Assessment of Health Risks Associated With Air Pollution in Onitsha, Anambra State, Nigeria

Valentine Ifenna, Onwukeme., Chinenye Chidiogo Egemba., Obinwa Linda Nwajiaku

Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University Awka, Nigeria

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ABSTRACT

This study assessed the air quality around Onitsha metropolis by monitoring the concentration of selected air pollutants namely; particulate matter ($PM_{2.5}$, PM_{10}) nitrogen dioxide (NO_2), sulphur dioxide (SO_2), hydrogen sulphide (H_2S), ammonia (NH_3), carbon monoxide (CO), methane (CH_4), volatile organic carbon (VOCs) and ozone (O_3); as well as different meteorological parameters, including atmospheric temperature, relative humidity, wind speed, wind direction and noise. Seven locations were studied between the months of July and February using portable hand-held air quality monitoring devices. Sampling was carried out daily for one week between 8am-5pm in each of the selected location. The concentrations of all the measured air pollutants were found to be higher during the dry season than at rainy season. The mean concentration of pollutants during the dry season are $PM_{2.5}$ 170.711 ±11.67 g/m^3, PM_{10} 180.28 ± 111.60 g/m^3, CO 10.3 ±18.30 ppm, NO_2 0.357 ±0.336 ppm, VOCs 2.4286 ±1.8830 ppm, CH_4 1.1643±1.2378 ppm, H_2S 0.0286 ±0.03485 ppm; and during the rainy season $PM_{2.5}$ 38.914 ±27.81 g/m^3, PM_{10} 62.557 ± 47.08 g/m^3, CO 3.786 ±2.76 ppm, SO_2 0.2500 ±0.353, NO_2 0.671 ±1.578 ppm, VOCs 0.2900 ±0.2115 ppm, CH_4 0.01 ±0.00 ppm, H_2S 0.00 ±0.00 and 0_3 0.00 ±0.00 ppm. Air quality was determined using the WHO air quality index (AQI) technique. The overall air quality of Onitsha metropolis was found to be hazardous during the dry season but unhealthy for sensitive groups during the rainy season. The prevailing atmospheric condition per season (wind speed, relative humidity, temperature and wind direction) in the locations assessed contributed significantly to the dispersion and transportation of the pollutants. This study therefore recommends continuous monitoring of air pollution levels in Onitsha metropolis as well as other urban cities and appropriate environmental safety measures to reduce the risk posed by air pollution.

Keywords: Air quality, risk assessment, particulate matter, pollution, Onitsha.

INTRODUCTION

Air pollution is a major global threat to human health and of global concern, it has been identified as one of the major challenging environmental problems bothering both the developed and developing countries of the world [1]. Air pollutants have been linked with numerous environmental and health problems responsible for the increasing morbidity and mortality rates especially in industrialized areas of Nigeria [2]. Statistics from the United Nations Environment Programme (UNEP) classifies air pollution as the greatest environmental threat to public health globally, accounting for over 8 million deaths yearly [3].

Air Pollution is caused by both natural (volcano, forest fires etc.) and anthropogenic sources. Human activities contribute significantly to the emission of gaseous pollutants such as carbon monoxide, generated through incomplete combustion of fuel in form of natural gas, coal or wood or from vehicle exhaust. Sulphur oxides resulting from combustion of sulphur containing coal and petroleum, as well as emission from some industrial processes and automobiles. Nitrogen oxides are produced from high temperature fuel combustion especially with motor vehicles, automobile exhaust, wood-burning stoves, heaters and gas stoves [4].

It is estimated that, about 5.13 million deaths occur annually as a result of exposure to ambient air pollution from use of fossil fuel alone [5]. This implies that the dangers associated with ambient air pollution are severe. The high amounts of pollutants particularly toxic gasses, airborne particles with diameters of ≤2.5 micrometres

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($PM_{2.5}$) and airborne particles with diameters of ≤10 micrometres (PM_{10}), which are released into the atmosphere, cause serious harm to human health and render the environment unsafe for habitation.

Onitsha, the largest and most populous city in Anambra State is well known for its high level of commercial and industrial activities. It plays hosts to several manufacturing industries like, plastics, breweries, pharmaceuticals, batteries, electrical wire and cables, paints, greases, motor oils and other petroleum products. It is a commercial hub for sale of both new and fairly used auto-spare parts, electrical and electronic products, building materials, it also hosts hundreds of petrol stations. Furthermore, Onitsha has a substantial artisan workforce engaged in welding, soldering, brazing, sheet metal fabrication, electrical installation and other services. Most of these commercial and industrial activities release particulate matter (smoke, dust, aerosols, fumes etc) and gases into the environment. The accumulation of these pollutants in high concentrations poses potential risks to human health and the entire ecosystem.

Air quality assessment and monitoring is therefore very vital in determining the nature and extent of population exposure to atmospheric pollutants which may result in various health issues. Onitsha metropolis with its characteristic features of rapid urbanization and industrialization, high population and heavy vehicular traffic is one of such areas where regular air quality monitoring is very vital. The aim of this research therefore is to assess the quality of air around Onitsha, Anambra State, Nigeria.

METHODS

Study site description

Onitsha is one of the largest commercial cities in Nigeria and is considered the largest urban trade centre in Africa. It is a major gateway to South-East Nigeria, with air, water and land way access. The 2025 United Nations estimated population for Onitsha is 1.767million [6] and majority of its adult residents are traders.

The climate in Onitsha is predominantly influenced by two trade winds. The South-West trade wind prevails during the rainy season (April to October) bringing moist air and rainfall while the North-East wind takes over during the dry season (November to March) with associated high temperatures and low rainfall. The dry season includes the harmattan season which peaks in December characterised with attendant cold, dry and dusty air.

Onitsha lies in latitude 6.13° N and longitude 6.79° E as shown in fig. 1.

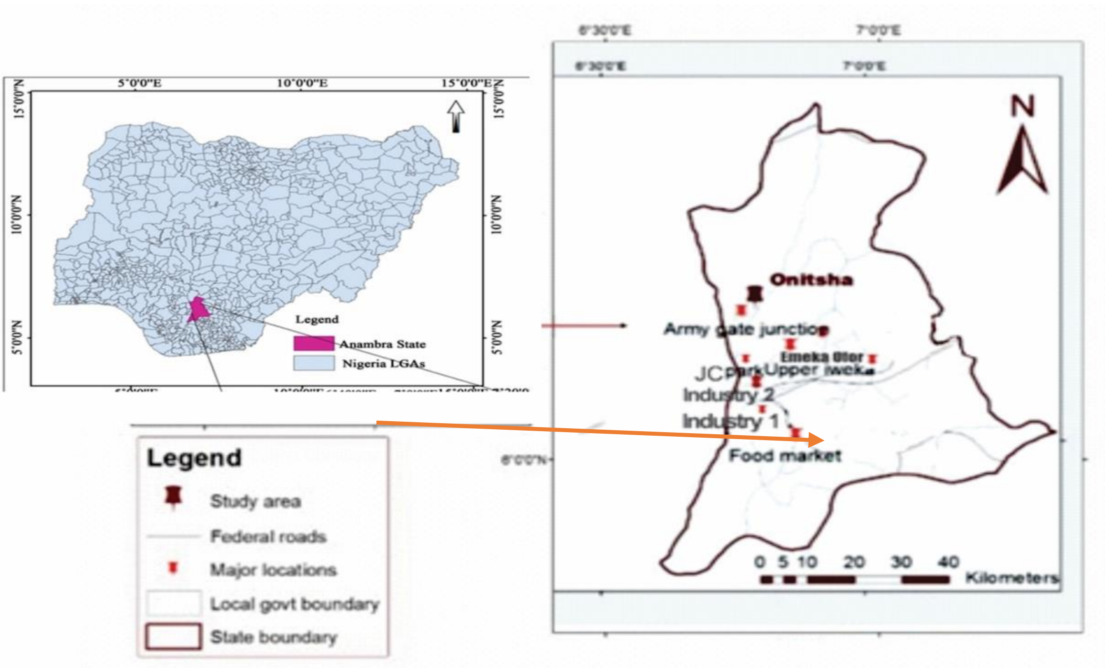

Figure 1: Map showing the sampling locations in Onitsha, Anambra State, Nigeria.

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Sampling procedure

Seven sampling locations were chosen randomly within Onitsha metropolis. They consist of two motor parks (JC Park and Upper Iweka), two industries (Industry 1 and Industry 2) and three markets (Emeka Offor, Army gate and food market) all in Onitsha, Anambra state, Nigeria. These sampled locations are surrounded by fuel stations, shopping plazas, roadside shops, auto repair workshops, electronics market, hospitals and residential houses.

Air quality measurements at the seven stations were made using hand held air samplers (Drager Xam detector and Temptop LKC detector). All equipment were pre-calibrated before use for quality assurance purposes. Metrological parameters including relative humidity (RH), wind direction (WD), wind speed (WS), and temperature (TEMP) were measured using a Krestel (5200) professional portable weather meter. Noise levels were measured with a pre-calibrated digital readout noise meter REED (R8050). The sensor of the noise meter was directed towards the source of noise and the average reading over a period of 5 minutes was taken to be the noise level at each point.

Air quality monitoring was carried out daily for one week from 8am-5pm at the selected stations. All the measurements were done at the seven sampling locations for both the rainy and dry seasons. Mean concentration of the pollutants was compared with WHO recommended levels [1] as in table 1.

Table 1: WHO recommendations on Air Quality Guideline (AQG) levels

Pollutant	WHO 24 Hour AQG level
$PM_{2.5}$	15 µg/m^3
PM_{10}	45 µg/m^3
CO	4 mg/m^3
SO_2	40 µg/m^3
NO_2	25 µg/m^3
O_3	60 µg/m^3 (peak season) 100 µg/m^3 (8 hours limit)
H_2S	-
CH_4	-
VOCS	-

Source: WHO, 2021

Risk assessment

The risk of exposure to ambient air at these locations were assessed using the air quality index (AQI). AQI was calculated using the US EPA method [7] as in equation 1 below. Results were compared with the current World Health Organisation (WHO) global air quality guideline [7] given in table 2.

$$I_P = \frac{I_{Hi} - I_{lo}}{BP_{Hi} - BP_{Lo}} X \left(C_p - BP_{Lo}\right) + I_{Lo} \qquad \text{Equation 1}$$

where, I_P= Index of pollutant P or AQI

$C_p = truncated\ concentration\ of\ pollutant\ p$

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BP_{Hi}= concentration breakpoint greater than or equal to Cp

BP_{lo} = concentration breakpoint less than or equal to Cp

I_{Hi}= AQI value corresponding to BP_{lo}

I_{Lo} = AQI value corresponding to BP_{HI}

Table 2. WHO air quality index (AQI)

AQI	LEVEL OF HEALTH CONCERN	AQI DAILY COLOUR CODE	POLLUTION LEVEL
0 -50	Good	GREEN	LEVEL 1
51-100	Moderate	YELLOW	LEVEL 2
101-150	Unhealthy for sensitive people	ORANGE	LEVEL 3
151-200	Unhealthy	RED	LEVEL 4
201-300	Very unhealthy	PURPLE	LEVEL 5
301 and higher	Hazardous	MAROON	LEVEL 6

Source: US EPA (2006)

RESULTS AND DISCUSSION

Dry season pollution profile

The mean concentration of the selected air pollutants during the dry season are presented in table 3 below.

Table 3: Mean concentrations of particulate matter (µg/m^3) and gaseous pollutants (ppm) from sampling locations during dry season in Onitsha.

Location	$PM_{2.5}$	PM_{10}	CO	SO_2	NO_2	VOC_S	CH_4	H_2S	O_3
JC Park	249	284	14.0	0.10	0.202	4.1	0.90	0.01	0
Upper Iweka	320	304	10.3	0.20	0.500	5.2	2.00	0.05	0
Emeka Offor	247	170	6.0	0.03	0.026	2.0	1.50	0.01	0
Army Gate	205	282	2.0	0.50	0.150	0.1	0.20	0.1	0
Industry 1	35	75	1.0	0.20	0.200	0.2	0.15	0.01	0
Food Market	39	27	0.5	0.40	0.020	2.5	0.00	0.01	0
Industry 2	100	120	4.0	0.40	0.100	2.9	3.40	0.01	0
Mean	170.71	180.29	5.40	0.26	0.17	2.43	1.16	0.028	0.00
SD	112.68	111.60	0.09	0.17	0.16	1.88	I.23	0.035	0.00

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During the dry season (table 3) PM_{10} had the highest average concentration 180.29 among all pollutants measured across the seven locations reaching 180.29 µg/m^3. This mean concentration exceeded the WHO average daily limit of 15 µg/m^3 by an alarming 91.68%, denoting a significant air quality concern. In a similar research on the air quality in Onitsha city, a mean concentration of 263 µg/m^3 was obtained for PM_{10} in Onitsha metropolis [8]. Furthermore, Onitsha was ranked as one of the most polluted cities in the world by the World Health Organisation (WHO) in 2016, its air quality with respect to PM_{10} was reportedly 30 times higher than the WHO recommended level. Other Nigerian cities in the WHO ranking of polluted cities were Kaduna (fifth place), Aba (sixth place) and Umuahia (sixteenth place) [9], this buttresses the challenge of air pollution across the country. The high concentration of PM_{10} obtained during the dry season is closely followed by $PM_{2.5}$ with a mean concentration of 170.71 µg/m^3. This is also well above the 45 µg/m^3 WHO daily limit for $PM_{2.5}$. Out of the seven locations assessed, concentration of PM_{10} remained within WHO safe limits at only one location – the food market while the concentration of $PM_{2.5}$ exceeded the WHO safe level at all the locations. Moreso, according to WHO statistics, the mean concentration of PM_{10} and $PM_{2.5}$ across Africa were 56.3 µg/m^3 and 31.1 µg/m^3 respectively from 2010-2019 [10]. A close look at the results obtained for the two pollutants in this research show that the mean concentration of PM_{10} and $PM_{2.5}$ in Onitsha during the dry season exceeded the average concentration for the entire African region by 68.77% and 81.66% respectively, these are very worrisome outcomes.

Particulate matter, a key indicator of air quality consists mainly of water, black carbon, mineral dust, nitrates, ammonia, sulphates, sodium chloride and dust [11]. The high level of particulate matter obtained in the study may be from windblown dust, particles suspended in the air during movement of vehicles and tricycles, plus large human traffic walking around the dusty roads, busy motor parks and markets. Notably, the concentration of particulate matter recorded around the motor parks and market were higher than the concentration obtained from industrial areas, this suggests that human and vehicular movements are perhaps the largest contributors to air pollution with respect to particulate matter. The health risk resulting from exposure to particulate matter is associated with the size of the particle, the smaller the size the more problem it portends. These particles when inhaled can get deep into the lungs and bloodstream leading to numerous health challenges such as asthma, cancer, heart diseases, lung diseases, cough, breathing difficulties and death.

For the gaseous air pollutants measured at the selected locations during the dry season, ground level ozone (O_3) was not detected at any of the locations while the concentration of SO_2, NO_2, CH4, H_2S and VOCs were within the WHO set limits given in Table 1. On individual site basis, the concentration of carbon monoxide at JC park (14.0ppm), Upper Iweka (10.3ppm) and Emeka Offor (6.0ppm) were higher than the maximum 4ppm recommended by the WHO. Carbon monoxide is a well-known poisonous gas formed from the incomplete combustion of different forms of fuel namely, charcoal, kerosene, coal, natural gas etc or from the emissions of equipment like generators and machines with internal combustion engines. These three locations are characterised by heavy vehicular traffic and buzzling commercial activities where most retail shops make use of generators as the source of electricity. Elevated levels of CO outdoors are particularly worrisome for people living with certain types of heart diseases as it further reduces their ability to get oxygenated blood to their hearts. Inhalation of carbon monoxide at low concentrations can lead to fatigue in healthy people, and chest pain in persons with heart disease. At higher concentrations, CO causes headaches, confusion, nausea, dizziness, impaired vision and coordination; very high concentrations have fatal effects [12].

Notably, Upper Iweka, a very popular and busy motor park in the heart of Onitsha city had the highest concentration of most pollutants including, PM_{10}, $PM_{2.5}$, NO_2 and VOCs. This collaborates the findings of numerous research where vehicle emissions have been identified as the largest contributor to air pollution in urban areas [13]14]. Motorist vehicles burn gasoline or diesel and emit toxic gasses including carbon dioxide (CO_2) and carbon monoxide (CO), oxides of nitrogen (NOx) in the form of nitric oxide (NO) and nitrogen dioxide (NO_2), oxides of sulphur (SO_X) in forms of sulphur dioxide (SO_2) and sulphur trioxide (SO_3), hydrocarbons (HC), and particulate matter (PM_{10}). These pollutants constitute serious hazards to the environment and human health. Nitrogen oxides and sulphur oxides contribute tremendously to acid rain which further degrades soil and water quality. Also, greenhouse gasses including carbon dioxide, nitrous oxide and methane trap heat from the sun leading to greenhouse effect and climate change.

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Rainy season pollution profile

The mean concentration of the selected air pollutants during the rainy season are presented in table 4 below.

Table 4: Mean concentrations of particulate matter (µg/m^3) and gaseous pollutants (ppm) from sampling locations during rainy season in Onitsha.

Location	$PM_{2.5}$	PM_{10}	CO	SO_2	NO_2	VOCs	CH_4	H_2S	O_3
JC Park	22.8	37.9	4	0	0.02	0.54	0.01	0	0
Upper Iweka	70.1	145	6	0	0.45	0.15	0.01	0	0
Emeka Offor	90.1	122.5	8	0	0	0.58	0.01	0	0
Army Gate	14.5	29.5	0	0	0	0.08	0.01	0	0
Industry 1	39.2	60	4.5	1	0	0.14	0.01	0	0
Food Market	12.7	20.6	0	0	0	0.09	0.01	0	0
Industry 2	23	22.4	4	0	0	0.45	0.01	0	0
Mean	38.9143	62.5571	3.7857	0.2500	0.0671	0.2900	0.01	0.00	0.00
Sd	27.8069	47.0846	2.7573	0.3531	1.5775	0.2115	0.00	0.00	0.00

As seen from the measurements presented above, PM_{10} was the major pollutant across all the locations except for Industry 2. The concentration of PM_{10} ranged from 20.6 -145 µg/m^3. This implies that the city is a hotspot for deposition of airborne particles with diameters of ≤10 micrometres. Furthermore, the mean concentration of $PM_{2.5}$ across the seven locations was 38.91 µg/m^3 while that of PM_{10} was 62.56 µg/m^3. These mean values exceeded the WHO standard for $PM_{2.5}$ (15µg/m^3) and PM_{10} (45µg/m^3) underscoring a significant health concern. Onitsha is somewhat the gateway from Southwest Nigeria to all other states in the Southeastern part of the country resulting in high vehicular movements, asides this, Onitsha is a commercial hub, hosting numerous markets that brings traders from all parts of the world. Windblown dust, movement of vehicles and tricycles on the unpaved and poorly maintained roads across the study area as well as ongoing construction works in the areas may have contributed to additional sources of particulate matter. There is strong evidence that subjection to high concentration of particulate matter can cause cardiovascular disease especially ischemic heart disease [18]. People with asthma, pneumonia, diabetes, respiratory and cardiovascular diseases are especially vulnerable to the effects of particulate matter. $PM_{2.5}$ followed by PM_{10}, are strongly associated with diverse respiratory diseases, because their small size allows them to pierce interior spaces [19].

Notably, the mean values of other pollutants were within the WHO limits (see table 1). In addition, two pollutants O_3 and H_2S were not detected at any of the locations. CH_4 was consistently recorded at 0.01 across all locations. SO_2 was only detected at industry 1 while NO_2 was detected exclusively at the motor parks - JC Park and Upper Iweka. High vehicular movements peculiar to this area may have contributed to the elevated NO_2 levels at these locations. This assertion is supported by recent reports from the United States showing that emission of the oxides of nitrogen occur mostly near urban areas with high vehicle traffic and industrial activity [17]. Notable variability was observed with carbon monoxide; its concentration ranged from 0ppm at two locations to 8ppm at Emeka Offor. These two locations with zero CO levels are markets for only food items whereas the other locations with elevated CO levels host activities involving fuel combustion in generators, vehicles or industrial machines.

Comparative analysis

The mean concentration of all the pollutants during the rainy season (as shown in table 4) were lower than was obtainable at the dry season (table 3), implying improvement in the air quality. This lower concentration of

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pollutants in the rainy season is in line with the findings of numerous researchers who opined that pollutant dispersion is highest in the dry season and lower in the rainy season because heavy rainfall cleans the atmosphere of pollutants emitted by both natural and anthropogenic sources [15] by the process of precipitation scavenging.

The concentration of SO_2 and CO in particular, increased at some locations during the rainy season. At industry 1, the concentration of SO_2 rose from 0.2 ppm in the dry season to 1 ppm during the rainy season. Similarly, the level of CO rose from 6 ppm to 8 ppm at Emeka Offor and from 1ppm to 4.5 ppm at Industry 1. These values though within the WHO limits appear to have gone against the usual pattern where concentration of pollutants reduce during the rainy season. The precipitation scavenging effect may have been outweighed by additional emission sources such as incomplete combustion of fuel. The nature of the businesses situated at these two locations require high energy for their operations, additionally, the frequent power outages experienced during the rainy season, make these businesses rely on fuel powered generators and gas engines for power supply. Emissions from these sources contribute significantly to increased SO_2 and CO levels. Moreso, these emissions may have been further escalated by suboptimal combustion conditions like high humidity or low temperature typical at rainy seasons.

Furthermore, none of the 7 locations met the WHO standard for $PM_{2.5}$ during the dry season, but with the transition to rainy season, levels of $PM_{2.5}$ at two locations - Army gate and Food Market dropped to acceptable limits. Similarly, the number of locations with acceptable levels of PM_{10} increased from only one in the dry season to four (JC Park, Army gate, Food market and Industry 2) in the rainy season.

Meteorological profile

The meteorological data at the dry and rainy seasons are presented in tables 5 and 6 respectively.

Table 5: Meteorological data from sampling locations during dry season in Onitsha.

Location	RH	WD	WS	TEMP	NOISE
JC Park	45.0	SE	1.4	38.2	82.7
Upper Iweka	45.6	SW	1.5	38.0	69.0
Emeka Offor	45.3	NE	1.2	38.4	68.6
Army Gate	47.6	SE	0.9	37.0	70.3
Industry 1	47.7	NE	1.0	38.4	81.2
Food Market	59.9	SE	0.9	37.0	50.0
Industry 2	59.9	NE	1.2	36.0	72.0
Mean	50.14		1.15	37.6	70.54
SD	6.75		0.237	0.919	10.74

Table 6: Meteorological data from sampling locations during rainy season in Onitsha.

Location	RH	WD	WS	TEMP	NOISE
JC Park	68.5	SE	1	28.7	88.6
Upper Iweka	63.5	SW	1.9	28.5	89.3

Emeka Offor	60	NE	0.5	27.5	82
Army Gate	61	SE	0.4	28	81.2
Industry 1	60	NE	1.1	26.1	81.2
Food Market	65.5	SE	1.4	29.5	50
Industry 2	83.9	NW	0.4	28.4	72
Mean	64.4		0.95	28.59	78.28
SD	9.01		0.53	1.701	12.60

The meteorological parameters given in Tables 5 and 6 show that the relative humidity (RH) ranged from 45-59.9% in the dry season but increased to 60 – 83.9% during the rainy season. These findings are in line with previous report [20] where monthly mean humidity above 80% was recorded from June to October (rainy season) but was lowest in January (dry season). Humidity at the rainy season is naturally higher due to the increased moisture content in the air.

Temperatures were between 36 -38.4^{o}C during the dry season but reduced to 26.1-28.4^{o}C in the rainy season. The high temperature observed during the dry season could be linked to reduction in the moisture content in the air following the prevalence of the dry, cold, and dust-laden North-East trade wind. Similarly, the mean values of wind speed were higher in the dry season across all the study locations. Higher wind speed during the dry season contribute to the dispersion of pollutants from their primary sources to downwind areas resulting to increased levels of most pollutants in the atmosphere during the dry season.

Noise during the dry seasons ranged from 50 – 82.7dB but were between 50 - 89.3dB in the rainy season. The noise levels at individual locations were higher in rainy season except at food market and industry 1, this may be because both locations are at the outskirts of the town where noise from other sources are very minimal. High noise levels could be from anthropogenic activities such as; conversations in the market, movement of vehicles, sounds from motor engines and music. Natural causes including wind movements, thunder storms and rainfall also contribute to noise during the rainy season. Noise pollution is a major problem in urban areas around the world. Increased noise levels disturb sleep, interrupt conversation, induce stress, frustration and hearing loss, it could also affect cognitive ability and consequently reduce work efficiency. Noise level above 85 dBA is considered hazardous and could lead to hearing loss and other health problems [21].

Air quality index (AQI)

Table 7 presents the air quality indices for the seven locations across both seasons.

Table 7: Air quality index (AQI) from sampling locations in Onitsha city.

LOCATION	AQI ONITSHA DRY SEASON	LEVEL OF HEALTH CONCERN	AQI ONITSHA RAINY SEASON	LEVEL OF HEALTH CONCERN
JC Park	299	Very unhealthy	73.5	Moderate
Upper Iweka	370	Hazardous	158.5	Unhealthy
Emeka Offor	297	Very unhealthy	160	Unhealthy
Army Gate	255	Very unhealthy	57.5	Moderate

Industry 1	110	Unhealthy for sensitive groups	146.5	Unhealthy for sensitive groups
Food Market	110	Unhealthy for sensitive groups	56	Moderate
Industry 2	174	Unhealthy	76	Moderate
Mean	457	hazardous	128.63	Unhealthy for sensitive groups
Standard deviation (SD)	138.05		63.78	

The AQI values ranged from 110– 370 during the dry season and 56 -160 during the rainy season. These values further underscore the improved air quality experienced during the rainy seasons. Overall, the air quality within Onitsha metropolis is hazardous during the dry season which is so far the worst case. This places the population at very high risk of respiratory problems, sensitive groups consisting of the elderly, children are persons with cardiopulmonary diseases face greater risk of aggravated heart or lung diseases or death. The WHO advises the general public with such air conditions to avoid outdoor exertion while sensitive groups are to remain indoors [7]. On the other hand, the air quality during the rainy season is generally unhealthy for sensitive groups. This exposes vulnerable population to increased likelihood of respiratory problems including, aggravated heart or lung diseases and possible premature death.

CONCLUSION

This study assessed air quality during dry season and rainy season across selected locations within Onitsha in Anambra state, Nigeria. The results showed that the concentration of most pollutants during the dry season were higher than their levels in the rainy season. The prevailing meteorological conditions per season significantly influenced the dispersion and deposition of pollutants, however some pollutants exhibited pollution patterns devoid of meteorological influence. These findings highlight the contribution of local emission sources when analyzing pollutant trends. The levels of particulate matter ($PM_{2.5}$ and PM_{10}) particularly exceeded the standard limits for outdoor air in both seasons. Overall air quality was found to be "unhealthy for sensitive groups" during the rainy season and "hazardous" during the dry season. Emissions from vehicular movement and incomplete combustion of fuel from generators and engines, suspension of windblown dust by vehicular and human movements around the busy motor parks and markets were implicated as the major source of air pollution around Onitsha. Noise levels around the entire research area were above tolerable limits. Given the severe health impact of polluted air on public health and environment, the following recommendations are proposed; continuous monitoring of ambient air across urban cities, educating residents on the impact of air pollution and encouraging citizens cooperation in combatting air pollution, regular environmental sanitation, restrictions on vehicular movements at peak periods and decongestion of motor parks and markets in urban cities. Additionally, the operational activities of local businesses and industries should be monitored and transition to clean energy alternatives must be encouraged.

Future research should include hourly variations in pollutant levels; this will aid identification of peak periods and further provide better insights for strategic policy-level responses and remedial actions. Hospital admissions on account of respiratory problems in specific areas may also be compared with the air quality index in the area.

RESEARCH LIMITATIONS

Handheld air samplers and noise meters used for measurements in this research may have limitations in precision compared to more advanced monitoring stations. Additionally, air quality monitoring was conducted at only seven locations and for a short period this may not fully represent the air quality across the entire city and its surrounding areas, additionally long-term pollution pattern may not be fully obtained.

Ethical Considerations

Conflict of Interest: The authors report there are no competing interests to declare. Also, no funds were received for this research or its publication.

Ethical Approvals: The authors declare that this research did not directly involve human subjects or animals and therefore had no need for ethical approvals

Data Availability

The authors declare that all the data utilized for this research are fully included within the article.

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REFERENCES

1. World Health Organization (2021). WHO global air quality guidelines. Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide, Geneva, pp 5-134. https://www.who.int/publications/i/item/9789240034228
2. Sogbanmu, T.O., Sobowale, K.O., Dopemu, O.C., Togun, O.V., Afolabi, O.T. and Magami, J.I. (2020). Air Pollution in Nigeria: A Review of the Causes, Effects, Control and Management. In J. A Opara (Ed.), *Our Changing Environment and Development.* Metropolitan International University Press. pp.368-375. https://research.miu.ac.ug/wp-content/uploads/2020/05/OUR-CHANGING-ENVIRONMENT-AND-DEVELOPMENT-edited-by-Prof-J.A.-Opara.pdf
3. United Nations Environment Programme (2021). Pollution Action Note- Data you need to know. https://www.unep.org/interactives/air-pollution-note/
4. Ukemenam, O.S. (2014). Causes and consequences of air pollution in Nigeria. South American Journal of Public Health, 2(2), 293-307.
5. Lelieveld, J., Haines, A., Burnett, R., Tonne, C., Klingmuller, K., Munzel, T. and Pozzer, A. (2023). Air pollution deaths attributable to fossil fuels: observational and modelling study. BMJ 2023;383:e077784. https://doi.org/10.1136/bmj-2023-077784
6. United Nations (2024). World Population Prospects. https://population.un.org/wpp/
7. United States Environmental Protection Agency (2006). Guidelines for the Reporting of Daily Air Quality – the Air Quality Index (AQI). https://archive.epa.gov/ttn/ozone/web/pdf/rg701.pdf
8. Ekweozor, C.O, Umunnakwe, J.E, Osuji, L, O. and Weli, V. C. (2021). Ambient Air Quality in Onitsha Metropolis. Global Journal of Engineering and Technology 1(1), 8-14.
9. Ogbeche, D. (2016, May 13). WHO ranks Onitsha worlds most polluted city. *Daily Post* https://dailypost.ng/2016/05/13/who-ranks-onitsha-worlds-most-polluted-city/
10. World Health Organization (2023). WHO ambient air quality database, 2022 update: status report. https://iris.who.int/bitstream/handle/10665/368432/9789240047693-eng.pdf
11. World Health Organisation (2024). Ambient (outdoor) air pollution https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health#:~:text=Particulate%20matter%20(PM),carbon%2C%20mineral%20dust%20and%20water.
12. United States Environmental Protection Agency (2024). Carbon monoxide's impact on indoor air quality. https://www.epa.gov/indoor-air-quality-iaq/carbon-monoxides-impact-indoor-air-quality#:~:text=At%20higher%20concentrations%2C%20impaired%20vision,blood%2C%20which%20inhibits%20oxygen%20intake.

13. Kumar, P. G., Lekhana, P., Tejaswi, M. and Chandrakala, S. (2019). Effects of vehicular emissions on the urban environment- a state of the art. Materialstoday: Proceedings 45(7), 6314-6320. https://www.sciencedirect.com/science/article/abs/pii/S2214785320383620
14. Achmad Rizki Pratama, A.R., Joni Arliansyah, J and Melawaty Agustien (2019). Analysis of Air Pollution due to Vehicle Exhaust Emissions on The Road Networks of Beringin Janggut Area. Journal of Physics: Conference Series 1198(8). DOI10.1088/1742-6596/1198/8/082030
15. Hoek, G., Krishnan, R.M., Beelen, R. (2013). Long-term air pollution exposure and cardio- respiratory mortality: a review. *Environ Health* 12, 43. https://doi.org/10.1186/1476-069X-12-43
16. Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. *Frontiers in public health*, *8*, 14. https://doi.org/10.3389/fpubh.2020.00014
17. United States Environmental Protection Agency (2023). Overview of Nitrogen Dioxide (NO_2) Air Quality in the United States. https://www.epa.gov/system/files/documents/2023-06/NO2_2022.pdf
18. Wang, R., Cui, K., Sheu, H., Wang, L and Liu, X (2023). Effects of Precipitation on the Air Quality Index, $PM_{2.5}$ Levels and on the Dry Deposition of PCDD/Fs in the Ambient Air. Aerosol and Air Quality Research 23(4), 1-14. https://aaqr.org/articles/aaqr-22-11-dr-0417
19. Akinwumi, S.A., Olaoluwa , A. A., Omotosho, T.V., Mastorakis, N. E. (20230 Monthly and Seasonal Variation of Cloud Cover, Humidity and Rainfall in Lagos, Nigeria. *WSEAS transactions on environment and development.* DOI:10.37394/232015.2023.19.123
20. US-National Institute for Occupational Safety and Health (2024). Understand Noise Exposure. https://www.cdc.gov/niosh/noise/prevent/understand.html