levels were 14.5 ±0.42 ppm in Thika dumpsite, 10 ±0.43 ppm in Ngong dumpsite and 14.5 ±0.34 ppm in Kawangware dumpsite (Table 1).

3.1.3 H2S Levels

The levels of H_2S gas in both Thika and Ngong dumpsites were 0.5±0.1 ppm, while Kawangware dumpsite recorded 0.25±0.1ppm (Table 1).

Table 1: Levels of O_2, CO, & H_2S in the dumpsites

Study site	O_2%			CO ppm			H_2S ppm		
	Mean/n±	Range		Mean/n	Range		Mean/n	Range	
Thika	20.53±0.21	20.32	20.74	14.5±0.42	14.08	14.92	0.5±0.1	0.6	0.4
Ngong	20.60±0.23	20.37	20.83	10.0±0.43	9.57	10.43	0.5±0.1	0.6	0.4
Kawangware	20.45±0.15	20.3	20.6	14.5±0.34	14.16	14.84	0.25±0.1	0.15	0.35
Control									
Thika	21.00±0.1	21.10	20.90	0±0.1	-0.1	0.1	0±0.1	-0.1	0.1
Ngong	20.90±0.1	20.80	21.00	0±0.1	-0.1	0.1	0±0.1	-0.1	0.1
Kawangware	20.80±0.1	20.70	20.90	0±0.1	-0.1	0.1	0±0.1	-0.1	0.1

Key: ppm-parts per million, O_2-oxygen, CO-carbon monoxide, H_2S- hydrogen sulfide, R-range, n-average/mean, ±-plus or minus

3.1.4 Statistical analysis of H2S, O2 and CO levels in the dumpsites

The inferential statistics using student t-test are presented in Table 2. The mean O_2 levels at the control sites (M± = 20.90% ± 0.10) was significantly higher than those at the dumpsites (M± = 20.53%, ± 0.08). The probability (Sig. = 0.72) for F = 0.14 is greater than 0.05, the variance of the mean O_2 percentage levels between the dumps and control sites were equal. Therefore, there was a statistically significant difference between mean O_2 levels in the dumpsites and control sites, t (4) = -5.17, p = 0.01 in this study.

The mean CO gas was significantly higher at the dumpsites (M± = 13.00 ppm, ± 2.60) than at the control sites (M± = 0.00 ppm, ± 0.00). The probability (Sig. = 0.02) for F = 16.00 was less than 0.05, the variance of the mean CO between the dumping and control sites were not equal. Therefore there was a statistically significant mean difference of CO between dumping and control sites, t (2) = 8.67, p = 0.01. In the case of the current study, there were significant variations between the dumpsite mean carbon monoxide and the control sites.

The mean H_2S was significantly high at the dumping sites (M±= 0.042 ppm, ± 0.14) compared to control sites (M± = 0.00 ppm, ± 0.00). Since the probability (Sig. = 0.02) for F = 16.00 was less than 0.05, the variance of the mean H_2S between the dumping and control sites were not equal. Thus there was a statistical significant mean difference of H_2S between dumping and control sites, t (2) = 5.00, p = 0.04.

Table 2: Statistical analysis of H_2S, O_2 and CO levels in the dumpsites

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% CI of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	SE Difference	L	U
Mean O_2 (%)	EVA	0.14	0.72	-5.17	4.00	0.01	-0.37	0.07	-0.57	-0.17
	EVNA			-5.17	3.71	0.01	-0.37	0.07	-0.58	-0.17
Mean CO (ppm)	EVA	16.0	0.02	8.67	4.00	0.00	13.00	1.50	8.84	17.16
	EVNA			8.67	2.00	0.01	13.00	1.50	6.55	19.45
Mean H_2S (ppm)	EVA	16.0	0.02	5.00	4.00	0.01	0.42	0.08	0.19	0.65
	EVNA			5.00	2.00	0.04	0.42	0.08	0.06	0.78

Key: *EVA- Equal variances assumed, EVNA- Equal variances not assumed, SE- Std. Error, df-degree of freedom, O_2-Oxygen, H_2S-Hydrogen sulphide, CO-Carbon monoxide, L-lower bound, U-upper bound, t- 2tailed test, F-f test, CI-Confidence interval*

Table 3 shows an analysis of variance of H_2S, CO and O_2. The one-way analysis of variance (ANOVA) revealed that the $F(2, 3) = 0.111$, $p = 0.90$ hence there was no significant difference in the mean H_2S among Kawangware, Thika and Ngong' dumping sites. The O_2 analysis showed that the $F(2, 3) = 0.164$, $p = 0.86$ hence there was no significant difference in the mean O_2 levels among Kawangware, Thika and Ngong' dumping sites.
The results for CO were $F(2, 3) = 0.039$, $p = 0.96$ therefore there was no significant difference in the mean CO among Kawangware, Thika and Ngong' dumping sites. This can be explained by the fact that all are dumpsites had received similar waste and activities that took place within the dumpsites were almost similar in nature such as waste burning that releases smoke.

Table 3: Analysis of variance of H_2S, O_2 and CO measurements in the dumpsites

Parameters		Sum of squares	df	Mean Square	F	Sig.
Mean O_2 (%)	Between Groups	0.02	2	0.01	0.164	0.86
	Within Groups	0.22	3	0.07		
	Total	0.24	5			
Mean CO (ppm)	Between Groups	6.75	2	3.38	0.039	0.96
	Within Groups	260.25	3	86.75		
	Total	267.00	5			
Mean H_2S (ppm)	Between Groups	0.02	2	0.01	0.111	0.90
	Within Groups	0.28	3	0.09		
	Total	0.30	5			

Key: *%-percentage, df-degree of freedom, Sig-level of significance (p-value), F-f test, ppm-parts per million*.

4.0 Discussion

The marginal difference of gases among and within the sites can be linked to the relative difference in the observed irregular fires. The O_2 levels in the three dumpsites were lower as compared to control sites. The Occupational Safety and Health Act, 2007 recommends monitoring the O_2 content of the ambient air to ensure the safety of workers (OSHA, 2007). However this was not done within the dumpsites. The O_2 levels in a work environment should not fall below 18% by volume under normal atmospheric pressure. This would generally cater for a combination of all gases polluting the environment. In this study, sporadic fires within the dumpsites can be attributed to varying O_2 levels in the ambient air compared to control sites. There were several smouldering fires in all the dumpsites which were not present in the control sites. When oxygen is adequate, open combustion produces carbon dioxide while carbon monoxide is produced when oxygen is inadequate during combustion.

All the sites recorded higher CO levels compared to control sites which were 0ppm. The incomplete combustion of waste at the dumpsites gave rise to dark smoke with an unpleasant smell emanating from non-flaming fires in the studied dumpsites. A large amount of trash deemed unrecoverable was burnt making O_2 inadequate and producing smoke accompanied by a foul smell. However, CO within the study sites was below the set limits of 50ppm for an 8-hour shift according to factories and other places of work or Hazardous Substances rules of 2007 hence was deemed safe for dumpsite workers in this study. This does not concur with a study done by Rim-Rukeh that recorded the presence of CO ranging between 133.7 - 141.6 ppm being above regulatory limits at the dumpsites in Nigeria attributed to dumpsite fires (Rim-Rukeh, 2014). Another study conducted in Metropolitan Manila by Cointreau showed that carbon monoxide averaged at $55mg/M^3$ which is five times higher than the WHO 10-hour standard (Cointreau, 2006)

There were no observable large amounts of decomposing organic materials in the control sites and this explains the lack of detectable H_2S gas. The H_2S gas in this study was below the occupational exposure limit (OEL) of <10ppm (World Health Organization, 2014) for an 8-hour shift hence the levels in the dumpsites was safe. In a similar study in Kenya, respondents indicated that the health issues of concern in the dumpsites varied by activity (Mugo et al., 2015). According to another study, exposure to H_2S within 2.0 -7.0 ppm levels may cause nausea, tearing of the eyes, headaches, loss of sleep and airway problems (Li et al., 2012). The population identified as vulnerable to dumpsites gases include; workers at the dumpsites, residents around the dumpsite, animals seen grazing and dogs roaming about the dumpsites, and largely, the entire environment. In general, dumpsites cause groundwater contamination through leaching and air pollution through emissions and smoke thereby posing significant risks to the environment and its inhabitants. Clean air is essential to maintaining a delicate balance of life on this planet not just for humans, but wildlife, vegetation, water and soil. Workers working in the selected dumpsites were exposed to different hazards and gases as discussed earlier although all the gasses were within the OEL (OSHA, 2007)

The study revealed that CO and H_2S within the dumpsites were higher compared to the control sites ($p \leq 0.05$). However, these parameters were below the occupational exposure limits according to different established occupational safety and health standards. These gasses and noxious matter discharged remains a nuisance to the workers and the environment albeit being within the occupational accepted exposure limits.

5.0 RECOMMENDATIONS

The presence of these gases in the dumpsites calls for an effective dumpsite gas monitoring and control design to prevent increases beyond regulatory levels therefore protecting dumpsite workers. Air quality monitoring is important because many dumpsites are located near residential areas hence continue posing serious problems to health and the environment.

6.0 ACKNOWLEDGMENTS

The authors acknowledge the waste handlers and county officials for allowing us to conduct the study in the dumpsites. We are also grateful to the JICA BRIGHT project for providing gas monitoring equipment.

7.0 REFERENCES

Cointreau, S. (2006). Occupational and Environmental Health Issues of Solid Waste Management, World Bank, Washington, DC, USA.

GoK, (2010). The Constitution of Kenya 2010. The government of Kenya constitution. Nairobi: Government Printers

Karak, T., Bhagat, R. M., & Bhattacharyya, P. (2012). Municipal solid waste generation, composition, and management: the world scenario. Critical Reviews in Environmental Science and Technology, 42(15), 1509-1630.

Li, X., Wang, Y., Lei, Y., & Gu, Z. (2012). Highly sensitive H 2 S sensor based on template-synthesized CuO nanowires. Rsc Advances, 2(6), 2302-2307.

Mugo, K.K, Gichanga, J.M, Gatebe, E. and Njogu P.M. (2015). Assessment of the Safety and Health Hazards in Existing Dumpsites in Kenya. *Sustainable Research and Innovation* (SRI) Conference; 6 - 8 May,

OSHA, (2007) Occupational Safety and Health Act of year 2007. The government printer Nairobi.

Panyako, T. J. (2016). Quantification of Methane and Heavy Metals Levels in Leachate. A Case Study of Dandora Dumpsite, Nairobi, Kenya (Doctoral dissertation, University of Nairobi).

Ramos, N. F., A. B. De Castilhos, F. A. Forcellini, and Graciolli, O. D. (2013). "Profile study of waste pickers in Brazil: requirements for the development of a collection vehicle and optimized routing," Journal of Urban and Environmental Engineering, vol. 7(2): 231–246.

Rim-Rukeh, A. (2014) An Assessment of the Contribution of Municipal Solid Waste Dump Sites Fire to Atmospheric Pollution. Open Journal of Air Pollution, 3, 53-60

Tampa, T. (2011). Five years on east Pasco landfill proposal still in dispute. New York Washington DC.

Tsuma, J. P. E., Wandiga, S. O., & Abong'o, D. A. (2016). Methane and heavy metals Levels from leachates at Dandora dumpsite, Nairobi County, Kenya. Journal of Applied Chemistry, 9(9): 39-46

World Health Organization. (2014). Public health and environment in the African region: report on the work of WHO, 2012-2013.