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Spatial Variations in Key Greenhouse Gas Emissions across Illegal Dumpsites in Ibadan, Nigeria

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Abstract

Illegal dumpsites are common in Nigerian cities and these wastes are one of the significant contributors of greenhouse gas emissions (GHGEs). The study was designed to characterize GHGEs from the wastes as obtained from selected illegal dumpsites in Ibadan Southwest, Nigeria. Three dumpsites were randomly selected from the high (Okefoko), medium (NTC Joyce B) and low (Iyaganku GRA) density areas. Two most critical GHGEs (carbon dioxide, CO_2 and methane, CH_4) were estimated. Values of CO_2 measured three times per week at specific periods of the day for 12 weeks during the months of January to April, 2011in parts per million (ppm) using a Telaire 7001 connected to a HOBO U12 data logger (Onset Corp, Bourne, MA). The CO_2 values obtained were compared with available USEPA guideline limits (300 – 400 ppm). Short-term CO_2 concentrations ranged from 212-580 ppm for Okefoko, 224-1157 ppm for NTC Joyce B and 240-548 ppm for Iyaganku GRA. Highest (1157 ppm) CO_2 emission was recorded at the medium density area between 8 and10 am. The highest temperature (39.4°C) was also recorded in the medium density area in the morning. The percentage composition of CH_4 in the total potential gas emissions from the dumpsites in the high, medium and low density areas were 0.000158 Gg/yr., 0.000026 Gg/yr. and 0.000012 Gg/yr. respectively. Levels of CO_2 near dumpsites were within guideline limits, while CH_4 exceeded guideline limits. Evacuation of waste from illegal dumpsites to authorized locations for recovery of GHGEs and material recycling should be promoted in urban areas of LDCs.

Variations spatiales des émissions de gaz greenhouse dans les décharges illégales à Ibadan, au Nigéria

Abstrait

Les décharges illégales sont courantes dans les villes nigérianes et ces déchets sont l'un des principaux contributeurs aux émissions de gaz greenhouse. L'étude visait à caractériser les émissions de gaz greenhouse provenant de déchets dans des décharges illégales sélectionnées dans le sud-ouest d'Ibadan, au Nigéria. Trois dépotoirs ont été choisis au hasard dans les zones de densité élevée (Okefoko), moyenne (NTC Joyce B) et faible (Iyaganku GRA). Deux GHGES les plus critiques (dioxyde de carbone, CO2 et méthane, CH4) ont été estimés. Les valeurs de CO2 ont été mesurées trois fois par semaine à des périodes spécifiques de la journée pendant 12 semaines, de janvier à avril 2011, en parties par million (ppm) à l'aide d'un Telaire 7001 connecté à un enregistreur de données HOBO U12 (Onset Corp, Bourne, MA). Les valeurs de CO2 obtenues ont été comparées aux limites indicatives disponibles de la USEPA (300 à 400 ppm). Les concentrations de CO2 à court terme allaient de 212 à 580 ppm pour Okefoko, de 224 à 1157 ppm pour NTC Joyce B et de 240 à 548 ppm pour Iyaganku GRA. L'émission de CO2 la plus élevée (1157 ppm) a été enregistrée dans la zone de densité moyenne entre 8 h et 10 h. La température la plus élevée (39,4 ° C) a également été enregistrée dans la zone de densité moyenne le matin. La composition en pourcentage du CH4 dans les émissions de gaz totales des dépotoirs dans les zones de densité élevée, moyenne et faible était de 0,000158 Gg / an, 0,000026 Gg / an. et 0,000012 Gg / an. respectivement. Les niveaux de CO2 près des dépotoirs étaient dans les limites recommandées, alors que le CH4 dépassait les limites recommandées. L'évacuation des déchets des dépotoirs illégaux vers des sites autorisés pour la récupération des GHGES et le recyclage des matériaux devrait être encouragée dans les zones urbaines.

Introduction

The challenge of solving emergent issues as regards global warming and climate change has become so enormous that the outflow of greenhouse gas has added to an already groom situation. Greenhouse gases usually make the planet warmer by confining and emitting the heat received from radiant energy which is the combination of electromagnetic and gravitational radiation (IPCC, 2007). Persistent rise in greenhouse gases has being observed to be caused to a large extent by human activity such as the burning of landfills (UNFCCC, 2005). Landfills contribute to greenhouse gas (GHG) effect through emission of methane (CH_4) (IPCC, 2006; 2007) and carbon dioxide (CO_2) gas that are produced during the decomposition process of waste organic content under anaerobic conditions ((Ishigaki *et al.,* 2005, Abushammala *et al.,* 2009). The impact of geogenic/natural activity also leads to GHG effect even though it may not be too pronounced (Hansen, 2004, YeSeul *et al.,* 2010, Marc Lallanilla, 2019).

Evaluation of emission rate for gaseous pollutants from landfills proves highly difficult to control, owing to several factors, such as; gas production rate, gas migration properties through the waste layers and through the top layer of the landfill, gas collection efficiency, and meteorological factors (Papageorgiou, 2009). In the United States enteric fermentation associated with domestic livestock, decomposition of wastes in landfills, and natural gas systems are among factors responsible for increase in greenhouse gas (GHG) emission (IPCC 2007, USEPA, 2009).

The problem becomes more pronounced in developing nations such as Nigeria, which has a major human activity challenge ranging from indiscriminate dumping and burning of refuse (this could be in the form of open dump and landfills), to burning of animals, agricultural practises, emissions from car exhaust and many others (Lou 2009; Chalvatzaki and Lazaridis, 2010). In Nigeria, waste generation and composition is greatly influenced by population, income, economic growth, season, climate and social behaviour, and the waste stream consisting of plastics, paper, textile, metal, glass, etc. The density ranges from 280 – 370 kg/m^3(Ogwueleka, 2009), while generation rate is 25 million tons annually [0.44 kg/cap/day in rural areas; 0.66 kg/cap/day urban areas] (Ogwueleka, 2009).

Disposal of solid waste leads to production of greenhouse gas in Nigeria through various ways; anaerobic decomposition of waste in landfills which produces methane; incineration of waste that produces carbon dioxide as a byproduct, this reflects the main sources of GHG in Nigeria and Ibadan the most populous city after Lagos and Kano is not left out of GHG effect.

Ibadan, located in the southwestern part of Nigeria, is 128km northeast of Lagos and 530km southwest of Abuja with a population of over three million. Even though the growth of the city has nothing to do with industrialisation (with only few industries), it is related to the age long role of the city as regional administrative capital since the colonial era. The city is thus characterised by poor housing planning and quality, inaccessible quality drinking water facility, indiscriminate dumping and burning of solid wastes with waste generation of 0.51kg/capita/day (Ogwueleka, 2009), consequently leading to diverse GHG problem in the city (Agboola and Omueti, 1982, Oyeniyi, 2011).

The study was therefore designed to assess annual carbon dioxide (CO_2) and methane (CH_4) emissions from selected illegal dumpsites in Ibadan Southwest, Nigeria.

Materials and Methods

Study Design

The study area Ibadan Southwest was selected based on the established illegal dumpsites. The LGA was stratified into high, medium and low density areas (Figure 1) where three illegal dumpsites each were randomly selected:

High density area; Oke-foko: Amole (I), Amule (II) and Ede (III)
Medium density area; NTC - Joyce B, Road: Genesis (IV), Cele (VII) and Jogor (VI)
Low density area; Iyaganku GRA: Area 1 (VII), Area 2 (VIII) and Area 3 (IX)

Onsite observations

The nature of the selected dumpsites was documented using a well-designed observation checklist reflecting indicators such as presence of combustion activities, scavenging, and farming within the vicinity.

Determination of Ambient Temperature

The maximum and minimum ambient temperature around the dumpsite were recorded

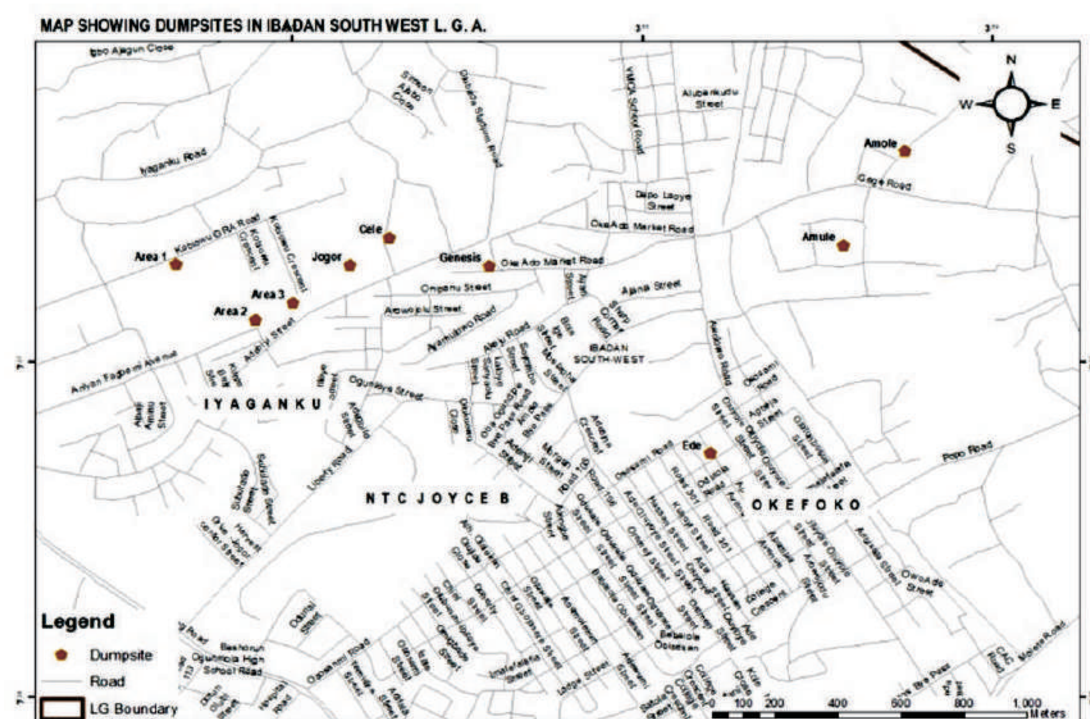


Figure 1: Map showing the Selected Dumpsites in the Study Area

using the temperature mode of the carbon dioxide metre (Telaire 7001 Model) and the values were expressed in degrees Celsius (^oC).

Determination of Carbon dioxide (CO_2) Levels

A carbon dioxide metre (Telaire 7001 Model) made in Mexico was used to measure the concentration of CO_2 emissions at the dumpsites thrice weekly at specific periods of the day (8-10am, 12-2pm, and 4-6pm), for 12 consecutive weeks. The values for CO_2 were measured in parts per million (ppm) and compared with the US EPA outdoor levels (300 – 400ppm) for CO_2 in the environment (IDPH, 2011) and near roadways (e.g., Shendell *et al.,* 2012).

Determination of Methane (CH_4) Levels

The 2006 Intergovernmental Panel on Climate Change (IPCC) waste model was used to estimate the CH_4 emitted in a year from each dumpsite using the following parameters: weight of the wastes, temperature and population of the areas which was 36255, 5850 and 2681 in Oke-foko, NTC and Iyaganku GRA respectively (NPC, 2006).

The methane emission is expressed in Gg/year using the equation below:

Methane emissions (Gg/yr) = (MSWT • MSWF • MCF • DOC • DOCF • F • 16/12-R) • (1-OX)

Where:

MSW_T = Municipal Solid Waste generation rate for Ibadan x population of study site
= 0.51 kg/cap/yr x population of study site
For Okefoko = 0.51 x 36,255 = 18,490.05
NTC Joyce B = 0.51 x 5850 = 2983.5
Iyaganku GRA = 0.51 x 2681 = 1367.3

MCF = methane correction factor
Default value for shallow unmanaged dumpsite with depth >5m = 0.4
For deep unmanaged dumpsite = 0.8
MSW_F = fraction of MSW disposed to the dumpsite default value for Nigeria = 0.4
DOC_F = fraction of DOC actually converted to gas = 0.014T + 0.28

Table 1: West Africa default data on waste composition of MSW

Waste type	Default Composition by percentage (%)
Food waste	40.4
Paper/cardboard	9.8
Wood	4.4
Textile	1.0
Plastics	3.0
Metals	1.0

Source: IPCC 2006

Where T is the temperature of the dumpsite
Mean temperature for Okefoko = 29^oC
Mean temperature for NTC Joyce B = 29.6^oC
Mean temperature for Iyaganku GRA = 28.9^oC
Therefore, the DOC_F for the three density areas are:
DOC_F Okefoko = (0.014 x 29) + 0.28 = 0.686
DOC_F NTC Joyce B = (0.014 x 29.6) + 0.28 = 0.694
DOC_F Iyaganku GRA = (0.014 x 28.9) + 0.28 = 0.685

Default (National) values for DOC generation or each waste type

DOC (by weight) = 0.4 (A) + 0.17 (B) + 0.15 (C) + 0.30 (D)

Where
A = fraction of MSW comprising paper and textile i.e. 0.108 (i.e. 9.8 + 1 = 10.8 / 100)
B = fraction of MSW comprising mainly other non-food organic putrescible i.e. no default value available
C = fraction of MSW comprising food waste i.e. 0.404
D = faction of MSW comprising wood or straw i.e. 0.044

DOC (by weight) = 0.4 (0.108) + 0.17 (0) + 0.15 (0.404) + 0.30 (0.044)
= 0.0432 + 0 + 0.0606 + 0.0132
= 0.117
F = 0.5 default value
16/12 = conversion of Carbon to CH_4
R = methane recovery = 0
OX = oxidation factor = 0 since the dumpsite is shallow
(Note: 1000 tonnes = 1Gg)

Data Management and Statistical Analysis

Data obtained were analysed using descriptive statistics and ANOVA. Descriptive statistics was used to analyse the mean CO_2 and CH_4 levels for the duration of sampling. ANOVA was used to test for the significant difference ($p<0.05$) that exists between GHG (CO_2 and CH_4) emission, the location and time of sampling.

Results

Nature of dumpsites

Oke-foko and Iyaganku GRA lacked skip bins or any form of waste storage/collector. NTC had very few numbers as most of them had been removed from the area. Almost all the dumpsites had flourishing vegetation and all were exposed to rainfall. The walls and roofs of the buildings around the dumpsite were moderately adequate to adequate in the low and medium density areas while in the high density area they were not adequate, the walls were cracked and roofs rusty. Most of the dumpsites were within 40 – 50 m^2 in size.

Amole was mainly surrounded by residential quarters and exposed to rainfall and sunlight. This site was very large and situated around a water channel. There were few scavengers. Amule was also a large dumpsite situated along a water channel and exposed to rainfall. Animal and human scavengers were observed. The dumpsite was next to shops and homes and also along the road. Ede is a partially abandoned dumpsite containing more of nylon and metal wastes. Smoke was observed at some point during the study. It is situated along the roadside and a fish market was spotted behind the dumpsite.

Genesis dumpsite was located along the road, and had a non-functional skip bin with refuse spilling all over the road. Scavengers were observed and burning occurred in the dumpsite. There were small shops by the side and across the road. Cele dumpsite was also situated along a water course though not as large as those earlier described. Scavengers were observed. Wood shops and other little shops were situated close to it. Jogor dumpsite was situated a little behind residential areas, also along water channel and had episodes of refuse burning. It was composed mainly of nylons.

Area 1 dumpsite was situated near some residential quarters and featured refuse burning as well. It consisted mainly of organic wastes. It was a smaller dumpsite which could be easily cleared. Area 2 dumpsite was situated by the roadside and consisted mainly of organic wastes particularly fruits perhaps due to the close proximity of fruit-sellers in the area. Area 3 dumpsite was also situated by the roadside but was however made up mainly of nylons. It was situated opposite an automobile shop and scavengers were absent (Table 1).

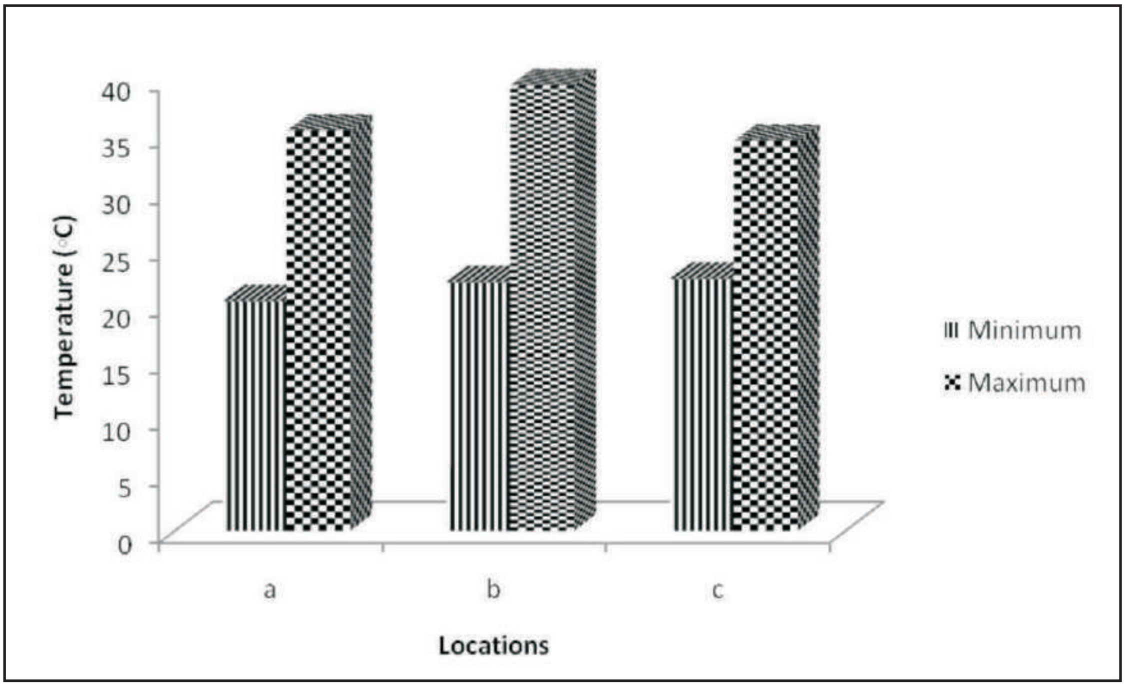
Table 2: Nature of activities at the waste dumpsites in the three density study locations in Ibadan, Nigeria, January – April 2011

Density Area	**Dumpsites**	**Activities at the Dumpsites**					
		Presence of Smoke	Near motor way	Human Scavengers	Plant growth	Animal loitering	Exposure to rainfall
Oke foko(a)	I	-	-	+	++	-	+++
	II	-	++	+++	++	+	+++
	III	++	+++	+++	+	+	+++
NTC Joyce B (b)	IV	++	+++	++	+++	++	+++
	V	-	-	-	++	++	+++
	VI	+++	-	++	+++	+	+++
Iyaganku GRA(c)	VII	++	+	-	+	-	+++
	VIII	-	-	-	+++	-	+++
	IX	-	-	-	+++	+	+++

Key: +++ (Highly present), ++ (Moderately present), + (Present), - (Absent)

Temperature profile across the three density study locations

The highest maximum temperature reading (34.5 °C) was recorded at NTC Joyce B while the lowest minimum temperature reading (20.3°C) was recorded at Oke Foko Figure 2.



Key: a – Okefoko; b – NTC Joyce B; c – Iyaganku GRA

Figure 2: Minimum and Maximum Temperature readings across the density locations

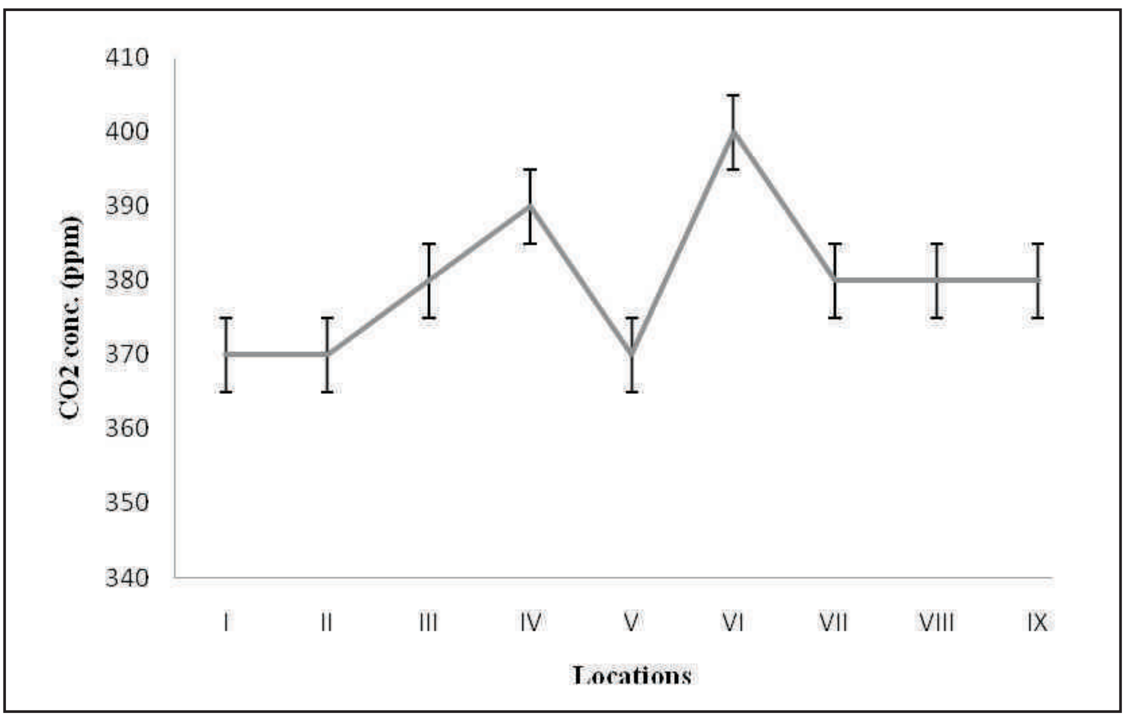


Figure 3: Variations in Mean CO_2 concentration across the selected dumpsites

Spatial variation in CO_2 Levels across study dumpsites

The following results were obtained based on the measurements of CO_2 emissions from each dumpsite over a period of 12 weeks. Table 2 showed the minimum and maximum CO_2 levels for each of the density areas. The highest maximum CO_2 level (1160 ppm) was recorded in the morning at location 'b' while the lowest minimum CO_2 level (210 ppm) was recorded in the evening at location. The mean CO_2 concentrations for each of the dumpsite over the 12 weeks period are depicted with the highest mean concentration (400 ppm) recorded at dumpsite VI in Jogor area (Figure 3). Across study locations, mean CO_2 concentrations recorded were within the normal outdoor level (300 – 400 ppm). The correlation (Figure 4) between CO_2 and ambient air temperature was weak, due likely in part to the relatively consistent warm and humid conditions prevalent in Ibadan, Nigeria during both the wet and dry seasons of the year, i.e., the prominent sources, their attributes and their emissions over time, are the factors to be considered.

Table 3: Minimum and maximum short-term carbon dioxide (CO2) levels for each density area, Ibadan, Nigeria, January – April 2011.

	Morning		Afternoon		Evening	
LOCATIONS	Min. (ppm)	Max. (ppm)	Min. (ppm)	Max. (ppm)	Min. (ppm)	Max. (ppm)
Oke-foko (a)	290	580	270	530	210	440
NTC Joyce B (b)	300	1160	280	800	220	460
Iyaganku GRA (c)	310	550	250	550	240	470

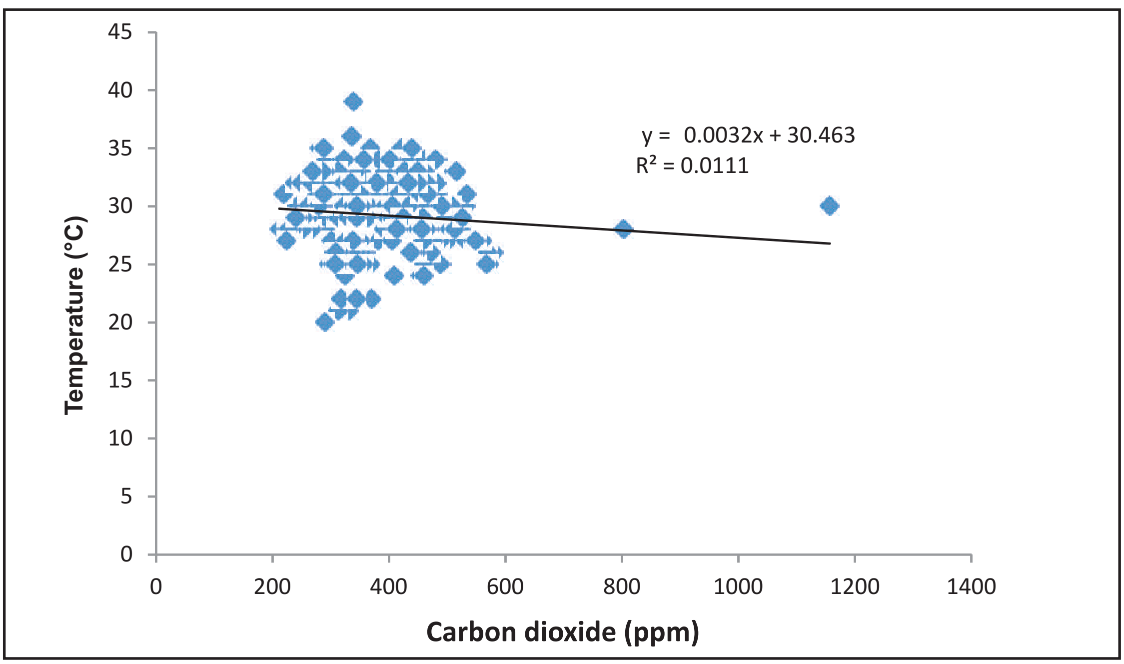


Figure 4: Correlation between CO_2 and Ambient Temperature

Table 4: Estimation of CH_4 emission levels using the 2006 IPCC waste model

Parameters	Study Locations		
	a	b	c
MSW_T (tonnes/yr)	18490.05	2983.5	1367.3
MCF	0.4	0.4	0.4
MSW_F	0.4	0.4	0.4
DOC_F	0.686	0.694	0.685
DOC	0.117	0.117	0.117
F	0.5	0.5	0.5
16/12	16/12	16/12	16/12
R	0	0	0
OX	0	0	0
CH_4 (kg/yr)	158.298	25.840	11.689
CH_4 (tonnes/yr)	0.158	0.026	0.012
CH_4 (Gg/yr)	0.000158	0.000026	0.000012

Key: (a) Okefoko; (b) NTC Joyce B; (c) Iyaganku GRA, Note: 1000 tonnes = 1Gg

The composition of solid waste landfill/dumpsite emissions is typically 50 to 60 percent methane, with the balance being mostly carbon dioxide (IPCC, 2001b; IPCC, 2006). The methane is generated when organic wastes are anaerobically decomposed. In the absence of oxygen, the level of methane increases with increase in organic wastes composition. The generation rate is directly proportional to the population of the area, i.e., the larger the population, the more the generation rate of wastes.

The estimated (modelled) data for the present study are summarized in Table 3. The methane emission for Oke-foko, NTC and Iyaganku GRA were 0.102 Gg/yr., 0.017 Gg/yr. and 0.008 Gg/yr. respectively. Oke-foko was seen to have more organic wastes in composition compared to the other areas. From the estimated methane emission generated in each of the areas, it can be seen that the quantity generated is quite small. However a combination of all the methane emissions from all the dumpsites in every nook and cranny in Ibadan southwest local government area accumulated every year for the next 50 years could be enormous.

Discussion

In this paper, we assessed the spatial variations in key greenhouse gases emitted from illegal dumpsites in Ibadan Southwest Local Government Area, Oyo State, Nigeria. The key greenhouse gases determined were CO_2 and CH_4 since they are known to have higher Global Warming Potentials (GWP) than other greenhouse gases. In the past previous investigations, documented levels of CO_2 from different urban sites in Nigeria were document but there were no records relating the emissions level of the GHGs particularly CH_4 from dumpsites. To the best of our knowledge, this is the first major attempt at determining the CH_4 levels using the 2006 IPCC default waste model.

Based on the onsite observation, smoke was seen from most of the dumpsites in the high and medium density locations indicating active open burning of refuse. Arising from these open combustion processes, the highest temperature reading was observed at NTC Joyce B and this also led to a corresponding increase in the burden of CO_2 in the area which incidentally recorded the highest CO_2 concentration in comparison with other areas. The bulk of these emissions are from human activities according to Young (2009). The richness of the dumpsites in organic wastes, coupled with the fact that the terrain is rich in moisture both from precipitation and surface runoff increases the putrefaction capacity of the dumpsites. Hence, its viability as a veritable source of CH_4 emissions in the area. This perhaps explains the reason why Oke-foko with the highest volume of wastes rich in organic matter, recorded the highest CH_4 levels.

Robinson (1989) explained the process of methane formation from municipal solid wastes using the following equation

(Aerobic phase)

$$6(CH_2O)_x + 5O_2 \rightarrow (CH_2O)_x + 5CO_2 + 5H_2O + \text{Energy}$$

(Organics in solid wastes) (bacterial cells)

Anaerobic phase

Formation of organic acid

$$5(CH_2O)_x \rightarrow (CH_2O) + 2CH_3COOH + \text{Energy}$$

(Organics in solid wastes) (bacterial cells) (organic acid)

Formation of methane

$$21/2\ CH_3COOH \rightarrow (CH_2O)_x + 2CH_4 + 2CO_2 + \text{Energy}$$

(Organic acid) (Bacterial Acid) (Methane)

This anaerobic reaction can be affected by the temperature of the dumpsite. In a study carried out by Zhang *et al.* (2006), it was reported that the higher the temperature, the faster the generation rate of the gas. Hanson *et al.*, (2005) noted that higher temperatures were measured at greater depths and in older wastes up to certain limits while temperatures of wastes at great depth (approaching bottom liner elevations) were lower than peak values measured towards the centre of a waste mass. Temperatures for wastes with ages greater than approximately 10 years had lower temperatures than peak values measured for wastes with ages between 5 and 7 years.

When CO_2 increases, temperature also increases and this may be due to the relationship between temperature and the solubility of carbon dioxide in the surface ocean. However, it is believed that the major reason for this relationship is consistent with a feedback between carbon dioxide and climate (National Oceanic and Atmospheric Administration, 2008). This relationship may have been partially observed in NTC Joyce B location which had a maximum CO_2 level of 1157 ppm and the highest temperature of 39.4°C. The Earth needs CO_2 for its warmth because without it, temperature of the earth will be below freezing. However, excess of CO_2 in the environment leads to global warming, more accurately climate change, and this is due mainly to anthropogenic activities.

The estimated methane emission for Oke-foko, NTC and Iyaganku GRA were 0.000158Gg/yr., 0.000026 Gg/yr. and 0.000012 Gg/yr., respectively based on the (IPCC, 2006) Waste Model. The estimation of CH_4 emission from landfills is important for assessing landfills emission inventories. This Default Waste Model allows countries with limited waste management data to estimate National CH_4 emissions over a time series. According to Carol Bogart (2009), much of this CH_4 originates from human activities including landfill activities. Although there is no immediate danger from the methane emitted in atmosphere from landfills; still, high concentrations displace oxygen and cause oxygen deprivation which leads to suffocation (Health Protection Agency, HPA, 2010). It could also accumulate inside the landfill mass, thus increasing its concentration (Chalvatzaki and Lazaridis, 2010). Methane emissions levels vary greatly depending on the local geography.

High variation in CH_4 emission rates within and between the sites was expected because it could be affected by waste characteristics, climatic condition, disposal methods, age of disposal site, and gas migration within and across the site boundaries. Studies have shown that methane gas has a warming potential 21 times that of carbon-dioxide gas. Therefore, for every effect caused by 1ppm of carbon-dioxide, 1Gg of methane will cause the effect 21 times more (USEPA, 2007). It is important to mention here that the sources of these gases are numerous but in this study the focus was mostly on emissions from solid waste dumpsites. In effect, the pool of greenhouse gases not only from a mono but from multiple sources accounts for the total GHG burden recorded in the developed and developing countries.

Globally, efforts are being made to control greenhouse gas (GHG) emission from various sources including the waste sector (Chalvatzaki and Lazaridis, 2010). However, waste statistics are lacking due to the low level coverage of waste collection. Yet, such information is necessary for understanding the likely impact of the sector on emissions of greenhouses gases (USEPA 1998; ADB 1998; IPCC 2006). This is one major drawback in this study as the age of the dumpsites and key characteristics of the sites were either not known or inadequate.

Conclusion

The present study assessed the spatial variation in key greenhouse gases (GHGs, carbon dioxide or CO_2 and methane or CH_4) emitted from illegal dumpsites in Ibadan Southwest LGA. On the other hand, based on the waste model, the estimated CH_4 emissions in a year across dumpsites in the three density zones were 0.000158Gg/yr., 0.000026 Gg/yr. and 0.000012 Gg/yr, while the CO_2 were within its guideline limit. Although, the current levels of CO_2 and CH_4 were mostly from the waste dumps, it is obvious there are other present sources of GHG emissions in the environment in these localities in the study area of Ibadan, Nigeria. Future investigations should carry out in-depth investigations to create more accurate waste and dumpsite profiles as well as contributions from other key sources.

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