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Determination of Greenhouse gas emission from incineration of municipal solid waste in Kano, Nigeria

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Abstract— The amount of carbon dioxide which is a greenhouse gas emission from incineration of municipal solid waste disposal in four waste disposal sites in Kano, Nigeria was determined. The total estimated carbon dioxide emission from the four disposal sites was found to be 69, 409.61 tonnes per year, while carbon dioxide emission per kilogram of the municipal solid waste range from 0.227 kg/kg to 0.422 kg/kg of municipal solid waste.

Index Terms— Greenhouse gas, Carbon dioxide, Incineration, combustion

1 INTRODUCTION

Greenhouse gas (GHG) is a gaseous compound in the atmosphere that is capable of absorbing infrared radiation, thereby trapping and holding heat in the atmosphere. By increasing heat in the atmosphere, green house gases are responsible for the greenhouse effect which ultimately leads to global warming. The primary greenhouse gases in the earth atmosphere are water vapour, carbon dioxide, methane and nitrous oxide. Municipal solid waste (MSW) disposed in waste disposal sites produces carbon dioxide, water and heat in aerobic biodegradation while methane and carbon dioxide are produced in anaerobic biodegradation. Incineration is a common technique for treating municipal solid waste. It produces energy in the form of steam for heating and electricity generation if it is combined with an appropriate energy recovery system. Incineration processes takes place between 750^o C to 1000^o C librating heat energy, inert gases, ash and can be coupled with steam and electricity generation process [1]. A solid waste volume reduction of 80 – 90% is possible by this method [1]. Electricity production in combination with energy recovery from flue gases in thermal treatment plants is an integral part of Municipal solid waste management for many industrialized nations [2]. Nigeria with a population of over 170 million (World Bank, 2014) generates about 25 million tonnes of municipal solid waste per annum with a generation rate ranging from 0.66 kg/ (capita day) to 0.44 kg/ (capita day). According to Ogwueleka [3], about 60% of the waste is organic while about 8% are recycled.

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Kano is the Capital city of Kano State in Northern Nigeria, it is located between latitude 12^o 25′ N and 12^o 40′N and longitude 8.0^o 35′E and 8.0^o 45′E. The natural vegetation is that of Sudan Savannah and the climate of the area is tropical wet and dry type with wet season lasting for 4.5 months between May to mid October while dry season extends from mid October to mid May [4], [5]. Kano city has an urban population of about three million three hundred and forty eight thousand seven hundred (3,348,700) [3] based on 2006 census. It has been estimated that Kano Metropolis generates about 156,676 tonnes of solid waste per month and with a population of about 3,348,700 the per capita solid waste generation is about 0.56 kg per capita [3], this makes Kano city the second to Lagos in terms of waste generation in Nigeria. According to Nigeria National Bureau of Statistics Demographic Report [6], the population growth rate in Nigeria between 2006 to 2014 was 3.0 percent, therefore the projected Kano urban population by 2014 was about four million one hundred and fifty two thousand, three hundred and eighty eight (4,152,388). Most of the waste generated are dumped in an open uncontrolled waste disposal sites scattered within the urban areas of the city which is typical of most developing countries where the dominant disposal method is open dumping compared to the wide use of sanitary landfills in western countries [7]. The waste disposal sites in Kano are filling up frequently with waste due to increase in waste generation resulting from persistent population growth in the city and characterized by odour and smoke coming from spontaneous fires which causes air pollution problems to the environment and can lead to serious health hazards. According to Intergovernmental Panel on Climate Change (IPCC), gaseous emissions from solid waste disposal sites particularly methane can be a local hazard and is considered a greenhouse gas (GHG) that contribute to global warming [8].

The aim of this paper is to determine the greenhouse gas emissions from incineration of municipal solid waste in four major municipal solid waste disposal sites in Kano metropolis.

2.0 MATERIALS AND METHODS

Municipal solid waste disposal data of waste dumps in Kano Metropolis were collected from Kano State Refuse management and Sanitation Board (REMASAB). Average monthly municipal solid waste disposals in the four wastes dump sites of Maimalari (Bompai), Hajj camp, Ubagama and Court road in Kano metropolis are shown in Table 1.

2.1 Ultimate Analysis

Solid waste samples were collected from the four waste disposal sites and ultimate analysis conducted. The ultimate analysis involves the determination of nitrogen, hydrogen, carbon, oxygen and sulphur in the solid waste samples. Nitrogen was determined using the Kjeldahl method, the carbon and hydrogen were determined by heating the waste sample in a current of pure oxygen gas, when the carbon and hydrogen were completely oxidized into H_2O and CO_2, these were then absorbed separately in calcium chloride and potassium hydroxide solution. The increase in weight of the absorbents gives the amount of CO_2 and H_2O formed and the amount of C and H were then calculated. The Sulphur determination involves the oxidation to sulphate which is then gravimetrically determined as barium sulphate. Oxygen is calculated by subtracting the sum of the percentages of ash, sulphur, nitrogen, carbon and hydrogen from 100.

2.2 Combustion of Municipal Solid Waste

The combustion of municipal solid waste involves the basic elements of the organic components of the waste, carbon (C), hydrogen (H) and sulphur (S) [9]. The equations for stoichiometric combustion of the waste are as follows [10], [11]:

$$C + \left(O_2 + \tfrac{79}{21}N_2\right) \rightarrow CO_2 + \tfrac{79}{21}N_2 \qquad (2.1)$$

$$H + 0.25(O_2 + 3.76N_2) \rightarrow 0.5H_2O + 0.94N_2 \qquad (2.2)$$

$$S + (O_2 + 3.76N_2) \rightarrow SO_2 + 3.76N_2 \qquad (2.3)$$

The percentage volumes of oxygen and nitrogen in air are assumed to be 21 and 79%, while the percentage masses are 23.3% and 76.7% respectively. The small traces of other gases in dry air are included in the nitrogen, which is sometimes called 'atmospheric nitrogen' [12].

The theoretical oxygen required for complete combustion was calculated based on the following equations:

Combustion of Carbon (C): Consider the oxidation reaction of carbon as follows;

$12kgC+32kgO_2 \rightarrow 44kgCO_2$ (2.4)

The amount of oxygen required for complete combustion of Carbon may be expressed as:

$O_2=\%Cx(32/12)=\%Cx2.667/kgMSW$ (2.5)

Carbon dioxide produced = %C x (44/12) = %C x 3.667/kg MSW (2.6)

Since municipal solid waste (MSW) is a heterogeneous mixture of waste, in terms of sources of CO_2, a distinction has to be drawn between carbon of biogenic origin and carbon of fossil origin. The proportion of climate relevant CO_2 is assumed to be at an average of 0.415 tonne per tonne of waste [13]. Therefore the climate relevant CO_2 emission was calculated as follows as;

$CO_2=\%Cx0.415x3.667/kgMSW$ (2.7)

Combustion of Hydrogen (H): Consider the oxidation reaction of hydrogen as follows:

$2kgH_2+16kgO_2 \rightarrow 18kgH_2O$ (2.8)

The amount of oxygen required for complete combustion of hydrogen may be expressed as:

$O_2=\%Hx(16/2)=\%Hx8/kgMSW$ (2.9)

Steam produced=%Hx(18/2)=%Hx9/kgMSW (2.10)

Combustion of Sulphur (S): Consider the oxidation reaction of sulphur as follows:

$32kgS+32kgO_2 \rightarrow 64kgSO_2$ (2.11)

The amount of oxygen required for complete combustion of sulphur may be expressed as:

$O_2=\%Sx32/32/kgMSW$ (2.12)

SO_2 produced=%Sx64/32=%Sx2/kgMSW (2.13)

Where %C, %H, and %S represent the percentage by mass of carbon, hydrogen and sulphur respectively in the municipal solid waste (MSW) composition.

The composition was obtained from the ultimate (elemental) analysis of the waste. The oxygen required per kilogram of MSW was obtained from the sum of the oxygen required for the complete combustion of the elements in the MSW. Therefore the amount of air required for stiochiometric combustion of the waste is given as:

$$A_r = {}^{O_2}/_{0.233} \quad kg \qquad (2.14)$$

Where: A_r is air required per kg of MSW; O_2 is oxygen required.

Air is assumed to contain 23.3% oxygen by mass.

3.0 RESULTS AND DISCUSSIONS

Preliminary data on solid waste disposal to the four dumpsites was collected as shown in Table1.

Table 1: Average monthly waste disposals in of Kano metropolis (2012-2013)

Dumpsite	Average waste disposal rate (Tonnes)	
	Monthly	Daily
Court Road	10,674.72	355.82
Maimalari	11,849.81	394.99
Haajj camp	13,046.88	434.90
Ubagama	6,429.65	214.32

Source: Kano State Refuse management and sanitation Board.

Solid wastes from different collection centers within Kano municipality are collected by trucks to these dumpsites. The data in the table 1 shows the average monthly and daily disposals of solid wastes the four major dumpsites in Kano, with Hajj camp dumpsite having the highest disposal rate of 434.90 tonnes/ day while Ubagama dumpsite having the least with 214.32 tonnes / day.

Ultimate Analysis

The results of the ultimate analysis from the four waste disposal sites are shown in Table 2.

The results show the percentage Nitrogen, Carbon, Hydrogen, Oxygen and Sulphur content of the municipal solid waste from the four waste disposal sites.

Table 2: Ultimate analysis

Dump site	Nitrogen (N) % wt.	Carbon (C) % wt.	Hydrogen (H) % wt.	Oxygen (O) % wt.	Sulphur (S) % wt.
Court road	0.560	6.200	0.950	0.067	2.800
Mai-malari	0.597	11.500	0.600	0.053	1.970
Hajj camp	0.565	8.500	0.930	0.350	9.630
Uba-gama	0.457	10.37	0.920	0.060	3.470

Combustion of the municipal solid waste

The Carbon dioxide, steam, sulphur dioxide per kilogram that would be produced from combustion of municipal solid waste from the waste disposal sites are computed from equations (2.6), (2.10) and (2.13) respectively. Also the stoichiometric air requirements for complete combustion per kilogram of the waste were computed using equation (2.16). Table 3 show the combustion products and stoichiometric air requirement for complete combustion.

Table 3: Air requirement and expected Combustion products per kg MSW

Dumpsite	Air required (kg/kg MSW)	CO_2 emission expected (kg/kg MSW)	H_2O expected (kg/kg MSW)	SO_2 emission expected (kg/kgMSW)
Court road	1.150	0.227	0.086	0.056
Maimalari	1.605	0.422	0.054	0.039
Hajj Camp	1.708	0.312	0.088	0.193
Ubagama	1.649	0.380	0.083	0.069

Greenhouse gas Emission

The average annual climate relevant carbon dioxide emissions that would result from incineration of the Solid wastes from the waste disposal sites were computed using Tables 1 and 2 and equation 2.7. The results are shown in Table 4.

Table 4: Average annual GHG Emissions from incineration of MSW (2012-2040)

Dumpsite	CO_2 Emission from incineration of MSW (tonne/yr)
Court road	12,067.344
Maimalari	24,903.087
Hajj camp	20,271.720
Ubagama	12,167.470
Total	69,409.621

The result of the estimated climate related Carbon dioxide emissions from incineration of MSW in the four dumpsites as shown in Table 4 indicate that MSW from Court road dumpsite would have climate related annual CO_2 emission of 12,067.344 tonne/yr, MSW from Maimalari dumpsite would have annual CO_2 emission of 24,903.087 tonne/yr, the MSW from Hajj Camp dumpsite would have annual CO_2 emission of 20,271.720 tonne/yr, while MSW from Ubagama dumpsite would have annual CO_2 emission of 12,167.470 tonne/yr. The total estimated Carbon dioxide emission from the four solid waste disposal sites would amount to 69,409.61 tonnes/yr.

4.0 CONCLUSION

Incineration of municipal solid waste produces carbon dioxide. The amount of carbon dioxide produce depends on the percentage carbon content in the composition of the solid waste. The results show that carbon dioxide emission from incineration of the solid waste in the solid waste disposal sites range from 0.227 kg/kg to 0.422 kg/kg of MSW. The total annual estimated carbon dioxide emission from the four waste disposal sites was found to be 69,409.61 tonnes/yr.

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