

# CHARACTERIZATION AND MODELING OF GASEOUS POLLUTANT MOVEMENT FROM GWARI VEGETABLE MARKET DUMPSITES, YOLA, NIGERIA

Burmamu, B. R.<sup>1</sup>, Aliyu, B.<sup>1</sup> and Timtere, P.<sup>2</sup>

<sup>1</sup>Department of Agricultural and Environmental Engineering, Modibbo Adama University, Yola

<sup>2</sup>Department of Physics, Modibbo Adama University, Yola

Corresponding email: [benburi2@gmail.com](mailto:benburi2@gmail.com)

## ABSTRACT

*Global warming as a result of gaseous pollutants has been a concerning component of climate change all over world. As such, the aim of the present research was to apply Land GEM software version 3.02 to predict air pollutants movement by means of gaseous concentrations, annual wastes mass received and dumpsites open years from the study area using both site specific and default model parameters. Emission concentration rates were determined through field and laboratory work from vegetable waste dumpsites using scientific calibrated instruments. Data obtained were applied on Land GEM computer-based model in order to predict gaseous pollutant flow from the market environment and her surroundings. The model was tested to ascertain its validity where the measured and simulated values indicated good match with an error of 3.8%. The closure year of the case study dumpsite A was predicted to be in 2074 having reached hazardous level in 2024 while control dumpsite B predicted a closure year of 2023 and hazardous level in 2022 with a modeling efficiency of 64%. Understanding the types of gases emitted from decomposing vegetable waste dumpsites: CH<sub>4</sub>, CO<sub>2</sub>, NMOCs, H<sub>2</sub>S and other movement patterns could go a long way in ensuring control measures of these pollutants thereby having a sustainable zero waste market to boost economic activities.*

**Keywords:** Movement, Gaseous Pollutants, Dumpsites, Model, Land GEM

## 1 INTRODUCTION

Pollution is a devastating concept no matter how you look at it. You can perceive it when the air is polluted and taste it when water supplies and soils are polluted. This confirms a scientific fact that, climates have actually changed throughout the earth's history with the most recent ice age, global warming resulting from greenhouse effects for which gas emissions are contributory factors in polluting the environment. The increasing number of cases of outbreak of air pollution from various sources is alarming [1, 2] observed that cumulative effects of changes observed in the environment at a global scale are driven by such activities as indiscriminate dumping and disposal of solid, industrial, municipal, agricultural and other sources of wastes in open surroundings such as Gwari Vegetable Market, Yola. The implication of this environmental pollution is that it can pose significant health risk to humans, particularly on elevated concentrations above international body requirements. [3] predicted that, the concentration of atmospheric carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) could reach 600ppm each or more. Air pollution is caused by introduction of different air pollutants that are able to not only cause harm to our environment but also to our health. Harvard School of Public Health has recently come up with a data that, approximately 4% of all deaths in the United States can be attributed to air pollution. According to another data from World Health Organization, 2.4 million people die each year from causes directly connected to air pollution, with 1.5 million of these deaths being the result of

indoor air pollution [4]. It can be said that vegetables are good pretty nourishing fibres that form important part of our diet. It lamented that they contain 65 to 95% water and natural minerals and vitamins. They also help in protecting our bodies against cancer, diabetes and heart diseases, none has cholesterol; but most vegetables die and decay naturally on their own overtime mainly due to oxidation especially when food and water reserves are exhausted. Such injury often results into internal bruising, splitting and skin breaks, thus rapidly increasing water loss. Roy [5] wrote that, poor ventilation at the vegetable dumpsites with stacking patterns that block air movement can lead to accumulation of carbon dioxide (CO<sub>2</sub>), H<sub>2</sub>O, NH<sub>3</sub>, H<sub>2</sub>, H<sub>2</sub>S, CH<sub>4</sub>, etc., through the secretion of enzymes as a result of bacterial activities on the organics. When the concentration of carbon dioxide increases, it quickly ruins down the vegetables and finally decays. Vegetables can also decay due to extreme exposure to temperature levels; relative humidity, temperature of vegetables, its surrounding atmosphere and air velocity all affect the decay rate of vegetables. Similarly, moisture content of vegetables, biochemical activities and respiration rate account for vegetables decay to give out bad odour [6]. In realising the importance of vegetables to humans, a suburban vegetables Gwari market was established in Yola, the Adamawa State capital in the north eastern Nigeria in 1999. The market is known as, International Vegetable Gwari Market as it attracts vegetables produced from neighbouring countries such as Cameroun, Chad and Niger Republics. Recently, the market and its environs has become a source of environmental pollution as some spoiled and remnant vegetables are dumped close to the market and the decay of these dumped vegetables release emissions that pollute the atmosphere; and leachates from these dumpsites migrate to contaminate agricultural soils and water. That is why there is a need to study the movement mechanisms of these pollutants with the aim to determining the types and concentration levels generated for the application of modelling techniques in order to predict their mobility. Decayed vegetable dumpsites near (Gwari) Market, Yola have become a source of environmental pollution to the residents around the market and to the customers that come to buy these vegetables from the market due to the bad odour emitting from these dumpsites. These dumpsites are under threat from pollution and lethal to human life, manifested by the low level of hygiene as practiced in Yola. There is neglect of removing dumpsites at the market which constitute environmental health hazard. This can affect all air quality factors and lead to unpleasant circumstances in the surroundings of humans, animals and plants thereby deteriorating their health and well-being [7]. [8] reported that these gases can contribute to global warming and ozone layer depletion which are very critical to climate change, data on modelling of environmental pollution from dumpsites is lacking in this area and there have been no systematic published studies on environmental pollution with respect to decayed vegetable waste dumpsites within vegetables growing regions and commercial centres in Yola, Nigeria. With these dumpsites, there is reduction of land use at the research area leading to social and environmental impact. Hence there is a need for this research with the view to controlling air pollution at the market environment through recommendations to pollution mitigating agencies. Educationally, the study could be adopted as a model design, which environmental institutions can develop for use in environmental pollution control. This will enhance teaching and learning, encourage more innovative models with the availability of much simpler methods of modeling by both staff and students. It will also make environmental sanitation easier and improve the work and practice of industrial, public, commercial and agricultural pollution control. Economically, industries in the study area can adopt the outcomes of this research for healthier production. It can as well reduce the importation of some environmental control facilities in Nigeria and serve as an export article of trade to other African countries outside West Africa. This development will give opportunities to business men in environmental sanitation cycle to have its kind in Nigeria. If this happens, the demand for environmental control packages from outside the country will reduce to an extent that Nigeria will be enlisted as a contributory nation to environmental pollution control thereby contributing towards the control of global climate change in the world. The data gathered will help to assist with understanding of air pollution occurrences and flow processes within the system and to support the development of numerical models. This helps to meet the needed control target as it may identify effective wastes minimization strategies. The specific objectives of this work are: to characterize the varieties of vegetables at dumpsites, air pollutant concentrations and analysis of meteorological data for use in model development by applying Land GEM tool for predicting movement of air pollutants from decayed vegetable waste dumpsites into the biosphere. It was also to calibrate the model to determining its validity and Provide air pollution control model for achieving zero-waste market and her environs.

## **2 MATERIALS AND METHODS**

### **2.1 Description of Study Area**

The area under the study was located at the northern part of the market. Two dumpsites selected and investigated based on their volumes. The capacity of dumpsite A was 500,000 tons covering an estimated area of 6,210 m<sup>2</sup>; the length was 90 m, width of 69 m and depth of 4.5 m which has been in operation since 1999. The study site was surveyed to determine the total area of Gwari Market and decayed vegetable dumpsites. Number of decayed vegetable dumpsites co-disposed with other items from the market was identified. Heights, volumes, lengths, widths and other dimensions of the dumpsites formed part of the measurements carried out. There were two main dumpsites for vegetable wastes labeled as 'A' and 'B' (Plates 1 and 2). Plate 2 a dug experimental in-situ pit in a clean site within the study area where vegetable wastes were dumped every day throughout the study period. These dumpsites were located at a distance of 1.5 km up River Benue at Yola.



Plate 1. Decayed vegetable wastes Dumpsite 'A' at Gwari Market, Jimeta, Yola



Plate 2. Dug experimental in-situ pit for decayed vegetable wastes dumpsite 'B' within the study area

### **2.2 Methods of Data Collection**

In selecting a location for air sampling, the wind direction and speed were considered and measurement of gas emissions was done along the predominant wind direction. Gas analyzers such as vacuum gas extraction device, portable gas monitors, and BIOGAS 5000 analyzer were used. Air was extracted from the dumpsites atmosphere through a vacuum sampler connected to the portable gas monitors and Biogas 5000 analyzer arranged on a tripod stand about 1 m above the ground level facing each dumpsite and along the wind direction. The analyzers contain modules of different gases and inserting the module of a particular gas automatically measures the type and quantity of the gas. In this way, modules of CO<sub>2</sub>, CO, CH<sub>4</sub>, H<sub>2</sub>S, NH<sub>3</sub>, SO<sub>2</sub>, NO<sub>2</sub>, O<sub>2</sub>, etc., were used to quantify their concentrations in the decayed vegetable dumpsites. The concentrations of the pollutants in the sampled gas were calculated as the proportion of captured pollutant's mass to the volume of gas sampled.

## 2.3 Method of Data Analysis

### 2.3.1 Modelling of gas emission rates from dumpsites using Land GEM

The landfill Gas Emissions Model (Land GEM) is an automated tool with a Microsoft Excel interface for estimating emission rates of total landfill gas, methane, carbon dioxide, non-methane organic compounds, and individual air pollutants from landfills and dumpsites. It can be used either with site-specific data to estimate emissions or default parameters if no site-specific data are available. Land GEM contains two sets of default parameters. The CAA defaults are based on requirements for MSW landfills laid out by the Clean Air Act (CAA), including the inventory defaults based on emission factors in the U.S. Environmental Protection Agency's compilation of Air Pollutant Emissions Factors (AP42). This model was selected for this research because it contains both site specific and default parameters for determination of dumpsite gas emission rates into atmosphere.

### 2.3.2 First-Order Decomposition Rate Equation

The model is based on a simple degradation equation known as first-order decay (FOD) exponential reaction for quantifying emissions from the decomposition of landfill/dumpsite wastes and to estimate the mass of methane and other gases generated using the methane generation capacity and the mass of the waste deposited over a time period based on user specification. The Land GEM emission methodology can be described mathematically as:

$$Q_{CH_4} = \sum_{i=1}^n \sum_{j=0.1}^1 kL_o \left( \frac{M_i}{10} \right) \left( e^{-kt_{ij}} \right) \quad (1)$$

Where  $Q_{CH_4}$  = annual methane generation flow rate in the year of calculation ( $m^3yr^{-1}$ );  $i = 1$  yearly time increment;  $n = (\text{year of the calculation}) - (\text{initial year of waste acceptance})$ ;  $j = 0.1$  year time increment;  $k = \text{methane generation rate (year}^{-1}\text{)}$ ;  $L_o = \text{potential methane generation capacity (m}^3\text{/Mg)}$ ;  $M_i = \text{mass of waste accepted in the } i^{\text{th}} \text{ year (Mg)}$ ;  $t_{ij} = \text{age of the } j^{\text{th}} \text{ section of waste } M_i \text{ accepted in the } i^{\text{th}} \text{ year (decimal years, e.g. 3.2 years)}$ .

## 3 RESULTS AND DISCUSSION

### 3.1 Varieties of Vegetables found at the waste Dumpsites

Different varieties of leafy and fruit vegetables identified at the waste dumpsites were presented in Table 1. The results showed that the acidity of leafy vegetables ranged from 4.3 to 8.0 indicating moderately acidic to slightly alkaline, while the acidity levels in fruit vegetables varied from less than 3.7 to 7.0 depicting a condition of very acidic to less acidic fruits. This agrees with the findings of [9] in his studies on acidified and low acidic food from Southeast Asia that vegetables were less acidic than most fruits and that is why food poisoning bacteria are able to grow in many vegetable products. Other discarded materials found at the dumpsites include: plastic bags, batteries, broken motor parts, metals/irons, lubrication oil containers, and cattle, sheep, goat dung's, textile, human faeces, broken electronic parts, glass, biodegradable food wastes, old car tyres, old newspapers, broken furniture, and cans. They were mixed up and decayed together (Plates 1 and 2). As a result, other materials discarded on the dumpsites could affect the models outcome because releases from these discarded items increase the concentration of pollutants there by overshooting models and observed natural values. This is similar to the outcome of the work of [9].

Table 1. Varieties of Vegetables Identified and their Levels of Acidity at Dumpsites

Leafy Vegetables	Level of Acidity (pH)	Fruit Vegetables	Level of Acidity (pH)
Spinach ( <i>Spinacia oleracea</i> L.)	5.0 – 7.0	Orange ( <i>Citrus sinensis</i> )	< 3.7
Amarath leaf	6.5 – 7.0	Banana ( <i>Musa paradisiacal</i> )	> 4.5
Okra ( <i>Abelmoschus esculentus</i> )	6.0 – 8.0	Apple ( <i>Malus sylvestris</i> )	3.3 – 4.0
Kale leaf ( <i>Brassica oleracea</i> <i>Acephala</i> grp.)	6.0 – 7.0	Pineapple ( <i>Ananas comosus</i> )	3.7 – 4.5
Egg plant ( <i>Solanum melongena</i> )	5.0 – 6.0	Papaya ( <i>Carica papaya</i> )	> 4.5
Sweet pepper ( <i>Capsicum annum</i> )	5.2 – 5.9	Mango ( <i>Mangifera indica</i> )	3.7 – 4.5
Hot pepper ( <i>Capsicum spp.</i> )	4.6 – 5.5	Guava ( <i>Psidium guajava</i> )	3.7 – 4.5
Onionleaf ( <i>Allium cepa</i> )	6.0 – 6.5	Garlic ( <i>Allium sativum</i> )	4.5 – 6.0
Tomato( <i>Lycopersicon esculentum</i> )	4.3– 4.9	Ginger ( <i>Zingiber officinale</i> )	5.5 – 7.0
Salad ( <i>Valerianella locusta</i> )	6.1 – 6.5	Grape ( <i>Citrus paradisi</i> )	< 3.7
Bitter leaf	5.5 – 6.5	Water melon ( <i>Cucumis melo</i> )	> 4.5
Kale leaf ( <i>Brassica oleracea</i> var. <i>acephala</i> )	Not available	Cucumber ( <i>Cucumis sativus</i> )	> 4.5
Moringa	5.6 – 6.6	Lime fruit ( <i>Citrus aurantifolia</i> )	< 3.7
Kumbi and Ugu leaves	Not available	Tamarind	< 3.7
Banana leaves ( <i>Musa paradisiacal</i> )	4.5 – 5.2	Tangarine ( <i>Citrus reticulate</i> )	< 3.7
Pumpkin Leaves ( <i>Cucurbita spp.</i> )	5.0 – 7.0	Onion bulb ( <i>Allium cepa</i> )	5.3 – 5.8
Cabbage ( <i>Brassica oleracea</i> var. <i>capitata</i> )	6.6 – 6.8	Carrot edible ( <i>Daucus carota</i> <i>spp. sativa</i> )	5.5 – 7.0
Green beans ( <i>Phaseolus</i> and <i>vigna spp.</i> )	5.6 – 6.50	Leek bulb ( <i>Allium porrum</i> L.)	> 4.5
Lettuce ( <i>Lactuca sativa</i> )	6.5 – 7.0	Lemon ( <i>Citrus limon</i> )	< 3.7

### 3.2 Characterization of the Site-specific Data at the Vegetable Dumpsites

The methodology was applied to two dumpsites (Dumpsite A; being the case study dumpsite and Dumpsite B; being the in-situ experimental dumpsite for comparison). The capacity of dumpsite A was 500,000 tons covering an estimated area of 6,210 m<sup>2</sup>; While dumpsite B (control) had a volume of 0.6 m<sup>3</sup>. The annual acceptance rate of wastes was 6,000 ton/yr for dumpsite A and 152 kg/yr for dumpsite B (Table 2).

Table 2. Site specific and model Data for Dumpsite A and dumpsite B to run the Land GEM

Parameters	Symbols	Dumpsite A Values	Dumpsite B Values
Methane generation rate constant (m <sup>3</sup> / yr)	k	0.05	0.09
Methane generation capacity (m <sup>3</sup> /mg)	L <sub>0</sub>	170	160
Methane emission content	CH <sub>4</sub>	50%	50%
Water addition factor	WAF	1.0	1.0
Methane correction factor	MCF	0.8	0.4
Waste mass disposed in the i <sup>th</sup> year (ton)	mi	20,833 ton/yr	152 Mg/yr
Yearly time increment (m <sup>3</sup> /yr)	i	11.385 m <sup>3</sup> /yr	1.8 m <sup>3</sup> /yr
0.1 year time increment	j	11.385 x 0.1	1.8 x 0.1
(Year of calculation)–(initial year of wastes acceptance)	n	15	1
Age of the jth section of waste mass disposed in the ith year (decimal year)	tij	0.1	0.1

Model and site parameters based on Clean Air (CAA, 2005) Regulations.

Note: Other dimensions of Dumpsites A and B as indicated in section 3.2 were not required as input parameters in Land GEM software. k values of 0.05 m<sup>3</sup>/yr are for dumpsite heights of less than 5 meters; while k values of 0.09 m<sup>3</sup>/yr are for dumpsite heights less than 3 meters [10].



### 3.3 Results on Measured Gaseous Emissions from Decayed Vegetable Dumpsites and Control Pit

Table 3 presents a summary of concentration levels on seven air pollutants measured around the case study dumpsites and the experimental pit (control). The concentrations of methane (CH<sub>4</sub>) and NMVOCs were again compared with the 8 hourly permissible limits recommended by the Nigerian Federal Ministry of Environment [11] for discussion of their implications on humans and environment. The trace gases monitored include: Ammonia (NH<sub>3</sub>), Carbon (II) Oxide (CO), Hydrogen Sulphide (H<sub>2</sub>S), Nitrogen (iv) Oxide (NO<sub>2</sub>), Carbon dioxide (CO<sub>2</sub>), Sulphur (iv) Oxide (SO<sub>2</sub>), and Methane (CH<sub>4</sub>).

Table 3. Concentration levels of air Pollutants from Case Study and Control Dumpsites

Location	NH <sub>3</sub> (ppm)	CO (ppm)	H <sub>2</sub> S (ppm)	NO <sub>2</sub> (ppm)	CO <sub>2</sub> (ppm)	SO <sub>2</sub> (ppm)	CH <sub>4</sub> (ppm)
A	1.00	9.30	0.10	0.03	28.03	0.21	2.70
B	2.70	10.30	0.20	0.20	30.43	1.40	2.20
C	1.70	9.70	0.20	0.10	29.56	0.80	0.20
FME (1991)	0.20	10.0	0.20	0.04	<600	0.01	1000

Abbreviations preceding the sampling locations are: A – in-situ experimental pit (control), B – case study dumpsite, C – another case study dumpsite; 2 m away from dumpsite B.

### 3.4 Computer Simulation Results and Discussion from Land Gem

The simulation results for the amount of gas emissions from dumpsites A and B using Land Gem tool are shown in Figures 1 and 2.

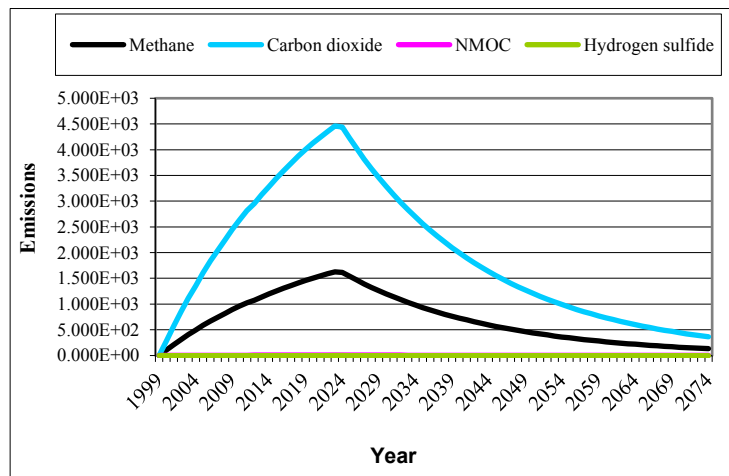


Figure 1. Annual emission rates (mg/yr) of CH<sub>4</sub>, CO<sub>2</sub>, NMOC and H<sub>2</sub>S for dumpsite A (1999

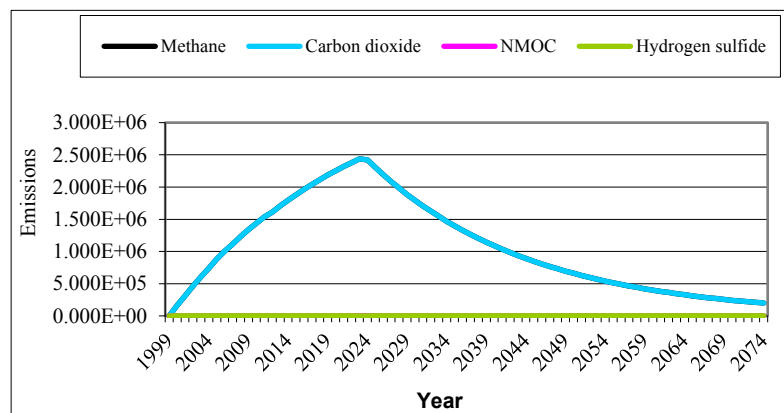


Figure 2. Annual emission rates (m<sup>3</sup>/yr) of CH<sub>4</sub>, CO<sub>2</sub>, NMOC and H<sub>2</sub>S for dumpsite A (1999- 2023)

The maximum value for methane gas production at the case study dumpsite A has been estimated to be 1.700E+03 (Mg/yr) which occurred during the year 2014 and reduces to almost zero after closure in 2074. The maximum emission rate of CO<sub>2</sub> is 4.500E+03 (Mg/yr) which also occurred

in 2014 and ceases after 2074 while NMOCs and H<sub>2</sub>S emissions were insignificant. These results are in good comparison with the work of [12] who obtained maximum and reduced CO<sub>2</sub> emission rates of 4.436E+02 and zero (Mg/yr); and maximum methane estimate of 1.74E+03 (Mg/yr) within the first three years of waste disposal. The figures show a general decreasing trend in total gas emissions after closure year. The difference in absolute values is significant when the highest amount of emission is between the years of 2000 – 2014 and decreased to around zero in 2074. With a design capacity of 500,000 tons, Land GEM estimated the closure year of dumpsite A to be in 2023. Similarly, the simulation results for annual gas production in Mg/yr and m<sup>3</sup>/yr from the experimental control dumpsite B using Land GEM estimation tool is shown in Figures 3.

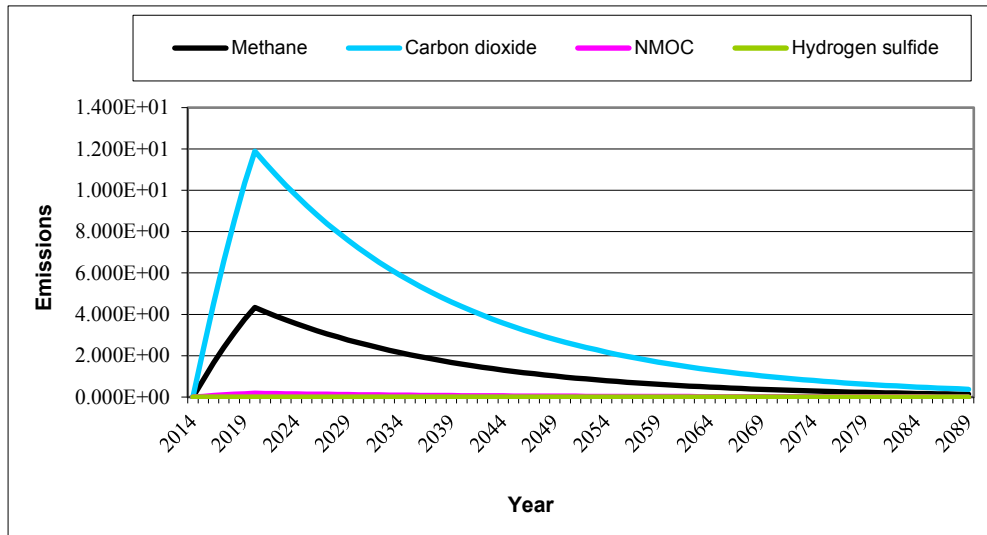


Figure 3. Gas emission rates in Mg/yr from Experimental Control Dumpsite B for 2022

Figure 3 shows the annual increasing gas emission from the in-situ experimental vegetable waste disposed at dumpsite B in Mg/yr as a control. The open year for the dumpsite was 2022 and the Land Gem simulated year is 2023. From this predicted graph, the maximum value for methane gas production was 4.195E+00 Mg/yr which occurred in 2022, five years after waste disposal and decreased to almost zero value in 2079. Furthermore, the highest production of carbon dioxide was 1.200E+01 Mg/yr to occur in 2022 and reduces to 1.385E+00 Mg/yr in 2089. This result is very clear because [13] reported that methane is 21 times more efficient at trapping heat than carbon dioxide, but carbon dioxide remains in the atmosphere longer than methane. The estimated highest emission rate of NMOCs of 1.620E-01 Mg/yr was observed in 2022 while the least value of it estimated at 3.623E-02 Mg/yr is to occur in 2063. Hydrogen sulphide produced the maximum quantity of 4.067E-01 Mg/yr in 2022 and the minimum value of it estimated to be 1.289E-03 Mg/yr was observed in 2023 respectively. All these values compare favorably with the studies of [14] on estimation of green house gas emissions from landfills in Chania, Greece who reported results of maximum and minimum values of H<sub>2</sub>S as 4.11E-02 Mg/yr and 1.10E-03 Mg/yr accordingly.

### 3.5 Model Validation of Land GEM (Confirmation)

This is the process of refinement of the model for the purpose of comparison between the predicted and measured values to achieve an acceptable degree of correspondence between these two set of values. Simulated versus measured gas emission rates were plotted in Figure 4 for points corresponding to the observation dumpsites during the period of experiment from March to November, 2022. The figure compares values of dumpsites A and B and shows a good match, throughout the period modeled between simulated and measured gas emission rates at these dumpsites. On this basis, it was concluded that Land GEM model provides a reasonable representation of the variation in gas emissions across the modeled area of study. The model can be used for predicting future conditions of the gas emissions in that environment. Qualitative method of calibration [15] was employed in this research with focus on adjustment of model data until the best fit of predictions match the measured parameters to see if they are in agreement after modeling work was completed which was also to verify the accuracy of the model due to uncertainties from environmental conditions. Based on their results; Standard Error

of Estimation (SEE) was 0.053 Mg/yr and a normalized Root Mean Square Error (RMS) was 0.038 Mg/yr (3.8%).

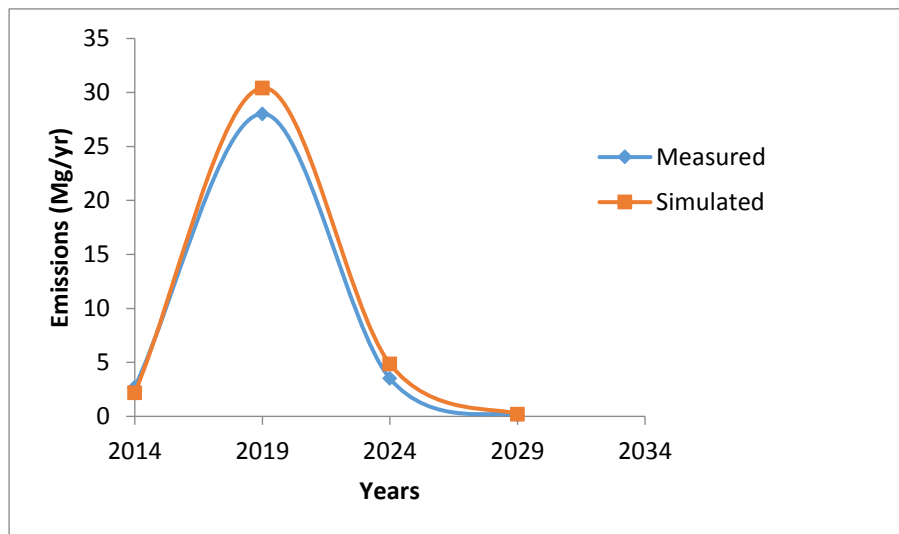


Figure 4 Model validation between Measured Vs Simulated Air Emission Rates in Mg/yr for In-situ Experimental Dumpsite A

The simulated emission rates were compared to the measured emission rates. The modeling efficiency (EF) was 64%. This suggests that the model performance under transient conditions has reasonable results. Typically, an error of about 5% is indicative of an acceptable performance, as recommended by [16]. The error represents a small part of natural gas emission rate variations.

#### 4 CONCLUSIONS

The work was undertaken to model pollutants movement from decayed vegetable waste dumpsites at Gwari market, Yola, to evaluate emission of gaseous pollutants in that environment for planning and control purposes. It can be concluded that the dumpsites closure year is 2023; waste design capacity was 500.000 tones; and the maximum methane content was 4.195E+00 Mg/yr which occurred in 2022, dumpsites open year was 1999. Unlike in some previous studies that used some air pollution models (AP-42, ISCST5 and SCREEN3 models) to compare emission releases from industrial-based stacks, this current research introduced the use of only one Land GEM tool to compare quantities of emissions released into the ambient air from each of the two dumpsites to determine which one could give out more GHGs over time. The study was also able to determine that by the year, 2023, the dumpsites would reach hazardous level if not removed according to the municipal solid waste requirements; that Nigeria is to reduce environmental pollution by 20% by the year, 2025. Based on these findings, the key recommendations from this research are that, there should be vigorous studies on the effects of climate change due to open dumping of wastes in Yola; and government should provide a befitting modern landfill equipped with leachates and emissions collection facilities for use; this can help to reduce air pollution in Yola.

#### REFERENCES

1. Schulman, I.I., Strimaitis, D.G. and Scire, J.S. (1997). Development and evaluation of PRIME plume rise and building downwash model. *Journal of air and water management Association*, vol. 50, pp. 380-390.
2. Roy, M.H. (2007). Principles of Environmental Chemistry. *Published by the Royal Society of Chemistry (RSC) Cambridge, UK*, pp. 3-25.
3. Polkowska, Z., Gorecki, T. and Namiesnik, J. (2011). Determination of Atmospheric Pollution in wet deposition. *Environmental Revampment, Published by NRC Research Press*, vol. 19, pp. 185-213.



4. Rubina, C. and Robit, G. (2014). Comparison of two methods for methane emissions at proposed landfill site and their contributions to climate change: Indore city. *International Journal of Application or Innovation in Engineering and Management*, vol. 3, no. 5, pp. 9-16.
5. Aafapcasia, T. (2010). Estimation of methane production by Land GEM simulation model from Tanjunglansat municipal solid waste landfill, Malaysia. *International Journal of Science and Technology*, vol. 1, no. 9, pp. 481-487.
6. Adepelumi, A., Ako, B. and Ajayi, I.T. (2001). Groundwater contamination in basement complex areas of Ile-Ife, Southwestern Nigeria. A case study of using the electrical conductivity of geographical method. *Hydrogeology Journal*, vol. 9, no. 16, pp. 610-620.
7. Aniko, S. B., Anderson, P. F. and Postma, D. (2009). A manual of instructional problems for USDS MODFLOW model. *United States Environmental Protection Agency*, pp. 121-127.
8. Aurora, A.B. (2004). Transport of air pollution in principles and practices, 2<sup>nd</sup> edition. *John Wiley*, pp. 2-15
9. Dibofori-Orji, A.N. and Baide, S.N. (2013). Emission of NO<sub>x</sub>, SO<sub>x</sub>, and CO from combustion of fossil fuels, 1<sup>st</sup> edition. *John Wiley*, pp. 52-55.
10. Lee, H.N. Igarashi, Y., Chiba, M., Aoyama, M., Hirose, K. and Tanaka, T. (2006). Global model simulations of the transport of Asian and Sahara Dust: *Total deposition of dust mass in Japan. Water, Air and Soil pollution*, pp. 137-625.
11. Martins, O. (2001). Water resources management and development in Nigeria-issues and challenges in a new millennium. *Inaugural lecture, University of Agriculture, Abeokuta, Ogun State, Nigeria*, pp. 621-625.
12. Masters, G.M. (1990). Introduction to Environmental Science and Engineering, Prentice Hall. *Upper Saddle River*, pp. 371-384.
13. Matejicek, L. and Benesova, L. (2002). Modeling of Environmental Pollution in Urban Areas with GIS: Solving Environmental Problems in the 21<sup>st</sup> Century. *Halifax, Nova, Scotia, Canada*, pp. 119-145.
14. Songodoyin, A.Y. (1991). Ground and surface water pollution by open refuse dump in Ibadan, Nigeria. *Discovery and Innovation*, vol. 3. no. 1, pp. 37-43.
15. Todd, W.G. (2005). What kind of gases does decaying food give off. *Madsci Network*, pp. 1-5.
16. Tuberose, C. (2011). Heavy metals toxicity, available at [tuberose.com/heavy-metal-toxicity-](http://tuberose.com/heavy-metal-toxicity-)  
[www.ijejjournal.com](http://www.ijejjournal.com), accessed on 1/1/2023.