Determination of levels of gaseous air pollutants emitted at Ajakanga dump site, Ibadan, Nigeria

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Abstract

Municipal solid waste dump sites have been reported to generate different kinds of air pollutants the world over. Air pollutants, such as CO, H_2S, NH_3, NO_x and SO_2 have significant adverse effects on man, plants and other animals. There is a need for regular monitoring of their levels in the atmosphere. In this study, the concentrations of three gaseous air pollutants (SO_2, NO_x and NH_3) emitted from municipal solid waste at Ajakanga dump site, Ibadan, Nigeria, were determined using uv/visible spectrophotometry. The ranges of concentrations obtained for SO_2, NO_x and NH_3 were 255.86–503.66 µg/m^3; 246.67–1,155.79 µg/m^3 and 777.51–1,852.48 µg/m^3 respectively in air samples collected at the dump site. The increasing order of the gaseous air pollutants at the dump site is SO_2 < NO_x < NH_3. The emission rates of SO_2, NO_x and NH_3 must be controlled because of their adverse health effects on the environment.

Keywords: Ajakanga, Dump site, Emission Factors, Ibadan, Nigeria, Solid Waste.

1 Introduction

Environmental pollution is one of the causes of deteriorating living conditions as the breathing of safe air is as important as safe water or food; however the human population in developing countries are compelled to breathe polluted air from biomass combustion and other diffused sources (Abdulraheem *et al*., 2009). Air is a universal gas, without which existence of man and other forms of life is possible. Air quality is very essential to sustain life. Air pollution due to human activities is an abuse to the environment thereby degrading the air quality (Ghauri, Lodhi and Mansha, 2007; Ojo and Awokola, 2012). Pollution is a threat to the survival of humankind and is the most important issue of this era.

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 a potential for the population to start interfering with the atmosphere, with global-scale environmental impact being the result (UNEP, 2007). Several million tonnes of municipal solid wastes (MSW) are disposed of in sanitary landfills (controlled landfill) and dumpsites (uncontrolled landfills) daily around the world. Solid wastes, mounds of rubbish, garbage and sewage are produced every day and in an attempt to dispose of these materials, the environment has been carelessly polluted (Bogner *et al*. 2001). Solid waste management has become a serious environmental problem and is one of the major concerns of urban areas the world over.

Despite lower levels of commercial and industrial activity in developing countries, their solid waste is not necessarily devoid of hazardous substances because regulatory frameworks and enforcement systems to segregate and separately collect such wastes are almost non-existent or are dysfunctional (Oketola and Akpotu, 2014). Open dumping of municipal solid waste, which is practised in most developing countries and territories of the world is a primitive stage of waste disposal. These dump sites cause environmental pollution through waste burning in the open, ground and surface water pollution through leaching and run-off, the breeding of disease vectors, etc (Ogunrinola and Adepegba, 2011). The said situation produces gastrointestinal, dermatological, respiratory, genetic, and several other kinds of infectious diseases. Consequently, dumping sites have a very high economic and social cost in the public health services, and have not yet been estimated by governments, industries, and families (Salam, 2010; Ogunrinola and Adepegba, 2011).

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 (Jimoda *et al*., 2013). Common gaseous air pollutants from municipal solid waste include carbon monoxide,

sulphur dioxide, chlorofluorocarbons (CFCS), methane, nitrogen oxides and volatile organic compounds (VOCs). Volatile sulphur compounds (VSCs) have been identified as the predominant odorants emitted during organic waste composting (Lemieux *et al*., 2004). VSCs consist of volatile organic compounds (VOCs) that contain sulphur and reduced sulphur compounds (RSCs) such as hydrogen sulphide (H_2S), methyl mercaptan (MM), dimethyl sulphide (DMS), dimethyl disulphide (DMDS), carbonyl sulphide (OCS) and carbon disulphide (CS_2). These compounds are characterized by a low detection threshold and strong odour activities and therefore contribute to odour pollution when present at very low emission concentrations (Bent and Robert, 2010). The concentrations of pollutants that may be permitted in an urban atmosphere are limited by the effects on the health of population in that environment, on plant life and on materials. This, in turn, is linked via legislation, urban planning measures or other means to the control of the emission of pollutants. A central part of this interrelationship is an accurate knowledge of the concentrations of the pollutants present in the atmosphere (Nasralla, 1985).

In Nigeria, as in many developing countries of the world, much attention are being given to general industrial pollution, pollution in oil industries and pollution caused by mobile transportation sources of air pollution while pollution resulting from emission of gaseous air pollutants at the various municipal solid waste dump sites has received just little attention. Ibadan, the capital city of Oyo State of Nigeria, has over the years experienced population explosion leading to increasing annual rate of solid waste generation. Despite the observed annual rate of increment in waste generation in Ibadan, however, not much significant work has been done with regard to the determination of the concentrations of gaseous air pollutants emitted from municipal solid waste dump sites in the city. Consequently, this study was conducted to determine the levels of three gaseous air pollutants: sulphur (iv) oxide (SO_2), nitrogen oxides (NO_x), and ammonia (NH_3) emitted into the atmosphere from municipal solid waste at Ajakanga dump site, Ibadan, Nigeria.

2. Materials and methods

2.1. Description of study area

Ibadan is located at longitude 7°2′ and 7°40′E and latitude 3°35′ and 4°10′N, and was founded in 1829. It is approximately 128 km northeast of Lagos and 345 km southwest of Abuja, the federal capital. Like other parts of Nigeria, Ibadan experiences two local climates (rainy and dry seasons) (Falade, 1998). The rainy season runs from March to October and the

dry season is from November to February, with highest rainfall of 170 mm (6.69 inches) in the month of September. Temperature in Ibadan ranges from 21 to 35°C (69.8–95°F).

This study was carried out at Ajakanga dump site, one of the four major dump sites legally approved by the government of Oyo State, Nigeria, for the disposal of municipal solid waste in Ibadan. Figure 1 is a map of Ibadan showing the four major dumpsites, including Ajakanga dump site among others, legally approved by the government of Oyo State for disposal of municipal solid waste generated in the city. Ajakanga dump site is located over an approximate 10 hectares (0.10 km^2) of land along Challenge road in Oluyole local government area of Oyo State. The dump site lies between latitude 7°18′ 45″ N and longitude 3°51′ 26″ E.

2.2 Solid Waste Characterization

Samples of solid waste were collected from Ajakanga dump site for the purpose of characterization. This procedure involved the use of a 50 × 50 cm^2 quadrant. The quadrant was placed upon heap of waste at a particular location within the dump site. All forms of solid waste that were directly under the area covered by the quadrant were collected into a polythene bag. The process was repeated at ten other different locations within the dump site. Solid wastes from each location were packed into different polythene bags. 2.0 kg of solid waste was weighed out of each polythene bag into another empty polythene bag and mixed thoroughly. Thereafter, 2.0 kg of the mixed solid waste sample was accurately weighed to obtain a representative sample.

The characterization of the solid waste involved the separation of each constituent of the weighed representative sample into:

(1) Cellulose (textiles, paper, leaves).
(2) Solid (glass, metal, tin and sand).
(3) Leather.
(4) Plastics.
(5) Nylon.

The weights of the components of the municipal solid waste were obtained and their percentage compositions were equally calculated.

2.3 Air pollutant emission prediction from municipal solid waste

An emission factor approach was used to predict the ammonia, sulphur (iv) oxide, and nitrogen oxide pollutant emission from municipal solid waste in Ibadan. The procedure for emission prediction is shown in the emission factor calculation equation shown in equation 1:

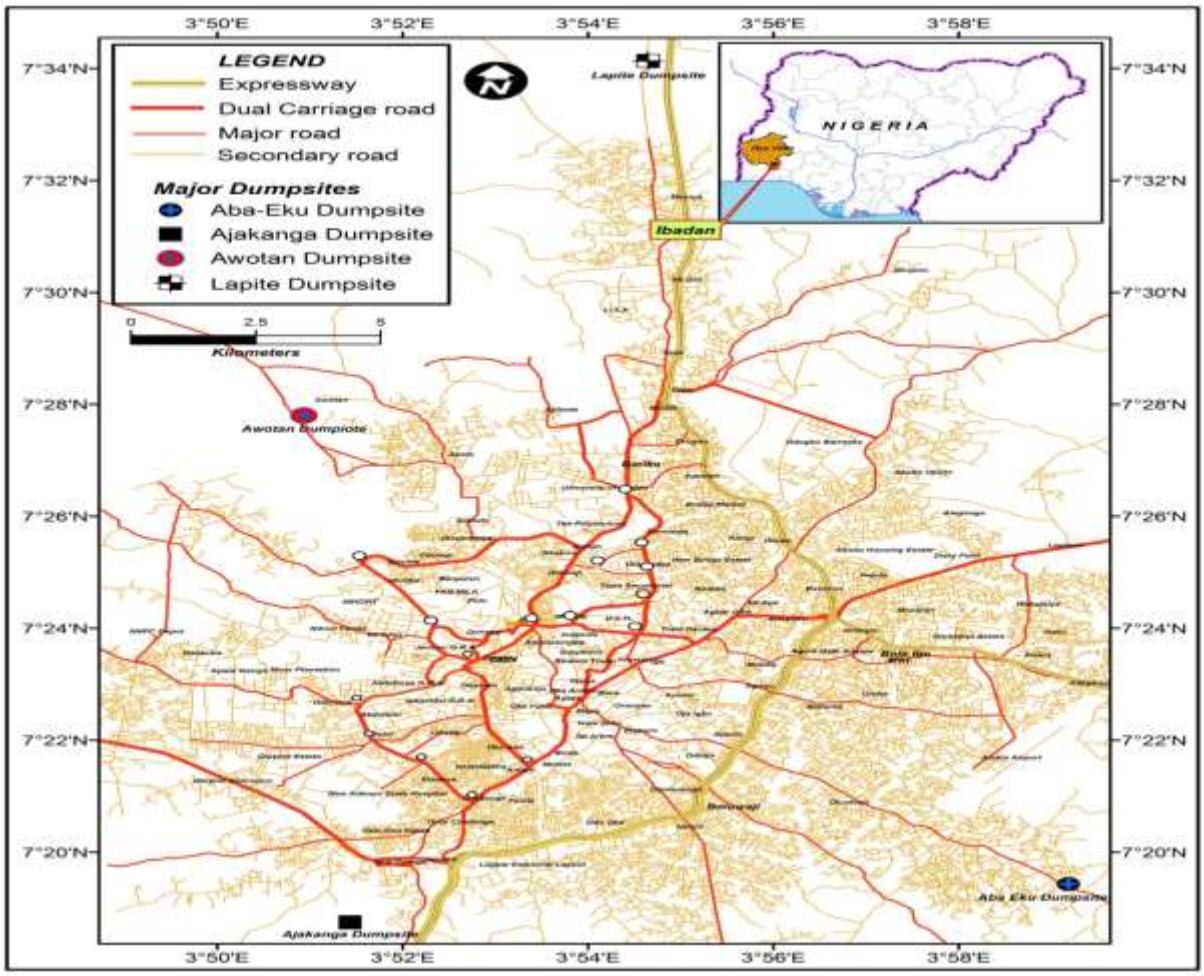

Figure 1: Map of Ibadan showing Ajakanga dump site.

$$\text{API (ton/yr)} = \frac{\text{EFP}}{\text{1mg of solid waste burnt}} \times \frac{\text{1 mg}}{\text{1000 kg}} \times \text{AYSWG} \qquad (1)$$

Where

API = air pollutant emitted in ton/ yr,

EFP = emission factor of pollutant in kg/mg,

AYSWG = average yearly solid waste generated (ton/annum).

The emission factor of NO_x is 3.0 kg/mg from (EPA, 1995); that of SO_2 is 4.4×10^{-1} kg/mg (EPA, 1995) while that of NH_3 is 7.30 kg/mg (Emission Inventory Improvement Program, 2004) from municipal solid waste.

2.4 Sample Collection and Determination of Gaseous Air Pollutants

This study was conducted during April – May, 2016. The monitoring of SO_2, NO_x and NH_3 was carried out by the use of an air sampling train. The modified West and Gaeke procedure was used for the determination of SO_2 in air samples (West and Gaeke, 1956; CPCB, 2001; Onianwa *et al.*, 2001). The method employed for the determination of NO_x was the

intersociety committee method of analysis which is based on the Griess-Saltzman colorimetric azo-dye forming reagent (CPCB, 2001; ASTMD 3608-95, 2011). The Nesslerization method was used to determine the concentration of NH_3 present in samples of air (O'Dell, 1993; Rathbone and Majors, 2003).

In order to determine the degree of variation during a daytime cycle of activities within the dump site, air was sampled at each location during six defined one-hour periods of any sampling day. The sampling periods were 8 a.m. – 9 a.m.; 9.15 a.m. – 10.15 a.m.; 10.30 a.m. – 11.30 a.m.; 1 p.m. – 2 pm.; 2.15 p.m. – 3.15 pm.; and 3.30 p.m. – 4.30 pm. for all locations. At each sampling site, the sampling train was mounted on a stand, about 2 m high, at a suitable open space within the dump site. The sampling trains were configured with critical orifices calibrated to a flow rate of 549 mL/min for SO_2; 1012 mL/min for NOx and 860 mL/min for NH_3 respectively. The bubblers were filled with 15 cm^3 of 0.1 M potassium tetrachloromercurate (II), sulphanilic acid-glacial acetic acid-N-(1-naphthyl)-ethylenediamine dihydrochloride (NINE) mixture and 0.5 M dilute sulphuric acid respectively for absorbing SO_2; NOx and NH_3. Each sampling was operated for 1 h. After each air intake, the bubblers were removed and the absorbent solutions were quantitatively transferred into vials. The solutions were subsequently analyzed by the West-Gaeke procedure for SO_2; by the Griess-Saltzman procedure for NOx and by the Nesslerization method for NH_3. The West-Gaeke procedure involves the addition of *p*-rosaniline, formaldehyde and hydrochloric acid, followed by absorbance measurement at 560 nm; the Griess-Saltzman procedure involves absorbance measurement at 550 nm; while the Nesslerization method involves the addition of Nessler reagent followed by absorbance measurement at 440 nm. Calibration curves were prepared from standard sodium sulphite; sodium nitrite and ammonium chloride solutions. Reagents used were of analytical reagent (AnalaR) grade and distilled water was further deionised. Reagent blanks were analysed for each daily sampling and analysis. The wavelength setting of the spectrophotometer used (Spectrumlab 752s uv/vis) was routinely checked by standard instrument calibration procedures.

3 Results and Discussion

3.1 Characterization of municipal solid waste

The percentage weight of each component contained in the samples of waste collected for characterization at Ajakanga dump site are as follows: cellulose (15.2%); solid (50.0%); leather (3.5%); plastics (11.7%) and nylon (19.6%). The decreasing order of the components of waste characterized at Ajakanga dump site is solid > nylon > cellulose > plastics > leather.

Non-combustible solid was heavier than other components because the waste deposited at the dump site were mainly from the residential areas where household waste such as glass, tin, and metal are part of their waste. Plastic took a smaller proportion of waste component due to the fact that waste scavengers were actively busy picking them up for recycling at the dump site.

3.2 Air pollutants emission prediction from municipal solid waste in Ajakanga dump site, Ibadan.

The calculated average emission of air pollutants from municipal solid waste shows that 90.13 tonnes/annum; 614.49 tonnes/annum and 1495.27 tonnes/annum respectively were levels of SO_2, NO_x and NH_3 predicted to be emitted from Ajakanga dump site, Ibadan, Nigeria. The average of total metric tonnes of solid waste moved to the dump site for three years (2012 – 2014) was used for the prediction. The total amount of solid waste moved to the dump site was high (614,493.38 metric tonnes), hence, higher emission of air pollutants were expected at the dump site. Similar trend have been observed in studies conducted in Ogbomoso, Nigeria (Jimoda *et* al., 2013).

3.3 Concentrations of SO_2, NO_x and NH_3 in air samples collected at Ajakanga dump site, Ibadan, Nigeria.

Figures 2 and 3 respectively contain the daily and weekly concentrations of SO_2, NO_x and NH_3 in samples of air collected at Ajakanga dump site, Ibadan, Nigeria. The results presented in the two figures were mean values of four weeks air sampling and analyses.

As shown in Figs. 2 and 3, 1 hourly concentrations of SO_2, NO_x and NH_3 emitted at Ajakanga dump site respectively ranged 255.86 – 503.66 µg/m^3, 246.67 – 1155.79 µg/m^3 and 777.51 – 1,852.48 µg/m^3 while the weekly concentrations of SO_2, NO_x and NH_3 respectively ranged 374.72 – 448.31 µg/m^3, 570.78 – 784.13 µg/m^3 and 1,176.13 – 1,475.18 µg/m^3.

Statistical analysis of SO_2 concentrations in air samples collected over the 4-week sampling period shows that no significant difference ($p = 0.4526$) exist among the various SO_2 concentrations at the dump site. SO_2 is a major air pollutant and has significant impacts upon human health. Inhaling SO_2 is associated with increased respiratory symptoms and diseases, difficulty in breathing and premature death. In addition, the concentration of SO_2 in the atmosphere can influence the habitat suitability for plant communities as well as animal life. SO_2 emissions are a precursor to acid rain and atmospheric particulates (Rim-Rukeh, 2014).

The various concentrations of NO_x obtained in samples of air collected over the 4-week sampling period were compared with one another using ANOVA and the results show that no significant difference ($p = 0.3341$) exists among the various NO_x concentrations at Ajakanga

dump site. NO_x (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 them, causing premature death in extreme cases (Rim-Rukeh, 2014).

The result of ANOVA calculation carried out on the concentrations of NH_3 recorded in air samples collected over the 4-week sampling period shows that there is no significant difference ($p = 0.7310$) among the various levels of the gaseous pollutant recorded in samples of air collected at Ajakanga dump site. People are exposed daily to levels of NH_3 in the environment from the natural breakdown of manure and dead plants and animals. NH_3 is flammable with a lower explosive limit of 15% and an upper explosive limit of 25% and it can therefore pose as an explosion hazard.

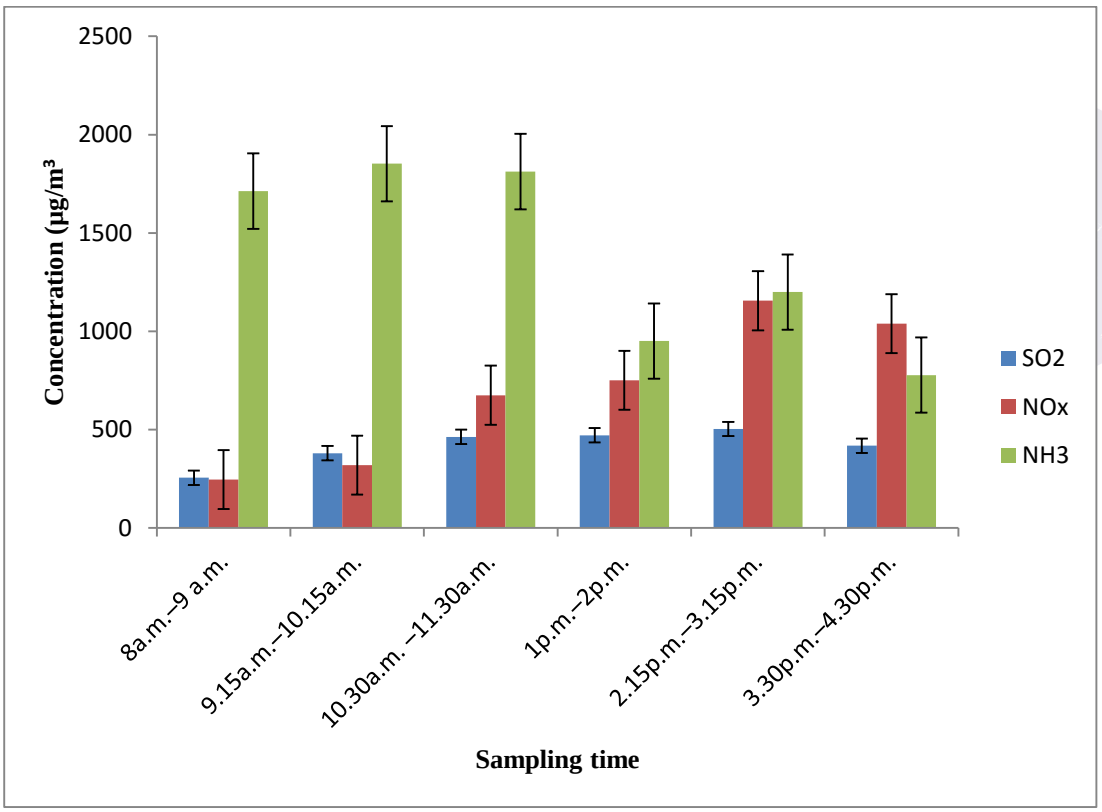

Fig 2: Daily concentrations (µg/m^3) of SO_2, NO_x and NH_3 in air samples collected at Ajakanga dump site, Ibadan, Nigeria.

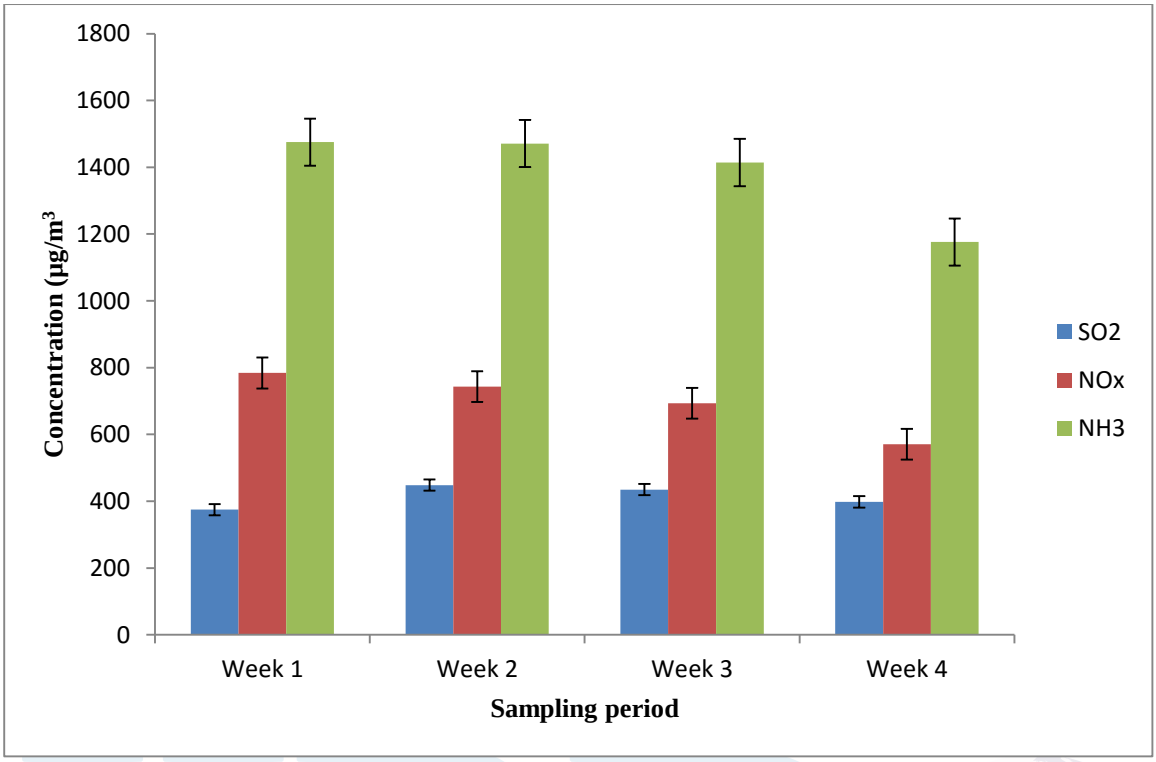

Fig 3: Weekly concentrations (µg/m^3) of SO_2, NO_x and NH_3 in air samples collected at Ajakanga dump site, Ibadan, Nigeria.

Table 1: Comparing mean concentration of air pollutants obtained in this study to some national air quality guidelines.

Place / Body	NO_X (µg/m^3)	NH_3 (µg/m^3)	SO_2 (µg/m^3)	Averaging time	Reference
Ajakanga, Ibadan.	698	1,384	414	1 hr	This study
Nigeria			260	1 hr	FEPA (1991)
UK			266	1 hr	UKAQ (2005)
EU			100-150	24 hr	EEA (2006)
National Standard (US)	188		196	1 hr	USEPA (2011)
Washington DC (US)		1740		1 hr	NIOSH (1977)
WHO	200		500	1 hr	Kryzyzanowskiz and Cohen (2008)
EU			40 - 60	1 yr	EEA (2006)

Results of coefficient of correlation calculations carried out on the concentrations of gaseous air pollutants collected at Ajakanga dump site, Ibadan, Nigeria showed that positive correlation exists between SO_2 and NO_x (r = 0.6655), while negative correlations exist between SO_2 and NO_x (r = -0.2957) as well as NO_x and NH_3 (r = -0.7284).

Table 1 compares the levels of SO_2, NO_x and NH_3 obtained in this study with specific air quality guidelines for Nigeria and some other countries. The levels of SO_2 obtained in this study were lower than WHO guideline (Kryzyzanowskiz and Cohen, 2008) but were higher

than most other national standards and guidelines (FEPA, 1991; EEA, 2006; UKAQ, 2005; USEPA, 2011). Nitrous oxides levels recorded in this study were observed to be higher than EU and WHO Guidelines (EEA, 2006; Kryzyzanowskiz and Cohen, 2008). Ammonia concentrations were lower than the Washington DC recommended standard (NIOSH, 1977).

4 Conclusion.

The results obtained from this study revealed that there was an enhanced gaseous air pollution of the dump site's environment with the three air quality monitoring parameters investigated (i.e. SO_2, NO_x and NH_3). The annual average of waste deposited at Ajakanga dump site was high; hence, gaseous air pollutants emitted from municipal solid waste at the dump site were predicted to be high. The decreasing order of the daily average, the weekly average as well as the overall average concentrations of the three gaseous pollutants emitted at the dump site is $NH_3 > NO_x > SO_2$.

The emission of SO_2, NO_x and NH_3 into the atmosphere at Ajakanga dump site constitutes a major public health hazard to the dump site workers that are regularly exposed to the gaseous emissions in particular and to the people living very close to the dump site in general. In order to combat this environmental nuisance, the following recommendations are suggested:

(1) The emission rate of SO_2, NO_x and NH_3 from municipal solid waste must be controlled at the dump site.

(2) Better practices with regard to municipal solid waste open dump site operation should be developed.

(3) Regular monitoring of the levels of these three gaseous air pollutants and others emitted into the atmosphere at the dump site.

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