Ife Journal of Technology, Vol. 18 (2), 35-41, 2009

Full Paper

EMISSION INVENTORY OF ANTHROPOGENIC ACTIVITIES AT SOUTHEASTERN LAGOS

L.A. Jimoda
Department of Chemical Engineering
Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
lukumanjimoda@yahoo.com

J.A. Sonibare
Department of Chemical Engineering
Obafemi Awolowo University, Ile-Ife, Nigeria

F.A. Akeredolu
Department of Chemical Engineering
Obafemi Awolowo University, Ile-Ife, Nigeria.

ABSTRACT

Air inversion accompanying foggy dispersion and visibility reduction to less than 20meters has become a permanent feature of Okobaba midsection part of the Third Mainland Bridge in the Southeastern part of Lagos in the last 10 years. This paper estimates the criteria air pollutants from some dominant sources in the area using emission factor approach. Mass of sawdust combusted in the area, average house fuel consumption for cooking, fuel consumption by vehicles, power generations, industries and domestic activities are combined with the appropriate emission factors to quantify the air pollutants from these sources. Particulate matter is emitted most from sawdust combustion followed by oxides of nitrogen (NO_x), oxides of sulphur (SO_x) and carbon monoxide (CO), in the reducing order. Emission from traffic showed that CO is emitted most from gasoline bus while diesel bus emits the lowest CO with the value, 11.1562×10^{10} tons/year and 14.9788×10^{8} tons/year respectively. NO_x has its highest value of 14.8735×10^{6} tons/year, from truck/trailer. It is followed by gasoline bus, car, diesel bus in the reducing order while it is least emitted from motorcycle with the value $330{,}340 \times 10^{3}$tons/year. In the power generation and industries, CO_2 emission per year has the highest value while aldehyde emission is the lowest. Most CO and CO_2 emissions from household activities in the area come from wood emission. This emission inventory information is expected to guide researchers and policy makers to know the fate and effects of aerosol emission in the area for adequate air quality management.

Keywords: Air Pollutants, Emission Inventory, Emission Factor

1. INTRODUCTION

The ongoing plan of Lagos State Government to turn Lagos into mega city status in the last five years has led to increasing researches into natural and anthropogenic emissions of air pollutants in the state. Air quality laws in most industrial cities are based on minimum permissible concentration of pollutants (O'Neil, 1993). To plan and execute air pollution control programs designed to meet the requirement of these laws, there is a need for emission inventory for identification and quantification of pollutants from possible sources. Dara (2003) gave the composition of a clean, dry air to be major components (Nitrogen. Oxygen and Water vapour), minor components (Argon and Carbon dioxide) and trace components (Neon, Helium, Methane, Nitrous oxide, Hydrogen, Sulphur dioxide, Nitrogen dioxide, Ammonia, Carbon monoxide, Ozone and Iodine). The proportion of these components of the atmosphere more or less remain constant up to a height of about 16km from the earth surface, above this height, gravitational separation begins which becomes significant above 130km. At this height, the atmosphere is a dynamic system with gases and particulate matters entering, undergo chemical transformation and leaving.

Air pollutants in the atmosphere are either natural r anthropogenic (man made). Natural pollution includes volcanoes, tornados, sea spray, sand storm, harmattan dusts and erosion re-entrainment. Anthropogenic pollution comprises of pollutants from transportation, domestic heating, electric power generation, refuse burning and industrial fuel burning/process emission. The presence of natural anthropogenic pollutants in the atmosphere has been linked to the formation of haze and changes in the atmosphere's radiative balance as well as adverse effects on human health, crops and materials (Weber, 2003).

The emissions from refuse burning are composed of SO_2, hydrocarbon, CO, particulate matter, NO_x (Jimoda, 1996). However, trash and wood burning produces Aldehyde apart from H_xC_y, NO_x, CO, SO_2 and particulate matter while burning plastics and treated wood produces heavy metals and dioxin. HCl gas is emitted from burning chlorinated organic plastics while mercury and mercury compounds are emitted from burning newspapers. Plastics such as polyvinylchloride (PVC) emit chlorinated dioxins and furans which are carcinogenic (Dara, 2003). Summarily, air pollutants from most solid wastes including sawdust contain particulate matters, sulphur oxides, carbon monoxide, oxides of nitrogen, poly-nuclear hydrocarbons, volatile organic compounds, aldehydes, dioxins and ferrous, heavy metals such as Hg, HCl gas and H_2S. However, determination of emission from open burning of sawdust in Southeastern Lagos requires estimates of its generation rate. According to Nest (1991), about 20kg of solid wastes is generated per capital per annum in Nigeria on the average, but Achankeng (2003) reported 0.3kg of solid wastes per capital per day for the city of Lagos. Similarly, Kofoworola (2007) gave an approximate of 1.1kg per capital per day of solid wastes in Lagos while a field survey of solid waste generation for households in the urban area of central Nigeria gave solid waste generation as 0.54kg per capital per day (Sha'Ato et al, 2007). Smith et al (1993) estimated the global carbon monoxide emission to be about 1100Tg/year of which about 350Tg/year is from biomass burning. Khalil and Rasmussen (1990) reported CO globally estimates from combustion of fossil fuel to be about 500Tg/year and ten years later, Jain (2007) reported estimated global CO emissions to be between 320 and 390Tg for the year 2000.

Transportation in Southeastern Lagos, like other areas of Lagos is mostly by road, either by public transport or private-owned like other developing countries (Figueroa et al, 2006). There is potential for vehicular emissions to concentrate on over 300 public transport routes and terminals. Southeastern Lagos which houses the popular third mainland bridge is not left out in its concentrated traffic throughout the days. Though, emissions from an individual car are generally low, in numerous cities across the world, the personal automobile is the single polluter as emissions from numerous vehicles on the road add up (EPA, 1992). Car ownership in Lagos is about 4.3 cars per 1000 in 1999 (Odeleye, 2001), there is usually traffic congestion (Khezwana and Maunder, 1994). Road transport emissions are in form of combustion emissions, evaporative emissions and fugitive dust emissions from paved and unpaved roads. Road transport combustion emissions are SO_2, NO_X, CO, PM, VOC, CO_2, CH_4, Pb and N_2O. Benzene at times constitutes road transport emission and accounts for about 24% of United Kingdom emission (Ginlay, 1997).

Industrial sources by far represent the most diversified type of pollution emission. Industrial pollutions are continually changing, this necessitate changes in the types and amount of emissions. Samara et al (2003) obtained three receptor sites within the urban area of Thessaloniki in an industrialized region of Northern Greece. In his studies, chemical source profiles were constructed for particulate emissions (PM_{10} of PM_{20}) from several urban and industrial sources. Pacyna et al (2001) estimated the anthropogenic emissions of mercury from anthropogenic sources in Europe in 1995 to be about 342 tons which corresponds to a decrease of about 45% compared to this emission in 1990. Combustion of fuels particularly coal was traced to be the main source of about half of the total emissions of mercury in the area. The decrease in mercury emissions in Europe in the last one decade was concluded to be the reduction of mercury emissions from industrial sources

Power generation is one of the sources of air pollutants emitting suspended particulate matters, SO_2, NO_x, CO, SO_3, metallic organic compounds and lead (Jimoda, 1996). In Nigeria, electricity availability from the national grid is a major problem. Presently, Nigeria consumes about 5,000 MW of electricity daily, but it has an average production of only 2,500 MW (Sonibare and Jimoda, 2009). Hence, the additional 2,500 MW comes from private electricity generators which rely on both gasoline (PMS) and diesel (AGO) for operation (Sonibare and Jimoda, 2009). Between 1991 and 1992 alone, 7438 generating sets were imported into the country (Akarakiri, 1999) and about 97 percent of firms operating in the country presently own generators (Tyler, 2002).

The common forms of cooking energy in use in Nigeria are wood fuel, kerosene, liquefied petroleum gas (LPG) and electricity (Anozie et al, 2007). The southeastern Lagos people are not different in term of energy carrier for cooking in this wise. Scarcity of kerosene always necessitates consideration of wood fuel as alternative (Dionco-Adetayo, 2001; Tabuti et al, 2003) and it has a major share of the energy consumption in Nigeria with over 50.45% (Ikuponiyi, 2006). Jabber and Probert (2002) found out that un-vented combustion appliances like portable kerosene and liquefied petroleum gas (LPG), stoves employed in domestic heating emits high rate of CO. Also, Rogaume et al (2002), concluded that a reduction in NOx may be a benefit from a reduction in temperature and a reduction in oxygen concentration while Akeredolu 1989, estimated CO emission to be about 6.42 x 109 kg from wood fuel in 1981 in Nigeria. Raiyani et al (1993) reported that about 50 – 80% of the TSP emissions from biomass and coal burning cooking stoves are in respirable fraction of ≤ 2μm size.

2. Materials and Methods

The description of the Okobaba area of Southeastern Lagos where about 327 sawmill industries and 34 burning points were identified was discussed here. Also, source categories in the area which include sawdust combustion transportation, power generation, industries and household activities together with emission factor approach for estimating the criteria air pollutant were discussed.

2.1. The Study Area/Sampling Site

Southeastern Lagos is within Lagos Mainland Local Government and it is characterized by towns and villages comprising of Yaba, Ebute-metta, Iddo-Otto, Akoka, Maroko, Ijero, Oko Baba, Abule-ijesha and Olaleye. Major sources of emission present in this location make it an area of special interest in the emission inventory study. The site of interest is located at the center of Oko Baba which is characterized by about 327 sawmills and 34 burning points of sawdust between Ebute-metta and Oyingbo on the edge of the Lagoon. This is quite visible on the third mainland bridge, a major link between the mainland and the island parts of the city which is surrounded by various species of freshwater and water fishes around state's island and Atlantic coaster water (Abegunde, 1986). Figure 1 shows the sampling sites in the Southeastern part of Lagos State.

2.2. Emission Inventory of the Study Area

An emission factor base approach for the source categories identified in Okobaba area of southeastern Lagos was used to quantify the criteria air pollutants in the area. The procedure for emission estimate is shown in the emission factor approach calculation equations below:

2.2.1. Emission Factor Approach Calculation Equations

Akeredolu (1996) defined emission factor as number value which show the amount of pollutants emitted compared to some given base. This may be the amount of materials produced, raw materials used, size of process equipment or plant capacity. An emission factor based approach for source category is often used to determine the

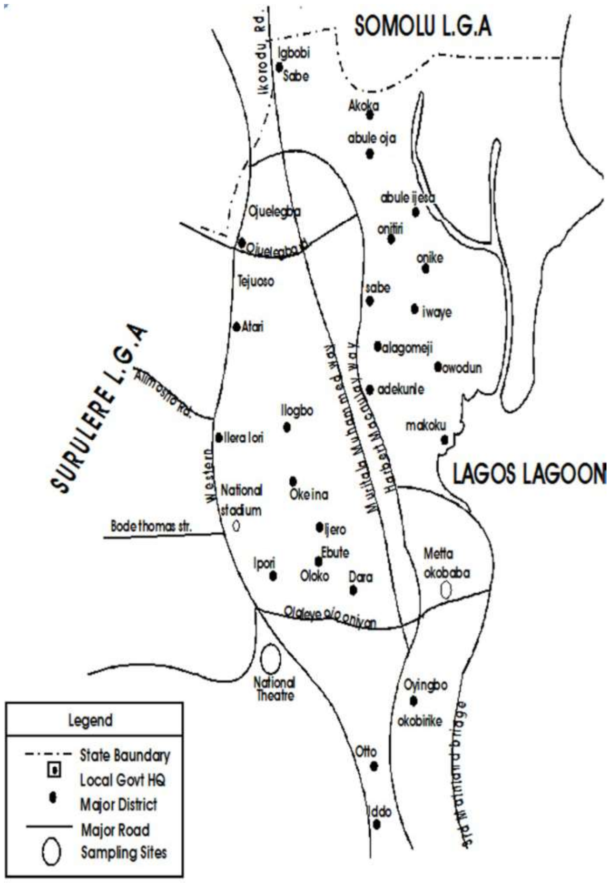

Fig 1: Map of Lagos Mainland Local Government Area showing sampling sites. Source: Abegunde (1986)

contribution of combustion activities to criteria air pollutants (Sonibare and Jimoda, 2009).

For sawdust combustion, criteria air pollutants which include NOx, SO_2, CO and particulate matters are estimated as:

$$\text{Criteria Air Pollutant Emitted/Year} = \frac{\text{Emission Factor (g) of Criteria Air Pollutant}}{\text{1Kg of Sawdust Combusted}} X \; \textit{Mass of Sawdust Combusted / Year (Kg)}$$

For transportation the criteria air pollutants emitted per year is estimated as:

$$\text{Criteria Air Pollutant Emitted/Year} = \frac{\text{Emission Factor (g) of Criteria Air Pollutant}}{\text{1Kg of Fuel Burnt}} X \; \textit{Yearly Fuel Consumption for each category of Traffic (Kg)}$$

For power generation:

$$\text{Criteria Air Pollutant Emitted/Year} = \frac{\text{Emission Factor (g) of Criteria Air Pollutant}}{\text{1Kg of Fuel Burnt}} X \; \textit{Yearly Fuel Consumption Level (Kg)}$$

The emission factors for gasoline fuel and diesel fuel are converted from ng/J to ng/kg using heating values of diesel and gasoline which are 44,900 J/g and 47,200 J/g respectively.

Similarly, for industries:

$$\text{Criteria Air Pollutant Emitted/Year} = \frac{\text{Emission Factor (g) of Criteria Air Pollutant}}{\text{1Kg of Fuel Burnt}} X \text{ Yearly Fuel Consumption Level for Industries (Kg)}$$

The emission factor approach calculation due to emissions from household activities is estimated as:

$$\text{Criteria Air Pollutant Emitted/Year} = \frac{\text{Emission Factor (g) of Criteria Air Pollutant}}{\text{1Kg of Household Fuel Burnt}} X \text{ Average Yearly Household Fuel Consumption from Cooking (Kg)}$$

2.2.2. Emission from Sawdust Combustion

Determination of emission from open burning of sawdust in the Southeastern Lagos requires sawdust generation rate. Volume of container used to dump sawdust at the burning points, total number of sawmills in operation, and average number of times the sawdust is being dumped per day was used to estimate mass of sawdust produced in the area. The daily rate was eventually obtained using 454kg/m3, the density of sawdust (Dosumu and Ajayi, 2002). The mass of sawdust produced from 327 sawmilling machines per week, per month and per annum was estimated using the number of days in a week, a month and a year respectively. This was estimated to be 57,174.3677kg per day, 400,220.5739kg per week, 1,715,231.031kg per month and 20,868,644.21kg per year. The calculated annual sawdust generation was combined with the emission factor for sawdust from AP-42 (EPA, 1995) to predict the criteria air pollutants generated from the combustion of sawdust in the area.

2.2.3. Emission from Transportation

In the emission prediction from transportation, fuel consumption and vehicle fleet are important parameters in emission factor approach. Traffics from the area are categorized as motor cycles, cars, buses and trucks/trailers. Traffic counts are used to know the numbers of each category of vehicles with counting done for weekdays and weekends from which annual traffic volume was estimated. The fuel consumption of different categories of vehicles is combined with the density of Diesel (AGO, 840kg/m^3), and Petrol (PMS, 750kg/m^3) to compute the mass of AGO/PMS consumed for transportation. These values were finally combined with the fuel based emission factors from European Countries (EU, 2006) and Asian nations (Yli-Tuomia et al, 2005) to predict the criteria air pollutants from traffic in the area.

2.2.4. Emissions from Power Generation

In the area, 327 sawmilling machines were identified using 42 electric power generators with each generator consuming an average of 50litres of AGO per day. Also, about 68 plane machines comprising of 37 diesel engines and 31 petrol engines are located in the area with each consuming about 25litres of AGO per day while the petrol engine consumes about 20litres per day. Therefore, for the sawmilling machines and plane machines, total fuel consumption per day is estimated to be 3,025litres AGO and 620litres of PMS.

Emission calculations from these electric power generators in the southeastern Lagos were done using fuel consumption level consumed in the area and the emission factor from electric power generations (using diesel and petrol) available in AP-42 (EPA, 1995).

2.2.5. Emissions from Industries

Industrial emissions depending on the raw-materials, products and by-products from the industries in the area are computed by identifying the emissions from the particular industries. The emission factors from such industries from AP-42 (EPA, 1995) were then used to estimate the emissions from the industries.

Four pure water manufacturing industries were identified in the area with an average consumption of 80litres of diesel per day. A tile manufacturing company is also located there. However, interaction with the Production Manager showed that the company is only polishing the imported materials. No significant pollutant was identified. However, the company has 2 diesel consuming standby generators with an average daily consumption of 60litres of diesel per day. Hence, the total daily consumption of diesel fuel was estimated to be 440litres for electric power generation. This consumption level was combined with emission factor from AP-42 (EPA, 1995) to estimate the emissions from industries in the area.

2.2.6. Emissions from Household Activities

The average house fuel consumption for cooking in Lagos for five years (Table 13) was combined with the relevant emission factor from AP-42 (EPA, 1995) to compute the potential emission of air pollutants from the combustion of wood fuel, LPG and kerosene for cooking. The population of Lagos Mainland relative to the population of the entire Lagos State (FGN, 2007) was used to get the average house fuel consumption for cooking in the area.

3. Results and Discussion

The criteria air pollutants were calculated to be 36.1028 x 104kg, 0.4173 x 104kg, 2.7129 x 10^4kg and 0.2629 x 10^4kg for particulate matters, SO_X, NO_X and CO respectively. Particulate matters were identified as the main criteria air pollutant from sawdust combustion which is followed by NO_x, SO_x, and lastly CO. CO_2, Total Organic Carbon (TOC), POM and Aldehydes were not available in the AP-42 (EPA, 1995) and hence could not be estimated.

From Table 1, it can be seen that there are more cars on the road in the area estimated as 7,197,800 per annum while trucks/trailers were the lowest with the value 1,565,120 per annum. The annual estimates for buses and motor cycles were 5.004880 and 1,789,960 respectively. The annual estimates for traffic counts in weekend days are lower than their corresponding values for weekdays for all categories of vehicles. As shown in Table 3, the daily emission of CO was calculated to be 336214710.1g followed by car with the value 252195777.2g while diesel bus emits the lowest value of 4514167.309g. The daily emission of CO for truck/trailer and motorcycle were estimated to be 135778815.1g and 75474931.03g respectively.

As shown in Table 3, carbon monoxide (CO) was emitted mostly from gasoline bus with the value 122,718,360,000g per year followed by trucks/trailers which emit 49,559,267,000g per year while diesel bus emits the lowest value of CO of 1,647,671,068g per year. The CO emitted per year for motorcycles and cars were estimated to be 27,548,349,000g and 92,051,458,000g. NO_x had its highest daily emission of 448243834.3g from truck/trailer. This was followed by gasoline bus, car, diesel bus and motorcycle in the reducing order. Their values were 33213533.54g for gasoline bus, 24035525.77g for car, 8603175.956g for diesel bus and 995707.9976g for motorcycle respectively. Particulate matters were mainly from diesel bus and truck/trailer with values1811194.938g and 32101562.38g respectively.

From sawmilling and plane machines in southwestern Lagos, the emissions from gasoline and diesel consumed due to power generation are reported in Table 4. The results showed that for power generation due to gasoline, CO_2 was most emitted with daily emission of 1.4658715 x 106g while aldehyde has the lowest value of 6.3650523 x 102. Similarly, daily emission of CO2 of 8.10813 x 106g was the highest value for diesel-consumed power generation while aldehyde daily emission was the lowest with the value of 3.1946477 x 103g.

Industrial emissions from the area were taken as the emissions due to power generation from the identified industries in the area. Their daily emissions are 1.1793643 x 10^6g of CO_2, 3.1465205 x 10^4g of NO_X, 6.8041848 x 10^3g of CO, 2.2404023 x 10^3g of PM, 2.0910421 x 10^3g of SO_X and 4.6467603 x 10^2g of aldehyde in the reducing order. The tile-polishing and pure water industries in the area do not emit any significant pollutants in the area. The calculated emissions using emission factors as shown in Table – show that CO_2 is emitted most for all the household fuel types. However, CO_2 due to wood emission has the highest value of 2.25318 x 10^{10}g while CO_2 emission from LPG is the lowest. Particulate matter which is very important in the aerosol studies due to its health effect and visibility impairment was mainly from wood emission. SO_x from the wood emission also recorded the highest value of 2,650.8kg per year followed by 654kg per year from kerosene while SO_x emission from LPG was very low (3.50kg per year). NO_x emission was mostly from Kerosene with the value 61,104kg per year, followed by wood emission (17,230.2kg per year) and lastly, LPG emission of NO_x value 496kg per year. Over 95% of CO emitted came from wood emission, while CO_2 emissions were equally from wood emission. Total VOC, POM and Aldehydes emitted from wood emission were 151,095.6kg per year, 10.6kg per year and 15,904.8kg per year respectively. LPG emission and kerosene did not record any value for these since there were no values for these in the emission factor in AP-42 (EPA, 1995).

4. Conclusion

The criteria air pollutant from different sources is as summarized in the Table 8. The estimates represented above suggest that particulate matter emissions in the area are mostly from traffic, saw dust combustion and from household activities. SO_x is emitted mostly from power generation, saw dust combustion and household activities. Over 95% of NO_x and CO emitted in the area is from traffic while the remaining comes from other sources. Information such as CO_2, TOC, POM and Aldehydes for saw dust combustion, TOC, POM for power generation and industries, CO_2, TOC, POM and Aldehydes for traffic could not be obtained because they are not available in the emission factor data. The emission inventory information is important for policy makers studying the fate and effects of aerosol emissions in Southeastern Lagos. However, it is important to keep in mind that emission data are never complete or entirely accurate.

Table1: Traffic Counts of Vehicles at Third Mainland Bridge (Weekdays and Weekends)

Time	Motor cycles		Cars		Buses		Trucks/Trailers	
	Wd	We	Wd	We	Wd	We	Wd	We
Day 1	202	78	741	480	621	239	179	102
Day 2	217	84	823	531	519	331	181	113
Day 3	194	91	901	579	574	237	176	99
Mean Traffic Counts (1hour)	204	84	822	530	571	269	179	105
Annual Estimate	1,789,960	735,840	7,197,800	4,642,800	5,004,880	2,356,440	1,565,120	919,800
	1,789,960	735,840	7,197,800	4,642,800	5,004,880	2,356,440	1,565,120	919,800

Wd = Weekdays; We = Weekends

Table 2: Fuel Consumptions for Various Categories of Traffic at Third Mainland Bridge

	Motorcycle (Kg)	Car (Kg)	Gasoline bus (Kg)	Diesel bus (Kg)	Truck/Trailer (Kg)
Per Day	132407.9784	1656480.067	1382169.519	387007.4654	14725487.33
Per Week	926855.8488	11595360.47	9675186.633	2709052.258	103078411.3
Per Month	3972239.352	49694402.02	41465085.57	11610223.96	441764619.8
Per Year	48328912.12	604615224.5	504491874.4	141257724.9	5374802875

Table 3: Daily Criteria Air Pollutants in Lagos Southwest

	CO (g)	NO_X (g)	PM (g)
Motorcycle	75474931.03	995707.9976	0
Car	252195777.2	24035525.77	0
Gasoline bus	336214710.1	33213533.54	0
Diesel bus	4514167.309	8603175.956	1811194.938
Truck/Trailer	135778815.1	448243834.3	32101562.38

Table 4: Daily Emissions from Power Generation.

	$NO_{X(g)}$	$CO_{(g)}$	$SO_{X(g)}$	$PM_{(g)}$	$CO_{2(g)}$	Aldehydes $_{(g)}$
PMS	1.5341971×10^4	5.9144505×10^5	7.9014443×10^2	9.6573208×10^2	1.4658715×10^6	6.3650523×10^2
AGO	2.1632329×10^5	4.677877×10^4	1.4375914×10^4	1.5402765×10^4	8.10813×10^6	3.1946477×10^3

Table 5: Criteria Air Pollutants from Industries using EF

	NO_X (g)	CO (g)	SO_X (g)	PM (g)	CO_2 (g)	Aldehyde(g)
Per Day	3.1465205×10^4	6.8041848×10^3	2.0910421×10^3	2.2404023×10^3	1.1793643×10^6	4.6467603×10^2
Per Week	2.20256435×10^5	4.76292936×10^4	1.46372947×10^4	1.56828161×10^4	8.2555501×10^6	3.25273221×10^3
Per Month	9.4395615×10^5	2.04125544×10^5	6.2731263×10^4	6.7212069×10^4	3.5380929×10^7	1.39402809×10^4
Per Year	1.14847998×10^7	2.4835274×10^6	7.63230366×10^5	8.17746839×10^5	4.3046797×10^8	1.6960675×10^5

Table 6: Household Fuel Consumptions for Cooking in Lagos (2000-2004)

Year	LPG (x 10^3 litres)	Kerosene (x 10^3 litres)	Wood Fuel (x 10^5 tons)
2000	11,740	99,350	3.5
2001	10,027	80,426	3.6
2002	9,171	75,547	3.8
2003	5,007	86,987	3.9
2004	5,445	87,358	4.0

Source: NNPC (2005).

Table 7: Yearly Emission from Cooking Fuel Combustion.

Air Pollutants	Wood Emission(g)	LPG Emission (kg)	Kerosene (kg)
PM	229294200	14.5899	1460.02
SO_X	2650800	3.5015	654.112
NO_X	17230200	496.0592	61104.0021
CO	1673980200	58.3599	7472.2911
CO_2	2.25318×10^{10}	437699.25	41041124.31
TOC	-	17.50797	1524.721
Total VOC	151095600	-	-
POM	10603.2	-	-
Aldehydes	15904800	-	-

Table 8: Yearly Criteria Air Pollutants from Different Sources

Air Pollutants	Sawdust Combustion	Power Generation	Industries	Traffic	Household
$PM \times 10^4$kg	36.1028	0.5975	0.0818	1237.8156	23.0769
$SO_X \times 10^4$kg	0.4173	0.5536	0.0763	-	0.3308
$NO_X \times 10^4$kg	2.7129	8.4558	1.1458	18800.8489	7.8830
$CO \times 10^4$kg	0.2629	23.2952	0.2484	29352.5105	168.1511
$CO_2 \times 10^4$kg	-	349.4510	43.0468	-	6401.0624
$TOC \times 10^4$kg	-	-	-	-	15.2638
$POM \times 10^4$kg	-	-	-	-	0.0011
$Aldehydes \times 10^4$kg	-	0.0349	0.0169	-	1.5905

They need continuous upgrading and revision using the outcome of the latest research carried out within major international organizations and programmes.

Acknowledgements

Authors acknowledged the support of Mr. Alliyu of Regional Space Centre of Obafemi Awolowo University for providing Geographical Information System (GIS) equipment. Equally acknowledged is the assistance of Afolabi Teslim, Adeyemi Olufunmi, Tijani Monsur, and Ilyas Teslim, in the collection of traffic counts data from the field.

References

Abegunde, A., Description and Characteristics of Physical Environment of Lagos State, *Unpublished B.Sc*; These Department of Geography, Lagos state university, 1986.

Achankeng, E., *Globalization, Urbanization, and Municipal Solid Waste Management in Africa* (African Studies Association of Australian and the Pacific), Conference Proceedings- Africa on a Global Stage, pp. 22, 2003

Akarakiri, J.B., Private Electric Power Generation as an Alternative in Nigeria, *Energy* 24(5), 445-447, 1999.

Akeredolu, F.A., *Environmental Engineering Notebook*, Department of Chemical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria (Unpublished), 1996.

Akeredolu, F.A., Atmospheric Problem in Nigeria, An Overview, *Atmospheric Environment* 23(4), 783 – 792, 1989.

Anozie, A.N., Bakare, A.R., Sonibare, J.A. and Oyebisi, T.O., *Evaluation of Cooking Energy Cost, Efficiency, Impact on Air Pollution*, 2007.

Dara, S.S., *A Textbook of Engineering Chemistry* (revised 10th edition), Chand S. and Company Ltd, Ram Nagar, New Delhi, 2006.

Dionco-Adetayo, E.A., Utilization of Wood Wastes in Nigeria: a feasibility overview, *Technovation* 21, 55-60, 2001.

Dosunmu, O.O. and Ajayi, A.B., *Problems and Management of Sawmill Waste in Lagos*, Proceedings of International Symposium on Environmental Pollution Control and Waste Management, 7-10 January 2002, Tunis, EPCOWM' 2002, 271-278, 2002.

EPA, *Compilation of Air Pollutant Emission Factors*, Vol. I, Stationary Point and Area Sources, fifth ed. (Research Triangle Park NC, USA, 1995), United States Environmental Protection Agency, Office of Air Quality Planning and Standards, 1995.

EPA, *Automobile Emissions,* An Overview U.S. Environmental Protection Agency, EPA 400-F-92-007, 1992.

EU, *Emission Inventory Guidebook*, Road Transport Activities, Laboratory of Applied Thermodynamics, Aristotle University Thessalonica, GR-54124, Thessalonica, Greece, 2006.

FGN, *Legal Notice on Publication of the Details of the Breakdown of the National and State,* 2006 Census, Federal Republic of Nigeria Official Gazette, Vol. 94, No 24, 1-26, 2007.

Figueroa, M.J., Daridson, O.R. and Mackenzie, G.A., *Matching Transport and Environment Agenda in Developing Countries,* World Energy Council, WEC, US, 2006.

Ginlay, A.J., "*The chemistry of atmospheric pollutant*", 1997, http//:www.Aetat.co.uk/airquil/ bulletins/welcome.html.

Ikuponiyi, F.S., Status of Renewable Energy in Nigeria, International Conference on Making Renewable Energy, *A*

Reality, Abuja/Port Harcourt/Calabar, Nigeria, pp. 48, November 21-27, 2006.

Jaber, J.O. and Probert, S.D., Purchased Energy Consumptions in Jordan's Commercial and Public-service Sector, *Applied Energy* 71, 31-43, 2002.

Jain, A.K., Global Estimation of CO Emissions using three sets of Satellite Data for Burned Area, *Atmospheric Environment*, In Press, 2007.

Jimoda, L.A., *Environmental Engineering Notebook*, Department of Chemical Engineering, Obafemi Awolowo University, Ile Ife, Nigeria (Unpublished), 1996.

Khalil, M.A.K. and Rasmussen, R.A., The Global Cycle of Carbon Monoxide: Trends and Mass Balance, *Chemosphere* 20, 227-242, 1990.

Khezwana, M. and Maunder, D.A.C., International Experiences of Deregulated Urban Public Transport Systems, *Indian Journal of Transport Management*, 457-464, July 1994.

Kofoworola, O.F., *Recovery and Recycling Practices in Municipal Solid Waste Management in Lagos, Nigeria,* Waste Management, In Press, 2007.

NEST, *Nigeria's Threatened Environment:* A National Profile. Nigeria Environment and study/Action Team, NEST, Ibadan, 1991.

NNPC, *Annual Statistical Bulletin*, January – December (2000–2004), Nigerian National Petroleum Corporation, Corporate Planning and Development Division (CPDD), Abuja, Nigeria, pp. 83, 2005.

Odeleye, J.A., *Towards Gender Sensitive Urban Transport Planning and Operations in Metropolitan Lagos, Nigeria,* Presented at the 4th IFUP Congress, Marrech, Morocco, pp. 19, October, 2001.

O'Neil, P.O., *Environmental Chemistry*, 2nd edition, Chapman and Hall, New York, 1993.

Pacyna, E.G., Pacyna, J.M. and Pirrone, N., European Emissions of Atmospheric Mercury from Anthropogenic Sources in 1995, *Atmospheric Environment* 35, 2987-2996, 2001.

Raiyani, C.V., Shan, S.H., Desai, N.M., Venkaiah, K., Patel, J.S., Parikh, D.J. and Kayshyap, S. K., Characterization and Problems of Indoor Pollution due to Cooking Store Smoke, *Atmospheric Environment* 27A11, 1643-1655, 1993.

Rogaume, T., Auzanneau, M., Jabouille, F., Goudeau, J.C. and Torero, J.L., The Effects of Different Airflows on the Formation of Pollutants during Waste Incineration, *Fuel*, 2277-2288, 2002.

Samara, C., Kouimtzis, T., Tsitouridou, R., Konias, G. and Simeonov, V., Chemical Mass Balance Source Apportionment of PM_{10} in an Industrialized Urban of Northern Greece, *Atmospheric Environment* 37, 41 – 54, 2003.

Sha' Ato, R., Aboho, S.Y., Oketunde, F.O., Eneji, I.S., Unazi, G. and Agwa, S., Survey of Solid Waste Generation and Composition in a Rapidly Growing Urban Area in Central Nigeria, *Waste Management* 27, 352-358, 2007.

Smith, K.R., Khalil, M.A.K., Rasmussen, R.A., Thorneloe, S.A., Manegdeg, F. and Apte, M., Greenhouse Gases from Biomass and Fossil Fuel Stoves in Developing Countries: A Manila Pilot Study, *Chemosphere* 26, 1-4, 479-505, 1993.

Sonibare, J.A. and Jimoda, L.A., Criteria Air Pollutants from Some Anthropogenic Combustion Processes in Lagos, Nigeria, *Energy Sources*, Part A, 31, 1-13, 2009.

Tabuti, R.R.S., Dhillion, S.S. and Lye, K.A., Firewood Use in Bulamoyi, Uganda Species Selection, Harvesting and Consumption Patterns, *Biomass and Bioenergy* 25, 581-596, 2003.

Tyler, G., *Public and Private Electricity Provision as a Barrier to Manufacturing Competitiveness*, Findings 221, World Bank, pp. 4, December 2002.

Weber, R., Short-term temporal variation in $PM_{2.5}$ Mass and chemical composition during the Atlanta Supersite Experiment, 1999; *Air and Waste Management Association* 53, 84-91, 2003.

Yli-Tuomia, Aarnioa, T., Pirjolab, C.L., Makela, T.D., Hillamod, R. and Jantunena, M., Emissions of Fine Particles, NO_X and CO from on-road vehicles in Finland, *Atmospheric Environment* 39, 6696-6706, 2005.