Assessment of Landfill-emitted Gaseous Pollutants and Particulate Matters in Alimosho Local Government of Lagos state, Nigeria

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Abstract

Information on landfill-emitted pollutants in Nigeria cities has consequently become a priority. This study was designed to assess the air quality of landfill sites and the nearby communities in the Alimosho Local Government Area of Lagos state, Nigeria. Five public landfills in use since about thirty years ago were chosen for this study. A lightly populated area, free from other sources of air pollution served as control. Target points for the study were the centre of landfill (CLF), 50M from CLF, 100M from CLF, and a radius of 100M away from landfill. Levels of selected gaseous pollutants (NO_2, O_3, H_2S and CO) and particulate matters (PM2.5 and PM10) were determined in the landfill environments and control (unpolluted area), using

Aeroqual Series 500 with sensors for NO_2, O_3, H_2S, CO, PM2.5 and PM10. The result showed that levels of H_2S were significantly ($p<0.001$) higher at the CLF, 50M from CLF and 100M from CLF compared with unpolluted area. There was no significant ($p>0.05$) difference when the level of H_2S in 100M radius was compared with the unpolluted area. Levels of CO were significantly ($p<0.001$) higher at the CLF, 50M from CLF, 100M from CLF and 100M radius compared with unpolluted area. The levels of O_3 were significantly ($p<0.001$) higher at the CLF, 50M from CLF, 100M from CLF and 100M radius compared with unpolluted area. Levels of VOC were significantly ($p<0.001$) higher at the CLF, 50M from CLF, 100M from CLF and 100M radius compared with unpolluted area. The levels of NO_2 were significantly ($p<0.001$) higher at the CLF, 50M from CLF, 100M from CLF and 100M radius compared with the unpolluted area. The levels of PM2.5 increased significantly ($p<0.001$) at the CLF, 50M from CLF, 100M from CLF and 100M radius compared with the unpolluted area. The levels of PM10 were also significantly ($p< 0.001$) higher at the CLF, 50M from CLF, 100M from CLF and 100M radius compared with the unpolluted area. In conclusion, communities close to landfills may be polluted with toxic gases and particulate matters. Further investigation is needed to validate the safe distance of residential areas from landfills to avert the risks of toxicity associated with gaseous pollutants.

Keywords: Landfill, emitted pollutants, dispersion, environment.

Introduction

Landfilling is the most common waste management practice in Nigeria and many other developing countries. The landfills are unwillingly converted to markets, restaurants, shopping malls and motor parks. Available reports show that biodegradation of the landfill particles contribute to the biogenic emissions of pollutants into the environment through combustion and physicochemical changes (Ajao, 2002). Nag et al (2016) reported that landfills emit high levels of greenhouse gases such as nitrogen oxide during the biodegradation of solid waste or combustion of nitrogen-containing solid waste during the microbial process of nitrification and de-nitrification. Gases including non-methanic volatile organic compounds, polychlorinated dibenzo-p-dioxins, dibenzofurans, dioxin-like polychlorobiphenyls, polycyclic aromatic hydrocarbons, benzene and vinyl chloride monomer and odor emitted by the landfills are produced through microbial anaerobic *digestion* (Palmiotto et al, 2014; *Powell et al, 2015*). However, the biogenic hydrocarbons are actively involved in the chemistry of the atmosphere. Once certain chemicals enter the stratosphere, reactions catalyzed by ultraviolet radiation convert them into highly reactive species including sulfur dioxide

(SO_2), hydrogen sulphide (H_2S), carbon monoxide (CO_2), ozone (O_3) and oxides of nitrogen that can have a devastating effect on stratospheric ozone (Kumar, 2008). For example, O_3 production is enhanced when sunlight strikes a mixture of hydrocarbons to yield varieties of hydrocarbons and their oxidation products. The oxidation products including NO_2 and O_3 are built in the mixture (Blacet, 1952). Each time this cycle of reactions occurs, a molecule of NO is oxidized to NO_2; and O_3 is increased through the subsequent photolysis of NO_2. Anderson (2010) also reported that photochemical O_3 and smog are created by nitrogen oxides and hydrocarbons as they react in sunlight. Reactions of nitrous oxides and volatile organic compounds in the atmosphere aided by sunlight, combustion of fossil fuels and emissions from motor vehicles and stationary sources can lead to the production of O_3 and other gaseous pollutants. The nature of O_3 allows it to be transported by wind hence O_3 can be found hundreds kilometers from their origins. These emitted gases and particles have potentials to pollute the immediate natural environment, and spread to nearby communities. The consequent adverse environmental changes could be more in highly populated communities without proper waste management. Varied concentrations of gaseous pollutants (SO_2, NO_2 and NH_3) at weekdays and weekends have been reported along a populated urban region of Kolkata (Karar et al., 2016). Palaniswamy et al. (1995) reported that the gaseous pollutants could affect development and growth of crop plants. Multiple exposures to such high levels of gases have been associated with upper respiratory track irritation, disruption of oxygen transport, and finally central nervous system disorders (Jumpponen et al, 2013). Numata et al. (2008) also reported lower body weight in landfill birds, In a study conducted by Richard et al. (2009), several organic pollutants were reported in pregnant females.

Particulate matters (PM) originate from many anthropogenic and natural sources that form secondary inorganic and organic particles with variable physical, chemical, and morphological characteristics. Previous study by Kroll et al. (2013) reveals that the components of PM include chloride, nitrate, ammonium, sulfate, 68 chemical elements and endotoxins. These PM may elicit various effects and thus, may affect the degree of pro-inflammatory response and oxidative potential due to exposure. The mean concentrations of metals in the PM10 in Dhanbad region at Jharkand, India were found in the order of Fe>Cu>Zn>Mn>Cr>Cd>Pb>Ni (Dubey *et al,* 2012). The consequences of exposure to these particulate matters range from infant mortality to respiratory, cardiovascular and mental disorders. Previous studies confirmed that an increase in PM2.5 results in an increased risk of hospitalization for myocardial infarction, heart failure, cardiac arrest and inflammatory responses (Higgins et al. 2010; Huttunen et al. 2012). With regard to non-fatal outcomes, the risk of myocardial infarction has been estimated to be 1.48 times greater for a small increase in particulate air pollution (25μg/m3 in the preceding two hours). This study was designed to determine the air quality of the landfill and a radius of 100M distance from the landfills to predict the predisposition of the communities to pollutants.

Materials and Methods:

Materials:

Five landfills in Alimosho Local Government Area of Lagos state, Nigeria were chosen for this study. The local government is a densely populated area where commercial and government waste collectors use the landfills regularly. The landsfills, each occupying an area of about two kilometer square contained organic, inorganic, condemned electronics etc; and had being in use since almost thirty years ago. Wind from Atlantic Ocean drives the potential pollutants toward the residential areas. A serene lightly populated area with less commercial activities, about fifteen kilometers away from the landfill areas served as a control for this study. This control community did not have landfill or manufacturing industry that could cause pollution. Target points for the study were the centre of landfill (CLF), 50M from CLF, 100M from CLF and a radius of 100M away from landfill.

Methods:

Levels of gaseous pollutants and particulate matters were measured in all the landfill areas and unpolluted area (control) by using Aeroqual Series 500 with sensors for NO_2, O_3, H_2S, CO, PM2.5 and PM10 as recommended by the manufacturer.

Statistical analysis:

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) for windows, version 21. The data were expressed as Mean±SD. Student (t) test was used for the comparison of gaseous pollutants and particulate matters in landfills and control. The changes were considered significant, when p-values were less than 0.05.

Results:

As demonstrated in Table 1, there were significant ($p<0.05$) differences observed in the distributions of landfill-emitted pollutants. The levels of pollutants varied with the distance from the center of the landfills (Table 2). H_2S were significantly ($p<0.001$) higher at the CLF, 50M from CLF and 100M from CLF compared with unpolluted area. There was no significant ($p>0.05$) difference when the level of H_2S in unpolluted area was compared with 100M away from the landfill. Levels of CO were significantly ($p<0.001$) higher at the CLF, 50M from CLF, 100M from CLF and 100M away from the landfill compared with unpolluted area. The levels of O_3 were significantly ($p< 0.001$) higher at the CLF, 50M from CLF, 100M from CLF and 100M away from the landfill compared with unpolluted area. Levels of VOC were significantly ($p<0.001$) higher at the CLF, 50M from CLF, 100M from CLF and 100M away from the landfill compared with unpolluted area. NO_2 levels were significantly ($p<0.001$) higher at the CLF, 50M from CLF, 100M from CLF and 100M away from the landfill compared with unpolluted area. Table 3 shows that levels of PM2.5 increased significantly ($p<0.001$) at the CLF, 50M from CLF, 100M from CLF and 100M away from the landfill compared with unpolluted area. Levels of PM10 were also significantly ($p< 0.001$) higher at the CLF, 50M from CLF, 100M from CLF and 100M away from the landfill compared with unpolluted area.

Table 1: Levels of Gaseous Pollutants and Particulate Matter in Land Fill Areas and Controls

Pollutants	Center of landfill (CLF)	50M from CLF	100M from CLF	100M away from landfill	Unpolluted area (control)	F-Test	p-values
PM 2.5 (μg/m3)	57.9 ± 11.4	47.6 ± 12.6	35.2 ± 7.3	30.5 ± 7.0	13.1 ± 1.0	15.9	<0.001*
PM 10 (μg/m3)	122.0 ± 16.4	92.8 ± 15.2	74.0 ± 8.1	56.2 ± 12.9	34.6 ± 4.0	33.1	<0.001*
H_2S (ppb)	8.1 ± 1.1	6.5 ± 1.0	5.4 ± 0.5	4.7 ± 0.7	3.7 ± 0.5	20.9	<0.001*
CO (ppb)	1029.6 ± 30.9	990.8 ± 60.4	942.8 ± 6.25	880.0 ± 76.5	287.5 ± 34.0	122.7	<0.001*
O_3 (ppb)	136.6 ± 10.0	112.4 ± 18.2	93.0 ± 14.0	77.8 ± 12.5	44.8 ± 4.3	32.4	<0.001*
VOC (ppb)	220.0 ± 53.9	168.0 ± 23.9	148.0 ± 25.4	122.6 ± 25.6	47.8 ± 2.1	17.7	<0.001*
NO_2 (ppb)	150.0 ± 22.4	111.2 ± 30.5	93.6 ± 31.4	81.0 ± 28.3	8.6 ± 1.4	17.4	<0.001*

* = P<0.05 (significantly different from controls).

Table 2: Distribution of Gaseous Pollutants in Landfill Areas and Controls

Gaseous pollutants	H_2S (ppb)	CO (ppb)	O_3 (ppb)	VOC (ppb)	NO_2 (ppb)
Unpolluted area (control)	3.7 ± 0.5	287.5±34.0	44.8 ± 4.3	47.8 ± 2.1	8.6 ± 1.4
Center of land fill (CLF)	8.1 ± 1.1	1029.6±30.9	136.6±10.0	220.0±53.9	150.0±22.4
50M from CLF	6.5 ± 1.0	990.8 ± 60.4	112.4±18.2	168.0±23.9	111.2±30.5
100M from CLF	5.4 ± 0.5	942.8 ± 6.25	93.0 ± 14.0	148.0±25.4	93.6 ± 31.4
100M away from landfill	4.7 ± 0.7	880.0 ± 76.5	77.8 ± 12.5	122.6±25.6	81.0 ± 28.3
Pa	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*
Pb	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*
Pc	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*
Pd	>0.05	< 0.001*	< 0.001*	< 0.001*	< 0.001*

Pa= level of difference between values at CLF and control.
Pb= level of difference between values at 50M from CLF and control.
Pc= level of difference between values at 100M from CLF and control.
Pd= level of difference between values at 100M away from landfill and control.
* = P<0.05 (significantly different from controls).

Table 3: Distribution of Particulate Matters in Land Fill Areas and Controls

Particulate matters (PM)	Unpolluted area (control)	Center of landfill (CLF)	50M from CLF	100M from CLF	100M from landfill	pa	pb	pc	pd
PM2.5 (μg/m3)	13.1 ± 1.0	57.9±11.4	47.6±12.6	35.2±7.3	30.5±7.0	< 0.001*	< 0.001*	< 0.001*	< 0.001*
PM10 (μg/m3)	34.6 ± 4.0	122.0±16.4	92.8±15.2	74.0±8.1	56.2±12.9	< 0.001*	< 0.001*	< 0.001*	< 0.001*

Pa= level of difference between values at CLF and control.
Pb= level of difference between values at 50M from CLF and control.
Pc= level of difference between values at 100M from CLF and control.
Pd= level of difference between values at 100M away from landfill and control.
*P<0.05= significantly different from control.

Discussion:

Owing to increasing industrialization and increasing urbanization in many developing countries, proper waste management remains a major concern currently. The health implications of this growing problem is poorly recognized and investigated. This study consequently addresses this environmental challenge in one of the densely populated cities in Nigeria. The elevated levels of gaseous pollutants and particulate matters observed in this study confirmed the hypothesis that landfills emit pollutants into the nearby communities. Higher levels of NO_2 and CO were earlier reported in a densely populated area of Port Harcourt, Nigeria. Our findings therefore corroborate that of Paraskaki et al (2005) where concentrations of several landfill-emitted pollutants were significantly higher than the World Health Organization reference lifetime exposure health criteria. Significantly higher levels of H_2S, CO, O_3, VOC and NO_2 observed in this study could be due to decomposition of organic matters, oxidation and several other reactions favored by the environmental conditions of the landfill sites. Occasional burning of waste containing electric utilities in the dumping sites at very high temperatures could also contribute to significantly higher levels of NO_2 in the landfills. Also, the NO_2 could be a product of landfill-emitted N_2O (Jia et al, 2014).

Except H_2S, all other gaseous pollutants (NO_2, VOC, CO and O_3) showed significantly higher levels in nearby communities 100M away from the landfills. This could be due to high levels of emission and ability of the wind to transport the gases. Previous studies show that levels of pollutants beyond the WHO permissive limits have pathological effects. Halliwell et al (1999) stressed that excess intake of NO_2 could enhance in-vivo production of peroxynitrite, oxidative stress, other metabolic diseases and cancers (Choudhari et al, 2013). The higher level of NO_2 emitted by landfills could also cause acid rains, skin diseases and damaged roofing sheets (Reddy *et al.*, 2004). Elevated levels of CO in the landfills and communities 100M away from the landfills could pose dangers to the inhabitants of the landfill communities. Many of the common side effects of CO intoxication include its affinity (about 200 times that of oxygen) for haemoglobin, that enhances its ability to easily displace oxygen in the system. A similar study by Sroczyński et al. (1993) showed higher level of carboxyhaemoglobin in the workers of the furnace room and of the carbon derivatives department.

Several studies suggest that landfills emit particulate matters beyond the prescribed standards (Gurdeep and Puri, 2004). Praveena et al (2015) have reported high levels of heavy metals (Pb, Cd, and Cu) in the particulate matters deposited on windows, floor and fan at a primary school in Sri Serdang, Malaysia. Significantly higher concentrations of particulate matters observed in this study decreased with increase in the distance from the center of landfill. This study is the first to monitor the distribution pattern of landfill-emitted PM2.5 and PM10 in Nigeria. The significantly higher levels of PM2.5 and PM10 observed in these communities 100M away from the landfills could be a novelty of this study. This corroborates the previous reports of Sastry et al. (2015) that, dispersion of pollutants is wind dependent and can diffuse to distant communities. He et al. (2016) reported that PM2.5 has higher concentrations of Pb, Cu, As and polycyclic aromatic hydrocarbons, while PM10 contains higher amounts of microbial elements lipopolysaccharide, β-glucan, Si, Al, Fe, and Ti. This study may therefore suggest that landfills can emit dangerous particulate matters that can be dispersed to the neighboring communities. The present report and some previous ones could buttress the findings of Xu et al. (2017) and Wang et al. (2017) that short-term exposure to high levels of PM2.5 and PM10 caused the hospitalization of some people with inflammatory heart diseases and immediate decrease in lung function owing to the virtue of the loss of pulmonary epithelium integrity. Traversi et al (2015) also reported that a number of compounds found in particulate matters of an aerodynamic diameter <2.5 (PM2.5) can interact with DNA either directly or after enzymatic transformation to induce DNA modifications. Neisi et al (2017) also reported that higher values of inflammatory biomarker and impaired lung function were observed in individuals exposed to dust. Sato et al (2016) and Benmerad et al, (2017) stressed that a short-term exposure to high levels of particulate matters may have adverse effects on cough reflex and urge-to-cough thresholds, pulmonary function, cough-related quality of life and lower forced expiratory volume and forced vital capacity in lung transplant recipients.

Conclusion:

It could be concluded that population living in communities close to the landfills are likely to be polluted with gaseous pollutants and particulate matters. There is a high probability that the study conducted by Paraskaki et al (2005) in the Ano Liosia landfill site in the greater Athens, where the minimum downwind distance of the health-risk zone was calculated to be equal to 1.5 km from the landfill could differ from Nigerian environment. Since Nigeria has different weather and climatic conditions, the distance of the health-risk zone from the landfill may be different. Since pollution is a growing problem in many industrializing countries including Nigeria, further investigations may be needed to validate the safe distance of residential areas from landfills.

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Authors Contributions:
MOA, BBA, OOD, GOO, JAA, OBS, FAO and JIA designed the study, MOA, TEB and BBA did the analysis, and all authors prepared and approved the final manuscript.

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