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Investigation of No_2/No, So_2, Co and Volatile Organic Compounds Emission from Solid Waste in Ogbomoso

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Abstract

Emissions from burning of solid waste have been a major source of air pollutions in Ogbomoso Township in the last few years. This research work estimate the emissions of nitrogen oxides (NO_2/NO), carbon(II)oxide, sulphur (iv) oxide and volatile organic compounds from solid waste in Ogbomoso as a measure of control using the emission factors approach. Determination of the solid waste generation potential using per capita approach was combined with the appropriate emission factors for the estimation. On the average, nylon has the least generation potential with 8.85% while solid (glass, metal, tin and sand) has the highest with 44.825%. These generation potentials increased from 44,073 tonnes/annum in the year 2002 to 63,822.88 tonnes/annum in the year 2011 with the population of 242,167 to 350,627 per capita respectively. However, results obtained from nitrogen oxides (NO_2/NO), carbon (II) oxide, sulphur (iv) oxide and volatile organic compounds emissions rate shows an increased trend of 132.22 to 191.47, 1851.3 to 2680.6, 19.3 to 27.1 and 947.58 to 1372.19 tonnes/annum respectively in the year 2002 to 2011. The emission rate of NO/NO_2, SO_2, CO and volatile organic compounds must be controlled because of their adverse effect on the environment. The controlled could be by converting them for energy production owing to the high calorific value of the solid waste in Ogbomoso. Another controlled technique that can be employed in addition to conversion for energy production is by burning the waste in an incinerator since the solid waste consist of high percentage of combustible materials.

Keywords: Emission factor, Solid waste

1. Introduction

In the 1970s, the engineering profession became widely known actively aware of its responsibility to the society, particularly for the protection of public health and welfare. The decade saw the formation rapid growth of the U.S Environmental Protection Agency (EPA) and the passage of federal and state laws governing virtually every aspect of the environment. The end of the decade, however, brought a realization that only the more simplistic problems had been addressed. A limited number of large sources had removed substantial percentages of a few readily definable air pollutants for their emissions. (Taiwan EPA, 2003).

The human population has grown at an unprecedented rate this century and this has resulted in many localized environmental impacts. This is now believed to be the potential for the population to start interfering with the atmosphere, with global-scale environmental impact being the result. In this decade, human impacts on the carbon cycle, primarily from fossil fuel combustion and deforestation, have received much public and governmental attention because of the implications for enhancing the green house effect. However, less attention has been given to human impacts on the global nitrogen cycle, impacts which are quantitatively greater than the impacts on the carbon cycle. Fortunately, several members of the scientific community have recently published reviews raising concerns about the human-induced impacts on global nitrogen cycling.(Pourkashanian and Williams, 2009). Analogous to increase in atmospheric carbondioxide concentrations being labelled, “global warming,” the impact of human-induced interference of the global nitrogen has been called “global fertilization.” Unfortunately, interference on global nitrogen creates not only global fertilization, but also contributes to global warming and strastospheric ozone depletion.(Bernt and Robert, 2010).

Municipal solid waste (MSW) generation has been increasing at an annual rate of 8–10%, with over 150 million tonnes of MSW being produced each year now (Nie, 2008; Xu and Liu, 2007; Yuan *et al*., 2008).Common gaseous air pollutants from municipal solid waste include carbon monoxides, sulphur dioxides, chlorofluorocarbon(CFCS), nitrogen oxides and volatile organic compounds(VOCs). Volatile sulfur compounds (VSCs) have been identified as the predominant odorants emitted during organic waste composting (Komilis et al., 2004; Wu et al., 2010). VSCs consist of volatile organic compounds (VOCs) that contain sulfur and reduced sulphur compounds (RSCs) such as hydrogen sulfide (H_2S), methyl mercaptan (MM), dimethyl sulfide (DMS), dimethyl disulfide (DMDS), carbonyl sulfide (OCS) and carbon disulfide (CS_2) (Panetta et al., 2005). These compounds are characterized by a low detection threshold and strong odor activities and therefore contribute to odor pollution when present at very low emission concentrations (Yu et al.,2007). This study is therefore part of the contribution to the control and management of solid waste. While abandoned dumps/refuse pose a unique set of problems, innovative strategies are needed to deal with the waste by the appropriate conversion of these wastes to energy sources for use instead of causing more havoc to the society. The major environmental concerns associated with waste-to-energy facilities are potential impact on air quality and the disposal of ash. Air emissions aspects include particulate matter, acid gases (hydrochloric acid and sulphur oxides), organic compounds (including dioxins and furans), inorganic compounds (trace metals) and nitrogen and carbon oxides. Release pathways for air emissions for humans or for the environment can be direct (through inhalation) or indirect(through the food chain). Air emissions can also have impact on global atmospheric problems such as ozone layer depletion and the greenhouse effect. Proper design and operation, taking into consideration emission standards and regulations, control these effects. (Bernt and Robert, 2010).

2. Experimental

2.1 *Materials and Equipment*

The materials and equipment used for the research work includes: Geographical Positioning System (GPS), bomb calorimeter, weighing balance, dryer, hammer mill grinder, hand gloves, nylon, solid waste samples, benzoic acid, muffle furnace, nostril mask.

2.2 *Site Location*

Ogbomoso is a pre-colonial urban centre and the second largest city, both in terms of population and spatial extent, in Oyo State, Nigeria. The city is located at a distance of about 100 km north of Ibadan, the Oyo state capital and about 80 km from Ilorin and Oshogbo. It is one of the main gateways to the northern part of Nigeria from the Yoruba. Twenty (20) major dump sites were located from its two local governments. Geographical positioning system was used to take their coordinates which were then located on the map of Ogbomoso as represented in Figure 2.1. 2 Kg of municipal solid waste were taking as sample from each of these locations for proper analysis.

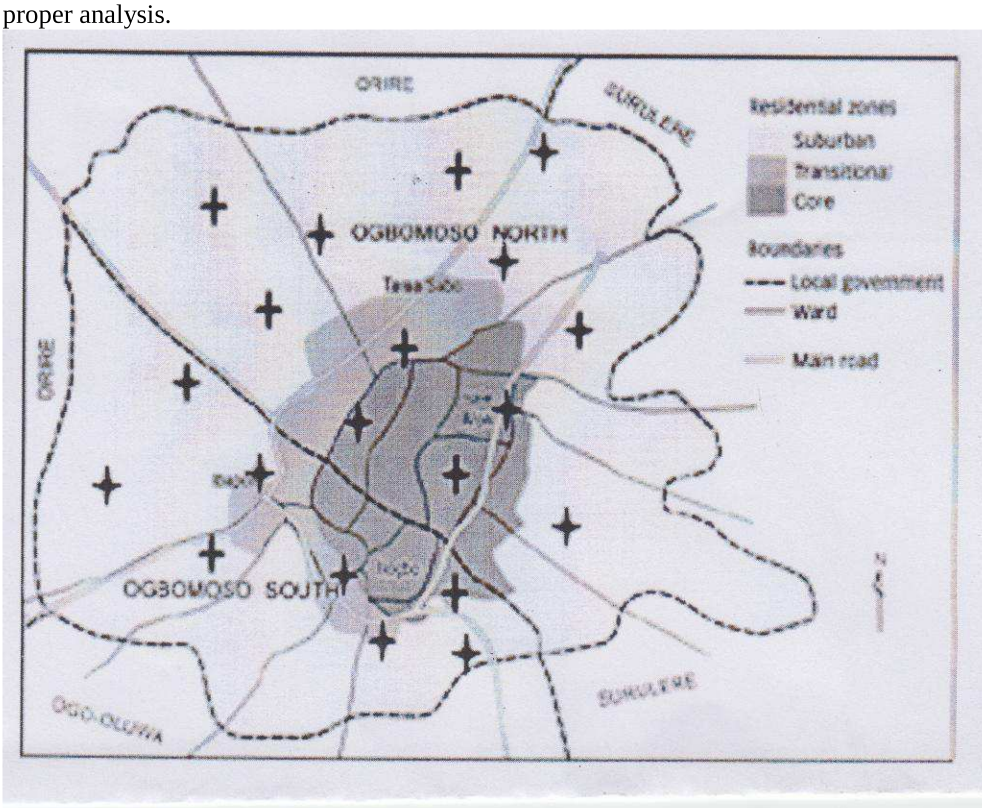

Figure 2.1: Map of Ogbomoso North and South LGA showing the Selected Dump Sites.

2.3 Solid Waste Characterization

Samples of solid wastes were collected from each dump sites for proper analysis and 2 kg was weighed from each samples using the weighing balance. The collected samples were characterized by separation of each constituent of the waste into; Cellulose(Textiles, Paper, Leaves), Solid (Glass, Metal, Tin and Sand); Wood; Leather; Plastics and Nylon. This is shown in Figure 3.1 and Figure 3.2

2.3.1 Quantification of Solid Waste Generated per Person in Ogbomoso

The lack of essential (weigh-bridges) at each final disposal sites makes the direct determination of disposed waste quantities impossible. Therefore, there is no information on generation as a function of season. The estimation of generation quantities of solid waste (Kg/capita/ annum) was based on previous studies; NEST(2001), Achankeng(2003), Koforowola(2007) and Sha'o et al. (2007). According to Nest (2001), 20 Kg of solid waste is generated per capital per annum in Nigeria but Achankeng (2003) reported 0.3 Kg per capital per day. However, Koforowola (2007) reported 1.1 Kg/capital/day, while Sha'O et al (2007) reported 0.54 Kg/capital/day for central Nigeria. This is shown in Table 3.1.

The rates were considered as potential for solid waste generation in Ogbomoso. Due to lack of agreement on the level of combustible component of solid waste, emission prediction was based on 100%. The quantity of waste generated per capital per annum was varied from 2002 to 2011. However, due to the variation of putrescible solid waste in Ogbomoso township, the quantity of solid waste generated per person was estimated using per capital approached as expressed below;

$$\text{Waste generated per person} = \frac{total\ mass\ of\ solid\ waste\ generated\ in\ Ogbomoso}{total\ population\ in\ Ogbomoso\ in\ a\ particular\ year} \qquad (1)$$

Total mass generated per capital per annum was varied as a function of population from 2002 to 2011 using the mass generated per person. This is shown in Table 3.2, Figure 3.3 and Figure 3.4.

2.3.2 Air Pollutant Emission Prediction from Solid Waste in Ogbomoso

An emission factor approach was used to quantify the carbon(I)oxide, sulphur (iv) oxide, nitrogen oxides and volatile organic compounds pollutant emission from solid waste in Ogbomoso,

The procedure for emission prediction is shown in the emission factor calculation equation shown below;

$$\text{Air pollutant emitted in ton/ yr} = \frac{Emission\ factor\ (Kg) of\ pollutant}{1\ Mg\ of\ Solid\ waste\ burnt} \times \frac{1 Mg}{1000\ Kg} \times \text{Average yearly solid waste generated (Mg / annum)}. \qquad (2)$$

From EPA (1995), the emission factor of carbon monoxide (CO) is 42 Kg/ Mg for solid waste management. The emission factor of nitrogen oxides is 3 Kg/ Mg for Municipal solid waste. The emission factor of SO_2 is 4.4×10^{-1} Kg/ Mg and that of volatile organic compounds is 21.5 Kg/ Mg from municipal solid wastes.

2.3.3 Determination of Calorific Value of Samples

After sorting the samples into combustible and incombustible material, the combustible were oven dried until constant weight was obtained. The samples were then grinded using a hammer mill grinder (of model 200 which is incorporated with 2 mm sieve). 2.5g of the grinded samples was weighed into the steel capsule. A 10 cm cotton thread was attached to the thermocouple to touch the capsule. The bomb was closed and charged in with oxygen up to 30 atm. The bomb was fixed up by depressing the ignite switch to burn the sample in an excess of oxygen. The maximum temperature rise in the bomb was measured with thermocouple and galvanometer system. The rise in temperature was compared with that obtained from benzoic acid standard of known calorific value. The calorific value of each sample was determined by the following stepwise calculation;

For Standardization:

Mass of Benzoic Acid (w_1) = 0.94 g

Calorific Value of 1 g Benzoic Acid = 6.32 Kcal/g

Heat released from Benzoic Acid = 6.32 × 0.94

= 5.94 Kcal/g

Galvanometer Deflection without sample, T_1= 0.42 ^{0}C

Galvanometer Deflection of Benzoic Acid, T_2= 1.37 ^{0}C

Distance in the galvanometer Deflection, T_2 - T_1= 0.95 ^{0}C

Calibration Constant $= \frac{6.32 \times W_1}{T_2 - T_1} = Y$

$Y = \frac{6.32 \times 0.94}{1.37 - 0.42}$

Y = 6.25. The standardizing is repeated five times and average value was calculated for Y.

For the sample;

Mass of Sample = M

Galvanometer Deflection with sample = T_3

Difference in the Galvanometer deflection with sample = T_3 - T_2

Heat release from the sample = (T_3- T_1) × Y Kcal

∴ Calorific Value of the sample $= (\frac{T_3 - T_1}{M}) \times Y \times 1000\ Kcal/kg$. This is shown in Table 3.5 and Figure 3.5

3. Results and Discussion

3.1 Results

3.1.1 Solid Waste Characterization

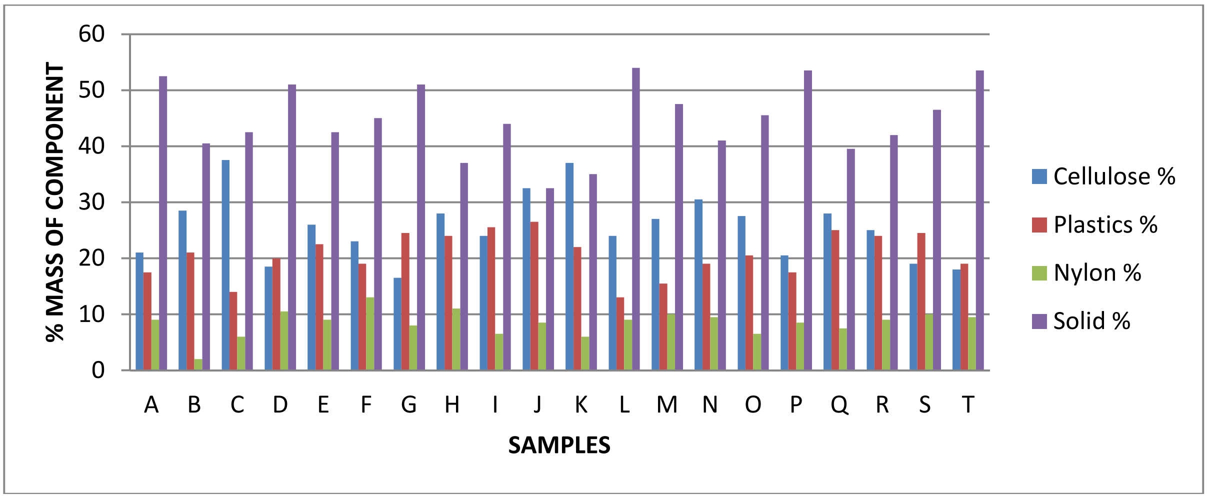

Figure 3.1 Bar Chart Showing Percentage Mass of Different Components for the Twenty Samples

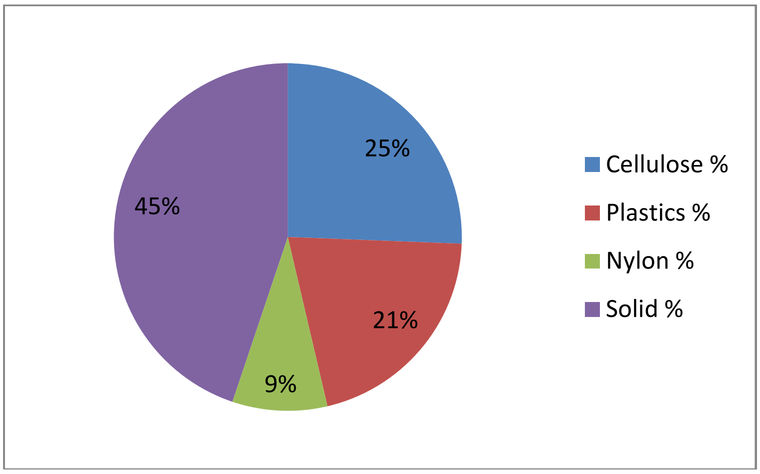

Figure 3.2: Pie Chart Showing the Total Percentage of Different Components in the Sample

3.1.2 Solid Waste Generation Potential

Table 3.1: Solid Waste Generated Per Person From Different Source.

Source	Waste generated per person	
	Kg/ capital/day	Kt/ capital/annum
NEST (2001)	0.0548	20×10^{-6}
Achankeng (2003)	0.3	109.5×10^{-6}
Koforowola (2007)	1.1	401.5×10^{-6}
Sha'o et al (2007)	0.54	197.1×10^{-6}

Table 3.2: Ten-Year Solid Waste Generation in Ogbomoso.

Year	Population	Solid Waste, t/ annum				
		NEST (2001)	Achankeng(2003)	Koforowola (2007)	Sha'o et al (2007)	Average
2002	242,167	4843.34	26,517.29	97,203.05	47,731.12	44,073.70
2003	249,916	4998.32	27,365.80	100,314.27	49,258.44	45497.71
2004	257,914	5158.23	28,241.58	103,552.47	50,834.85	46,946.78
2005	266,167	5323.34	29,145.29	106,866.05	52,461.52	48,449.05
2006	299,535	5990.70	32,799.08	120.263.30	59,038.35	54,522.86
2007	309,120	6182.40	33,848.64	124,111.68	60,927.55	56,267.57
2008	319,012	6380.24	34,931.814	128,083.32	62,877.27	58,068.16
2009	329,220	6584.40	36,049.59	136,411.63	64,889.26	59,926.27
2010	339,755	6795.10	37,203.17	140,776.74	66,965.71	61,843.90
2011	350,627	7012.54	38,393.66	11683.65	69,108.58	63,822.88

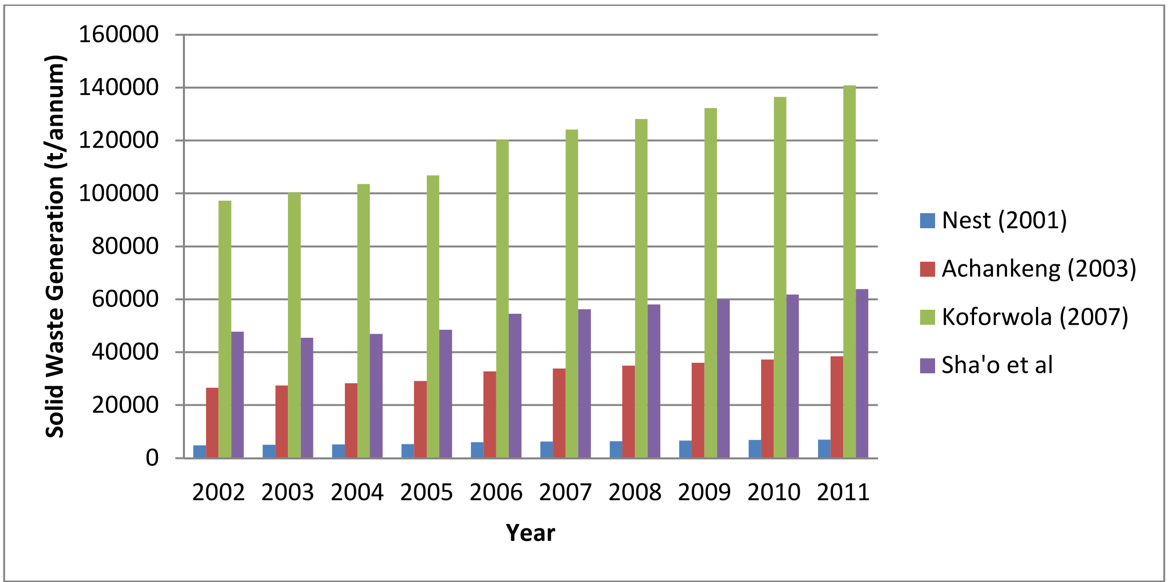

Figure 3.3 Solid Waste Generation Potential/Year

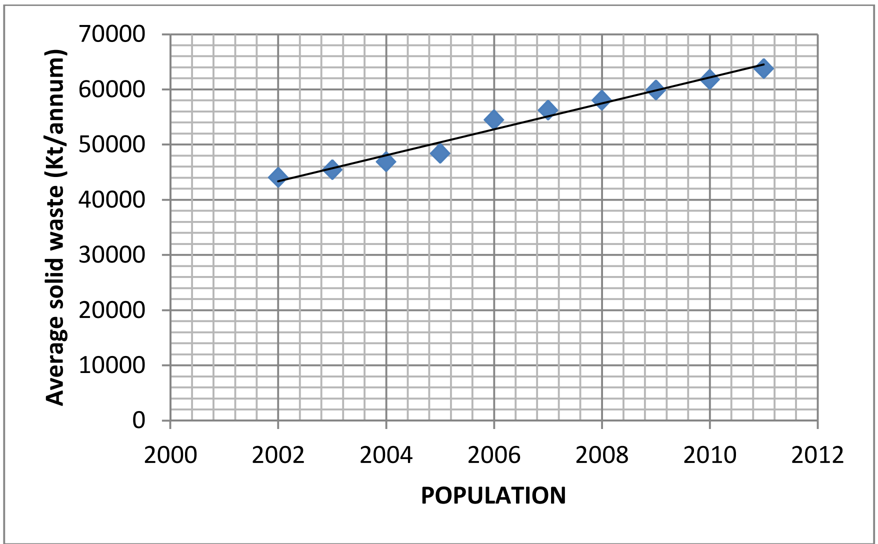

Figure 3.4 Average Solid Waste Generation Potential in Ogbomoso

Table 3.3 Result of Calorific Values of Solid Waste Samples

SAMPLE CODE	FINAL TEMPERATURE T_3(^{0}C)	CALORIFIC VALUE (Kcal/Kg)
A	6.85	16,075
B	7.84	18,550
C	9.23	22,025
D	8.72	20,750
E	9.55	22,825
F	9.78	23,400
G	10.45	25,075
H	6.90	16,200
I	13.55	32,825
J	9.25	22,075
K	10.75	25,825
L	12.60	30,450
M	11.96	28,850
N	13.90	33,700
O	12.30	29,700
P	7.85	18,575
Q	11.87	28,625
R	7.95	18,825
S	6.88	16,150
T	13.40	32,450

Mean of Calorific Value = 24147.5. Standard deviation = 5733.76

3.1.4 Emission from Solid Waste in Ogbomoso

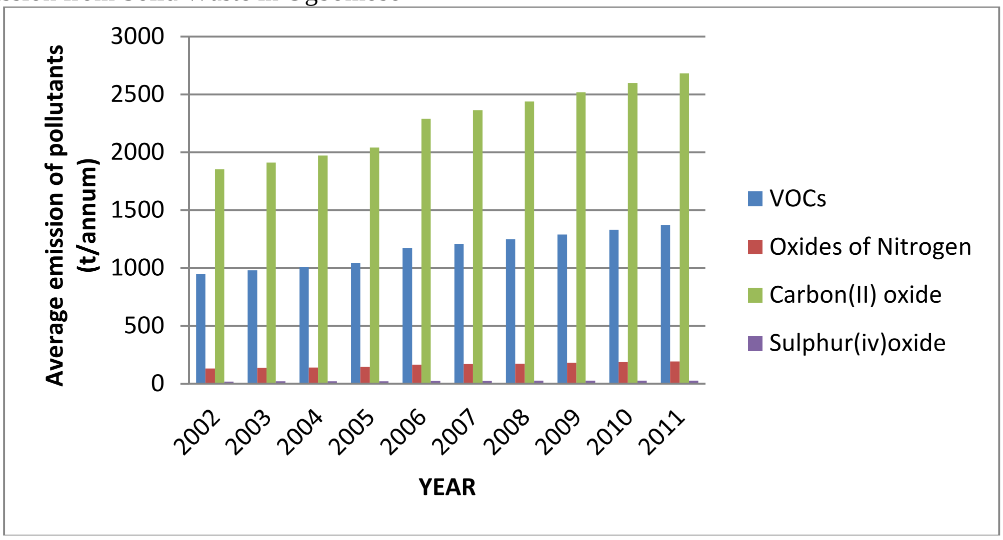

Figure 3.5 Graph of Average Emission of Pollutant (t/annum) versus Year(2002-2011)

3.2 Discussion of Result

Figure 3.1 shows the percentage of each component in each of the samples. The samples contained; plastics, nylon, cellulose (which consist of textiles, paper, leaves) and solid (which consist of glass, metal,tin and sand). The percentage weight of each component included are Solid (44.825 %), Cellulose (25.6 %), Plastics (20.725 %), Nylon (8.85 %) as shown in Figure 3.2.

From Figure 3.1 and 3.2, the major proportion of waste generated in Ogbomoso was non combustible solid (44.825 %) followed by cellulose (25.6 %), plastics and nylon. Non- combustible solid was heavier than cellulose and this was because these areas are residential, where household waste like glass, tin and metal are part of their waste. Plastic took a smaller proportion of waste components; this was due to the fact that there are some people who normally pick them up for recycling.

The combustible parts, which are plastics, nylon and cellulose takes the largest proportion waste generated in Ogbomoso (55.175 %) while that of non combustible was smaller (44.825 %). This means that appropriate and authorized burning of the waste generated in Ogbomoso will reduce the volume of waste to about 90 %.

The result also shows how the aesthetic nature of the environment was being destroyed. From table 3.3 and it can be seen that the calorific value of the solid waste is high and therefore can be converted for energy production. Also the calorific value increases with increase in the final temperature T_3. The mean calorific value of all the samples is 24.147 Kcal/g. Therefore the solid waste generated in Ogbomoso is high in energy value. The conversion of the pollutants for energy production will also serve as a way of controlling its emission to the environment.

From Figure 3.3 and 3.4, it can be seen that as the population size increases annually also the solid waste generation increases. There was an increase in the annual average solid waste generation from 44,073.70 to 63,822.88 from the year 2002 to 2011.

Figure 3.5 shows the emission of carbon(II)oxide from combustion of solid waste. From this result an increase in the carbon monoxide from the year 2002 to 2011 can be attributed to the increased in solid waste generation within the period. The result shows that carbon monoxide increases from 1851.3 to 2680.6 tonnes/annum from the year 2002 to 2011. Carbon monoxide is highly toxic. It combines with the haemoglobin to produce carboxyhaemoglobin, which is ineffective for delivering oxygen to body tissues. Concentrations as low as 667 ppm may cause up to 50 % of the body's haemoglobin to convert to carboxyhaemoglobin, which may result in seizure, coma, and fatality. The values of the emission of the gas from solid wastes will add to the quantity produced from natural sources which is higher than 5×10^{12} Kg/annum, therefore the emission of the gas from solid waste must be controlled.

Figure 3.5 also shows the emission of volatile organic compounds from combustion of solid waste. From this result an increase of volatile organic compounds from the year 2002 to 2011 can be attributed to the increased in solid waste generation within the period. The result shows that volatile organic compounds increase from 947.58 to 1372.19 tonnes/annum from the year 2002 to 2011. These emission values must be controlled because of the effects of volatile organic compounds which include damaging of the visual and audible senses.

Figure 3.5 also shows the emission of sulphur dioxide from combustion of solid waste. From this result an increase of sulphur dioxide from the year 2002 to 2011 can be attributed to the increased in solid waste generation within the period. The result shows that sulphur dioxide increases from 19.3 to 27.1 tonnes/annum from the year 2002 to 2011. Sulphur dioxide is a major air pollutant and has significant impacts upon human health. The United State Environmental Protection Agency reveals that inhalation of sulphur dioxide is associated with increase respiratory symptoms diseases, difficulty in breathing and premature death. The short term exposure limit of sulphur dioxide is 0.25 ppm according to the American Conference of Industrial Hygienists, therefore the emission of the gas from solid waste must be controlled.

Figure 3.5 also shows the emission of oxides of nitrogen (NO_2/NO) from combustion of solid waste. From this result an increase of oxides of nitrogen from the year 2002 to 2011 can be attributed to the increased in solid waste generation within the period. The result shows that oxides of nitrogen (NO_2/ NO) increases from 132.22 to 191.47 tonnes/annum from the year 2002 to 2011. Oxides of nitrogen (NO_2/ NO) reacts with moisture, and other compounds to form nitric acid vapour and related particles. Small quantity of these particles can penetrate deeply into sensitive lung tissues and damage it, causing premature death in extreme cases; therefore the emission of the gas from solid waste must be controlled.

The bar chart in Figure 3.5 shows that the emission of carbon monoxide is the highest for each of the years considered, followed by that of volatile organic compounds, and then the emission of oxides of nitrogen. The least is that of sulphur dioxide.

4. Conclusion

The analysis reveal that in Ogbomoso, there is a strong correlation between the population, waste generated per person per annum and the emission rate of NO/NO_2, SO_2, CO and volatile organic compounds. As the population increases from the year 2002 to 2011, there is an increase in solid waste generated for that particular year and a corresponding increase in the emission of NO/NO_2, SO_2, CO and volatile organic compounds. The highest emission rates were that of year 2011 with the minimal obtained in the year 2002. These studies identified the absence of emission factors for emission sources in Ogbomoso as a major challenge in accurate prediction and control of emissions from solid waste. The emission rate of NO/NO_2, SO_2, CO and volatile organic compounds must be controlled because of their adverse effect on the environment. The controlled could be by converting them for energy production owing to the high calorific value of the solid waste in Ogbomoso. Another controlled technique that can be employed in addition to conversion for energy production is by burning the waste in an incinerator since the solid wastes consist of 55.175% of combustible materials.

References

Achankeng, E. 2003. Globalization, Urbanization and Municipal Solid Waste Management in Africa. Africa Studies Association of Australia and the Pacific 2003 Conference Proceedings- Africa on a Global Stage. p.22

Adeboyejo A. T and Abolade O.(2007). "Household Response to Urban Encroachment on Rural Hinterland in Ogbomoso Urban Fringe" Department of Urban and Regional Planning, Ladoke Akintola University of Technology Ogbomoso, Nigeria.

Afon Abel, "An Analysis of Solid Waste Generation in a Traditional African city: the example of Ogbomoso, Nigeria", Environmental and Urbanization 2007 19: 527 DOI: 10.1177/0956247807082834.

Bent Johnke and Robert Hoppaus,(2010) 'Emission from Waste Incineration,' Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, (Germany)

Brent M Voelker, (2009) 'Waste- to Energy,' Solutions for Solid Waste Problems for the 21st century

EPA, Compilation of Air Pollution Emission Factors, Vol. 1, Stationary Point and Area Sources, fifth edition. (Research Triangle Park NC, USA, 1995), United States Environmental Protection Agency, Office of Air Quality Planning and Standard,1995.

Gidarakos E, Havas G, Ntzamilis P, 'Municipal Solid Waste Composition Determination Supporting the Integrated Solid Waste Management System in the Island of Crete' Laboratory of Toxic and Harzadous Waste Management, Department of Environmental Engineering, Technical University of Crete, 2005

Jimoda L.A. and Sonibare J. A. (2009) 'Criteria Air Pollutants from some Anthropogenic Combustion Process in Lagos, Nigeria' Energy Source. Part A, 31:923-935

Jimoda L.A., Sonibare J. A. And Akeredolu F.A. (2009) 'Emission Inventory of Anthropogenic Activities at Southeastern Lagos' OAU Ife Journal of Technology, Vol. 18 (2), 35-41.

Koforowola, O.F. (2007). Recovery and recycling practices in municipal solid waste management in Lagos, Nigeria. Waste management. 27: 1139 – 1143.

NEST. 2001. Nigeria's Threatened Environment; A National Profile. Ibadan, Nigeria: Nigerian Environmental and study/ Action Team (NEST).

Pourkashanian and A Williams, (2009) 'Measurement and Prediction of NO and NO_2 Emissions from Aero Engines'. Department of Fuel and Energy, University of Leeds, Leeds, United Kingdom. LS2 9JT

Pawar A. A and Kulkarni R. R (2008) "Numerical Prediction of NO_X in the Exhaust of a Compression Ignition Engine" World Academy of Science, Engineering and Technology.

Taiwan's Environmental Protection Administration (EPA). Environmental white paper. Tapei, Tapei, Taiwan: EPA; 2003.

United Nations Environmental Programme, 'Waste Characterization and Quantification with Projections for Future,' Developing Integrated Solid Waste Management Plan Training Manual Volume 1, (2009).