AIR QUALITY ASSESSMENT ALONG A LANDFILL SITE IN UYO

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ABSTRACT

Air quality assessment along a landfill site was carried out in Uyo using stratified sampling method. Spatially, the landfill site had the highest concentrations of SO_2 (0.26±0.15 ppm), NO_2 (0.24±0.14 ppm), CO (4.01±0.35 ppm), NH_3 (6.25±0.97 ppm), H_2S (0.55±0.01 ppm), HCN (1.23±0.21 ppm), $PM_{2.5}$ (75.50±13.50 µg/m^3) and PM_{10} (128.50±28.50 µg/m^3). TVOC (2.67±0.09 ppm) and CH_2O (0.37±0.02 ppm) were highest at Ibaoku Community; Cl_2 (0.41±0.01 ppm) was highest at Ibaoku Junction. Temperature ranged between 25.5ºC to 26.5ºC, relative humidity varied between 76.50% and 77.50% while wind speed varied between 0.47m/s and 1.53 m/s. Diurnally, SO_2 (0.24±0.08 ppm), NO_2 (0.18±0.06 ppm), CO (2.86±0.69 ppm), NH_3 (3.81±1.17 ppm), Cl_2 (0.30±0.08 ppm), $PM_{2.5}$ (61.00±9.53µg/m^3) and PM_{10} (106.00±17.15 ppm) were higher in the evening. H_2S (0.28±0.09 ppm), HCN (1.13±0.06 ppm), TVOC (2.13±0.43 ppm) and CH_2O (0.29±0.06 ppm) were higher in the morning. Temperature (27.75ºC) and wind speed (1.36±0.53 m/s) were higher in the evening while high relative humidity (79.75±0.48%) was observed in the morning. Air quality index showed good (minimal) concentrations of NO_2, SO_2 and CO in all locations while concentrations of particulate matters were unhealthy ($PM_{2.5}$) or moderate (PM_{10}). These results have implications in air pollution monitoring, providing baseline information in monitoring future trends of air pollutants in this region.

Keywords: Air Pollution, Dumpsite, Waste disposal, Atmospheric gases, Meteorological variables, Particulate matters

INTRODUCTION

Air pollution is one environmental problem challenging both developing and developed countries of the world. Its prevalence in the ecosystem has been allied to high mortality and morbidity rates (Laden *et al*., 2000; Pope *et al*., 2002). It is a condition where substances like gases (hydrocarbons, CO, NO_2, SO_2 and NH_3,), radioactive materials, particulate matters (dust, smoke, aerosols and fumes) and several others are present in quantities or levels that can exert undesirable effects on living things and the environment (Rai *et al*., 2011). Exposure of humans to these noxious gases on daily basis is inevitable especially in urban regions (Barman *et al*., 2012). The emission of these gases may be of natural and anthropogenic sources, though anthropogenic source of air pollution has been rated higher than the natural source due to the quest of humans for a better living standard and their exploitation of natural resources for urbanisation and industrialisation (Tawari and Abowei, 2005). Due to

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its detrimental effects on humans, air pollution has continually been a topical issue especially in this century. In this study, emphasis was laid on landfills as a potential source of air pollutants.

Landfills are major contributors to anthropogenic greenhouse gases globally, due to the vast quantities of CH_4 and CO_2 being released during the degradation process of wastes deposited in landfills (Kumar *et al*., 2004). Its operations are usually associated with malodorous odour, emissions of bioaerosols and volatile organic compounds (VOCs), noise from landfill bulldozers and contamination of surface and groundwater by leachate (Maqbool *et al*., 2011). The storage of leachate in open lagoons can influence the levels of odours experienced in a landfill site.

Residents who share proximity with landfills have expressed concerns as a result of diverse perilous pollutants originating from landfills and its operations (Palmiotto *et al*., 2014). The emissions of these toxic gases in higher or lower quantities in the landfills are, however, influenced by certain factors like age of the landfill, climatic conditions as well as the quantity and type of wastes deposited. For instance, Turner (1983) reported that when the degradation process in landfills moves slowly from aerobic to anaerobic conditions, CO_2 builds up in high quantities and later falls gradually as the concentration of methane increases (Turner, 1983). Palmiotto *et al*. (2014) also reported that several complex microbiological and chemical reactions occur in a landfill resulting in the formations of Persistent Organic Pollutants (POPs) (Polycyclic Aromatic Hydrocarbons, dioxins), gaseous pollutants, particulate matters and heavy metals.

The constant emissions of these toxic gases are not without health implications. Sharma *et al*. (2018) reported that inhaling methane continuously in high concentrations by humans can result in nausea, loss of coordination, vomiting and death. Boningari and Smirniotis (2016) in their studies reported inhalation of sulphur dioxide and nitrogen dioxide to be responsible for throat and nose irritations, dysproca, respiratory infections and bronchoconstriction in humans. Sharma *et al*. (2018) noted that these gases (NO_2 and SO_2) can elicit asthma attacks in patients who are asthmatic. Kampa and Castanas (2018) reported high contact of NO_2 as being responsible for vulnerability to respiratory infections in humans. Furthermore, when these acidic gases make their way into the atmosphere, the moisture in the atmosphere becomes acidified and fall down as acid rain. Due to the detrimental effects of these gases to human health, the consistent monitoring of air quality parameters is very apposite in order to assess the air quality at landfills and other waste-dumping sites.

Indiscriminate dumping of wastes is a common scenario around residential buildings in Akwa Ibom State. This unwholesome act, apart from defacing the environment and discharging a malodorous odour, pollutes the air humans breathe due to emission of toxic gases like SO_2, NO_2, NH_3, HCN, particulate matters and H_2S. The pollution of air as a result of the release of these toxic gases by wastes can be life-threatening especially when they are released in high concentrations. These gases tend to be very high in a landfill, being a reservoir of myriads of wastes. At high temperature, explosion of gases and combustion of these wastes are highly dominant in landfills. The explosion of gases and combustion of wastes in an uncontrolled manner at the dumpsites are exposing the neighbourhood to health risks from obnoxious smell, smoke and toxic gaseous emissions and these may have adverse impacts on the health of the people residing in the vicinity. Despite the observed increment in waste generation in the region, a lacuna exists in information regarding the levels of gaseous air pollutants emanating from this landfill. If this information were readily available, accounting for the contribution of this pollution source to atmospheric gaseous pollutants would have been made possible thereby providing a guide to future gaseous emission control programmes in the state. The dearth in information in this regard necessitated this study.

MATERIALS AND METHODS

Study Area

This study was conducted in four stations along Uyo Village where the popular landfill site is situated. The specific geographical coordinates of the stations are presented in Table 1. Uyo Village Road is in Uyo Local Government Area of Akwa Ibom State. Uyo is geographically bounded on the East by Uruan Local Government Area, Abak Local Government Area in the West, Ibiono Ibom Local Government Area in the North and Ibesikpo Asutan Local Government Area in the South. Uyo has a tropical climate with an average annual temperature of 26.4 °C. The annual rainfall averages 2509 mm.

Table 1: Coordinates of the sampled locations

Stations	Longitude	Latitude
Station 1 (Uyo L.G.A Secretariat)	7º 56'42" E	5º 1' 37" N
Station 2 (Landfill site)	7º 56' 3" E	5º 3' 14" N
Station 3 (Ibaoku community)	7º 55' 58" E	5º 3' 26" N
Station 4 (Ibaoku Junction)	7º 55' 56" E	5º 3' 24" N

Sampling Technique and Data Collection

Stratified sampling method was adopted in determining sampling points around residential building gradients along the landfill sites. This sampling technique enabled air quality data to be obtained across different locations, which makes it possible for comparison. Air quality and meteorological variables were sampled in the morning and evening. In marking sampling locations, special preference was given to the following: availability of open space with good configuration free from shed, accessibility, meteorological consideration of upward and downward directions and areas with minimal local influence from vehicular movement. In sampling, consideration was given to the sensitivity and stability of equipment used, recalibration of equipment and reproducibility of results.

Measurement of Gaseous Air Pollutants

Concentrations of air pollutants were measured at 4 stations in the downward and upward wind directions at a distance of 1.5 m above ground level. Highly sensitive digital portable meters were used for the measurement of NO_2, SO_2, H_2S, HCN, NH_3, TVOC, Cl_2, CO, CH_2O, $PM_{2.5}$ and PM_{10}. The portable meters used in the measurement of gaseous pollutants are presented in Table 2.

Table 2: Measurement of Gaseous Air Pollutants

Parameter	Equipment	Range	Alarm levels
Sulphur dioxide (SO_2)	SO_2 gas monitor Gasman Model 19648H	0-10 ppm	2.0 ppm
Nitrogen dioxide (NO_2)	NO_2 gas monitor Gasman model 19831N	0-10 ppm	3.0 ppm
Hydrogen sulphide (H_2S)	H_2S gas monitor Gasman model 19502H	0-50 ppm	10 ppm
Carbon monoxide (CO)	CO gas monitor Gasman model 19252H	0-500 ppm	50 ppm
Ammonia (NH_3)	NH_3 gas monitor Gasman model 19730H	0-50 ppm	25 ppm
Chlorine (Cl_2)	Cl_2 gas monitor Gasman model 19812H	0-5 ppm	0.5 ppm
Hydrogen Cyanide (HCN)	HCN gas monitor Gasman model 19773H	0-25 ppm	5 ppm
$PM_{2.5}$, PM_{10}, TVOC and CH_2O	Air Ae Steward Air Quality Monitor		

Determination of Meteorological and Air Quality Parameters

The field meteorological parameters consisted of temperature, wind direction, wind speed and relative humidity. The measurements were taken at 4 stations. The measurements of the meteorological parameters were carried out alongside air quality using *in situ* portable equipment. Wind speed, temperature and relative humidity were measured using Digital Anemometer (MASTECH MS6252A), Max-Min Thermometer and Hygrometer (KTJTA318).

Air Quality Index (AQI)

To calculate the air quality index, the concentrations of five pollutants were used. These were SO_2, NO_2, CO, $PM_{2.5}$ and PM_{10}. The Air quality index of the air pollutants was calculated using the equation:

$$I = \frac{I_{High} - I_{Low}}{C_{high} - C_{low}} (C - C_{low}) + I_{low}$$

Where,

I = the (air quality) index

C = the pollutant concentration

C_{low} = the concentration breakpoint that is ≤ C

C_{high} = the concentration breakpoint that is ≥ C

I_{low} = the index breakpoint corresponding to C_{low}

I_{high} = the index breakpoint corresponding to C_{high}

The ambient air pollutants were then classified into categories as presented in Table 3.

Table 3: Rating of Air quality Index

AQI Values	Health concern	Health Effects
0 – 50	Good	None
51 – 100	Moderate	Usually sensitive people should consider reducing prolonged or heavy exertion.
101 – 150	Unhealthy for sensitive groups	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly
151 – 200	Unhealthy	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population
201 – 300	Very unhealthy	Significant increase in respiratory symptoms and aggravation of lung disease, such as asthma; increasing likelihood of respiratory effects in general population.
301 – 500	Hazardous	Serious risk of respiratory symptoms and aggravation of lung disease, such as asthma; respiratory effects likely in general population

Source: US EPA (2011)

Statistical Data Analysis

Graph pad Prism 6.0 was employed for determining the mean values of the air pollutant concentrations estimated for measurements made in the morning and evening hours.

RESULTS

Spatial Dispersions of Atmospheric Gases

The spatial dispersion of atmospheric gases is presented in Table 4.1. From the results, the landfill site (station 2) had the highest concentrations of SO_2 (0.26±0.15 ppm), NO_2 (0.24±0.14 ppm), CO (4.01±0.35 ppm), NH_3 (6.25±0.97 ppm), H_2S (0.55±0.01 ppm), HCN (1.23±0.21 ppm), $PM_{2.5}$ (75.50±13.50 µg/m^3) and PM_{10} (128.50±28.50 µg/m^3), station 3 (Ibaoku Community) had high concentrations of TVOC (2.67±0.09 ppm) and CH_2O (0.37±0.02 ppm) while a high concentration of Cl_2 was recorded in station 4 (Ibaoku Junction) (0.41±0.01 ppm). Conversely, station 1 had the least concentrations of SO_2 (0.14±0.02 ppm), CO (1.61±0.45 ppm), NH_3 (2.17±0.16 ppm), H_2S (0.14±0.01 ppm), Cl_2 (0.14±0.01 ppm) and HCN (0.63±0.22 ppm), station 4 recorded the least values for gases such as TVOC (1.35±1.27 ppm), CH_2O (0.19±0.18 ppm), $PM_{2.5}$ (46.00±2.00 µg/m^3) and PM_{10} (80.50±3.50 µg/m^3) while station 3 recorded the least concentration of NO_2 gas (0.11±0.01 ppm). Values

obtained for SO_2, NO_2, H_2S, Cl_2 and HCN spatially were above FEPA limits. Conversely, the concentrations of CO and particulate matters ($PM_{2.5}$ and PM_{10}) were below FEPA limits.

Table 4: Spatial dispersion of atmospheric gases

Parameters	Station 1 (Uyo L.G.A Secretariat)	Station 2 (Landfill site)	Station 3 (Ibaoku community)	Station 4 (Ibaoku Junction)	FEPA limits
SO_2 (ppm)	0.14±0.02[a]	0.26±0.15[a]	0.15±0.04[a]	0.23±0.10[a]	0.10
NO_2 (ppm)	0.12±0.00[a]	0.24±0.14[a]	0.11±0.01[a]	0.16±0.03[a]	0.05
CO (ppm)	1.61±0.45[a]	4.01±0.35[a]	1.92±0.56[a]	2.51±1.14[a]	10
NH_3 (ppm)	2.17±0.16[a]	6.25±0.97[a]	3.32±0.14[a]	2.74±0.49[a]	-
H_2S (ppm)	0.14±0.01[a]	0.55±0.01[a]	0.16±0.02[a]	0.21±0.11[a]	0.008
Cl_2 (ppm)	0.14±0.01[a]	0.39±0.06[a]	0.20±0.01[a]	0.41±0.01[a]	0.03
HCN (ppm)	0.63±0.22[a]	1.23±0.21[a]	0.70±0.20[a]	1.04±0.72[a]	0.01
TVOC (ppm)	1.81±0.93[a]	2.33±0.06[a]	2.67±0.09[a]	1.35±1.27[a]	-
CH_2O (ppm)	0.23±0.11[a]	0.32±0.01[a]	0.37±0.02[a]	0.19±0.18[a]	-
$PM_{2.5}$ (µg/m^3)	52.00±5.00[a]	75.50±13.50[b]	61.00±11.00[c]	46.00±2.00[a]	250
PM_{10} (µg/m^3)	88.50±6.50[a]	128.50±28.50[b]	106.50±18.50[c]	80.50±3.50[a]	150

Means with different superscripts along the same row are significantly different ($p < 0.05$)
± Standard error

Spatial Distribution of Meteorological Variables

The spatial distribution of meteorological variables as presented in Table 5 shows that the temperature of the study area ranged from 25.50ºC (station 4) to 26.5ºC (station 1). For relative humidity, the values varied between 76.50 % (Stations 1 and 2) and 77.50 % (station 4). Wind speed varied between 0.47 (station 3) and 1.53 (station 1).

Table 5: Spatial distribution of meteorological variables

Parameters	Station 1 (Uyo L.G.A Secretariat)	Station 2 (Landfill site)	Station 3 (Ibaoku community)	Station 4 (Ibaoku Junction)
Temperature (ºC)	26.50±2.50[a]	26.00±2.00[a]	26.00±2.00[a]	25.50±0.50[a]
Relative humidity (%)	76.50±4.50[a]	76.50±3.50[a]	77.00±2.00[a]	77.50±1.50[a]
Wind speed (m/s)	1.53±1.41[a]	0.75±0.13[a]	0.47±0.285[a]	0.49±0.38[a]

Means with different superscripts along the same row are significantly different ($p < 0.05$)
± Standard error

Diurnal Dispersion Rates of Gases and Meteorological Variables

Table 6 shows the dispersion rates of gases and meteorological variables for morning and evening periods. In the study locations, the mean values for gases such as SO_2 (0.24±0.08 ppm), NO_2 (0.18±0.06 ppm), CO (2.86±0.69

ppm), NH_3 (3.81±1.17 ppm), Cl_2 (0.30±0.08 ppm), $PM_{2.5}$ (61.00±9.53 µg/m^3) and PM_{10} (106.00±17.15 ppm) were higher in the evening while H_2S (0.28±0.09 ppm), HCN (1.13±0.06 ppm), TVOC (2.13±0.43 ppm) and CH_2O (0.29±0.06 ppm) were higher in the morning. For the meteorological parameters, high values for temperature (27.75 ºC) and wind speed (1.36±0.53 m/s) were observed in the evening while high value for relative humidity (79.75±0.48 %) was observed in the morning. Values obtained for SO_2, NO_2, H_2S, Cl_2 and HCN for morning and evening were above FEPA limits. However, concentrations of CO and particulate matters ($PM_{2.5}$ and PM_{10}) were below FEPA limits.

Table 6: Diurnal dispersion of gases and meteorological variables

Parameters	Morning	Evening	FEPA limits
SO_2 (ppm)	0.14±0.01[a]	0.24±0.08[a]	0.10
NO_2 (ppm)	0.13±0.02[a]	0.18±0.06[a]	0.05
CO (ppm)	2.17±0.58[a]	2.86±0.69[a]	10
NH_3 (ppm)	3.42±0.68[a]	3.81±1.17[a]	-
H_2S (ppm)	0.28±0.09[a]	0.24±0.11[a]	0.008
Cl_2 (ppm)	0.27±0.06[a]	0.30±0.08[a]	0.03
HCN (ppm)	1.13±0.06[a]	0.67±0.26[a]	0.01
TVOC (ppm)	2.13±0.43[a]	1.94±0.62[a]	-
CH_2O (ppm)	0.29±0.06[a]	0.26±0.08[a]	-
$PM_{2.5}$ (µg/m^3)	56.25±6.56[a]	61.00±9.53[b]	250
PM_{10} (µg/m^3)	96.00±10.86[a]	106.00±17.15[b]	150
Temperature (ºC)	24.25±0.25[a]	27.75±0.63[b]	-
Relative humidity (%)	79.75±0.48[a]	74.00±0.91[b]	-
Wind speed (m/s)	0.26±0.12[a]	1.36±0.53[a]	-

Means with different superscripts along the same row are significantly different ($p < 0.05$)
± Standard error

Air Quality Index (AQI)

The spatial AQI of the study areas is presented in Table 7. In all the stations, the computed AQI for NO_2 and SO_2 was 0. For CO, the AQI values followed this decreasing order: Station 2 (45) > Station 4 (28) > Station 3 (22) > Station 1 (18). For $PM_{2.5}$, the AQI followed this decreasing order: station 2 (161) > station 3 (154) > station 4 (127) > station 1 (52). For PM_{10}, the AQI followed this decreasing magnitude: station 2 (87) > station 3 (154) > station 1 (127) > station 4 (52).

Based on the air quality rating, the concentrations of NO_2, SO_2 and CO in the atmosphere were good in all the study locations while the concentrations of the particulate matters across the study locations were unhealthy ($PM_{2.5}$) or Moderate (PM_{10}).

Table 7: Air Quality Index (AQI) around the Landfill

AQI Values					
Pollutants	Station 1	Station 2	Station 3	Station 4	Air Quality Rating
NO_2	0	0	0	0	Good
SO_2	0	0	0	0	Good
CO	18	45	22	28	Good
$PM_{2.5}$	52	161	154	127	Unhealthy
PM_{10}	67	87	76	63	Moderate

DISCUSSION

The dispersion of the atmospheric gases showed variations spatially in the sampled areas. Majority of the atmospheric gases such as SO_2, NO_2, CO, NH_3, H_2S, HCN, $PM_{2.5}$ and PM_{10} were predominantly higher at the landfill site when compared with the other three locations. The high concentrations of these gases substantiate landfill as being a potential source of noxious gases and pollutants in the vicinity. This validates the reports of several scholars who had attested earlier to this (Kumar *et al*., 2004; Annepu, 2012, Weli and Adekunle, 2014). However, the high concentrations of SO_2 and NO_2 further implicate the landfill site as a source of greenhouse gases and acid- forming gases which are precursors of acid rain. Similar findings were reported by Watson and Albritton (2001), Hamoda (2006) and Rim-Rukeh (2014). Furthermore, high concentration of gases such as CO, SO_2 and NO_2 may accentuate same source apportionments of these gases. This is not unrelated to consistent burning of wastes which is common in the landfill. High levels of CO in the landfill may also be a product of incomplete combustion of fossil fuel (Rim-Rukeh, 2014). Aside fossil fuel combustion, SO_2 may have also been discharged into the atmosphere as a result of organic decomposition (Mark and Léo, 2018). Ideriah and Stanley (2008) noted that the concentrations of SO_2 and NO_2 at dumpsites are a function of industrial solid wastes which make up the waste composition in the landfill site.

The high concentrations of gases such as NH_3 and H_2S in the landfill are not unprecedented but were expected due to high microbial putrefaction of organic matters from household and domestic wastes including plants and animal wastes in the landfill. Ideriah and Stanley (2008) and Rim-Rukeh (2014) also reported similar findings. These gases (NH_3 and H_2S) may further account for the odour emitted by landfills (Rim-Rukeh, 2014). This result corroborates the findings of Weli and Adekunle (2014) who reported high levels of NH_3 and H_2S in Rumuolumeni Landfill Site, Port Harcourt, Nigeria. The high concentrations of these gases in the landfill may imply that this vicinity could be risky to the health of workers and residents due to its oozing malodorous odour. According to the Connecticut Department of Public Health (CDPH) (1997), locations near the landfill will perceive this odour more than the far places particularly in the morning hours since this is when winds tend to be most gentle, providing the least dilution of the gas. This observation may further explain why H_2S gas is high in the morning.

The high levels of particulate matters ($PM_{2.5}$ and PM_{10}) in the landfill site is not unconnected to landfill operations characterised by several chemical and mechanical processes which generate and emit dust particles into the atmosphere (Chalvatzaki, 2010). Burning of wastes may have also contributed to elevated levels of particulate matters in the landfill. The high levels of the aforementioned gases in the landfill may be suggestive of the fact that protective measures such as wearing effective nose masks should be adopted by people working in this site.

Station 3 which was a bit distant from the landfill site (station 2) had high mean concentrations of TVOC and CH_2O. The accumulation of these gases in this location may, however, be problematic as this is a residential area. The concentrations of this gas around this location may be a function of wind dispersion since station 2 (landfill site) and station 3 (Ibaoku community) share proximity with each other. Also, the high concentrations of TVOC may be attributed to combustion of fossil fuels through the use of automobile engines, motor bikes and cars. This corroborates the findings of Bakeas and Siskos (2002). VOCs are very deleterious to human health because they are carcinogenic, mutagenic and/or teragenic (Riedel *et al*., 2018). According to Zhang *et al*. (1994), CH_2O could have been generated either from photochemical oxidation of hydrocarbons in the atmosphere or through the incomplete combustion of fuel. The high level of chlorine in station 4 may be attributed to wind dispersion. The low levels of atmospheric pollutants in station 1 (Uyo L.G.A Secretariat) may indicate that this region was characterised by activities that could magnify the levels of atmospheric pollutants.

Generally, the concentrations of gases such as SO_2, NO_2, H_2S, Cl_2 and HCN in all the sampled locations were above the FEPA permissible limits. This is an indication of severe atmospheric pollution in these locations. This may be highly critical and can pose serious health risks on residents of these locations. For instance, Mark and Léo (2018) stated that sulphur dioxide (SO_2) irritates the skin and mucous membranes (eyes, nose, throat and lungs), and can affect the respiratory system. Inhaling sulphur dioxide is associated with increased respiratory symptoms and disease, difficulty in breathing and premature death (Pope, 1995). A study in China revealed that air pollutants such as SO_2 may contribute to an increased risk for lung cancer mortality (Cao *et al*., 2011**)**. However, exposure to nitrogen dioxide (NO_2) can decrease lung function and increase the risk of respiratory symptoms (WHO, 2003). NO_2 emissions in particular calls for environmental concern as it is a greenhouse gas with a global warming potential. The NO_2 and SO_2 are precursors to acid rain and atmospheric particulates (Don-Pedro, 2009).

Exposure to HCN at high concentrations may result in rapid collapse and cessation of respiration (Hartung, 1994). If the exposure continues, unconsciousness is followed by death. At much lower concentrations, the earliest symptoms may be numbness, weakness, vertigo, some nausea and rapid pulse (Hartung, 1994). Acute exposure to chlorine gas may cause eye and throat irritation (Kim *et al*., 2014). Such exposures can result in symptoms of acute airway obstruction, including wheezing, cough, chest tightness and dyspnea (Kim *et al*., 2014). For H_2S, exposure to lower concentration of this gas can result in eye irritation, sore throat, cough, shortness of breath and fluid in the lungs (Antai, 2016). Long term, low level exposure may result in fatigue, loss of appetite, headaches, irritability, poor memory and dizziness (Antai, 2016). The fact that CO and particulate matters were below FEPA permissible limits does not mean it should be overlooked but rather it calls for consistent monitoring of these in the areas. This is because at higher concentrations they can be injurious to health.

The results obtained from the meteorological parameters revealed that station 1 had high temperature which may be attributable to the problem of urban heat and lack of vegetation in the area. It was also observed that the temperature increased with decreasing relative humidity and *vice-versa*. This confirms the inverse relationship of these parameters in the environment. This is also clearly seen in station 4 (Ibaoku Junction) where there was a high relative humidity with decreasing temperature. The highest wind speed in station 1 may be attributed to decrease in urban trees which would have reduced the wind speed. However, the low speed of wind in station 3 may be connected to the presence of vegetation especially trees in the vicinity. This corroborates the findings of Tahir and Yousif (2013) who observed that the more compact the foliage on the trees is, the greater the influence of these trees on wind speed.

The distribution of the gases showed that SO_2, NO_2, CO, NH_3, Cl_2, $PM_{2.5}$ and PM_{10} were higher in the evening while H_2S, HCN, TVOC and CH_2O were higher in the morning. For the meteorological parameters,

temperature and wind speed were higher in the evening while relative humidity was higher in the morning. The high concentrations of gases in the evening with increasing wind speed contrasts with the reports of Weli and Adekunle (2014) that low wind speed favoured the accumulation of pollutants in their study areas especially the dumpsite. However, this diurnal disparities and increase in gases may be attributed to the high temperature which was more evidenced in the evening than in the morning. Weli and Adekunle (2014) also reported a direct relationship between temperature and gases like NO_2, NH_3 and H_2S. Pillay (2011) noted that increased temperature accelerates microbiological activity up to an optimum level. Schenker (2003) reported that atmospheric chemistry was activated by the strong solar radiation, producing high levels of secondary pollutants. The high concentrations of gases in the evening have been influenced by temperature more than wind speed, as has also been observed by Weli and Adekunle (2014). The value obtained for wind speed in the study area for morning and evening fell between the range reported by Weli and Adekunle (2014). The peak values recorded for H_2S, HCN, TVOC and CH_2O in the morning may be explained to mean that the temperature was optimal for the retention of these gases in the atmosphere. Also, the calmness of the wind due to low wind speed may have further contributed to the abundance of these gases in the morning. Concentrations of gases such as SO_2, NO_2, H_2S, Cl_2 and HCN were above the FEPA limits for morning and evening, respectively. This may be responsible for the diurnal pollution levels in these locations.

Evaluation of the air quality revealed that out of the 5 criteria of pollutants, the concentrations of the particulate matters across the study locations were unhealthy ($PM_{2.5}$) or moderate (PM_{10}) while the concentrations of NO_2, SO_2 and CO were good. This is a pointer to a high particulate pollution problem in the area. The values recorded for particulate matters in this study fell within the range reported by Obioh *et al*. (2013) in Aba and Abuja, respectively. The unhealthy levels of $PM_{2.5}$ is an indication of the atmospheric predominance of fine particles in the study locations. The moderate levels of PM_{10} indicates moderate pollution by coarse particles in the locations. The high levels of these particulate matters have health implications. For example, US EPA (2011) reported that unhealthy levels of particulate matters result in increased aggravation of heart or lung disease, premature mortality in persons with cardiopulmonary disease and the elderly as well as increased respiratory effects in general population. Particulate matters seriously affect the skin, arteries, lungs, heart and eyes (Neghab *et al*., 2011). Exposure to particulate matter for a long time in the environment for many is linked to serious cardiovascular, respiratory and skin diseases. Short-term exposure led to morbidity incidents in all ages owing to cardiovascular and respiratory diseases caused by inhalation of airborne dust particles (Chen and Kan, 2008).

CONCLUSION

This study revealed that the outdoor air quality variables varied around the landfill. Spatially, gases such as SO_2, NO_2, CO, NH_3, H_2S, HCN, $PM_{2.5}$ and PM_{10} were predominantly higher at the landfill site than in the other three locations. The atmospheric concentrations of gases such as SO_2, NO_2, H_2S, Cl_2 and HCN in all the sampled locations were above the FEPA permissible limits. The study also revealed that the dispersion rates of these gases were influenced by the meteorological conditions such as temperature, relative humidity and wind speed. Diurnally, gases like SO_2, NO_2, CO, NH_3, Cl_2, $PM_{2.5}$ and PM_{10} were higher in the evening while H_2S, HCN, TVOC and CH_2O were higher in the morning. The air quality assessment showed that the concentrations of the particulate matters across the study locations were unhealthy ($PM_{2.5}$) or moderate (PM_{10}) while that of NO_2, SO_2 and CO were all good.

Areas where landfill is cited can be contaminated due to the emission of toxic gases. It is, therefore, recommended that:

i) people should not reside near landfills or where landfill operations are predominant.

ii) landfill should be sited far away from residential vicinity

iii) appropriate measures should be taken to control air pollution especially in residential areas

v) environmental workers at the landfill site should wear good nose masks to prevent inhalation of toxic gases.

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