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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

***Background**:Solid wastes disposal sites provide a livelihood to thousands of waste handlers and waste scavengers. Sporadic fires within the dumpsites and wastes decomposition lead to emission of fugitive gases such ascarbon monoxide (CO) and Hydrogen sulphide (H_2S); resulting to deleterious health effects to the exposed workers.Increased CO and H_2S in ambient air also displace oxygen (O_2) gas levels which in extreme cases can lead to asphyxiation. This study assessed the levels ofCO, O_2 and H_2S in selected dumpsites in Kenya.*

***Materials and Methods**: The study sites were inThika, Ngong, and Kawangware in Kenya. Levels of CO, O_2 and H_2S were determined using a Multi gas monitor (model GX2012) during working hours at the dumpsites and control sites away from active dump.Analysis of variance was used to analyze the different parameters in the dumpsites. Association between different dumpsites and parameters were tested using student t-test at 95% confidence interval.*

***Results**: The O_2 mean values in Thika dumpsite was 20.53% ±0.21, 20.6% ±0.23 in Ngong and 20.45% ±0.15in Kawangware.Thesewere relatively lower compared to control sites.In thesestudy control sites, O_2 levels were 21.00% in Thika, 20.90% in Ngong and 20.8% in Kawangware with a standard deviation of ±0.1. Thedumpsite CO gas mean values were 14.5 ±0.42ppm in Thika, 10±0.43ppm in Ngong and 14.5 ±0.34ppm in Kawangware. These were established to be higher compared to control sites (0ppm). The dumpsite H_2S gas levels in Thika and Ngongwereboth 0.25 ±0.1ppm, while Kawangwarelevels were 0.5 ±0.1ppm. These readings werehigher compared to control sites (0.0ppm). The study revealed thatworkers in the three sites were exposed to elevated levels of CO (13.00±2.60) ppmandH_2S (0.042 ±0.14ppm). These were higher compared to the control sites (0±0.1ppm).*

***Conclusion:**Exposure to elevated levels of H_2S and CO cause nausea, tearing of the eyes, headaches, loss of sleep and airway problems.The mean O_2 levels was 20.53% ±0.08; significantly different from control sites (20.90± 0.10%). Workers were exposed to fluctuating O_2 levels, however,they were within safe occupational exposure limits for an 8 hour shift.There was significance difference between the dumpsites and control sites ($p \leq 0.05$) on the levels of O_2, CO and H_2S. This calls for an effective dumpsite gas monitoring and control design in order to prevent increase to elevated levels.*

***Key words:**Dumpsite, workers, environment, Exposure limits, O_2, CO, H_2S*

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I. Introduction

High rate of urbanization in Kenya has resulted in increased solid and liquid waste generation and management besides other environmental impacts [1]. Landfills are options employed by many countries in waste management and disposal however there is no sanitarylandfill in Kenya[2].Clean air for the ever growing number of residents in the city of Nairobi and its environsis scarce due to increased waste generation coupled by its poor management which results to negative environmental impacts[3]. 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 of organic wastes, pollution of the local environment arising from contamination of ground water and/or aquifers by leakage and residual soil[4]. It also causes injuries to wild life; simple nuisance problems such as odours, excess heat, dust, noise pollution to dumpsite workers; damage of access roads by heavy trucks to the site and harbouring of disease vectors such as rats and flies[5].

Almost all the activities in solid waste management involve working with significant hazards whose likelihood of causing harm either to the worker directly involved, to the nearby resident 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 from the content, working methods being employed at the dumpsites and the equipment being used [6]. People living and working in the vicinity of solid waste processing and disposal facilities also are exposed to both environmental and health and safety hazards. These give rise toriskssconnected to emissions from the decay of organic solid wastes, pollution control measures used to manage these emissions such as open air burning, and the overall safety of the facility. As with other occupational risks, these risks are being managed considerably in high-income countries but are still largely unmanaged in most developing countries including Kenya [7]. In Kenya, the poor and needy are increasingly turning to scavenging/waste picking despite the associated socioeconomic impact 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.

II. Materials And Methods

Study Area

The study was undertaken in three dumpsites situated inKiambu, 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 Kawangwaredumpsite 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

Study design

The research utilized a cross-sectional study design where data is collected in a point in time without follow-ups.

Measurement of gases

Data collection methods included the use of 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 quadrats 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.

Data processing and analysis

Data was recorded in field notebooks and transferred to Excel spread sheet in 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. Among the measures that was analyzed include measures of dispersion and central tendency like mean, standard deviations. Analysis of variance (ANOVA) was used to analyze the data from different parameters in the dumpsite such as CO, H_2S and O_2. Association between different dumpsites and parameters were tested using student t-test. The level of significance was considered at 95% (0.05) confidence interval.

III. Results And Discussions

Levels of CO, H_2S and O_2in the dumpsites

Oxygen Levels

The CO, H_2S and $O_2$are end-products of the decomposition of biodegradable wastes and legally considered to be waste products. 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. The marginal difference among 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 OSHA[8] recommends monitoring the O_2 content of the air to ensure safety of workers. 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 varyingO_2levels in the ambient air compared to control sites. There were several smoldering fires in all the dumpsites which were not present in the control sites. When oxygenis adequate, open combustion produces carbon dioxide while carbon monoxide is produced when oxygen is inadequate during combustion.

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). The difference among the dumpsites is linked to the intensity of the sporadic fires within the dumpsites. 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 unpleasant smell emanating from non-flaming fires in the studied dumpsites. Large amount of trash deemed unrecoverable was burnt making O_2 inadequate and producing smoke accompanied by foul smell. However, the CO within the study sites was below the set limits of 50ppm for an 8 hr shift according to factories and other places of work (Hazardous Substances) rules, 2007 hence was deemed safe for dumpsite workers. This does not concur with a study done by Rim-Rukeh, [9]that recorded presence of COranging between 133.7 - 141.6 ppm being above regulatorylimits at the dumpsites in Nigeria attributed to dumpsite fires. Another study conducted in Metropolitan Manila by Cointreau, [7]showed that Carbon monoxide averaged at 55mg/M^3which is five times higher than the WHO 10-hour standard. Mulei*et al.*,[10]observed that, average CO_2 concentration of green building vared between 507 ppm to 564ppm with a mean 534ppm and standard deviation of 22.7 which were very high compared to theCO levels in the current study. The current study did not measure the Co_2 levels, it measured CO levels instead.

H_2S Levels

The levels of H_2S gas in both Thika and Ngong dumpsites were 0.25±0.1 ppm, while Kawangware dumpsite recorded 0.5±0.1ppm (Table 1). Decomposing organic materials and chemicals was also responsible for the foul rotten egg smell in the dumpsites which is a characteristic of H_2S gas.Higher concentration in Kawangware can be explained by the fact that the site being in an urban location, the quality of air is also impacted by other nearby market activities while the other sites were located in a more open space with less buildings and activities nearby compared to Kawangware site. This allows for quicker and cleaner aeration of the sites that in turn slows down the anaerobic decomposition of organic wastes producing less H_2S. 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 [1]for 8 hour shift hence the levels in the dumpsites was safe. In a similar study in Kenya by Mugo*et al.*,[11](2015), respondents indicated that the health issues of concern in the dumpsites varied by activity. Exposure to airborne hazards were identified as major issues by several operators. There was observed random fires and nuisance due to nauseating pungent odor. In the current study, the same factors were exposed to the participants hence were at risk to similar health issues as observed by Mulei*et al.*,[10] in another similar study. Irungu, [12]while investigating the exposure to H_2S concentration to workers in Olkaria geothermal power plants, found that in most occurrences (> 80%), the measurements of H_2S gas ranged between 0.1-1.0ppm hence is comparable to measurement of this study although the site activities cannot be compared. He also indicated that, 3.83 % of the respondents had reported cases of headaches due to H_2S gas exposurethough the same question was not asked the participants in the current study.

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

Study site	O_2%			COppm			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	0.25±0.1	0.15	0.35
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	20.0	20.1	0±0.1	-0.1	0.1	0±0.1	-0.1	0.1
Ngong	20.90±0.1	20.8	21.0	0±0.1	-0.1	0.1	0±0.1	-0.1	0.1
Kawangware	20.80±0.1	20.7	20.9	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

According to Li *et al*., [13]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. The population identified as vulnerable to these 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 therefore posing significant risks on the environment and its inhabitants. Clean air is essential to maintaining delicate balance of life on this planet not just for humans, but wildlife, vegetation, water and soil.

Statistical analysis of H_2S, $O_2$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 that at the dump sites (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 statistical significance 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 statistical significance mean difference of CO between dumping and control sites, t (2) = 8.67, p = 0.01. Mulei*et al.*,[10], in a similar study observed that performing t-test for carbon dioxide across the buildings indicate a significant variation between green buildings and non-green buildings. 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 statistical significance 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 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 significance difference in the mean H_2S amongKawangware, Thika and Ngong' dumping sites. The O_2 analysis showed that the F (2, 3) = 0.164, p = 0.86 hence there was no significance difference in the mean O_2 levels amongKawangware, Thika and Ngong' dumping sites. The results for CO were F (2, 3) = 0.039, p = 0.96 therefore there was no significance difference in the mean CO between Kawangware, Thika and Ngong' dumping sites.This can be explained by the fact that all are dumpsites receive similar waste and activities that take place within the dumpsites are 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,

Staff working in the selected dumpsites were exposed to different hazards and gases as discussed earlier although all the gasses were within the OEL [8]. There is a prohibition under the Public Health Act Cap 242 section 115 against causing nuisance or condition injurious or dangerous to human health. Such nuisance or conditions are defined under section 188 as wastes, sewers, drains or refuse pits in such a state, situated or constructed as in the opinion of the medical officer of health to be offensive or injurious to health. Noxious matter discharged from any premises into a public space is also deemed as a nuisance. Management of OSH so as to protect the staff and public is a responsibility of the organization involved and has legal consequences[14].

IV. Conclusion And Recommendations

The study revealed that CO, and H_2S within the dumpsites were higher compared to the control sites. There was statistical significance difference between the dumpsites and control sites (p≤0.05) on the levels of O_2, CO and H_2S levels in this study. 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 albeitbeing within the occupational accepted exposure limits.

The presence of these gases in the dumpsites calls for an effective dumpsite gas monitoring and control design in order to prevent increase to elevated levels thus protecting dump workers.This is important because many dumpsites are located near residential areas hence continue posing serious problems with regard to waste generation and waste disposal. The continued use of the dumpsites will also continue to pose a risk to air quality, therefore engineered dumpsite systems located on geologically impermeable soils is recommended.

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