Journal of Materials and Environmental Science
ISSN : 2028-2508
eISSN : 2737-890X
CODEN : JMESCN

J. Mater. Environ. Sci., 2022, Volume 13, Issue 12, Page 1370-1383

http://www.jmaterenvironsci.com

Effects of Vehicular Traffic on Ambient Air Quality of a Tropical City: Case Study of Owerri Metropolis, Southeastern Nigeria

Opara A.I. [1], Nkwoada A.U. [2], James N.J. [1], Onyenegecha C.P. [3], Ibe F.C. [4], Verla A.W. [4]

[1]*Department of Geology, Federal University of Technology Owerri, Nigeria*
[2]*Department of Chemistry, Federal University of Technology Owerri, Nigeria*
[3]*Department of Physics, Federal University of Technology Owerri, Nigeria*
[4]*Department of Chemistry, Imo State University Owerri, Nigeria*

Received 26 Oct 2022,
Revised 05 Dec 2022,
Accepted 06 Dec 2022

Keywords

- ✓ *Particulate matter*
- ✓ Gaseous pollutant
- ✓ Ambient air
- ✓ Air quality
- ✓ Air pollutant

Chemistryfrontiers@gmail.com;

Abstract

Monitoring air quality in a clustered urban city like Owerri metropolis is challenging given the absence of local monitoring stations. To develop inclusive data for air pollution in the Owerri metropolis, an In-situ monitoring campaign was set up around some designated city areas for a period of one month in August 2019. The measurements of air pollutants such as particulate matter (PM), sulfur dioxide, (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone were performed by using gravimetric and colourimetric method facilitated with a GPS device for Spatio-temporal pattern of air pollutants. Meteorological parameters such as relative humidity, wind speed, ambient temperature and even ozone levels were studied. The measurement period was divided into mornings (8 am to 11 am) and evenings (4 p.m to 7 p.m) on 8 hourly measurements. The data set was analyzed by splitting Owerri metropolis into eight different sampled locations. The air quality in Owerri metropolis was then compared with the national ambient air quality (NAAQS) and the environmental protection agency (EPA USA) guidelines to understand the risk of exposure to criteria pollutants to the residents in Owerri metropolis. Median concentration levels for particulate matter (PM) (2.5, 5.0 and 10) were lower than the annual EPA standard and NAAQS standard of $PM_{2.5}$ standard at 15 μg/m^3 and the 24-hour PM_{10} standard of 150 μg/m^3 Our findings suggest that criteria pollutant concentrations exceeded the AQI standard and NAAQS guidelines which are predominantly emitted from vehicular sources and pose a potential threat to public health.

1. Introduction

Owerri metropolis in the Imo State of Nigeria (5° 28' 34.7160" N and 7° 1' 33.0708" E) like the majority of cities around the world has developed rapidly from once a quiet town to a vibrant city, with community of people exposed to pollution resulting from urbanization influences [1]. The urbanization in the Owerri metropolis and the increasing expansion into the surrounding local government councils have remarkably bolstered the quality of life of the townsmen. Nevertheless, these have caused an increase in air pollution emission bases from generator fumes, industrial facilities, waste burning and vehicular activities. Creating public awareness of air pollution by authorities due to the air pollution detrimental effect has not been impressive over the past decade [2,3]. Several investigations have also shown that the area is prone to traffic and vehicular-related pollution which are well-known drivers for cardiovascular, respiratory, irritated asthma and airways, coughing and breathing difficulty, inflammation and allergic rhinitis [4,5].

Sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) are well–known common air pollutants species found in the Owerri metropolis. High exposure of residents to NO_2 and SO_2 is a serious threat to environmental health, which leads to increased morbidity and high mortality rates [6]. Besides, carbon monoxide (CO) and particulate matter (PM) have also been recognized as principal agents to the famed global warming concerns, owing to heat trappings on the earth's surface including CO_2 under solar irradiation at certain wavelengths [7,8]. Moreover detrimental effects such as fatigue, unconsciousness, irregular heartbeat, and diverse respiratory disease are induced depending on the size of PM when exposed to high levels of PM and CO [9].

In several countries like China, Japan, the USA, the UK and Malaysia, authorities have set up several air pollution monitoring sites and locations to monitor the activities and background concentrations of several pollutant species. For instance, the rural background air monitoring station located in Pahang Malaysia samples several pollutants [10]. Based on the data collected from such stations, better decisions can be made by environmental authorities in mitigating air pollution. However, advanced technologies via mobile monitoring campaign allows spatial integration study which has been on the increase. Contemporary research utilized continuously moving mobile platforms and found that several factors are consistent with remote sensing, vehicle chase and even dynamometer studies [11]. Accordingly, another research work used mobile air quality monitoring to obtain an improved spatial distribution of temporal resolution in the city of Stuggart [12]. In addition, another study determined chemical components in ultrafine and fine particles were in traffic related emissions and observed tht the increase in fine particles concentration was mostly caused by secondary ions [13]. In addition, another work applied an in-situ study of major air pollutants arising from road traffic emissions [14].

On the other hand, Owerri metropolis is a central town that provides road access to other southeastern states of Nigeria, which eventually resulted in unplanned areas and fast-developing suburbs in the city. The Owerri metropolis boasts of gentle undulating topography when compared to neighbouring regions like Orlu and Okigwe [15,16]. This resulted in an increased accumulation of pollutants in the town which is situated below ground level. Subsequently, to the best of our knowledge, the few published studies have not provided sufficient ambient air quality data in the Owerri metropolis. Therefore, this research will study the ambient air quality levels amid exposure to particulate and gaseous pollutants, explore them using Spatio-temporal characteristics, and be used as a reference by authorities to make decisions.

2. Materials and Methods

The Owerri metropolis is composed of three local governments with a total population of 1.5 million as of 2016 but may have grown exponentially to 2–3 million inhabitants presently [17]. The study area of approximately 100 square Kilometers has a diversity of wildlife and tropical vegetation owing to abundant sunshine and humus content of the soil. The Owerri metropolis has a tropical climate condition, which is characterized by rainy and dry seasons with an average air temperature of 27.5 ^oC throughout the year, and by having a rainy season (From April to October) in which the average monthly rainfall is 1646 mm for most of the month. Its relative humidity varies between 60% and 80 % during the rainy seasons, and 46% and 65 % during the dry seasons, without significant variation throughout the year [18,19].

The area is characterized by flat topography and undulating ridges accompanied by vibrant vegetation that influences air circulation in the metropolis of Owerri. With the understanding of the nature of the region which falls under the coastal plain being one of the largest geomorphological zone of Imo State and its varying air conditions, that is influenced by the geological position, and proximity to the seas, the samples were collected in eight distinct locations, with unique attributes as shown in Fig.1; Table 1.

Suspended particulate matter (SPM) and respirable particulate matter (RPM) were sampled using the gravimetric method while, SO_2 and NOx were sampled by colourimetry using the improved West and Gaeke method, and modified Jacobs and Hochheiser respectively. The procedures were validated using ISO 17025 as described by similar work from previous studies [20,21].

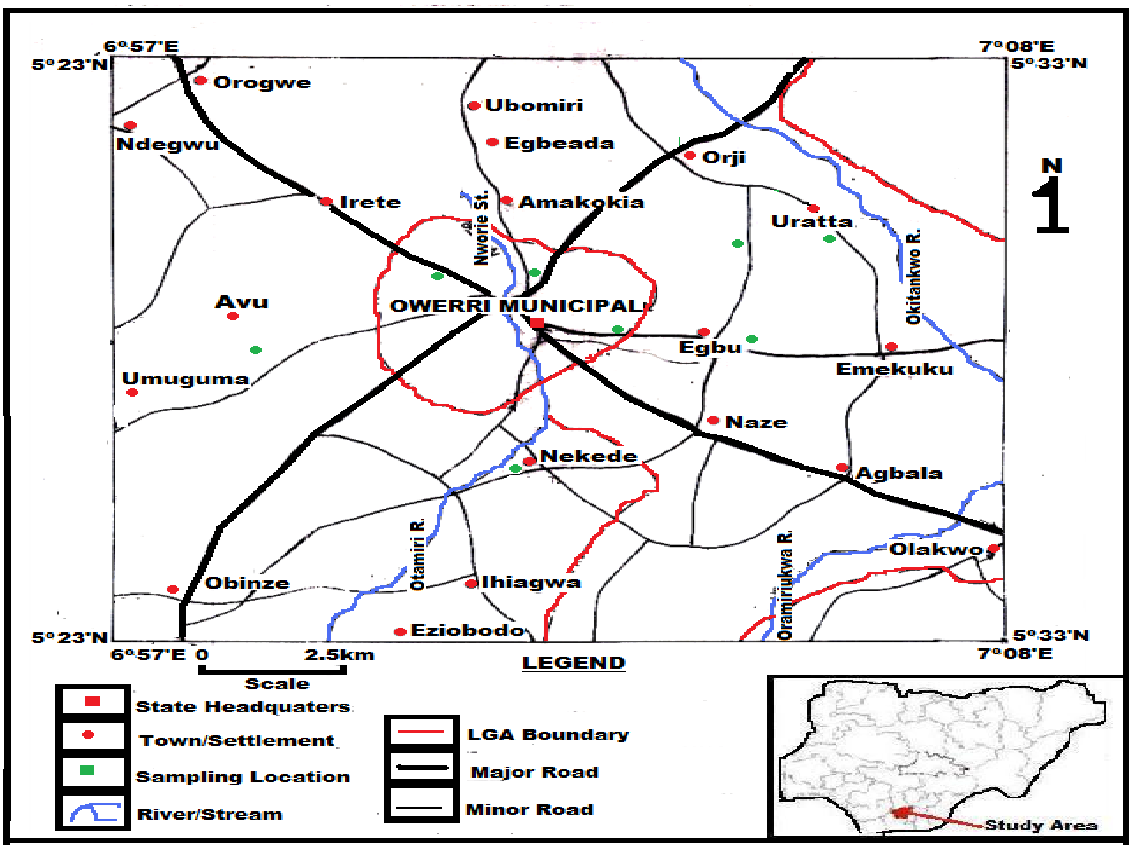

Fig 1 Sampling locations in the Owerri metropolis: Source Geology Department FUTO Owerri

Table 1: Main characteristics of the eight sampling sites within the Owerri metropolis

Sampling Site	Characteristic	Latitude	Longitude
Avu (Semi–Urban)	Semi-urban area with a concentration of rural and industrial activities	6° 58.562'	5° 26.727'
Control Post (Owerri City)	Urban location is characterized by a beehive of vehicular and commercial activities	7° 1.045'	5° 29.353'
Orlu Road Junction (Owerri City)	Central access roads are characterized by heavy vehicular and human activities	7° 1.577'	5° 29.433'
Nekede (Owerri Urban)	The highest density of industrial and commercial activities with a high flow of vehicles and people	7° 1.633'	5° 27.507'
Fire Service (Owerri City)	Urban area, crossed by four major access roads with heavy traffic from trucks, trailers, cars and buses	7° 2.395'	5° 28.800'
AGC Egbu (Semi–Urban)	Semi-urban area predominantly residential area and moderate industrial activity	7° 5.072'	5° 29.160'
IMSU Junction (Owerri City)	Intense traffic and high vehicular movement with access roads and commercial activities	7° 2.300'	5° 30.463'
Aladinma (Owerri City)	Predominantly residential and serene residential location consisting of bungalows	7° 2.733'	5° 29.858'

Summarily, sampling of PM, SO_2, NO_X and CO was done during the early hours of the day around 8:00-11:00 a.m. / 4:00-7:00 p.m. on dry weekdays which corresponds to peak vehicular movement and low photochemical reactivity. The continuous sampling period was 8/24 hours bases for a period of one month. A total of 25 samples at each zone were collected. We used a respirable dust sampler with a cyclone attachment for a period of 24 hrs which sucked a known quantity of air through the glass fibre filters. The concentration of PM is determined by measuring the weight of collected matter in a known volume of air. The device can measure six channels of the particle matter distribution ($PM_{0.3}$, $PM_{0.5}$, $PM_{1.0}$, $PM_{2.5}$, $PM_{5.0}$, PM_{10}) which comprises particles above and below 10 µ respectively.

For the determination of SO_2, a measured quantity of air is absorbed in a solution of sodium tetra chloromercurate that forms a stable dichlorosulphitomercurate complex. It is then reacted with formaldehyde and bleached pararosaniline to yield a magenta colour. The colour intensity is measured photometrically at 560 nm. During the NOx determination in ambient air by the Jacob Hochheiser method, oxides of nitrogen are collected from the bubbling air through sodium hydroxide solution and form a stable sodium nitrite. The nitrite ion produced is then analyzed photometrically by reacting with phosphoric acid, sulfanilamide and NEDA solution at 540 nm. After sampling, the equipment was returned to the laboratory and samples were analyzed within 60 min of collection time. All samples were run in triplicates and any difference greater than 20 % was unacceptable and the limit of detection for the photometer was below 0.2 mg/L [22].

On the contrary, the US.EPA has well-established procedures to be followed in quantifying the risks and hazard indices of both carcinogenic and non-carcinogenic effects owing to pollutant exposure. However, an inhalation RFC (reference concentration for inhalation exposure), IUR (Inhalation Unit risk) and IRIS (Integrated Risk Information System) are not derived for the criteria pollutants instead of regulatory standards [23,24]

The wind rose as a visual representation of local wind climatology is a useful tool in determining the quick orientation and the particular source affected concerning frequency. It provides the knowledge for understanding and evaluating the climatological behaviour of the local wind by using a system that analyzes tracks via graphics inspired by wind roses. It presents petals as elements that aggregate track which indicates wind direction alongside their average speeds within a particular area in a study map. The wind rose was applied to the interpretation of the dispersal of particulate matter [25].

Results and Discussions

The uncertainty estimate was 20 – 25 % for all samples. Descriptive data for the ambient pollution concentrations at the sampled locations are shown in table 1. The limit of detection was 0.01 ppm SO_2/25 mL, 0.05 ppm NOx/25 mL, 0.12 ppm CO /1 mL, and 0.075 ppm per sample for particulate matter [26]. The measured particle size distribution (PSD) and the density of deposited particles (on average 1.85 ± 0.15 g cm^{-3}) were used to estimate the mass fractions of particulate matter. Air monitoring data were collected in Owerri metropolis between mornings and evenings on 8-hour bases, while the meteorological parameters; relative humidity, wind speed and temperature were also measured in situ.

The meteorological parameters are displayed in the spatial representation below in Fig 2 showing the peak of wind speed to be at the IMSU junction, 82 % relative humidity at Avu and the highest recorded temperature at Aladinma, Control post and Nekede. Measured ozone levels also showed the highest concentration around the IMSU junction, Aladinma and Avu. The ambient temperature ranged from 28.30 - 32.20 ^oC with a mean temperature of 30.64 ^oC. The average wind speed during monitoring was 1.23 m/s (range 0.60-2.70) and was predominantly from south-westerly (40 %) or northeast wind (47 %); both of these wind directions often carry particulate and gaseous emissions away from the crowded areas like Orlu road junction, Fire service and IMSU Junction to less crowded areas like Aladinma and AGC Egbu. However, the mean concentration of ozone was 0.19 ppm which exceeded the ground level ozone standard for EPA is 0.070 ppm/8-hour outdoor exposure and the national ambient air quality (NAAQS) standard of 0.060 ppm, and are shown in Fig. 3 below [27]. In general, average median concentrations of PM, NO_2, SO_2, and CO were affected by relative humidity (75–90%) in the long term during the evenings than during the mornings (60–80%), especially in Avu and Nekede areas. Then again, from table 2 shown below, the hourly morning concentrations for PM were higher than evening concentrations owing to the peak of vehicular and commercial activities during rush hours. The average CO concentration levels from table 2 showed that Fire service > Imsu Junction > Orlu road Junction and each exceeded 16.5 ppm average respectively.

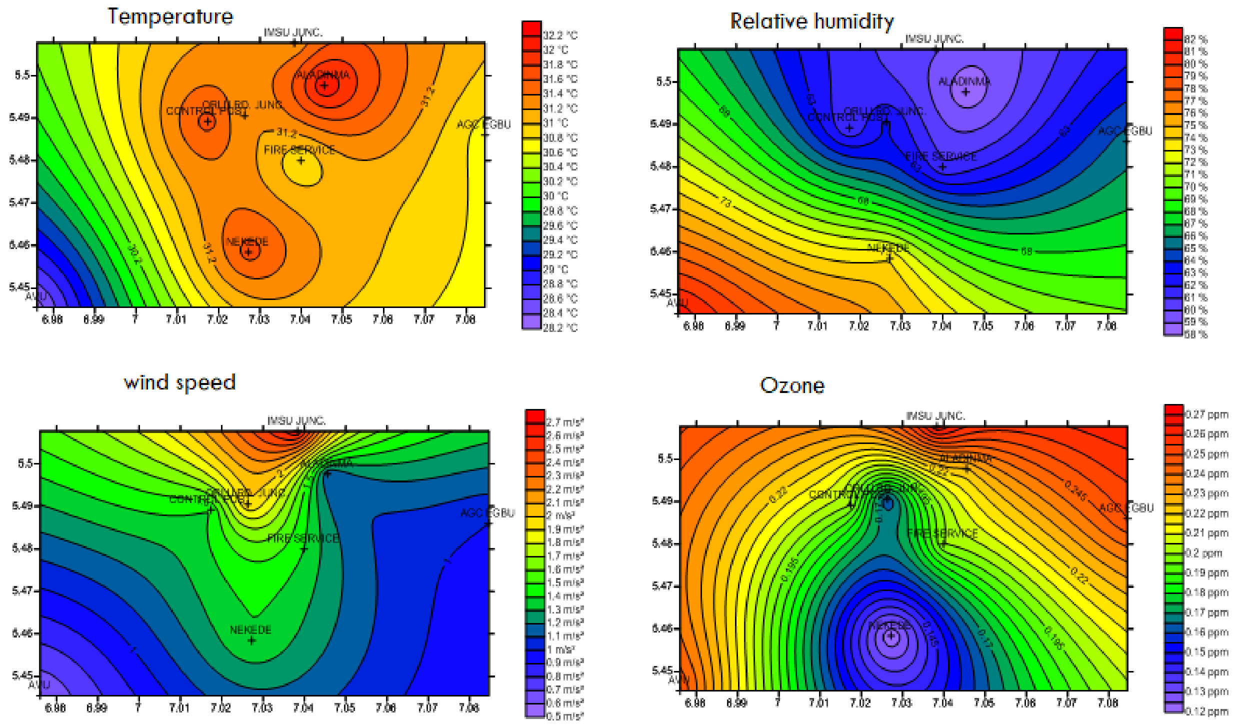

Fig 2 Spatial distribution of meteorological parameters and ozone over Owerri metropolis

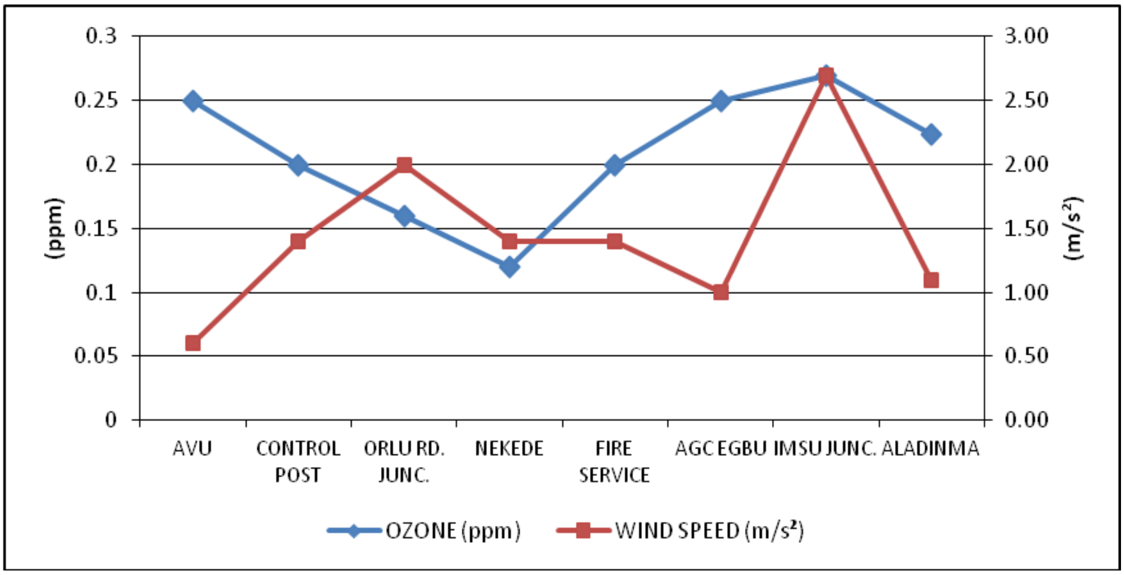

Fig 3 wind speed and ozone concentration levels at the sampled locations.

Fig. 4 is a representation of particulate matter concentrations as obtained in table 2 concerning specific sampling sites. Observation shows that Particulate matter concentrations within the sampled area had a characteristic trend $PM_{0.3} > PM_{0.5} > PM_{1.0} > PM_{2.5} > PM_{5.0} > PM_{10}$ regardless of sampling location.

Table 2: Concentration levels of gaseous ad particulate matter at Owerri metropolis.

Sampling Stations	Avu		Control Post		Orlu Rd Junction		Nekede		Fire Service		AGC Egbu		IMSU Junction.		Aladinma	
Parameters	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening
SO_2 (ppm)	0.89	0.86	3.90	4.80	5.50	5.30	1.70	1.64	7.60	5.20	0.65	0.36	4.60	4.40	1.90	1.50
NO_2 (ppm)	1.10	0.80	0.80	0.90	0.90	1.20	0.50	0.45	1.20	1.30	0.15	0.60	1.10	1.00	0.80	0.50
CO (ppm)	30.00	12.00	16.00	21.00	13.00	30.00	12.00	22.5	19.00	48.00	11.00	13.00	31.00	20.00	13.00	13.00
$PM_{0.3}$ (ppm)	78.4	9.13	215	214	245	242	134	180	173	174	94.1	11.1	134	132	68.9	12.3
$PM_{0.5}$ (ppm)	20.9	7.52	59.6	59.7	63.3	63.4	9.54	62.4	58.7	58.8	10.4	10.3	34.1	34.5	5.71	8.57
$PM_{1.0}$ (ppm)	5.35	5.36	16.5	16.5	18.1	18.1	7.63	26.8	23.7	23.7	12.6	6.28	9.47	9.30	10.1	6.30
$PM_{2.5}$ (ppm)	0.864	0.874	2.99	2.97	3.66	3.69	2.52	8.01	4.68	4.76	1.42	0.811	1.78	1.73	1.69	1.15
$PM_{5.0}$ (ppm)	0.108	0.102	0.235	0.235	0.514	0.495	0.273	1.51	1.18	1.18	0.155	0.101	0.1653	0.162	0.186	0.131
$PM_{10.0}$ (ppm)	0.091	0.028	0.0826	0.0795	0.178	0.185	0.102	0.537	0.502	0.531	0.075	0.041	0.051	0.047	0.093	0.035

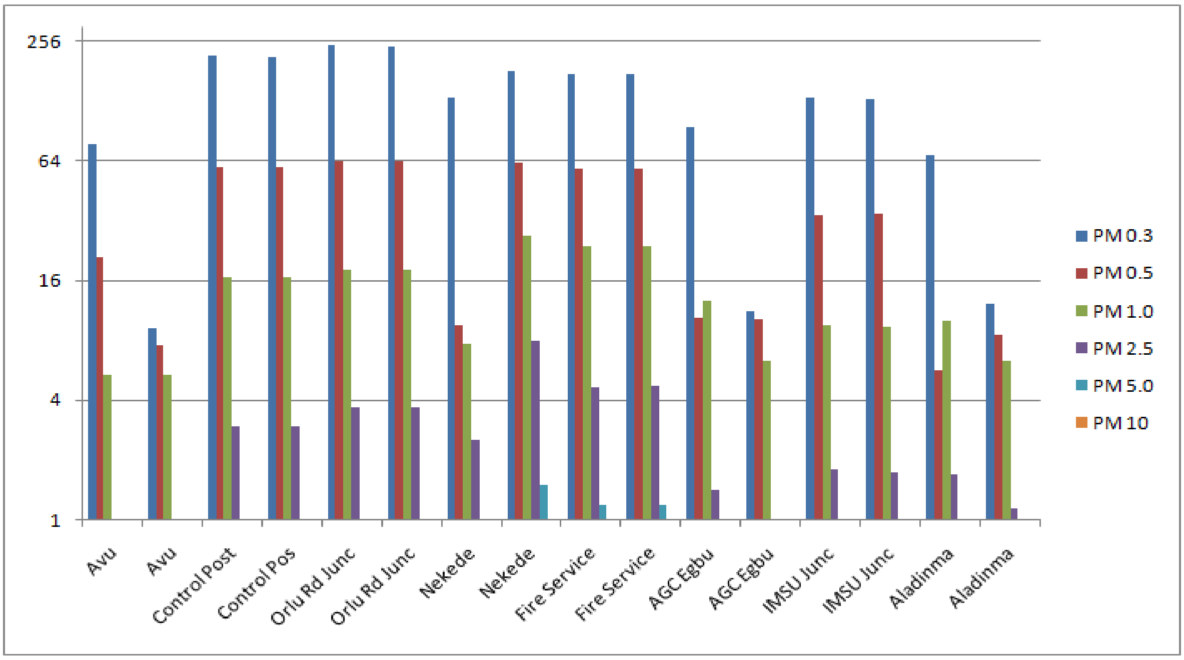

Fig 4. Concentration levels of PMs in column chat across the different sampling locations

Further observation shows that Fire service and Orlu road Junction consistently had higher concentrations of PM than other locations in both morning and evening, while Nekede was high in the evenings. PM_{10} concentration levels for all sampling locations were all below 1 ppm and similarly observed in $PM_{5.0}$ except at Nekede and fire service. On the other hand, only $PM_{0.3}$ exceeded 100 ppm concentration levels at the control post, Orlu road junction, Nekede, Fire service and IMSU junction in both mornings and evenings. This accordingly, resulted from heavy vehicular activities mainly caused by traffic congestion. Hence, there is a greater likelihood of respiratory-related challenges such as breathing difficulty, allergic rhinitis and coughing commonly experienced by the residents of these areas.

The overall median concentration of particulate matter for $PM_{2.5}$, $PM_{5.0}$ and PM_{10} was lower than the annual $PM_{2.5}$ standard at 15 µg/m^3, and the 24-hour PM_{10} standard of 150 µg/m^3, which is lower than the EPA standard as well as the NAAQS standard. However, the high concentration levels of $PM_{0.3}$, $PM_{0.5}$, and $PM_{1.0}$ (ultrafine and fine particulates) when compared to the previous findings showed that it could be attributed to three major factors. The improper disposal of waste from residential houses, the regular occurrence of open burning that contributes to high concentration levels, and the direct emissions from diesel soot; formed by photochemical reactions from gaseous precursors. Unfortunately, they have a large surface area per unit mass and are superb carriers for adsorbed organic and inorganic compounds, some of which could be potentially carcinogenic. In a recent study, it was noted that they can induce asthma and cough, pulmonary inflammation and also linked to diabetes. On the other hand, the study of fine and ultrafine particulate matter is generally hindered by the absence of global standards; however, more accurate studies of this nature and their precise roles will go a long way in defining their standards in the nearest future [28]

The spatial distribution of PM is shown in Fig. 5 and reveals that the eye of PM is at the control post area and fire service sampling points. The lowest is at AGC Egbu and Nekede area. The size, number and composition of the particulate matter play an important role in inducing health effects. Underlying health challenges due to exposure may include cardiovascular diseases, respiratory, irritating asthma, irritation of airways, coughing, breathing difficulty, and allergic rhinitis [29,30].

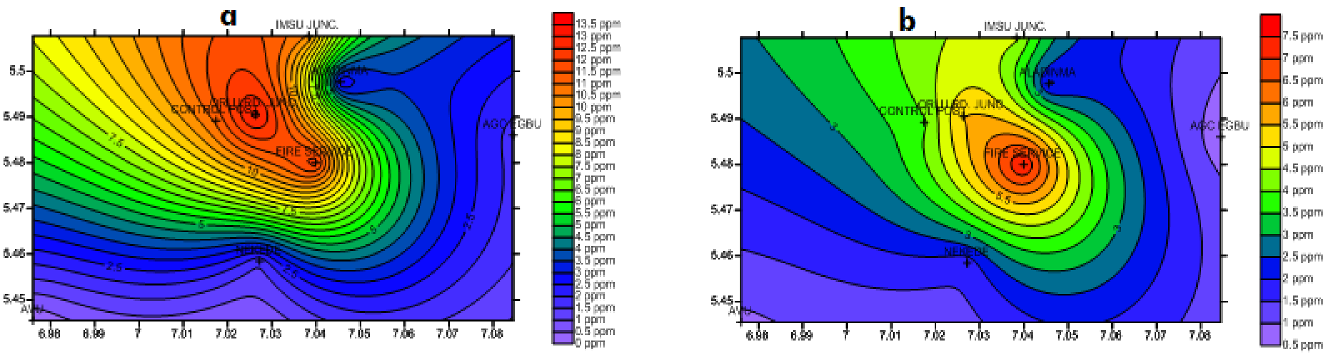

Fig.5 Spatial distribution of (a) Particulate matter and (b) SO_2 gas across the Owerri metropolis

The EPA standard for SO_2 is 0.5 ppm while the NAAQS standard is 0.1 ppm. This raise concerns over the volume of SO_2 gas introduced daily and monthly into the atmosphere in the Owerri metropolis given that the minimum recorded concentration was 0.65 ppm at AGC Egbu (evening) and the highest recorded concentration was 7.6 ppm at Fire service. This is shown in Fig. 5 above followed by the Orlu Road junction having an SO_2 concentration of 5.5 ppm. This source is typically man-made arising from fossil fuel combustion and enhanced by wind speed at 1.4 m/s at the Control post, Fire service and Imsu Junction sampled locations. In combination with other pollutants and moisture, SO_2 can cause visible corrosion on most metals, damage buildings, act as a respiratory irritant (high solubility) and can cause chest tightness, reflex cough and irritation. However, at less than 25 ppm the major effects are irritation to the eyes, lungs, throat, and mucous membrane [31,32].

NO_2 is of greater concern among all other constituents of NOx. The determined average mean is 0.84 ppm and only had AGC Egbu (0.15 ppm) and during mornings to be lower than near EPA standard (0.1 ppm) and NAAQS standard (0.06 ppm). This is also revealed in the spatial distribution shown in Fig 6. The standard deviation was 0.36 and the median is 0.9 which showed high pollution levels of NOx in the Owerri metropolis, especially in the fire service area. The Fire service area showed the highest concentration of NOx because it is a major road intersection with heavy traffic from trucks, trailers, cars and buses. The major sources of this pollutant level are vehicular activity and cause unanticipated consequences such as pulmonary irritation, disruption of the nervous system, suppression of the immune system through systemic inflammation of oxidative stress pathways, and reaction with other atmospheric pollutants to form acidic rain, and visibility impairment [32].

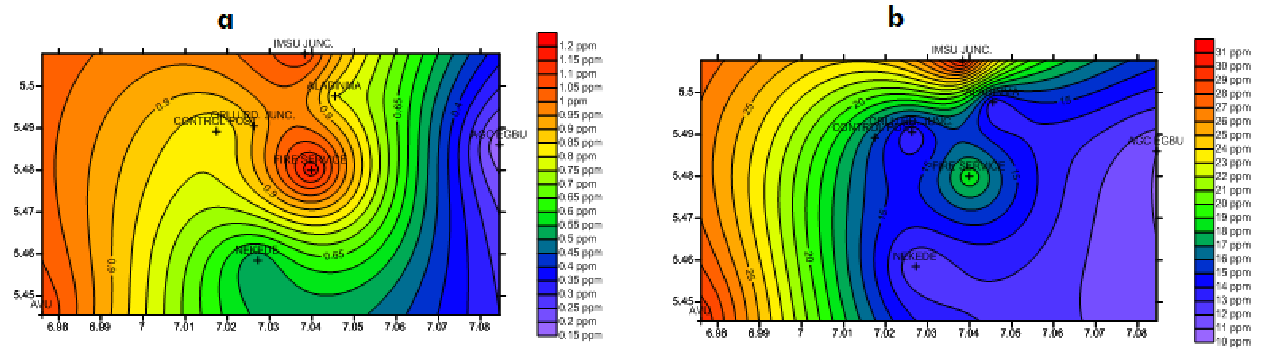

Fig 6 Spatial distribution of (a) NO_2 and (b) CO across the Owerri metropolis.

The median value of CO is 19 ppm and has a mean deviation of 11.16. This shows that the concentration levels of CO varied greatly across the sampled areas. Maximum concentrations were 30 ppm at Orlu road junction and Avu in the evening and mornings respectively which can be seen in Fig 5 above. This arises from heavy trucks that transport goods in the city of Owerri and converge at Avu during the mornings before heading down to the city in the evenings (Orlu road junction). Additionally, the EPA standard is 9 ppm/8-hour and NAAQS is 10 ppm. This shows that Owerri metropolis is a carbon monoxide-polluted city.

The sources of CO include vehicle exhaust, open burning and generators whose accumulated concentration levels exceeded 10 ppm NAAQS at all sampling points; hence an environmental concern. Accordingly, excessive inhalation can induce asphyxiation, dizziness or even death [9,33]. In Japan it was been reported to be responsible for over 4000 deaths; hence it is described as a silent killer [34]. Moreover, people with businesses in these areas may be prone to reoccurring headaches, convulsions, commas, confusion circulatory arrest and respiratory failure due to CO intoxication and respiratory inflammation. The air quality index was estimated using the well-known air quality index formula and briefly discussed below [35,36]

$$IAQI = \frac{IAQI_{HI}-IAQI_{LO}}{BP_{HI}-BP_{LO}}\left(C_p - BP_{LO}\right) + IAQI_{LO} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where IAQIp Is known as the individual air quality index pollutant P which is PM, SO_2, NO_2 and CO. The Cp is taken to be the daily mean concentration of the pollutant (P), where BP_{low} and BP_{high} are the nearest and lowest values of CP. Also, the $IAQI_{LO}$ and $IAQI_{HI}$ are the individual air quality indexes concerning BPHI and BPLO as shown in table 3. From table 04, the IAQI maximum is 400. Moreover, after the computation of individual air quality index (IAQIp) for every pollutant, the AQI is then determined by selecting the maximum IAQIp as shown below

$$AQI = \max(IAQI1, \ldots\ldots\ldots . IAQIn) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Besides, equation (2) above demonstrates that AQI estimation would not be the sum of all the pollutants that are involved but just the obtained maximum value of IAQI. Also, the air pollutant that has a maximum IAQI when AQI has a value greater than 50 is termed the primary pollutant [37,38]. A simple sketch is presented below in table 4 which highlights pollutants and areas of primary concern. From the eight studied locations in the Owerri metropolis, each sampling site experienced continuous pollution from a particular pollutant. It is important to note that all the pollutants shown in table 4 are classed as primary pollutants having exceeded the AQI value of 50 or less than 100 based on NAAQS 2012 recommendation. The SO_2 pollutant is the principal pollutant at the AVU location and poses the greatest risk to the general public with a greater tendency to cause health challenges. This is because the calculated AQI value is above 200 and is considered very unhealthy for all groups. Similarly, a high level of CO was estimated in the Fire service area which also exceeded the 200 AQI value and also detrimental to the general public. There were unhealthy levels of NO_2 at the control post, IMSU junction and AGC Egbu owing to their AQI values that ranged from 160 to 173.

Table 3 Air quality index for studied pollutants

Descriptor	AQI	Risk Message
Good	0 - 50	No message
Moderate	51 - 100	Unusually sensitive individuals (ozone)
Unhealthy for Sensitive Groups	101 - 150	Identifiable groups at risk – different groups for different pollutants
Unhealthy	151 - 200	General public at risk; groups at greater risk
Very Unhealthy	201 - 300	General public at greater risk; groups at greatest risk

Table 4 AQI levels of criteria pollutants in Owerri metropolis

Sampling Stations		Average AQI	Conditional pollutant
Avu	Morning	260	SO_2
	Evening	213	SO_2
Control Post	Morning	164	NO_2
	Evening	172	NO_2
Orlu Rd. Junction	Morning	137	NO_2
	Evening	194	NO_2
Nekede	Morning	109	O_3
	Evening	141	CO
Fire Service	Morning	192	NO_2
	Evening	226	CO
AGC Egbu	Morning	173	SO_2
	Evening	163	O_3
IMSU Junction	Morning	185	NO_2
	Evening	160	NO_2
Aladinma	Morning	162	NO_2
	Evening	143	NO_2

Although Aladinma and Orlu road Junction had moderate concentration levels of NO_2, however, Nekede similarly had moderate levels of ozone and CO. From table 4, their determined AQI values exceeded 100 and thus are all primary persistent pollutants. Interestingly, the particulate matter estimated values were all within the 0 to 50 AQI value and classed as a non-primary pollutant of Owerri Metropolis. The windrose diagram in Fig. 7 suggests the dispersal and migration of particulate matter as affected by wind speed and wind directions. It can be inferred from Fig.7 that there was a continuous variation in wind direction and wind speed over the studied area. In the IMSU Junction sampling area, the wind direction was northerly east wind driving the particulate matters and changes direction by afternoon to the south and northwesterly winds.

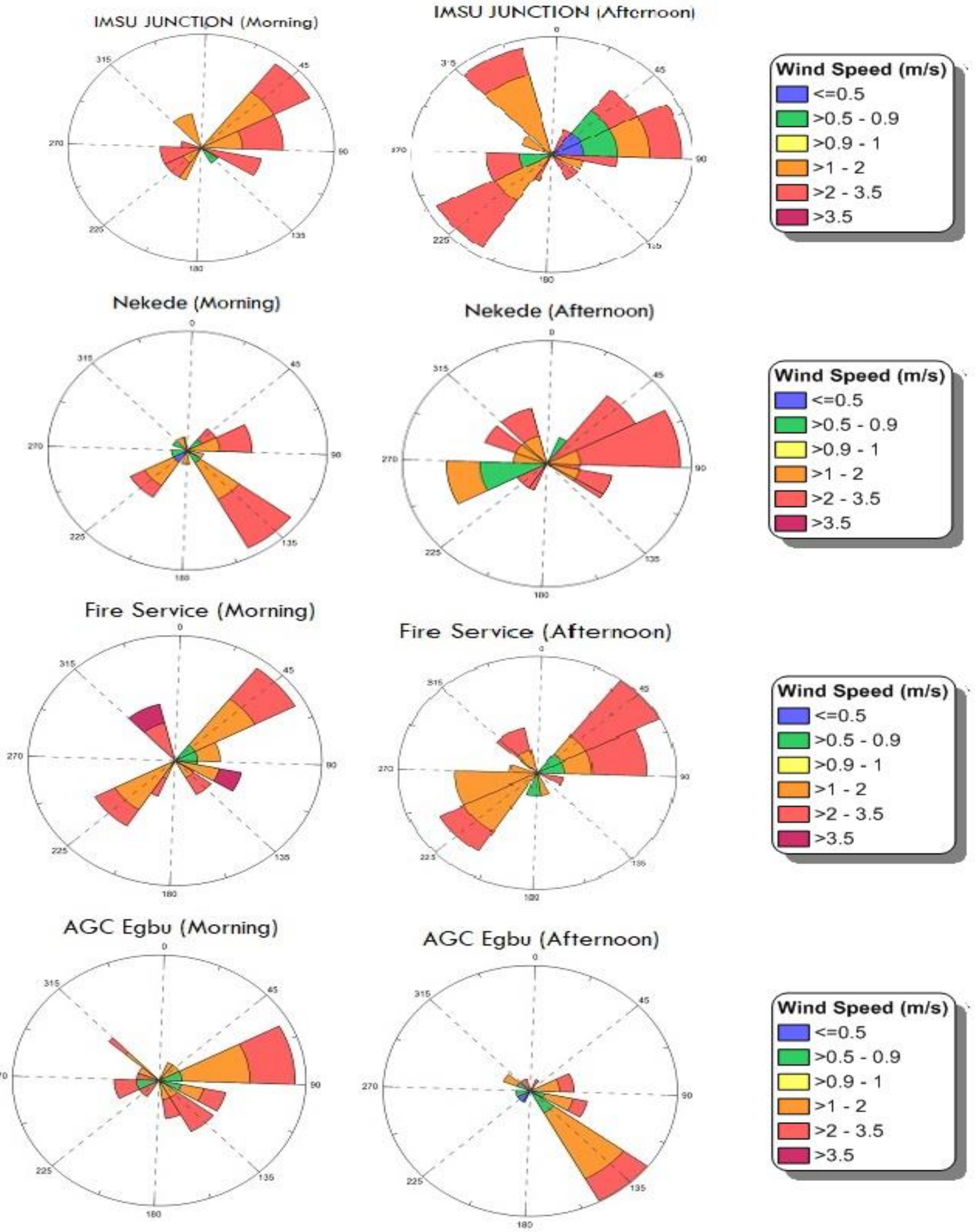

Fig 7 Wind rose diagram of Particulate matter for some selected areas in Owerri metropolis

The converse was recorded for the Aladinma sampling area. In Nekede, the south-easterly wind was responsible for particulate movement but became more active during the afternoon with Northeast winds, and remarkably, very similar to the control post area. Interestingly, northeasterly winds were strongly reported at the fire service for both morning and afternoon readings, while in AGC Egbu East winds changed direction from the north in the morning to south in the evening period as similarly obtained in the Avu axis. In summary, the IMSU junction showed the highest wind speed while AGC Egbu was the least recorded wind speed. In all, higher concentrations persisted more in the evenings than mornings due to enormous traffic congestion and heavy vehicular movements in the evenings [39,40].

Conclusion

There are few surprising published reports of ambient levels of particulate matter (0.3, 0.5, 1.0, 2.5, 5.0, 10) and gaseous pollutants in the Owerri metropolis, Nigeria and to our knowledge, this is one of the few improved studies to evaluate the ambient air quality in Owerri metropolis, Nigeria. In general, daily mean concentrations of criteria air pollutants were not dramatically impacted by meteorological parameters but potentially toxic levels including CO, NOx and SO_2 were elevated as a result of point source pollution from anthropogenic sources. Moreover, levels of CO, NO_2 and SO_2 exceeded the AQI standard NAAQS available guidelines based on established descriptors suggesting potential health challenges for the exposed populace. Unfortunately, public health messages are neither available nor relayed to citizens especially the vulnerable and nursing mothers. Furthermore, our findings have provided important information regarding the extent of pollution in the metropolis by the criteria pollutants. It is also important to note that continuous monitoring data was not gathered for the pollutants and hence, concentrations reported may under-represent the actual values in certain locations and when the peak concentrations occurred at days/times not monitored. In summary, our findings highlight the fact that the criteria pollutants including SO_2, NOx and CO remain within unacceptable levels. This is not particularly true for particulate matter having $PM_{0.3} > PM_{0.5} > PM_{1.0} > PM_{2.5} > PM_{5.0} > PM_{10}$ regardless of sampling location as meteorological parameters could have played an influential role over PM concentrations. Hence, this research has provided significant data for policy and decision-makers on criteria and particulate matter pollutants arising from vehicular emissions in the Owerri metropolis.

Acknowledgement: We would like to thank Prof. Alex Opara for his guidance and supervision during the sampling and monitoring episode. This study did not receive any direct funding from any organization.

Research Highlights

- High levels of the pollutants were significantly contributed by vehicular activities
- The particulate matter had low concentration levels and was not the primary pollutant in sampled locations.
- SO_2, CO_2 and NOx exceeded the AQI value of 50-100 and were found to be primary pollutants
- PM, NO_2, SO_2 and CO concentrations were affected by relative humidity (75–90%) in the long term during the evenings than during the mornings

References

[1] J.I. Nwachukwu, L.J. Clarke, E. Symeonakis, F.Q. Brearley, Assessment of human exposure to food crops contaminated with lead and cadmium in Owerri, South-eastern Nigeria, *J. Trace Elem. Miner.* 2 (2022) 100037. https://doi.org/10.1016/j.jtemin.2022.100037.

[2] K.E. Agbo, C. Walgraeve, J.I. Eze, P.E. Ugwoke, P.O. Ukoha, H. Van Langenhove, A review on ambient and indoor air pollution status in Africa, *Atmos. Pollut. Res.* 12 (2021) 243–260. https://doi.org/https://doi.org/10.1016/j.apr.2020.11.006.

[3] D. Aja, C.C. Okolo, N.J. Nwite, C. Njoku, Environmental risk assessment in selected dumpsites in Abakaliki metropolis, Ebonyi state, southeastern Nigeria, *Environ. Challenges.* 4 (2021) 100143. https://doi.org/10.1016/j.envc.2021.100143.

[4] F.C. Ibe, A.I. Opara, C.E. Duru, I.B. Obinna, M.C. Enedoh, Statistical analysis of atmospheric pollutant concentrations in parts of Imo State, Southeastern Nigeria, *Sci. African.* 7 (2020) e00237. https://doi.org/10.1016/j.sciaf.2019.e00237.

[5] A.F. Eghomwanre, O. Oguntoke, A.M. Taiwo, E.. Ukpebor, Air pollutant concentrations and health risk assessment around residential areas in Benin city, Nigeria, *J. Mater. Environ. Sci.* 13 (2022) 1081–1100.
[6] S. Ara Aksoy, A. Kiziltan, M. Kiziltan, M. Aydınalp Köksal, F. Öztürk, Ş.E. Tekeli, S.Y. Aslanoğlu, U. Im, N. Duran, A. Ünal, M. Baykara, N. Özyürek, P. Doğan, A.G. Yılmaz, C.E. Köksal, İ. Çetintürk Gürtepe, A.B. Yereli, M.E. Birpınar, G. Güllü, Mortality and morbidity costs of road traffic-based air pollution in Turkey, *J. Transp. Heal.* 22 (2021) 101142. https://doi.org/10.1016/j.jth.2021.101142.
[7] N. Rezaei Rahimi, R. Fouladi-Fard, M. Rezvani Ghalhari, H. Mojarrad, A. Yari, M.M. Farajollahi, A. Hamta, M. Fiore, The links between microclimatic and particulate matter concentration in a multi-storey car parking: a case study iran, *J. Environ. Heal. Sci. Eng.* 20 (2022) 775–783. https://doi.org/10.1007/s40201-022-00818-x.
[8] R.N. Liñán-Abanto, D. Salcedo, P. Arnott, G. Paredes-Miranda, M. Grutter, O. Peralta, G. Carabali, N. Serrano-Silva, L.G. Ruiz-Suárez, T. Castro, Temporal variations of black carbon, carbon monoxide, and carbon dioxide in Mexico City: Mutual correlations and evaluation of emissions inventories, *Urban Clim.* 37 (2021) 100855. https://doi.org/10.1016/j.uclim.2021.100855.
[9] I. Manisalidis, E. Stavropoulou, A. Stavropoulos, E. Bezirtzoglou, Environmental and Health Impacts of Air Pollution: A Review, *Front. Public Heal.* 8 (2020) 14. https://www.frontiersin.org/article/10.3389/fpubh.2020.00014.
[10] C.C. Lee, M.-V. Tran, C.W. Choo, C.P. Tan, Y.S. Chiew, Evaluation of air quality in Sunway City, Selangor, Malaysia from a mobile monitoring campaign using air pollution micro-sensors, *Environ. Pollut.* 265 (2020) 115058. https://doi.org/10.1016/j.envpol.2020.115058.
[11] A. Ganji, O. Youssefi, J. Xu, K. Mallinen, M. Lloyd, A. Wang, A. Bakhtari, S. Weichenthal, M. Hatzopoulou, Design, calibration, and testing of a mobile sensor system for air pollution and built environment data collection: The urban scanner platform, *Environ. Pollut.* (2022) 120720. https://doi.org/10.1016/j.envpol.2022.120720.
[12] A. Samad, U. Vogt, Mobile air quality measurements using bicycle to obtain spatial distribution and high temporal resolution in and around the city center of Stuttgart, *Atmos. Environ.* 244 (2021) 117915. https://doi.org/10.1016/j.atmosenv.2020.117915.
[13] T.-T. Huyen, K. Sekiguchi, B.-T. Ly, T.-D. Nghiem, Assessment of traffic-related chemical components in ultrafine and fine particles in urban areas in Vietnam, *Sci. Total Environ.* 858 (2023) 159869. https://doi.org/10.1016/j.scitotenv.2022.159869.
[14] A. Chawla, M. Khare, S. Khan, Evaluating the Effect of Speed Variation on Vehicular Emission Using an Integrated Modelling Approach BT - *3rd International Conference on Innovative Technologies for Clean and Sustainable Development, in: D.K. Ashish, J. de Brito, S.K. Sharma (Eds.), Springer International Publishing, Cham*, 2021: pp. 299–315.
[15] Y.A. Cipoli, A.C. Targino, P. Krecl, L.C. Furst, C. dos A. Alves, M. Feliciano, Ambient concentrations and dosimetry of inhaled size-segregated particulate matter during periods of low urban mobility in Bragança, Portugal, *Atmos. Pollut. Res.* 13 (2022) 101512. https://doi.org/10.1016/j.apr.2022.101512.
[16] U.P. Onydinma, L. Aljerf, A. Obike, O.E. Onah, N.J. Caleb, Evaluation of physicochemical characteristics and health risk of polycyclic aromatic hydrocarbons in borehole waters around automobile workshops in Southeastern Nigeria, *Groundw. Sustain. Dev.* 14 (2021) 100615. https://doi.org/10.1016/j.gsd.2021.100615.
[17] A.I. Opara, C.Z. Akaolisa, C.O. Akakuru, A.U. Nkwoada, F.C. Ibe, A.W. Verla, I.C. Chukwuemeka, Particulate matter exposure and non-cancerous inhalation health risk assessment of major dumpsites of Oerri metropolis, Nigeria., *Environ. Anal. Heal. Toxicol.* 36 (2021) e2021025-0. https://doi.org/10.5620/eaht.2021025.
[18] E.M. Okon, B.M. Falana, S.O. Solaja, S.O. Yakubu, O.O. Alabi, B.T. Okikiola, T.E. Awe, B.T. Adesina, B.E. Tokula, A.K. Kipchumba, A.B. Edeme, Systematic review of climate change impact research in Nigeria: implication for sustainable development, *Heliyon.* 7 (2021) e07941.

https://doi.org/10.1016/j.heliyon.2021.e07941.
[19] H.A. Ahmed, S.K. Singh, M. Kumar, M.S. Maina, R. Dzwairo, D. Lal, Impact of urbanization and land cover change on urban climate: Case study of Nigeria, *Urban Clim.* 32 (2020) 100600. https://doi.org/10.1016/j.uclim.2020.100600.
[20] T. Liu, Y. Zhou, J. Wei, Q. Chen, R. Xu, J. Pan, W. Lu, Y. Wang, Z. Fan, Y. Li, L. Xu, X. Cui, C. Shi, L. Zhang, X. Chen, W. Bao, H. Sun, Y. Liu, Association between short-term exposure to ambient air pollution and dementia mortality in Chinese adults, *Sci. Total Environ.* 849 (2022) 157860. https://doi.org/10.1016/j.scitotenv.2022.157860.
[21] V.M. Duong, A. Le Hoang, Characterization of indoor and ambient air quality in modern commercial and recreational complex buildings in Hanoi, *Atmos. Environ.* 291 (2022) 119405. https://doi.org/10.1016/j.atmosenv.2022.119405.
[22] C.M. da Silva, S.M. Corrêa, G. Arbilla, Preliminary Study of Ambiente Levels and Exposure to BTEX in the Rio de Janeiro Olympic Metropolitan Region, Brazil, *Bull. Environ. Contam. Toxicol.* 104 (2020) 786–791. https://doi.org/10.1007/s00128-020-02855-4.
[23] C.-T. Hsu, S.-C. Hsu, S.-K. Huang, C.-L. Lee, Y.-S. Shieh, Air quality in a hospital dental department, *J. Dent. Sci.* 17 (2022) 1350–1355. https://doi.org/https://doi.org/10.1016/j.jds.2022.03.011.
[24] P.K. Nagar, P. Gargava, V.K. Shukla, M. Sharma, A.K. Pathak, D. Singh, Multi-pollutant air quality analyses and apportionment of sources in three particle size categories at Taj Mahal, Agra, *Atmos. Pollut. Res.* 12 (2021) 210–218. https://doi.org/10.1016/j.apr.2020.09.001.
[25] H. Hu, Q. Chen, Q. Qian, X. Zhou, Y. Chen, Y. Cai, Field investigation for ambient wind speed and direction effects exposure of cyclists to PM2.5 and PM10 in urban street environments, *Build. Environ.* 223 (2022) 109483. https://doi.org/10.1016/j.buildenv.2022.109483.
[26] I. Troyanovskaya, O. Grebenshchikova, V. Erofeev, Pollution of the Atmosphere of Chelyabinsk by Transport Emissions of Non-Exhaust Origin, *Transp. Res. Procedia.* 63 (2022) 277–284. https://doi.org/10.1016/j.trpro.2022.06.014.
[27] M.-H. Huang, Y. Huang, J.-J. Cao, W.-Q. Tao, Study on mitigation of automobile exhaust pollution in an urban street canyon: Emission reduction and air cleaning street lamps, *Build. Environ.* 193 (2021) 107651. https://doi.org/10.1016/j.buildenv.2021.107651.
[28] S. Ohlwein, R. Kappeler, M. Kutlar Joss, N. Künzli, B. Hoffmann, Health effects of ultrafine particles: a systematic literature review update of epidemiological evidence., *Int. J. Public Health.* 64 (2019) 547–559. https://doi.org/10.1007/s00038-019-01202-7.
[29] R.D. Arias-Pérez, N.A. Taborda, D.M. Gómez, J.F. Narvaez, J. Porras, J.C. Hernandez, Inflammatory effects of particulate matter air pollution., *Environ. Sci. Pollut. Res. Int.* 27 (2020) 42390–42404. https://doi.org/10.1007/s11356-020-10574-w.
[30] S. Kumar, S.K. Dwivedi, Chemical and biological components of atmospheric particulate matter and their impacts on human health and crops: a review, *Aerobiologia (Bologna).* 38 (2022) 287–327. https://doi.org/10.1007/s10453-022-09749-4.
[31] M. Urrutia-Pereira, G. Guidos-Fogelbach, D. Solé, Climate changes, air pollution and allergic diseases in childhood and adolescence, *J. Pediatr. (Rio. J).* 98 (2022) S47–S54. https://doi.org/10.1016/j.jped.2021.10.005.
[32] M. Kowalska, M. Skrzypek, M. Kowalski, J. Cyrys, Effect of NOx and NO2 Concentration Increase in Ambient Air to Daily Bronchitis and Asthma Exacerbation, Silesian Voivodeship in Poland, *Int. J. Environ. Res. Public Heal.* 17 (2020). https://doi.org/10.3390/ijerph17030754.
[33] J.A. Chenoweth, T.E. Albertson, M.R. Greer, Carbon Monoxide Poisoning, *Crit. Care Clin.* 37 (2021) 657–672. https://doi.org/10.1016/j.ccc.2021.03.010.
[34] H. Kinoshita, H. Türkan, S. Vucinic, S. Naqvi, R. Bedair, R. Rezaee, A. Tsatsakis, Carbon monoxide poisoning, *Toxicol. Reports.* 7 (2020) 169–173. https://doi.org/10.1016/j.toxrep.2020.01.005.
[35] S.V. Razavi-Termeh, A. Sadeghi-Niaraki, S.-M. Choi, Effects of air pollution in Spatio-temporal

modeling of asthma-prone areas using a machine learning model, *Environ. Res.* 200 (2021) 111344. https://doi.org/10.1016/j.envres.2021.111344.
[36] D.P. Shah, D.P. Patel, A comparison between national air quality index, india and composite air quality index for Ahmedabad, India, *Environ. Challenges.* 5 (2021) 100356. https://doi.org/10.1016/j.envc.2021.100356.
[37] L.C. Anyika, C.O. Alisa, A.U. Nkwoada, A.I. Opara, E.N. Ejike, G.N. Onuoha, Spatio-Temporal Study of Criteria Pollutants in Nigerian City TI2 - *Asian Journal of Applied Chemistry Research* , (2020). https://doi.org/10.9734/ajacr/2020/v6i330160.
[38] Suman, Air quality indices: A review of methods to interpret air quality status, *Mater. Today Proc.* 34 (2021) 863–868. https://doi.org/https://doi.org/10.1016/j.matpr.2020.07.141.
[39] Y. Song, X. Yang, Z. Zhang, K. Bao, T. Du, H. Guo, A study on the pollutant control effect of a new push-pull exhaust hood under different pollutant velocities, *J. Build. Eng.* 53 (2022) 104570. https://doi.org/10.1016/j.jobe.2022.104570.
[40] R. Rocha, A.A. Sant'Anna, Winds of fire and smoke: Air pollution and health in the Brazilian Amazon, *World Dev.* 151 (2022) 105722. https://doi.org/10.1016/j.worlddev.2021.105722.

(2022); http://www.jmaterenvironsci.com