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AMBIENT AIR QUALLTY MONITORING OF AN EDUCATIONAL INSTITUTION IN NIGERIA

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Abstract

Air quality monitoring was conducted for 15 outdoor locations within an educational institution in Nigeria for 3 consecutive months during dry season using portable pre-calibrated gas monitors to obtain a scientific data on the ambient air quality status. Pollutants which include total volatile organic compounds (TVOCs) and formaldehyde (HCHO) were monitored using Air Ae Steward Air quality monitor. Carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), hydrogen sulphide (H_2S) hydrogen cyanide (HCN), ammonia (NH_3) and chlorine (Cl_2) were measured using gasman portable monitors. Meteorological parameters including temperature, relative humidity and wind speed were measured using Air Ae Steward Air quality monitor and MASTECH Anemometer, respectively. The pollutants concentrations ranges between 0.1±0.0 - 2.8±1.0 mg/m^3 (TVOCs), 0.1±0.0 - 0.8±0.0 mg/m^3 (HCHO), 0.1±0.0 - 0.3±0.0 ppm (NO_2), 0.1±0.0 - 0.3±0.0 ppm (SO_2), 2.0±0.0 - 6.5±0.5 ppm (CO), 2.0±0.0 - 6.0±0.0 ppm (NH_3), 0.3±0.0 - 0.7±0.1 ppm (Cl_2), 0.1±0.0 - 0.3±0.0 ppm (H_2S), 0.1±0.0 ppm (HCN). The results obtained were analysed by comparing with FEPA, WHO and US EPA guidelines and NO_2, NH_3 and Cl_2 were found in concentrations that exceeded recommended limits across all the locations while SO_2, H_2S and HCHO exceeded in some locations and CO, HCN and TVOCs were below the recommended limit across all the locations.

Keywords: Air Quality, Air Pollutants, Ambient Air Pollution, Gaseous Pollutants, Ambient Air, Health Effect, Meteorological Influence

Introduction

In recent years, air pollution has been considered as the greatest environmental and health concern that poses deleterious and life-threatening effects such as the increasing incidences of respiratory and cardiovascular diseases and cancer (So *et al.,* 2022), (Carlsen *et al.,* 2022), (WHO, 2014), (Baklanov *et al.,* 2016), (Costa *et al.,* 2019). It has also been proven to affect learning activities and social behaviour (Nway *et al.,* 2017), (Win-Shwe *et al.,* 2015), (Sasan Sadrizadeh *et al.,* 2022), (Gartland *et al.,* 2022). In the bid of man to live a better and comfortable life, his activities have altered the natural form of the air by introducing dangerous gases into the atmosphere.

Polluted air is considered as air with a poor quality and at high concentrations the human health is threatened. Unpolluted air although seen as a concept of what the air composition might have been if humans and their activities did not exacerbate the deterioration of pristine air contents. At remote locations such as the poles, deserts and mountaintops, vestiges of aged and diffused human mediated pollutants are still found. However, the gaseous composition (dry basis) of unpolluted air is composed of nitrogen 78.1%, oxygen 20.8%, and other gases like carbon dioxide, water vapour, methane and argon make the remaining 1%.

WHO in 2016 estimated worldwide Outdoor Air Pollution to cause 4.2 million premature deaths as a result of exposure to these toxic pollutants, which cause cancers, respiratory and cardiovascular diseases. About 6% of related premature deaths were due to lung cancer, 18% of deaths were due to chronic obstructive pulmonary disease and acute lower respiratory infections and 58% of death was due to ischaemic heart disease and strokes. 91% of these deaths come from low and middle-income countries as they suffer the highest burden of the Outdoor Air Pollution (Weitekamp and Hofmann, 2021), (WHO, 2016). The sources of Outdoor Air Pollution include; industrial activities, vehicle exhaust emission, agricultural, construction etc. Studies linking Outdoor Air Pollution to cardiovascular diseases are available (WHO, 2016), (Ebong and Mkpenie, 2016), (Efe, 2008). Health related issues are top on the list of draw backs associated with outdoor air pollution and loss in the use of an ideal environment. The action of policy makers working at the national, regional and local sectors of waste management, transport, agriculture, energy and urban planning is needed as most outdoor air pollution sources are beyond the control of individuals.

Air pollution has been associated with health related issues and as a result WHO and EPA have continued to give updates and guidelines on reducing and monitoring these pollutants to reduce their impact on health. In order to safeguard the health of the public, all the risk factors for non-communicable diseases should be addressed which include air pollution. The degree to which the toxic air pollutants affect a person's health depends on many factors that include but not limited to the frequency and duration of exposure and susceptibility of the person's health US EPA (2008).

The Health Effect Institute (HEI) chart noted 150 deaths out of 100,000 linked to air pollution in Nigeria and this result was compared to highly industrialized countries like Russia where there are 62 deaths out of 100,000 people; China 117 out of 100,000; Germany, 22 out of 100,000; United States, 21 out of 100,000; Canada, 12 out of 100,000; Japan, 13 out of 100,000 and United kingdom, 21 out of 100,000 deaths. Only in India 195 deaths out of 100,000 people; Afghanistan 406 out of 100,000; Pakistan 207 out of 100,000 were higher than Nigeria (Ogundipe, 2018).

Air pollution is also affected by meteorological conditions (wind speed, relative humidity, and temperature). Studies have shown that meteorological conditions could affect air pollution either negatively or positively (Deqing *et al.,* 2021), (Radzka, 2020).

There are few data on the air quality of educational institution in Nigeria. The air must be monitored to determine air quality based on the concentrations of a variety of air pollutants because air quality is an important determinant of health and wellbeing. Since poor air quality has been associated with detrimental effect to human health and environment, there is need to determine and document the status of air quality.

The objective of this study was to determine the status of ambient air pollution in the educational institution and to generate credible scientific data on the pollution levels in order to prevent undesirable health effects.

Materials and Methods

Study Area

The study area is an educational institution at Ogun state in Nigeria. Ogun state is an industrialized city in the South-Western Nigeria, within the tropical humid climatic of Nigeria. The state is generally characterized by heavy rain fall (monthly average ranges between 7.1mm and 208.27mm in January and June respectively) and high relative humidity the average relative humidity varies from 66.2 – 88.4% in January and to July respectively. The annual average temperature is 26°C. The monthly average rainfall ranges between 7.1mm and 208.27mm in the month of January and June respectively. It is characterized by two seasons (dry and wet) and derived forest vegetation, which has been altered by human activities (Solanke, 2015).

Methodology

The portable pre-calibrated air quality monitors and the equipment used for measuring other parameters are shown in (Table 1). The air quality monitoring was conducted for 3 months between December - March, 2019 (harmattan/dry season) from 06:00 am – 18:00 pm daily (morning: 06:00 am – 08:00 am, afternoon: 12:00 pm – 2:00 pm, evening: 04:00 pm – 06:00 pm). The monitoring time was chosen because it's the period when most human activities take place. All the air pollutants were monitored simultaneously during the period of the sampling periods. Duplicate concentrations of pollutants were collected to ensure consistent readings and accuracy. The coordinates and elevation were also measured using Garmin 76s GPS (Table 1). All monitoring equipment were positioned at the breathing zone (1.5m above ground level). The results obtained were compared against air quality guidelines/Standards (Table 4). The description of Air Ae Steward: air quality monitor and gasman monitor are shown in (Table 2). The monitoring locations and their corresponding coordinates and elevation are shown in (Table 3) below.

Table 1: Equipment used for air quality monitoring

Parameters	Equipment	Model	Manufacturer
Total Volatile Organic	Air quality monitor	NA	Air Ae steward
compounds (TVOCs)			
Formaldehyde (HCHO)			
Temperature			
Relative humidity			
Sulphur dioxide (SO_2)			
Nitrogen dioxide (NO_2)	SO_2 gas monitor		
Carbon monoxide (CO)	NO_2 gas monitor	Gasman	Crown Instrument
Hydrogen sulphide (H_2S)	CO gas monitor	19648H	Ltd Oxon, UK
Hydrogen cyanide (HCN)	H_2S gas monitor	Gasman	
Ammonia (NH_3)	HCN gas monitor	19831H	
Chlorine (Cl_2)	NH_3 gas monitor	Gasman	
Wind speed	Cl_2 gas monitor	19252H	
	MASTECH Anemometer	Gasman	Mastech Group
	Garmin GPS	19502H	limited
Coordinates		Gasman	Garmin Ltd
		19773H	
		Gasman	
		19730H	
		Gasman	
		19812H	
		MS6252A	
		GPSMAP 76s	

NA: Not available

Table 2: Description of gas monitors

Parameters	Gas monitors	Range (ppm)	Alarm levels (ppm)
Sulphur dioxide (SO_2)	SO_2 gas monitor	0-10	2.0
Nitrogen dioxide (NO_2)	NO_2 gas monitor	0-10	3.0
Carbon monoxide (CO)	CO gas monitor	0-500	50
Hydrogen sulphide (H_2S)	H_2S gas monitor	0-50	50
Hydrogen cyanide (HCN)	HCN gas monitor	0.25	5
Ammonia (NH_3)	NH_3 gas monitor	0-5	25
Chlorine (Cl_2)	Cl_2 gas monitor	0-5	0.5

Table 3: Coordinates and Elevation of monitored locations

Locations	Coordinates	Elevation
L 1	06°39'52.5"N 003°09'51.1"E	58
L 2	06°39'51.8"N 003°09'48.4"E	51
L 3	06°39'54.4"N 003°09'56.4"E	46
L 4	06°39'53.5"N 003°09'42.5"E	42
L 5	06°40'18.6"N 003°09'45.5"E	63
L 6	06°40'18.6"N 003°09'45.5"E	57
L 7	06°40'20.3"N 003°09'45.6"E	40
L 8	06°40'24.2"N 003°09'36.3"E	41
L 9	05°40'27.4"N 003°09'34.7"E	50
L 10	06°40'16.9"N 003°09'40.0"E	50
L 11	06°40'54.4"N 003°11'02.8"E	50
L 12	06°40'49.0"N 003°10'03.4"E	47
L 13	06°40'13.8"N 003°09'27.4"E	37
L 14	06°40'32.3"N 003°09'42.3"E	48
L 15	06°40'25.7"N 003°09'35.5"E	44

Table 4: Air Quality Standards/Guidelines

Pollutants	Limit	References
Particulates ($PM_{2.5}$)	10 µg/m³ annual average 25 µg/m³ 24-hour average	(WHO, 2016)
Particulates (PM_{10})	20 µg/m³ annual average 50 µg/m³ 24-hour average	(WHO, 2016)
Sulphur dioxide	0.1 ppm	(FEPA, 1991)
Carbon monoxide	10 ppm 8-hour average 25 ppm 1-hour average	(WHO, 2016)
Nitrogen dioxide	0.04 ppm - 0.06 ppm	(WHO, 2016)
Formaldehyde	0.1 mg/m³	(US EPA, 2008)
Total Volatile Organic Compounds (TVOCs)	0.133 mg/m³ 1-hour average 0.048 mg/m³ 24-hour average 3ppm	(US EPA, 2008) (WHO, 2016)
Ammonia (NH_3)	0.3 ppm	(FEPA, 1991)
Chlorine (Cl_2)	0.01 ppm	(FEPA, 1991)
Hydrogen Sulphide (H_2S)	0.1 ppm	(WHO, 2016)
Hydrogen Cyanide (HCN)	NA	NA

NA: Not available

Results and Discussion

The average air pollutants concentrations recorded are summarised in Tables 5

Table 5: Ambient air pollutants and meteorological concentrations (Mean±S.D)

Locations	Temp (°C)	RH (%)	WS (m/s)	NO_2 (ppm)	SO_2 (ppm)	CO (ppm)	TVOCs (mg/m³)	HCHO (mg/m³)	H_2S (ppm)	HCN (ppm)	NH_3 (ppm)	Cl_2 (ppm)
L 1	25.0±0.0	72.0±0.0	0.4±0.0	0.1±0.0	0.1±0.0	3.0±0.0	2.4±0.3	0.3±0.0	0.1±0.0	BDL	3.0±0.0	0.4±0.0
L 2	25.0±0.0	74.0±0.0	0.2±0.0	0.2±0.0	0.2±0.0	4.5±0.5	2.4±0.1	0.3±0.0	0.2±0.0	BDL	4.5±0.5	0.6±0.1
L 3	26.0±0.0	75.0±0.0	0.2±0.0	0.2±0.0	0.2±0.0	4.0±0.0	2.8±0.1	0.3±0.0	0.2±0.0	BDL	5.0±0.0	0.5±0.1
L 4	26.0±0.0	76.0±0.0	0.5±0.2	0.1±0.0	0.1±0.0	3.5±0.5	2.4±0.2	0.3±0.1	0.1±0.0	BDL	5.0±0.0	0.6±0.1
L 5	27.0±0.0	80.0±0.0	1.0±0.1	0.1±0.0	0.1±0.0	4.0±0.0	2.2±0.2	0.3±0.0	0.2±0.0	BDL	6.0±0.0	0.7±0.1
L 6	33.5±0.5	63.0±1.0	1.2±0.3	0.1±0.0	0.1±0.0	2.0±0.0	2.3±0.4	0.3±0.0	0.1±0.0	BDL	3.5±0.5	0.4±0.1
L 7	33.5±0.5	64.0±1.0	0.5±0.2	0.1±0.0	0.1±0.0	3.0±0.0	2.4±0.2	0.3±0.0	0.1±0.0	BDL	3.0±0.0	0.4±0.1
L 8	33.0±0.0	68.0±0.0	1.3±0.1	0.2±0.0	0.2±0.0	3.0±0.0	2.5±0.2	0.3±0.0	0.1±0.0	BDL	2.0±0.0	0.4±0.1
L 9	29.5±0.5	75.0±0.0	0.7±0.3	0.2±0.0	0.2±0.0	3.5±0.5	2.4±0.3	0.4±0.0	0.2±0.0	BDL	2.5±0.5	0.4±0.1
L 10	34.0±0.0	63.0±0.0	0.9±0.1	0.2±0.0	0.2±0.0	3.0±0.0	2.1±0.1	0.3±0.0	0.2±0.0	BDL	3.0±0.0	0.5±0.1
L 11	34.5±0.5	61.5±0.5	0.5±0.1	0.3±0.0	0.3±0.0	6.5±0.5	0.1±0.0	0.1±0.0	0.3±0.0	1.0±0.0	4.0±0.0	0.4±0.0
L 12	33.5±0.5	62.5±0.5	0.8±0.1	0.2±0.0	0.2±0.0	5.0±0.0	2.6±0.0	0.8±0.0	0.2±0.0	1.0±0.0	3.0±0.0	0.4±0.0
L 13	35.5±0.5	61.5±1.5	0.3±0.0	0.1±0.0	0.2±0.0	2.0±0.0	1.8±0.1	0.4±0.0	0.1±0.0	BDL	2.0±0.0	0.3±0.0
L 14	35.5±0.5	61.0±1.0	0.2±0.0	0.2±0.1	0.2±0.0	5.5±0.5	2.8±0.1	0.5±0.1	0.1±0.0	BDL	2.0±0.0	0.3±0.1
L 15	34.5±0.5	62.0±1.0	0.3±0.0	0.1±0.1	0.2±0.1	6.0±1.0	1.2±0.1	0.2±0.0	0.2±0.0	1.0±0.0	3.0±0.0	0.3±0.0

BDL – Below Detectable Limit

Concentration Trend

The concentrations of most of the Pollutants were revealed to be higher substantially than guidelines by FEPA, WHO and US EPA in some locations and for some pollutants (Table 5). World Health Organization estimation indicates that over 80% of urban population are exposed to concentration of pollutants above the acceptable limits (WHO, 2016). Some previous studies also lay claims to this fact (Fullerton, 2008), (Kaplan, 2010), (Hassan and Abdullahi, 2012).

Gaseous Pollutants

All the pollutants were detected in all the locations except HCN that was detected only in three locations (L11, L12 and L 15). TVOCs was detected between ranges 0.1±0.0 - 2.8±1.0 mg/m^3 (Table 5), which is higher than the limit 0.133 mg/m^3 recommended by US EPA in most of the monitored locations. The highest concentration 2.8±1.0 mg/m^3 was at L14 and L3. Elevated concentration levels of VOCs could lead to the health effects such as; Irritations to eyes, nose and throat, allergic reactions, such as asthma and rhinitis, cancers, fatigue, odour annoyance, dizziness, headache, respiratory infections, damage to the central nervous system (Dai *et al.,* 2016), (US EPA, 2010).

HCHO was detected between ranges 0.1±0.0 - 0.8±0.0 mg/m^3 (Table 5), which is higher than the limit 0.1 mg/m^3 recommended by US EPA in all the locations except L11 this could be attributed to the fact that the sources which emit the gaseous pollutant such as paints, markers, carpets, foams and furniture were not found at the L11. Formaldehyde has been designated a carcinogen by the International Agency for Research on Cancer (IARC, 2004) therefore, elevated concentration levels of HCHO could lead to associated health effects like cancers (US EPA, 1989).

NO_2 was detected between ranges 0.1±0.0 - 0.3±0.1 ppm (Table 5), these exceeded the limit 0.06 ppm by FEPA (Table 4) for gases in the atmosphere across all the locations. The highest concentration of 0.3±0.1 ppm was recorded at L11 which could be attributed to emissions from vehicle exhaust as a result of vehicle movement through the gate, Motor Park in the location and a major road directly opposite the L11. In the other locations NO_2 varied from 0.1 to 0.2 ppm. The result obtained was less than 0.1 – 0.4 ppm reported in Uyo and Lagos (Ebong and Mkpenie, 2016), (Njoku *et al.,* 2016) but higher than 0.00 reported in Port Harcourt (Tse and Oguama, 2014). Prolonged exposure could lead to the associated health effects which include mortality and morbidity in children, people suffering from chronic bronchitis and asthma are more at risk (Brunekreef *et al.,* 1994).

SO_2 was detected between ranges 0.1±0.0 - 0.3±0.0 ppm (Table 5), which exceeded 0.1 ppm recommended limit by FEPA (Table 4) in most of the locations. The highest concentration of 0.3±0.1 ppm was recorded at L11 which could be attributed to emissions from vehicle exhaust as a result of vehicle movement through and around the L11, Motor Park in the location and a major road directly opposite L11, Since automobile exhaust emission has been shown to be the major source of SO_2 pollution in the air (Ukemenam, 2014). The least concentration 0.1 was recorded at L1 – L5 which is obviously due to less vehicle activities in the locations. The result obtained is higher than 0.03 - 0.09 ppm reported in Kano (Okunola *et al.,* 2012) but lower than 0.23 – 0.60 ppm reported in Lagos (Adelagun *et al.,* 2012). Therefore, prolong exposure could lead to associated health effect which include headache and respiratory problem (Tse and Oguama, 2014).

CO was detected at ranges 2.0±0.0 – 6.5±0.5 ppm (Table 5) though the measured concentrations was less than 10ppm limit by

WHO (Table 4) across all the sampled locations the highest concentration was still obtained as 6.5±0.5 ppm at Main Gate could be attributed to emission from vehicle exhaust as a result of the high traffic of vehicle in the location (Okunola *et al.,* 2012). Exposure at short and long-term will not likely pose any health threat. The result obtained for CO in this study was lower than 24.00 – 60.0 ppm reported in Uyo, Akwa-Ibom (Ebong and Mkpenie, 2016).

NH_3 was detected between ranges 2.0±0.0 – 6.0±0.0 ppm (Table 5). Highest concentration value recorded as 6.0±0.0 ppm at L5 and least value as 2.0±0.0 ppm at L8, L13 and L14. This was found to be higher than the limit 0.3 ppm recommended by FEPA across all the monitored locations. Elevated concentration levels of NH_3 could lead to health effects such as, serious burns and irritation in the mouth, skin, throat and lungs, pulmonary oedema, intestinal fibrosis, airflow obstruction, gas exchange impairment, persistent bronchitis, laryngeal oedema and death at high levels of exposure. The results obtained were higher than the ranges 0.00 – 3.0 ppm reported in Port Harcourt (Tse and Oguama, 2014). The high concentration of NH_3 could be attributed to vehicular emission, decaying leaves and volatilization from soil household cleaners, disinfectants and bleaching agents, industrial cleaners, plastics, fumes and cigarette smoking (Adelagun *et al.,* 2012), (Behera *et al.,* 2013).

Cl_2 was detected between ranges 0.3±0.0 - 0.7±0.1 ppm (Table 5), Cl_2 was observed to be higher than 0.01 ppm specified by FEPA (Table 4) across all the locations. Highest concentrations of Cl_2 were obtained at L1 – L5 this could be attributed to the fact that sources of Cl_2 are used more in these locations such as chlorinated organic compounds, water purification, bleach, paper and pulp, some processed food and insecticides (Gorguner *et al.,* 2004). Concentrations below 3 ppm cause nose, throat, eyes, respiratory tract and lung irritation. Concentrations above 3 ppm cause pain in the chest, toxic pneumonitis, vomiting, pulmonary oedema, cramp in the larynx muscle (choking), suffocation as a result of swelling in the mucous membrane and death (Guloglu *et al.,* 2002). The results obtained were compared against the results from previous studies and was found to be higher than 0.27 – 0.40 ppm reported at Ibeno, Niger Delta (Asuoha and Osu, 2015) but lower than 0.2 – 1.50 ppm reported Utu, Akwa-Ibom (Pat-Mbano and Nkwocha, 2012) .

H_2S concentration ranged between 0.1±0.0 – 0.3±0.0 ppm (Table 5). It was observed to be higher than the recommended 0.1ppm limit specified by FEPA in most of the monitored locations. Highest Concentration value of 0.3±0.0 ppm was recorded at L11 could be attributed to vehicle exhaust emissions as a result of the high traffic of vehicle in the location. To avoid the associated health effects linked with prolonged exposures sources of H_2S should be controlled.

HCN was detected between ranges 0.1±0.0 ppm at L11, L12 and L15 (Table 5). The high concentration at the 3 locations could be attributed to vehicle exhaust emissions as a result of the high traffic of vehicle in the locations. The recommended limit was not available. However, it was compared against the equipment alarm level 5 ppm (Table 2). The concentration range was found to be lower than 1.0±0.0 - 2.3±0.3 ppm reported in Uyo, Akwa-Ibom (Udotong, 2015).

Meteorological factors

High wind speed cause greater spread of air pollutants, resulting in lesser concentrations of air pollution in areas with stronger wind speed (Handhayani, 2023), (Liu *et al.,* 2020), (Malgorzata and Beata, 2011), (Ediabonya *et al.,* 2013), (Huang *et al.,* 2021). The result obtained showed higher wind spend at L8, L6 and L5 and the concentrations of pollutants in these locations were observed to be relatively low compared to other locations with lower wind speed.

Conclusions

The concentrations of Pollutants (TVOCs, HCHO, CO, NO_2, SO_2, H_2S, HCN, NH_3 and Cl_2) were monitored in 15 locations in an educational institution. L11 had highest concentration of NO_2, SO_2, H_2S, CO and HCN, L5 had highest of Cl_2 and NH_3, while L3 and L12 had highest concentrations of TVOCs and HCHO respectively. NO_2, NH_3 and Cl_2 exceeded the recommended limits in across all the locations, TVOCs, HCHO, H_2S and SO_2 exceeded recommended limits in most of the location while CO and HCN were below the recommended limits across all the locations. The season could be a contributory factor to the exceedances. The air pollutants were observed to have exceded the recommended levels this could be a potential health effects to the inhabitants and this could ultimately negatively affect the learning outcome of the students. Meteorological factors affect the concentration of air pollutants consequently affecting the level of air pollution.

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