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CHARACTERIZATION AND MODELLING OF AIR POLLUTANTS TRANSPORT FROM PANTEKA MARKET, JIMETA-YOLA, NIGERIA

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ABSTRACT: *The primary motivation of the current research was to apply Land GEM model to predict gaseous pollutant mobility by means of pollutant concentrations, annual waste mass received, and dumpsite open year from the research area. Land GEM model is believed to have wide application on emission rates from landfills/dumpsites using both site specific and default model parameters. Emission concentration levels were achieved through field and laboratory experimental work from vegetable waste dumpsites using scientific calibrated instruments. Data obtained were applied on Land GEM computer based software; version 3.02 in order to predict air-pollutant transport 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 2019 with modeling efficiency of 64%. Understanding the types of gases emitted from decomposing vegetable waste dumpsites (CH4, CO2, NMOC, H2S) and their transport pattern could go a long way to ensuring control measures of these pollutions there by having a sustainable zero wastes market to boost economic activities under pleasant environment; hence healthy environment is a prerequisite of healthy life, and fighting pollution is definitely the best way of healthy life.*

KEYWORDS: Transport, Air Pollutants, Model, Land GEM, Dumpsites

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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.

LITERATURE REVIEW

The increasing number of cases of outbreak of air pollution from various sources is alarming! Martins (2001) and Aniko et al., (2009) 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. Gupta and Gupta (1998); Fernandez-

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Turiel *et al.* (2001) predicted that, the concentration of atmospheric carbon dioxide (CO_2) and methane (CH_4) could reach 600ppm each or more. As this happens, the earth surface is expected to become warmer by emissions from polluted environment.

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 percent 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 (Aafapcasia, 2010). It can be said that vegetables are good pretty nourishing fibres that form important part of our diet. Jontos (2004) lamented that they contain 65-95% 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 (2007) wrote that, poor ventilation at the vegetable dumpsites with stacking patterns that block air movement can lead to accumulation of carbon dioxide (CO_2), H_2O, NH_3, H_2, H_2S, CH_4, 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 (Song *et al.,* 2009; Sikora et al. 2010; Tuberose, 2011). 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. This is in compliance with Adamawa State Government's urban renewal and expansion programme to meet the capital territorial economic status of Yola in Nigeria. 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 transport mechanism 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 the International Vegetables (Gwari) Market, Yola that supplies dietary vegetables to people in commercial quantities 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 (Masters, 1990; Songodoyin, 1991; Khitoliya, 2007).

Adepelumi *et al.* (2001) reported that gases from decayed vegetables can pollute the atmosphere by causing respiratory, cancer, cardiac, and other problems. These gases can

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contribute to global warming and ozone layer depletion which are very critical to climate change that the whole world is concerned with. Besides, 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

The ultimate significance of modelling pollution transport from decayed vegetable dumpsites is to provide information necessary to protect and improve long term agricultural productivity, air quality, and habitats of all living organisms including humans. 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 modelling 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. It is important to study the leaching and emission rates of pollutants from dumpsites in order to estimate their generation, dispersion, transport, accumulation and survival in the atmospheric environment. 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 in the world thereby contributing towards the control of global climate change in the world. Another imperative significance is the ease it will afford in environmental control within the study area. 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 study of modelling pollution transport from decayed vegetable dumpsites can be helpful in identifying and quantifying trends in air quality, and can provide assessments in a form that resource management and regulatory agencies can use to evaluate alternatives and make necessary decisions at improving the practice of environmental pollution control in industries and public institutions.

The specific objectives of this study are: (i) Characterization of air pollutant concentrations and analysis of meteorological data for use in model development; (ii) Application of an automated LandGEM tool for predicting transport of air pollutants from decayed vegetable waste dumpsites into the biosphere. (iii) Validation of the model to determine its usefulness for achieving zero-waste market and her environs.

MATERIALS AND METHODS

Description of Study Area:

The study site was surveyed to determine the total area of Gwari market and decayed vegetable waste dumpsites. Number of decayed vegetable dumpsites co-disposed with other items from

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the market was identified together with other physical structures around the waste dumpsites. Heights, volumes, lengths, widths and other dimensions of the dumpsites formed part of the measurements carried out. The market is semi-rectangular in geometry with dimensions 637 m and 493 m in opposite lengths and 173 m and 111.13 m in opposite widths giving an area of (93,290.36 m^2). It is about 1.5 km away from River Benue and adjacent to the left side of Jimeta-Yola bye pass road to the bridge. There were two main dumpsites for vegetable wastes labeled as "A" and "B" with the following dimensions. Dumpsite A has length of 90 m, width of 69 m and height of 4.5 m giving a volume of 136,620 m^3 and area of 6,210 m^2 (Plate 1). While dumpsite B has length of 58 m, width of 28 m and height of 2.5 m respectively (Plate 2). Its volume was 32,480 m^3 and the area being 1624 m^2. A pit of diameter 1.18 m and depth of 0.5 m with an area of 1.1 m^2 and volume of 0.6 m^3 was dug in a clean site within the study area to serve as an in-situ experimental pit (Plate 2) where vegetable wastes were dumped every day throughout the study period of study.

Plate 1: **Decayed Vegetable Wastes Dumpsite A at Panteka Market, Yola**

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Plate 2: **Decayed Vegetable Wastes Control Dumpsite B in Experimental Pit at Panteka Market, Yola**

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. BIOGAS 500 analyzers, vacuum gas extraction device (a high-volume sampler pump for gas extraction) and a portable gas monitor (GASMAN MODEL) were used. Air was extracted from the dumpsites atmosphere through a vacuum sampler connected to the potable gas monitor and Biogas 5000 analyzer arranged on a tripod stand about 1 m above the ground level facing each dumpsite and along the wind direction. Similarly, gas chromatography device with control panel was used where the extracted gas was injected into gas chromatography flame ionization device (GCFID) through a filament for detecting other pollutant gases. The analyzers contain modules of different gases and inserting the module of a particular gas automatically measures the type and concentration of the gas. In this way, modules of (CO_2, CO, CH_4, H_2S, NH_3, SO_2, NO_2, O_2, etc) were used to quantify their concentrations in each decayed vegetable dumpsite. 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. Other instruments and reagents used for determination of gas emission rates were: A manometer connected to the velocity probe of the gas sampler, Absorbent Hexane solution and other chemical reagents

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METHOD OF DATA ANALYSIS

Method for 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 Clean Air Act (CAA) defaults are based on requirements for MSW landfills laid out by 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.

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 LANDGEM methodology used can be described mathematically as:

$$Q_{CH4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k L_o \left(\frac{M_i}{10} \right) \left(e^{-k t_{ij}} \right) \quad (1)$$

Where;

Q_{CH4} = annual methane generation flow rate in the year of calculation ($m^3 yr^{-1}$);

i = 1 yearly time increment;

n = (year of the calculation) – (initial year of waste acceptance);

j = 0.1 year time increment;

k = methane generation rate ($year^{-1}$);

L_0 = potential methane generation capacity (m^3/ Mg);

M_i = mass of waste accepted in the i^{th} year (Mg);

t_{ij} = age of the j^{th} section of waste M_i accepted in the i^{th} year (decimal years, e.g. 3.2 years)

RESULTS AND DISCUSSION

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) at the western part of the market, all located in the northwestern part of the city of Jimeta-Yola. The capacity of

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dumpsite A was 500,000 tons covering an estimated area of 6,210 m^2; the length is 90 m, width of 69 m and depth of 4.5 m which has been in operation since 1999. While dumpsite B (control) had a volume of 0.6 m^3, area of 1.1 m^2, pit diameter of 1.18 m and depth of 0.5 m. The annual acceptance rate of wastes was 6,000 ton/yr. for dumpsite A and 152 kg/yr. for dumpsite B. The two dumpsites were also located within the catchment of the Benue River Basin which is the main source of water supply for Jimeta-Yola metropolis.

Table 1: 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^3/ yr.)	k	0.05	0.09
Methane generation capacity (m^3/mg)	L_0	170	160
Methane emission content	CH_4	50%	50%
Water addition factor	WAF	1.0	1.0
Methane correction factor	MCF	0.8	0.4
Waste mass disposed in the i^{th} year (ton)	mi	20,833 ton/yr.	152 Mg/yr.
Yearly time increment (m^3/yr.)	i	11.385 m^3/yr.	1.8 m^3/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 parameters such as Dumpsite A: Length = 90 m; width = 69 m, height = 4.5 m; area = 6,210 m^2; volume 136,620 m^3; and Dumpsite B: Length = 58 m; width = 28 m; height = 2.5 m; area = 1624 m^2; volume = 32,480 m^3; In-situ Dumpsite: diameter = 1.18 m; outlined in the description of study site were not required as input parameters in Land GEM software. k values of 0.05 m^3/yr are for dumpsite heights of less than 5 meters; while k values of 0.09 m^3/yr. are for dumpsite heights less than 3 meters (USEPA, 2005).

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

Table 2 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_4) and NMVOCs were again compared with the 8 hourly permissible limits recommended by the Nigerian Federal Ministry of Environment (1991) and UNEP/WHO (1994) for discussion of their implications on humans and environment. The trace gases monitored include: Ammonia (NH_3), Carbon (II) Oxide (CO), Hydrogen Sulphide (H_2S), Nitrogen (iv) Oxide (NO_2), Carbon dioxide (CO_2), Sulphur (iv) Oxide (SO_2), and Methane (CH_4).

Table 2: Concentration levels of air Pollutants from Case Study and Control Dumpsites

Location	NH_3 (ppm)	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	CO_2 (ppm)	SO_2 (ppm)	CH_4 (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 preceeding the sampling locations are: A – in-situ experimental pit (control), B – case study dumpsite, C – another case study dumpsite; 2m away from dumpsite B.

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 were presented as follows:

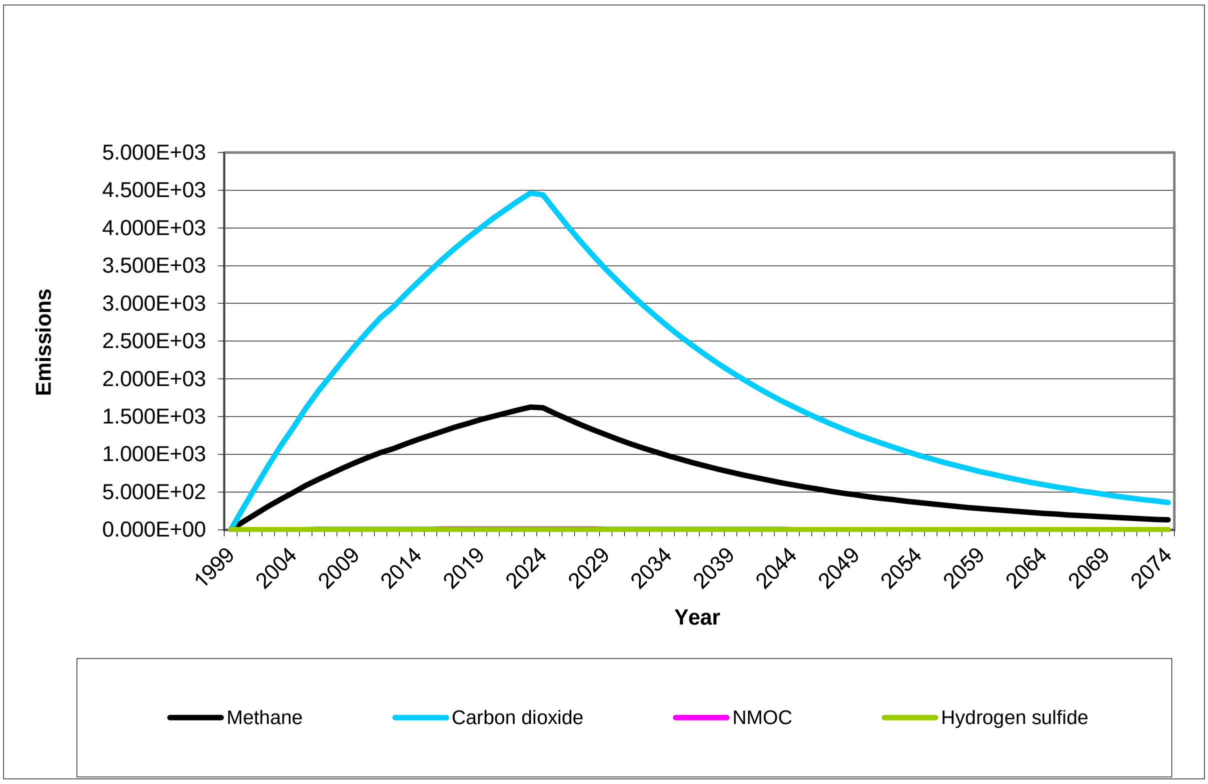

Figure 1: Annual emission rates (mg/yr) of CH_4, CO_2, NMOC and H_2S for dumpsite A (1999 -2023)

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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_2 was 4.500E+03 (Mg/yr.) which also occurred in 2014 and ceases after 2074 while NMOCs and H_2S emissions were insignificant. These results are in good comparison with the work of (Amin and Yang, 2012; Chalvatzaki and Lazaridis, 2010) who obtained maximum and reduced CO_2 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^3/yr. from the experimental control dumpsite B using Land Gem estimation tool is shown in Figure 2

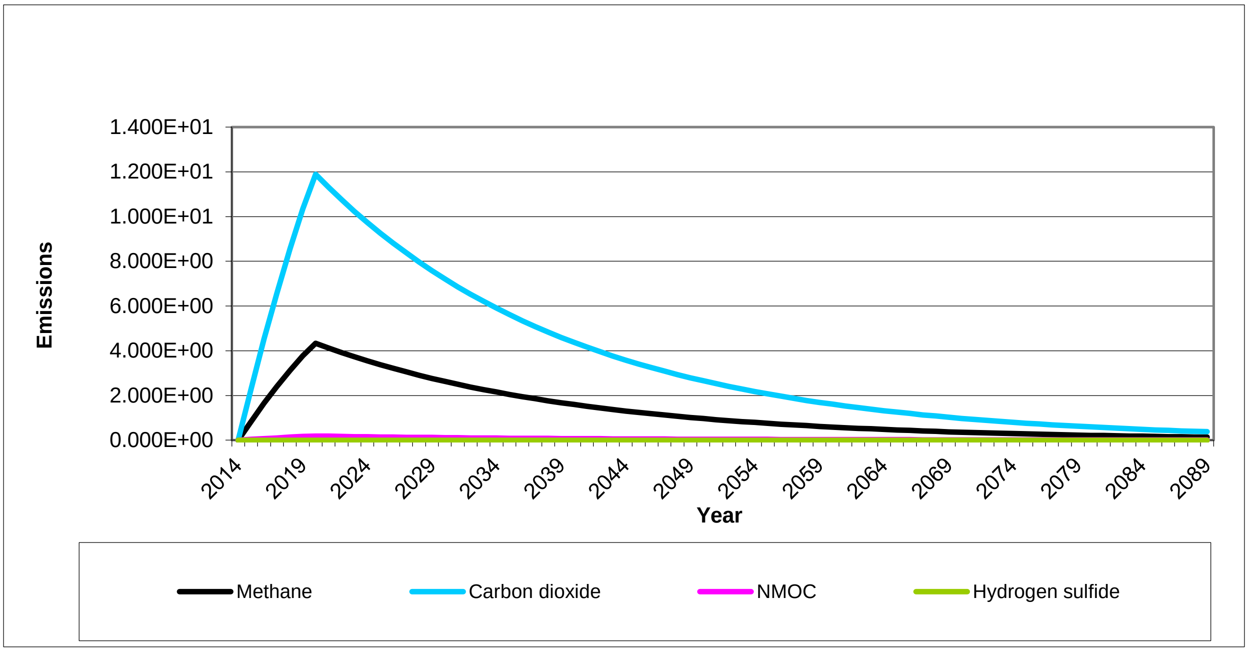

Figure 2: Gas emission rates in Mg/yr from Experimental Control Dumpsite B for 2014

Figure 2 shows the annual increasing gas emission from the in-situ experimental vegetable wastes disposed at dumpsite B in Mg/yr. as a control. The open year for the dumpsite was 2014 and the Land Gem simulated year is 2019. From this predicted graph, the maximum value for methane gas production was 4.195E+00 Mg/yr. which occurs in 2019, 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 2019 and reduces to 1.385E+00 Mg/yr in 2089. This result is very clear because Chaudhary and Garg (2014) 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 is to be observed in 2019 while the least value of it estimated at 3.623E-02 Mg/yr is to occur in 2063. Hydrogen sulphide would produce the maximum quantity of 4.067E-01

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Mg/yr in 2019 and the minimum value of it estimated to be 1.289E-03 Mg/yr was observed in 2015 respectively. All these values compare favorably with the studies of Chalvatzaki and Lazaridis (2010) on estimation of greenhouse gas emissions from landfills in Chania, Greece who reported results of maximum and minimum values of H_2S as 4.11E-02 Mg/yr and 1.10E-03 Mg/yr accordingly.

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 3) for points corresponding to the observation dumpsites during the period of experiment from March to September, 2014. 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 (ASTM, 1994) 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 modelling 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%).

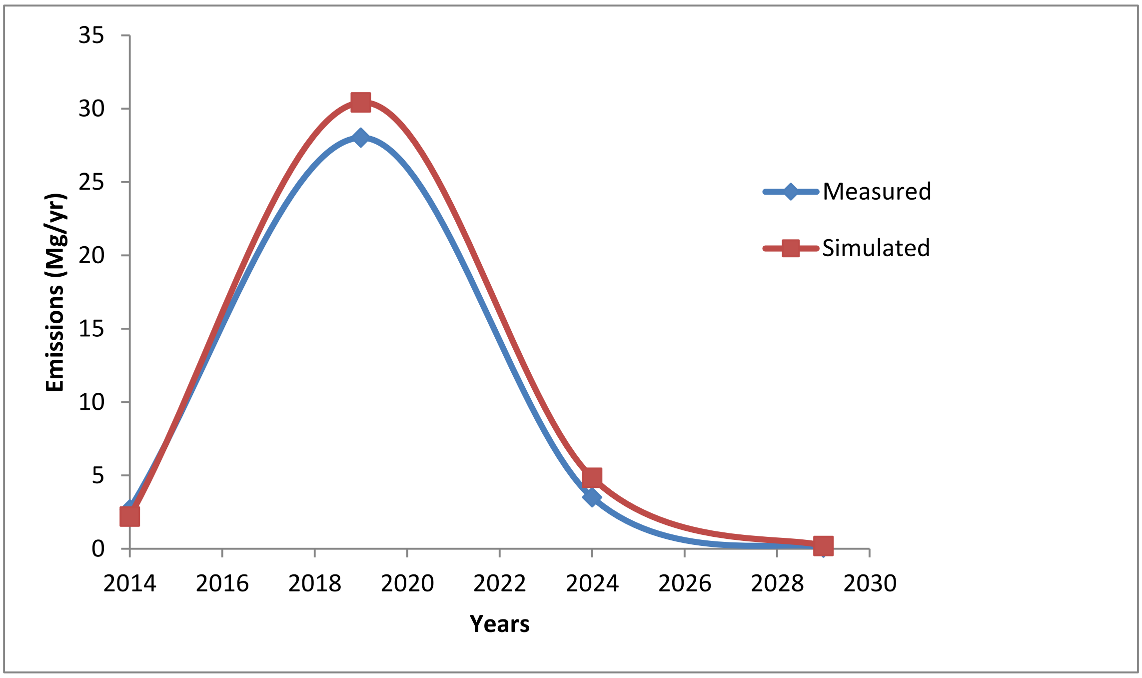

Figure 3: Model validation between Measured Vs Simulated Air Emission Rates in Mg/yr over Years for In-situ Experimental Dumpsite A

The simulated emission rates were compared to the measured emission rates. The modeling efficiency (EF) was 64%. This suggests that the model has reasonable results. Typically, an

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error of about 5% is indicative of an acceptable performance, as recommended by (Ani, 2010). The error represents a small part of natural gas emission rate variations.

CONCLUSION

The study was carried out to model pollutant transport from decayed vegetable waste dumpsites at Gwari market, Yola, with a view to evaluating the transport potentials of gaseous pollutants in that environment for planning and control purposes. The model outputs were in the form of excel spread sheets and include a summary of input data which includes the landfill closure year, 2023; waste design capacity 500,000 tones; methane content, landfill open year, 1999. The outputs figures also break down the emissions of greenhouse gases GHGs, criteria pollutant and presented the results in mega grams per year.

Unlike in some previous studies that used some air pollution models (AP-42, ISCST3 and SCREEN3 models) to compare emission releases from industrial-based stacks, chimneys, fan vents, and Gaussian plume rise in order to determine the effectiveness of these models; 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; one the case study dumpsite A (Plate 1) and the second was the in-situ (controlled) dumpsite B (Plate 2) to determine which one of these dumpsites could give out more (GHG) over time. Also, the study was able to determine that by the year 2023, the dumpsites would reach hazardous level if not removed according to the municipal solid wastes requirements. This is the novelty of this research. The study when implemented will actualize policies of National Environmental Sustainability Regulations and Enforcement Agency (NESREA) and Federal Environmental Protection Agency (FEPA) of the Federal Government of Nigeria to reduce environmental pollution by 20% by the year 2020. Based on these findings, the key recommendation from this research is that, there should be vigorous studies on the effects of climate change due to open dumping of wastes in Yola; and government should also provide a befitting modern landfill equipped with leachates and emissions collection facilities for use, this can help to reduce air pollution in Yola.

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