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Vertical Variations of Air Quality Indicators in selected Commercial Hubs in Owerri, Nigeria.

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ABSTRACT

Air pollution is a major environmental problem in many urban cities in developing countries. This study therefore is aimed at assessing the vertical variations of air quality indicators in selected urban hubs of Owerri, Nigeria. Some air pollutants such as PM2.5, PM10, SO2, NO2, CO, CH4 and H2S were sampled from Ama JK, Ekeonuwa Market, Ama Hausa, Tetlow by Wetheral Roads Junction and Relief Market, using Aeroqual 500 series instrument. The pollutants were sampled from 1 meter, 6 meters and 10 meters above ground level from 6.30-7.00am and 4.30-5.00pm. Air Quality index was calculated for all sampling areas using the daily average concentrations of the measured parameters. Results obtained showed that at Ama JK the mean concentration of PM2.5, PM10, SO2, NO2, CO, CH4, and H2S were 0.09ppm, 0.17ppm, 0.04ppm, 0.06ppm, 7.40ppm, 0.18LEL and 0.04ppm, respectively. The average concentrations of the pollutants at Ama Hausa were PM2.5 (0.17ppm), PM10 (0.29ppm), SO2 (0.05ppm), NO2 (0.06ppm), CO (8.83ppm), CH4 (1.01LEL), and H2S (0.04ppm). At Ekeonunwa study location the values were PM2.5 (0.12ppm), PM10 (0.16ppm), SO2 (0.04ppm), NO2 (0.10ppm), CO (6.02ppm), CH4 (0.40LEL), and H2S (0.02ppm). Other results indicate that the mean concentrations of PM2.5, PM10, SO2, NO2, CO, CH4, and H2S for Wetheral by Tetlow Road Junction were 0.12ppm, 0.15ppm, 0.02ppm, 0.05ppm, 5.48ppm, 0.30LEL, and 0.03ppm in that order. For the Relief Market study location, the average values of the pollutants were PM2.5 (0.19ppm), PM10 (0.29ppm), SO2 (0.48ppm), NO2 (0.10ppm), CO (12.71ppm), CH4 (0.40LEL) and H2S (0.00ppm). The air quality index for the various locations varied from 60.80 to 275 while the Health Risk Category of the pollutants ranged from moderate to very unhealthy. It was also generally observed that the concentrations of the parameters decreased with increase in height, with the evening period having higher values than the morning hours. It is recommended that people carrying out business activities in the study locations should wear masks to avoid inhalation of the pollutants, especially for children and others within the one meter breathing height. Also appropriate source correction method should be applied to reduce air pollutants in the study area.

Keywords: Air Pollution, Particulate Matter, Nitrogen dioxide, Air Quality

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1. INTRODUCTION

The emergence of Industrialization in developing countries has made air pollution a problem. The quality of air in the atmosphere which comprised of many layers and different gases should be kept in check to avoid environmental degradation because life on earth is dependent on the atmosphere and its quality is essential for our sustenance (Ojo and Awoko, 2012). Air pollution is a relative term, air is polluted when it contains substances at concentrations that cause harm to human health, as well as when it damages ecosystems and other socially valued materials, such as materials and structures.

Air near the earth's surface consists almost entirely (dry volume, 99.997%) of four gases; molecular nitrogen (N_2, 78.00%), oxygen (O_2, 20.94%), argon (Ar, 0.93%), and carbon dioxide (CO_2, 0.04%). Of these, only the concentrations of CO_2 have been increasing from just under 0.03% since the industrial revolution. Because Argon is a noble gas and the other three gases are very stable and non-reactive under atmospheric conditions of temperature and pressure, the atmosphere's dry composition remains very stable. Of course, the atmosphere is more complex than a dry mixture of permanent gases. It has other constituents especially varying concentrations of water vapour and other vapours (e.g., organic liquids), as well as liquid and solid phase constituents (aerosols or particulate matter (PM) held in suspension).

Air pollution is killing our planet Earth. It is caused by the burning of fossil fuel, like power plants, gasoline powered engines and other man-made machinery which cause carbon dioxide. There are other effecting greenhouse gases like sulphur dioxide and methane gases.

Air on Earth is one of the most important elements in our planet. Air has oxygen which makes most living things in our planet breath and without air/oxygen we would not be alive to this day (Vallero, 2014). The most common air pollutants in urban environment includes sulphur dioxide (SO_2); oxides of nitrogen(NO_X) such as nitrogen oxide; carbon monoxide; volatile organic compounds; ozone and suspended particulate matter also called particulates (Narayanan, 2009). In Nigeria, most of the urban pollution come mainly from vehicular emissions, generator fumes, construction sites e.t.c. The recent annual state of global air report published by the Health Effects Institute puts Nigeria as 4th highest in the world with a fatality of 150 deaths per 100,000 Nigerians and number one in Africa (Health Effects Institute, 2019).

2. STUDY AREA

The study location is in Owerri the capital of Imo State. It consists of three Local Government Areas; Owerri Municipal, Owerri North and Owerri West. It falls within the coordinates 5.485 N and 7.035E.

Owerri experiences tropical climate with two main seasons- dry season from November to March and rainy season from April to November. The two seasons are as a result of the North Westerly trade wind, a harbinger of harmattan season and the South Easterly trade wind, which brings the rainy season. The boundary between the two trade winds is called the inter-tropical convergence zone. It is the northwards, southwards movements or convergence of these winds that is responsible for the change in climate in the area.

Owerri has a rainfall pattern that peaks in July and September, then the dry season lasts from November to March with March as the hottest month and December as the driest month (Iloeje, 1979).The rainfall figures range from 2000mm to 2200mm/month for the wet season and 23mm or less for the dry seasons. The average temperature of Owerri is about 27°C, it might peak but never exceeds 35°C and does not get lower than 18°C.

The relative humidity is usually above 80% in rainy season and decreases to 45% in the dry season. The wind speed ranges from 0.3 to 4.5m/s in rainy seasons and 0.3 to 1.5m/s in the dry season. The South west wind is from the Atlantic ocean while the north east trade wind is from the Sahara (Ashton *et al.,* 1998).

Soils of Owerri region are loamy sand texture. The soil types are ferralitic soils which are found in flat areas and in wavelike topography characterized by good drainage which are rich in aluminium and iron compounds. This type of soil is found in most part of the eastern Nigeria. The second type of soil is the hydromorphic soil which is soil whose development is influenced by seasonal water-logging (Imo State government, 1984).

The vegetation type is predominantly Tropical Rainforest, although its density has drastically reduced due to anthropogenic activities such as urbanization, deforestation and agricultural activities. The vegetation is arranged in storeys with herbaceous plants forming the forest floor. The other vegetation type is the farmland/fallowing mosaic. There are scattered palm trees, raffia palm and other economic and food crops around the area.

Owerri currently has an urban settlement pattern with some areas used for residential, government establishments and commercial activities. All these places are linked by network of roads. Minor industrial and urban agricultural activities are also practised.

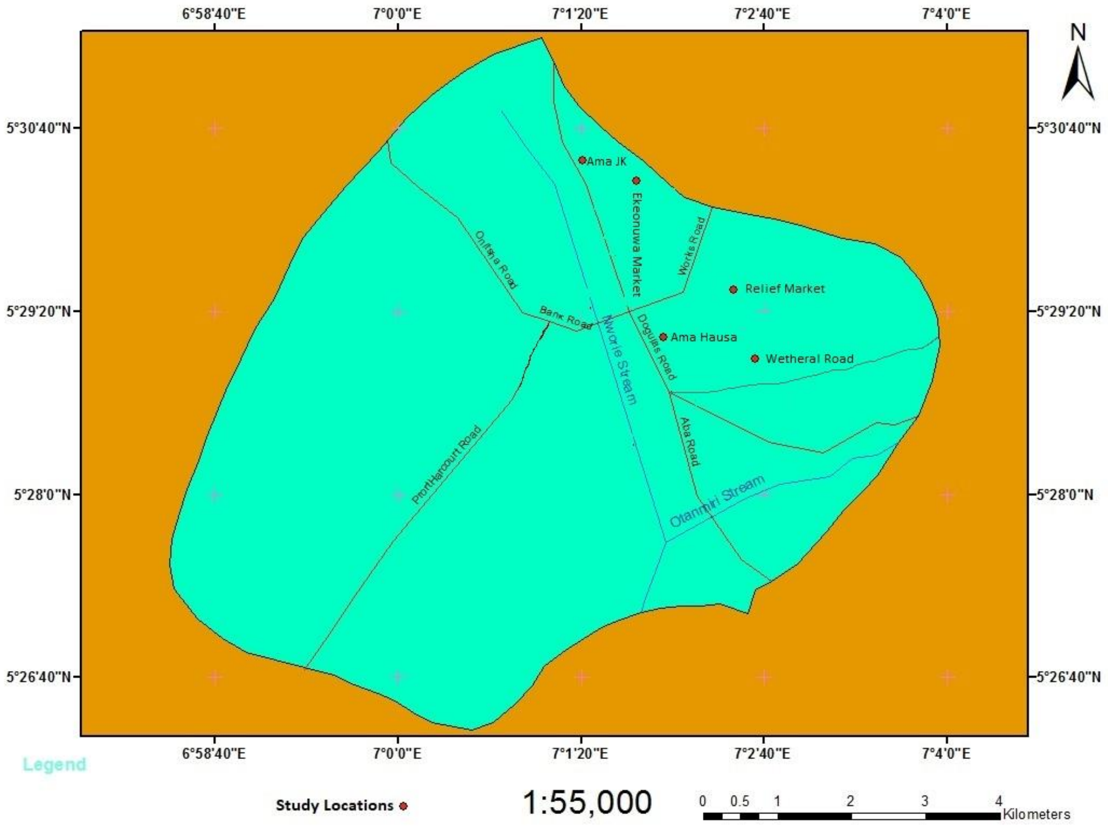

Figure 1: Map of Owerri town showing the study areas.

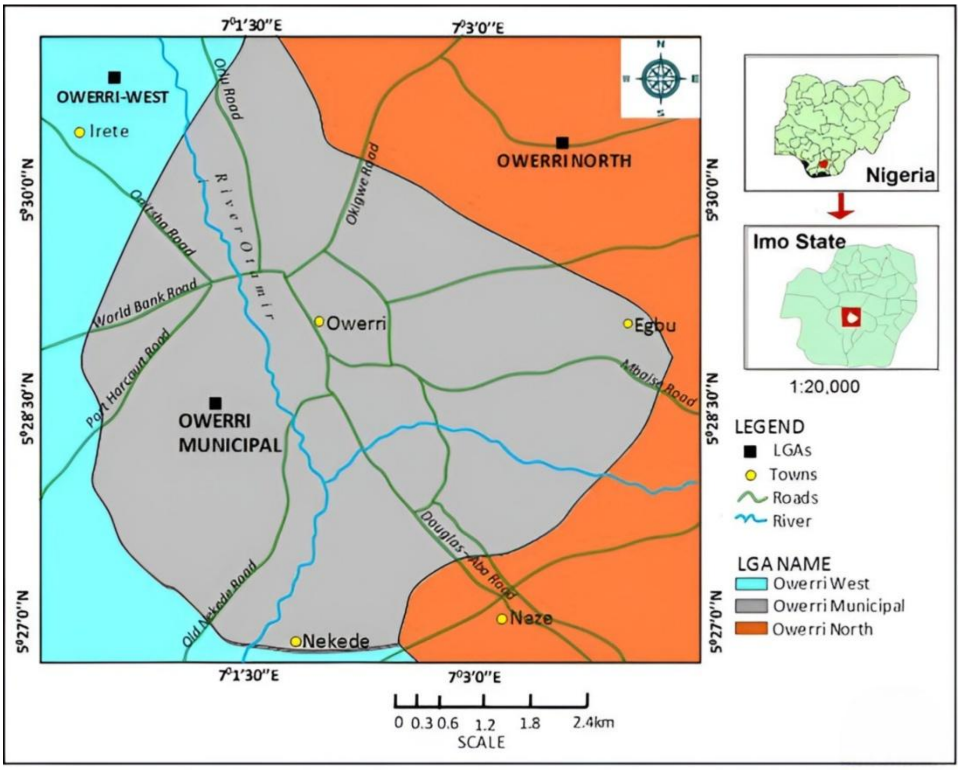

Figure 2: Map of Owerri showing the LGAs.

3. METHODOLOGY

Research Design

This study was commenced by conducting a reconnaissance survey of the study area to identify the appropriate sampling locations. The targeted areas were the commercial hubs that generate substantial amount of air pollutants in Owerri. The selected locations were:

Sampling location 1 (Ama JK)

Sampling location 2 (Ama Hausa)

Sampling location 3 (Ekeonunwa Market)

Sampling location 4 (Wetheral by Tetlow Road Junction)

Sampling location 5 (Relief Market)

Within each sampling location, a two-storey building strategically located for air pollutants sampling was selected.

Sources of Data

Primary data for this study were generated from field work and it covered measurements of air quality indicators above ground heights, and meteorological information such as temperature, wind speed and relative humidity. Secondary data were sourced from existing documents which included maps, textbooks, journals, e.t.c.

Data Collection

Data and information needed for this research work were collected by the use of instrument to measure the air pollution levels at the five sampling locations. The instrument for this sampling was Aeroqual 500 series gas monitor which was used to measure the air pollutants.

Figure 3: Aeroqual Series 500 Portable Air Quality Monitor.

Field Measurements

The following air quality parameters; $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S were determined using Aeroqual 500 series at heights of 1 meter, 6 meters and 10 meters above ground level. These heights were measured from the ground floor, first floor and third floor of two-storey buildings. The vertical profiles were measured in the morning hours (6.30 - 7.00am) and evening hours (4.30-5.00pm) for five days.

Temperature, Wind Speed, Relative Humidity

The monitoring campaign contains wind speed, temperature and relative humidity of the study locations which were measured with digital anemometer, HTC Digital-Thermometer and Humidity meter, respectively.

Statistical Techniques and AQI Computation

Computer aided statistical analysis was used to analyse and group the data obtained through the measurement with air monitoring equipment. Average level of each air quality parameter was calculated using excel spreadsheet. Descriptive statistics such as mean, standard deviation, bar charts were used. SPSS version 20 was used to compute test of significance (ANOVA) and Pearson Correlation.

The Air Quality Index (AQI) was calculated for all sampling areas using the daily average concentration of the measured parameters. The AQI is designed and arranged in tables in order to comprehend at first glance whether air contaminants are approaching unhealthy levels in the area.

4. RESULT PRESENTATION

Ama JK Study Location

Table 1 shows the variations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S at Ama JK study location. The $PM_{2.5}$ and PM_{10} values range from 0.02 to 0.20 μgm^{-3} and from 0.08 to 0.30 μgm^{-3}, respectively. The values for SO_2 and NO_2 were from 0.01 to 0.09ppm and 0.02 to 0.10 ppm in that order. Carbon monoxide (CO), CH_4, and H_2S concentrations were from 3.01 to 12.81, 0.00 to 0.05 (LEL), and 0.01 to 0.08 ppm, respectively. The results further indicate higher concentrations of the parameters at the 1 meter height than at the 6 and 10 meters heights.

Table 1: Variations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S concentrations at Ama JK study location (AJSL).

Height (m)	Time	Parameter						
		$PM_{2.5}$ (μgm^{-3})	PM_{10} (μgm^{-3})	SO_2 (ppm)	NO_2 (ppm)	CO (ppm)	CH_4 (LEL)	H_2S (ppm)
1.00	6:30-7:00am	0.06	0.19	0.03	0.05	6.40	0.03	0.03
1.00	4:30-5:00pm	0.20	0.30	0.09	0.10	12.81	0.05	0.08
6.00	6:30-7:00am	0.04	0.13	0.02	0.04	4.21	0.01	0.02
6.00	4:30-5:00pm	0.17	0.21	0.04	0.08	10.96	0.02	0.06
10.00	6:30-7:00am	0.02	0.08	0.01	0.02	2.01	0.00	0.01
10.00	4:30-5:00pm	0.06	0.10	0.02	0.04	8.00	0.00	0.02

(Source: Field Work, 2023).

Ama Hausa Study Location

Presented in Table 2 are the concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2 CO, CH_4 and H_2S for the Ama Hausa study location. The ranges for the values were; $PM_{2.5}$ (0.05-0.36μgm^{-3}), PM_{10} (0.12 - 0.41μgm^{-3}), SO_2 (0.01 - 0.15ppm), and NO_2 (0.02 - 0.12ppm). Other values were CO (4.36 - 15.12ppm), CH_4 (0.22 - 2.01 LEL) and H_2S (0.02 - 0.06ppm). This location shows relatively high pollution levels especially at the lowest height.

Table 2: Variations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S concentrations at Ama Hausa Study Location (AHSL).

Height (m)	Time	Parameter						
		$PM_{2.5}$ (μgm^{-3})	PM_{10} (μgm^{-3})	SO_2 (ppm)	NO_2 (ppm)	CO (ppm)	CH_4 (LEL)	H_2S (ppm)
1.00	6:30-7:00am	0.13	0.20	0.03	0.04	6.80	0.72	0.03
1.00	4:30-5:00pm	0.36	0.41	0.15	0.12	14.12	2.01	0.06
6.00	6:30-7:00am	0.10	0.20	0.02	0.03	5.81	0.66	0.03
6.00	4:30-5:00pm	0.30	0.30	0.08	0.09	11.53	1.62	0.05
10.00	6:30-7:00am	0.05	0.12	0.01	0.02	5.03	0.22	0.02
10.00	4:30-5:00pm	0.08	0.20	0.02	0.03	9.71	0.85	0.03

(Source: Field Work, 2023).

Ekeonunwa Market Study Location

Table 3 displays the values of $PM_{2.5}$, PM_{10}, SO_2, NO_2 CO, CH_4 and H_2S generated from Ekeonunwa market study location. The $PM_{2.5}$ and PM_{10} concentrations varied from 0.02 to 0.20μgm^{-3} and from 0.04 to 0.34μgm^{-3}, respectively. Sulphur dioxide and NO2 values varied from 0.01 to 0.08ppm and 0.03 to 0.20ppm, in that order. Similarly, CO and CH_4 concentrations were CO (2.26 - 9.61ppm) and CH_4 (0.10 - 1.60LEL). The values of H_2S ranged from 0.00 to 0.05ppm.

Table 3: Concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S at Ekeonunwa Study Location (ESL).

Height (m)	Time	Parameter						
		$PM_{2.5}$ (μgm^{-3})	PM_{10} (μgm^{-3})	SO_2 (ppm)	NO_2 (ppm)	CO (ppm)	CH_4 (LEL)	H_2S (ppm)
1.00	6:30-7:00am	0.12	0.16	0.03	0.08	4.21	0.21	0.01
1.00	4:30-5:00pm	0.20	0.34	0.08	0.20	9.61	1.60	0.05
6.00	6:30-7:00am	0.08	0.10	0.03	0.07	3.42	0.19	0.01
6.00	4:30-5:00pm	0.21	0.22	0.06	0.15	9.02	1.00	0.03
10.00	6:30-7:00am	0.02	0.04	0.01	0.04	2.26	0.10	0.00
10.00	4:30-5:00pm	0.07	0.08	0.03	0.03	7.61	0.08	0.02

(Source: Field Work, 2023).

Wetheral by Tetlow Road Junction Study Location

At the Wetheral by Tetlow road junction study location, table 4 displays the concentration of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S. The range of values obtained show that $PM_{2.5}$ were from 0.01 to 0.39μgm^{-3}, and PM_{10} from 0.02 to 0.41μgm^{-3}. The distribution pattern of the concentrations of the parameters in this study location is similar to other study locations by decreasing with height.

Table 4: Concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S at Wethral by Tetlow Roads Junction Study Location (WSL).

Height (m)	Time	Parameter						
		$PM_{2.5}$ (μgm^{-3})	PM_{10} (μgm^{-3})	SO_2 (ppm)	NO_2 (ppm)	CO (ppm)	CH_4 (LEL)	H_2S (ppm)
1.00	6:30-7:00am	0.03	0.04	0.02	0.04	4.31	0.03	0.03
1.00	4:30-5:00pm	0.39	0.41	0.04	0.09	9.10	1.20	0.05
6.00	6:30-7:00am	0.02	0.03	0.02	0.03	4.01	0.01	0.02
6.00	4:30-5:00pm	0.20	0.31	0.03	0.07	7.22	0.52	0.04
10.00	6:30-7:00am	0.01	0.02	0.01	0.02	3.11	0.00	0.01
10.00	4:30-5:00pm	0.06	0.10	0.02	0.03	5.10	0.00	0.04

(Source: Field Work, 2023).

Relief Market Study Location

Values presented in Table 5 show the variations of $PM_{2.5}$, PM_{10}, SO_2, NO_2 CO, CH_4 and H_2S concentrations at Relief market study location. The range of values for $PM_{2.5}$, PM_{10} and SO_2 were 0.06 to 0.36μgm^{-3}, 0.10 to 0.49μgm^{-3} and 0.01 to 0.06ppm, in that order. Also, the concentrations of NO_2, CO, CH_4 and H_2S varied from 0.02 to 0. 8.71 to 15.81ppm, 0.00 to 1.31LEL, and 0.02 to 0.05ppm, respectively. This study location also has high pollution level with generally higher concentrations in the evening than in the morning.

Table 5: Concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S at Relief Market study location (RSL).

Height (m)	Time	Parameter						
		$PM_{2.5}$ (μgm^{-3})	PM_{10} (μgm^{-3})	SO_2 (ppm)	NO_2 (ppm)	CO (ppm)	CH_4 (LEL)	H_2S (ppm)
1.00	6:30-7:00am	0.17	0.28	0.05	0.09	11.40	0.02	0.04
1.00	4:30-5:00pm	0.36	0.49	0.09	0.18	15.81	1.31	0.05
6.00	6:30-7:00am	0.12	0.20	0.04	0.04	10.90	0.01	0.03
6.00	4:30-5:00pm	0.30	0.40	0.06	0.15	15.01	1.02	0.04
10.00	6:30-7:00am	0.06	0.10	0.10	0.02	9.71	0.00	0.02
10.00	4:30-5:00pm	0.12	0.25	0.25	0.09	13.40	0.04	0.03

(Source: Field Work, 2023).

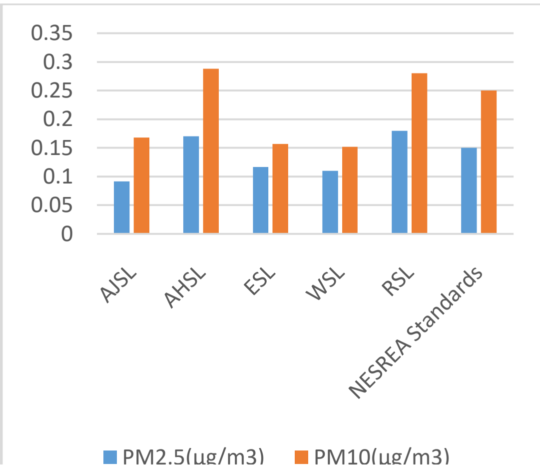

Figure 4: Mean concentrations of $PM_{2.5}$ and PM_{10} at AJSL, AHSL, ESL, WSL, and RSL study locations.

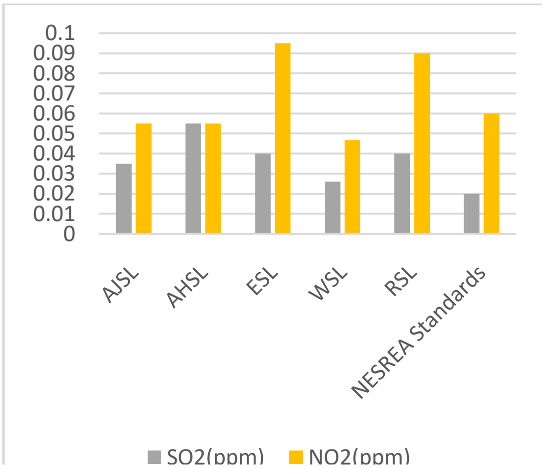

Figure 5: Mean concentrations of SO_2 and NO_2 at AJSL, AHSL, ESL, WSL and RSL sampling locations.

Table 6: Comparison of mean Concentration of Pollutants with NESREA Standards

		AJSL	AHSL	ESL	WSL	RSL	NESREA Standards
Mean Concentration Of Pollutants (µg/m3/ppm)	$PM_{2.5}$	0.092	0.17	0.116	0.11	0.18	0.15
	PM_{10}	0.168	0.288	0.157	0.152	0.28	0.25
	SO_2	0.035	0.055	0.04	0.026	0.04	0.02
	NO_2	0.055	0.055	0.095	0.047	0.09	0.06
	CO	7.398	8.833	6.021	5.475	12.71	9.00
	H_2S	0.037	0.04	0.02	0.023	0.06	0.03

AJSL (Ama JK Study Location), AHSL(Ama Hausa Study Location), ESL(Ekeonunwa Study Location), WSL(Wetheral by Tetlow Roads Study Location), RSL(Relief Market Study Location). (Source: Field Work, 2023)

Table 7: Air Quality Index (AQI) for the values of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4, and H_2S.

		AJSL	AHSL	ESL	WSL	RSL
AQI Of Parameters	$PM_{2.5}$	61.33	113.33	77.33	73.33	120
	PM_{10}	67.20	115.20	62.80	60.80	112
	SO_2	175	275	200	76.66	200
	NO_2	91.67	91.67	105	78.33	150
	CO	82.20	98.14	66.90	60.83	141.1
	H_2S	123.3	133.3	60.66	93.33	200

(Source: Field Work, 2023)

Table 8: Health Risk Category of Pollutants in sampling locations

Parameter	Location and Health Risk Category				
	AJSL	AHSL	ESL	WSL	RSL
$PM_{2.5}$	Moderate	Unhealthy for Sensitive groups	Moderate	Moderate	Unhealthy for Sensitive groups
PM_{10}	Moderate	Unhealthy for Sensitive groups	Moderate	Moderate	Unhealthy for Sensitive groups
SO_2	Unhealthy	Very Unhealthy	Unhealthy	Moderate	Unhealthy
NO_2	Moderate	Moderate	Moderate	Moderate	Unhealthy for Sensitive groups
CO	Moderate	Unhealthy for Sensitive groups	Moderate	Moderate	Unhealthy for Sensitive groups
H_2S	Unhealthy for Sensitive groups	Unhealthy for Sensitive groups	Moderate	Moderate	Unhealthy

5. DISCUSSION

Ama JK Study Location

Table 1 shows the variations in concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S at the Ama JK Study Location. From the results, all the parameters decreased significantly with increase in height from the one-meter to the ten-meter sampling locations above ground level. This agrees with the findings of Imhof (2005) that air pollutants such as particulate matter and NOx decreased with increase in height above ground surface.

The high concentrations observed at the one-meter height could be attributed to the proximity of the source of pollutants such as vehicle exhaust fumes, and dust particles from the ground level. From the one -meter height, the pollutants will move upward where they will disperse, dilute and reduce in concentration. This phenomenon was influenced to a large extent by micro-climatic factors such as wind speed, wind direction, air temperature, relative humidity, and atmospheric pressure (Zheng, Balli, Xiao-Bing, Wang, Li, and Peng, 2021).

The mean concentrations of $PM_{2.5}$ and PM_{10} were slightly below NESREA standard of 0.15 and 0.25µg/m^3, respectively. The AQI and Health Risk Category were moderate, indicating no serious threat to human health. The SO_2 mean concentration (0.035ppm) was higher than the NESREA standard (0.02ppm). Its AQI value was 175 which is categorized as unhealthy. However, at the tenth meter height the value was within NESREA standard and would pose no health threat.

Sulphur dioxide concentration in this location was probably being generated by automobile exhausts and power generators, since the location is used as motor park and for commercial activities.

At the lower height of this study area where majority of the people carry out their daily activities, the concentrations of the parameters were higher than NESREA standard. This is significant because SO_2 and NO_2 have been reported to cause respiratory disease in humans (Uwasomba *et al.,* 2020).

Ama Hausa Study Location

The mean concentrations of all the parameters (Table 6) were higher than the NESREA standard. The high levels of the pollutants in this study location can be attributed to a number of factors, such as high population density, high commercial activities and its associated waste generation, and high traffic congestion. This agrees with Njoku *et al.* (2016) finding from their study of Lagos Metropolis that the quality of air in a locality is dependent on extrinsic factor such as levels of industrialization, population of human, urbanization, waste and sanitary practices e.t.c. The AQI for this location ranges from 91.67 to 275 which by Health Risk Category is from moderate to very unhealthy condition.

Further findings from this location (Table 2) show that the concentrations of the pollutants decreased significantly with increase in height due to the influence of meteorological factors and probably density gradient where the pollutants have lower density than air.

Ekeonunwa Market Study Location

Ekeonunwa Market Study location had mean concentrations of SO_2 (0.067ppm) and NO_2 (0.095ppm) above NESREA limits of 0.02 and 0.06ppm, respectively while other parameters had their values within the limits.

However, from Table 3 the concentrations of all the pollutants were higher than NESREA standards at the one-meter height above ground level. These pollutants were probably generated from automobile exhaust fumes, grinding machines, food grains and wastes dumped indiscriminately in the market. High population density and unplanned nature of the market where buildings are clustered together make air circulation difficult, thus making the pollutants to concentrate more at the lower height than at the upper levels. The health risk category for this study location depicts moderate to unhealthy condition for sensitive people.

Wetheral by Tetlow Road Study Location

As presented in Table 5, the concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S from Wetheral by Tetlow Road junction study location indicate that the values of the pollutants were higher in the evenings (4:30-5:00pm) than in the morning hours (6:30-

7:30am). This is probably due to the high level of commercial activities during the evening period. It is also in line with Dubey, Patra, Joshi, Blankenberg and Nazneen (2022) assertion that time of the day had a significant impact on particulate matter concentration at different altitudes.

Similarly, the values of the pollutants were significantly higher at lower height (1 meter) than at the higher heights of 6 and 10 meters. At higher level, these pollutants were dispersed and diluted resulting in lower concentrations.

From the average concentration of the parameters (table 6), all the parameters were within NESREA standard. The AQI (table 7) range from 53.21 to 78.33 which indicate moderate health risk.

The moderate health risk condition of this study location can be linked to good planning of the area where traders stay in lock-up stores, no indiscriminate dumping of refuse and low vehicular traffic.

Relief Market Study Location

The concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S as sampled from the Relief Market Study Location are displayed in table 5.

Like in the other study locations, the levels of the pollutants were low in the morning (6:30 - 7:00pm) when compared with the concentrations in the evening (4:30 -5:00pm). This variation in pollutants concentrations was due to low level of commercial activities in the morning because many people were yet to come for their daily businesses, unlike in the evening when the market is fully populated and every activity at its peak.

Similarly, the concentration of the pollutants was also higher at the lower heights (one meter above ground level) when compared to higher heights (6 and 10 meters).The high values of pollutants observed at the lower height was due to the closeness of the sources of the pollutants (vehicular fumes, wastes, food particles, soil particles e.t.c.), coupled with poor road infrastructure that caused traffic gridlock in the area. This is corroborated by the findings of Assamoi *et al.* (2010) that pollution from the mobile sources is exacerbated by inefficient vehicles, disorganized road network, traffic congestion and fuel adulteration.

These pollutants are moved into the air through the influence meteorological factor such as temperature, wind speed and direction. As the pollutants move higher in height, they are dispersed and diluted resulting in low concentration. Such dispersion and dilution are not easily done at lower heights because of human and structural obstructions that reduce air movement. This decrease in pollution level with height is also in agreement with the findings of Micallef and Colls (2008) in their study of vertical profile of suspended particulate matter with height.

The AQI for Relief Market study location varied from 120 to 200 with health ratings of unhealthy for sensitive people (Tables 7 and 8).

DESCRIPTIVE COMPARATIVE GRAPHS OF ANALYSED PARAMETERS.

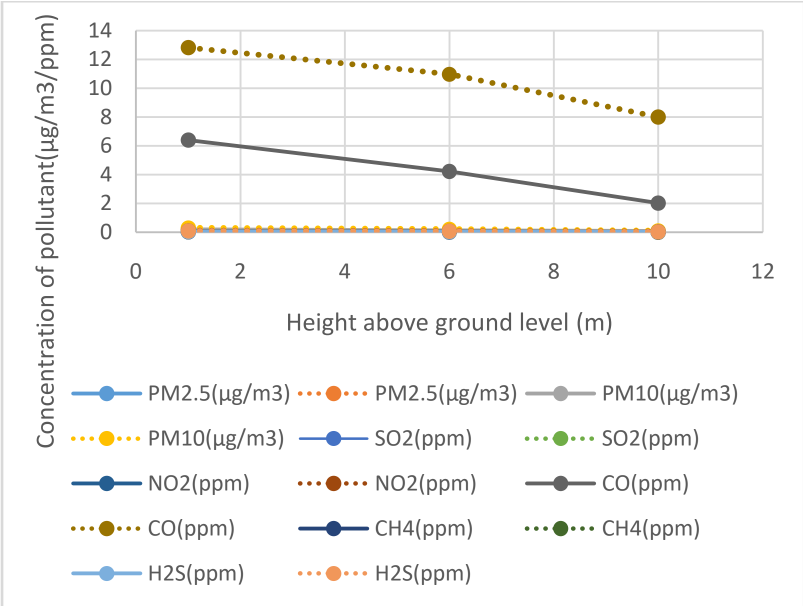

Figure 6: Graph of concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S above ground level at Ama JK Study Location (AJSL).

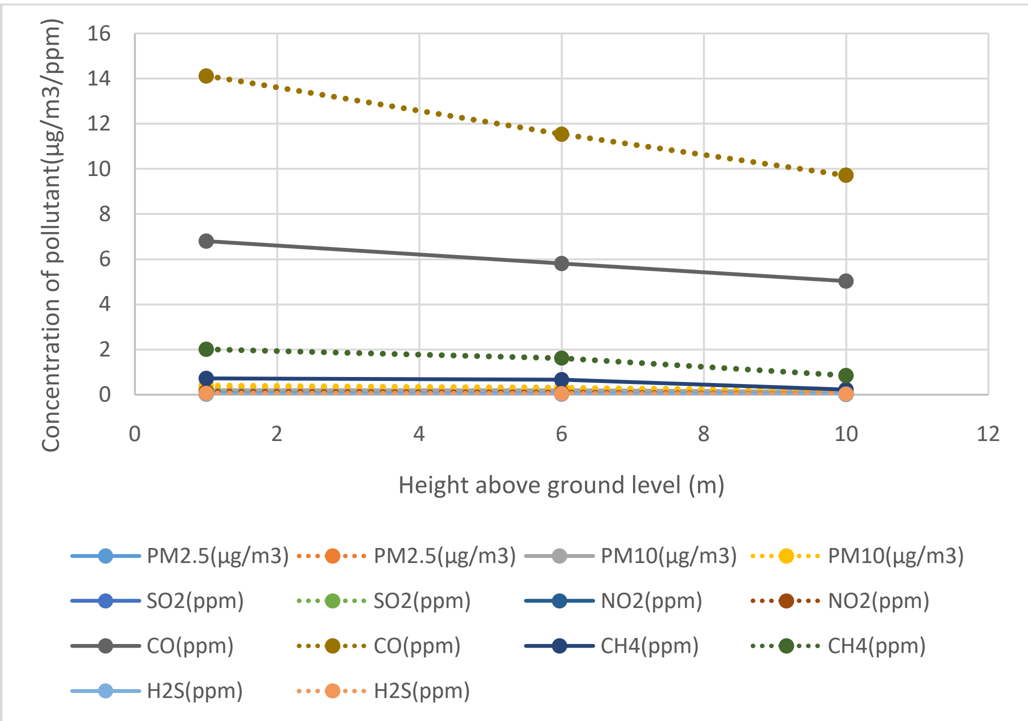

Figure 7: Graph of concentrations of $PM_{2.5}$, PM10, SO_2, NO_2, CO, CH_4 and H_2S above ground level at Ama Hausa Study Location (AHSL).

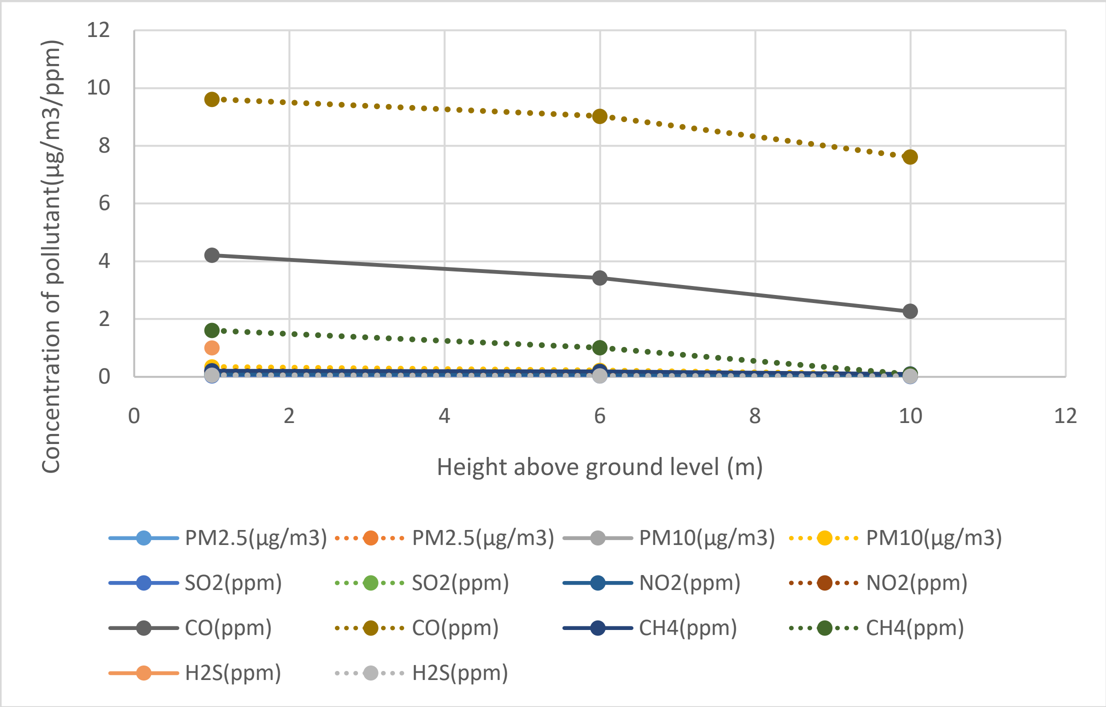

Figure 8: Graph of concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S above ground level at Ekeonuwa Market Study Location (ESL).

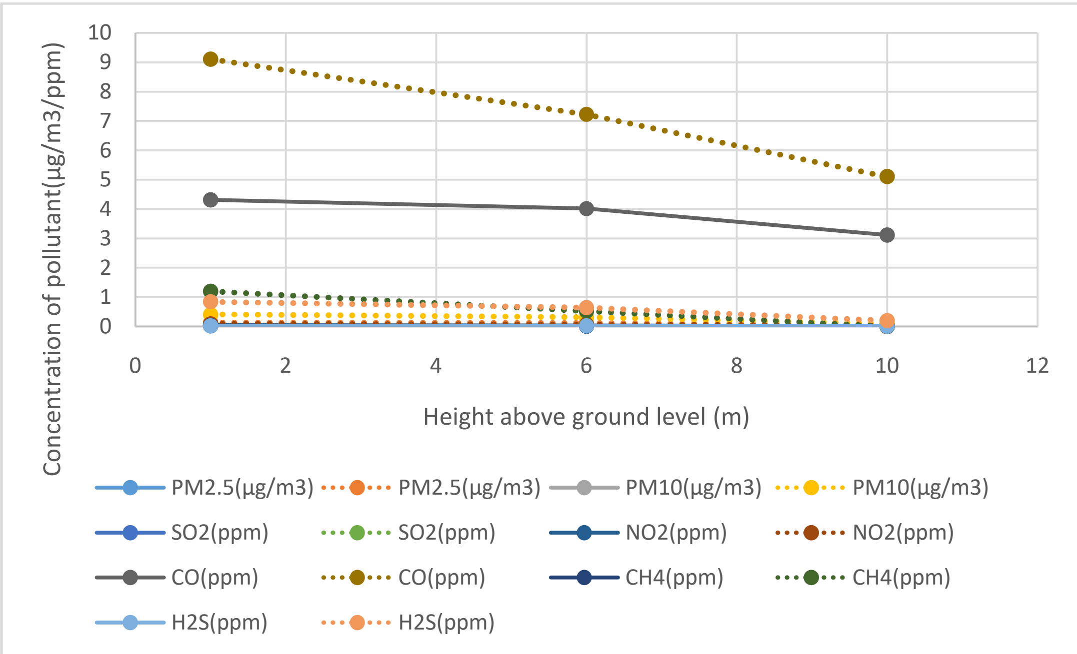

Figure 9: Graph of concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S above ground level at Wethral by Tetlow Junction Study Location (WSL).

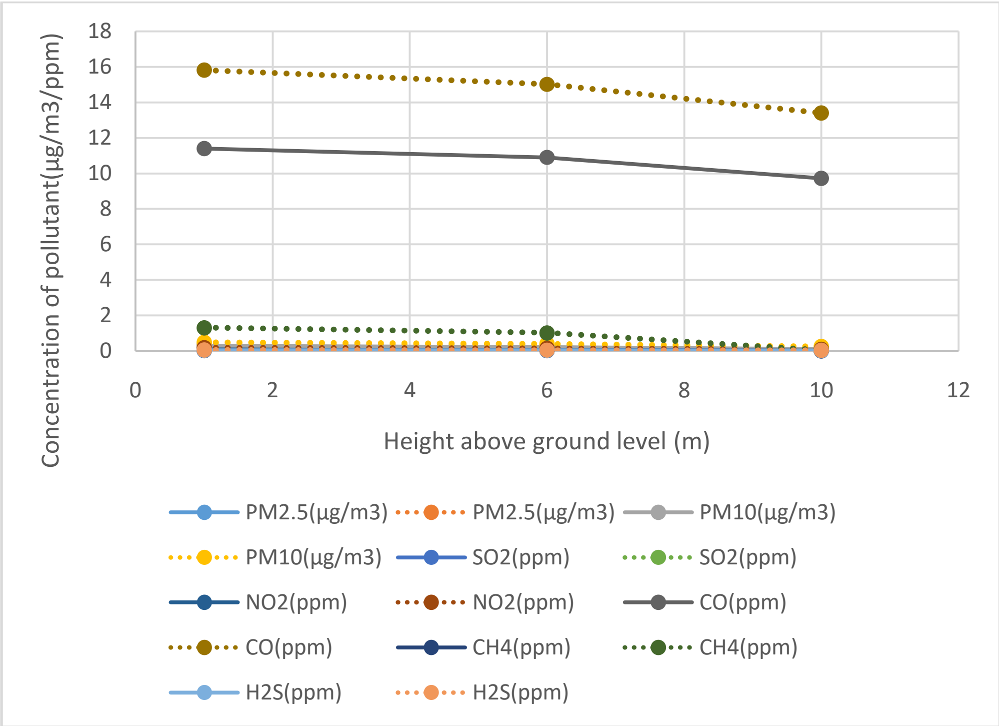

Figure 10: Graph of concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4 and H_2S above ground level at Relief Market Study Location (DSL).

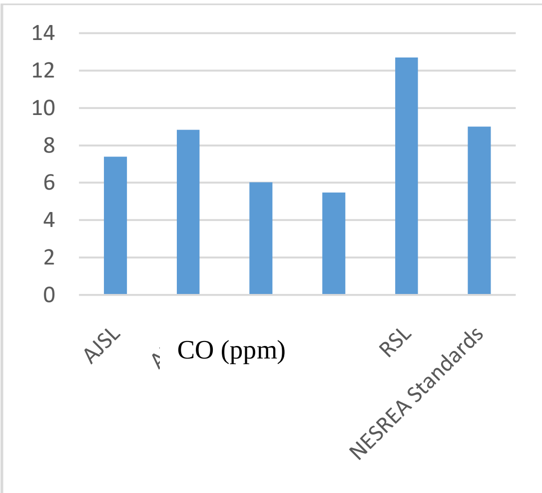

Figure 11: Average concentrations of CO at AJSL, AHSL, ESL, WSL, and RSL sampling locations.

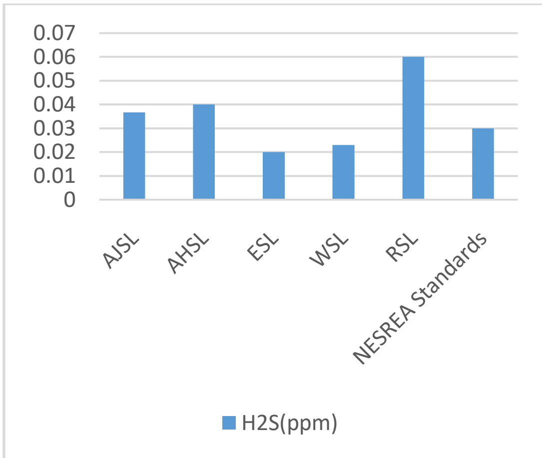

Figure 12: Average concentrations of H_2S at AJSL, AHSL, ESL, WSL and RSL sampling locations.

6. SUMMARY OF RESEARCH FINDINGS

The study examined the vertical variations of air quality pollutants in commercial hubs in Owerri. Five study locations within Owerri (Ama JK, Ama Hausa, Ekeonunwa, Wetheral by Tetlow Roads junction, and Relief Market) were selected. Air quality parameters such as $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, CH_4, and H_2S were sampled in the morning and evening. The above ground level sampling heights were 1 meter, 6 meters, and 10 meters.

The study revealed that there were significant differences between the values obtained between the sampling periods and heights. The evening time had higher concentrations of pollutants than the morning period, probably due to higher population and increased business activities that occur in the evening hours.

Similarly, the concentration of the parameters decreased with increase in height and this could be attributed to air dispersion and dilution caused by some meteorological factors such as temperature, wind speed and direction.

7. CONCLUSIONS

The assessment of vertical variations of air pollutants in selected business hubs in Owerri has revealed that air quality parameters decreased with increase in heights. This is due to the fact that the sources of the pollutants are from the ground surface, coupled with dispersion and dilution of the pollutants as they move up into the atmosphere.

It was also observed from the study that air pollutants in the business areas were more concentrated in the evening than in the morning.

Concentrations of some of the parameters were within NESREA limits while others were above the standard. The AQI for the various locations indicate that the health risk category varied from moderate to very unhealthy condition. The findings of this study are significant as they tend to show that in the study area children may be more exposed to higher concentrations of the pollutants than adults.

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