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ASSESSMENT OF AIR QUALITY IN AN INDUSTRIAL FACILITY IN RUMUEME, PORT HARCOURT, NIGERIA

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Abstract. Air quality in Port Harcourt, Nigeria is being assessed due to black soot, raising concerns among residents. The survey aims to assess airborne particulates in an industrial area in Rumueme, Port Harcourt, measuring pollutants with air sampling devices at different locations. GPS locates sampling spots, measurements taken at 1.6 m, and noise levels measured. Particulate matter analyzed using GC-FID method. The residential area was found to Unhealthy levels of PM2.5 are present above USEPA and WHO limits, at 38.70 $\mu g/m^{-3}$. Sensitive individuals are advised to minimize outdoor activities, restrict traffic, and wear masks. Nighttime noise levels exceed the recommended limit at 50.1 dB(A) and noise mapping can identify sources. In the office area, PM2.5 levels for sensitive individuals are above the WHO limit at 28.30 $\mu g/m^{-3}$, while PM10 levels are within limits at 60.57 $\mu g/m^{-3}$. The noise level is below 90 dB(A) and harmful gases are undetectable, with trace metals meeting USEPA and OSHA limits. The helipad area has moderate PM2.5 air pollution exceeding the WHO limit at 25 $\mu g/m^{-3}$, and PM10 at 65.30 $\mu g/m^{-3}$. The average noise level is 58.87 dB(A), which is below the limit of 90 dB(A). In the jetty area, PM2.5 levels are higher than WHO guidelines at 30.50 $\mu g/m^{-3}$, while PM10 levels are at 62.87 $\mu g/m^{-3}$ causing moderate health concerns. The warehouse has high AQI for PM2.5, suggesting a need to reduce traffic. Noise level averages 66.83 dB(A), recommended.

Keywords: quality of air, PM10, PM2.5, noise level, Port Harcourt.

1. Introduction

Crude oil exploration and refining are major industrial activities in Rivers State, Nigeria, which have led to an increase in airborne particulates, specifically soot, in the air around Port Harcourt city metropolis. These particulates contain toxic components, such as aromatic hydrocarbons condensates, that can have quantifiable health impacts. The scope of toxicity from soot may be greater than other air pollutants due to its mixed toxic components. The soot phenomenon in Rivers State appears to have a regional spread across the city of Port Harcourt, raising concerns about the overall air quality in the area.

Studies have shown that urban residents primarily spend their time indoors, with a significant portion of their day spent in residential buildings. Research by Kornartit et al. (Kornartit et al., 2010) and De Kluizenaar et al. (De Kluizenaar et al., 2017) revealed that over half of the day is spent at home. Survey on Patterns of human activity in the United States indicated that, on average, individuals spend approximately 16.6 hours per day in residential buildings (Klepeis et al., 2001). In New Jersey, observations by Baxter et al. (Baxter et al., 2013) showed a slightly higher range of 16.98 to 18.05 hours spent at home daily. Similarly, the Canadian Survey found that adult Canadians spend around 15.83 to 16.0 hours per day in their residences (Leech et al., 2002; Matz et al., 2015). For children in

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Windsor, Ontario, Van Ryswyk et al. (Van Ryswyk et al., 2014) documented a daily duration of 16.1 to 17.35 hours spent at home. Additionally, reports from seven European cities, as cited by Schweizer et al. (Schweizer et al., 2007), indicated an average of 13.95 hours per day spent in residential settings.

Based on research conducted in Germany, Belgium, and Denmark, individuals spend approximately 15.7 hours (Brasche and Bischof, 2005), 15.84 hours (Dons et al., 2011), and 17.3 hours (Bekö et al., 2015) per day at their residences. These findings highlight the significant amount of time spent in domestic settings. Residential environments are greatly influenced by pollution in the, particulate matter being a prominent factor. Extensive research has been dedicated to studying the impact of PM on health, with a focus on PM2.5. This Particulate matter measuring less than 2.5 μm in aerodynamic diameter, poses serious health risks as it can be easily absorbed by the lungs and distributed throughout the body, leading to severe morbidity and mortality (Zhu et al., 2018).

Multiple studies have shown a correlation between PM2.5 levels and health issues, such as respiratory and cardiovascular diseases (Sun et al., 2019). In a study conducted in urban outdoor environments, Cakmak et al. (Cakmak et al., 2018) investigated the relationship in ambient PM2.5 exposure linked to disease-related deaths in Canada. They found that a 10 $\mu g\ m^{-3}$ increase in long-term PM2.5 exposure led to a hazard ratio of 1.26 for lung cancer mortality. You et al. (You et al., 2017) studied PM exposure and element deposition in the human respiratory system near a highway in Singapore, while Perrone et al. (Perrone et al., 2013) analyzed the chemical composition of PM in Italian urban areas. Additionally, Zwozdziak et al. (Zwozdziak et al., 2017) estimated the inhaled dose of ambient PM in a southern urban area of Poland. In their 2008 study, Martuzevicius and colleagues estimated the levels of PM2.5 caused by traffic near major highways in Cincinnati, USA. Chen et al (Chen et al., 2017) conducted research in Guangzhou, China, to identify the chemical components of regional PM2.5 and their sources. Bai et al. (Bai et al., 2020) investigated the health risks of PAHs in PM2.5 in office indoor environments. Additionally, Chen et al. (Chen et al., 2018) studied the connection between PM2.5 and asthmatic or allergic conditions in Chinese preschoolers. In South Asia, Junaid et al. (Junaid et al., 2018) found that exposure to indoor PM emissions from human activities poses significant health risks. Lastly, Zhao et al. (Zhao et al., 2019) assessed the health risks associated with PAHs from cooking emissions in residential settings.

Martuzevicius et al. (Martuzevicius et al., 2008) estimated PM2.5 levels caused by traffic closer to highways in Cincinnati, USA. Chen et al. (Chen et al., 2017) conducted research in Guangzhou, China, to identify the chemical components of regional PM2.5 and their sources. Bai et al. (Bai et al.,(2020) investigated the health risks of PAHs in PM2.5 in office indoor environments. Additionally, Chen et al. (Chen et al., 2018) studied the connection between PM2.5 and asthmatic or allergic conditions in Chinese preschoolers. In South Asia, Junaid et al. (Junaid et al., 2018) found that exposure to indoor PM emissions from human activities poses significant health risks. Lastly, Zhao et al. (Zhao et al., 2019) assessed the health associated risks with PAHs from cooking emissions in residential settings.

Morawska et al. (Morawska et al., 2017) examined how outdoor airborne particles infiltrate indoor spaces like residences, schools, offices, and care facilities. While other researchers have reviewed air pollutants in office settings, they have not offered a comprehensive analysis of PM2.5 levels or the key factors affecting air quality in urban homes. Given that people spend a significant amount of time in residential buildings, especially in their living areas, it is crucial to thoroughly study PM2.5 concentrations in these spaces to effectively manage indoor air quality. Therefore, we present a review focusing on PM2.5 levels in urban residential buildings, with a specific emphasis on research conducted in these settings.

The goal of this study is to measure and characterize airborne particles in an industrial facility located in Rumueme, Port Harcourt. The findings will help assess the potential health risks faced by employees working at the facility, showcasing their dedication to safeguarding the health of nearby urban dwellers.

Study Objective: This study aims to evaluate the concentrations of airborne particles and determine the Air Quality Index within an industrial facility situated in Rumueme, Port Harcourt. These study objectives to: Evaluate the levels of key air quality indicators in the vicinity of the establishment. Compare these indicators with both local and global standards and examine the health implications in relation to the Air Quality Index. Document and categorize climate and meteorological data within the premises. Study the variations in air quality indicators throughout the establishment.

The focus of this research involves the monitoring of air quality and various meteorological factors in a designated area. These factors include wind speed, humidity, toxic gases (NH_3, SO_x, H_2S, NO_x, CO), noise levels, suspended particulates (PM2.5, PM10), hydrocarbons (PAHs), and trace metals. The primary objectives of the study are to determine the Air Quality Index, identify sources of pollution, and examine relationships between air quality metrics and meteorological conditions. The target audience for this research likely includes environmental scientists, policy makers, and organizations interested in enhancing air quality within the study region.

2. Materials and Methods

2.1. Area of Study

The research was carried out in Port Harcourt, Rivers State, Nigeria, situated between latitudes 4°51'30"N and 4°57'30"N and longitudes 6°50'00"E and 7°00'00"E. It is bounded by the Atlantic Ocean to the south, Bayelsa and Delta States to the west, Imo, Abia, and Anambra States to the north, and Akwa Ibom State to the east. The region falls within a sub-equatorial zone with a tropical climate, experiencing an average temperature of 30 °C, humidity ranging from 80 % to 100 %, and approximately 2,300 mm of rainfall per year (Mmom & Fred-Nwagwu, 2013). The predominant Air Mass System present is the Tropical Maritime Air Mass (mT), leading to the SW Monsoon Wind and significant precipitation. The Tropical Continental (cT) air mass has a minimal impact, resulting in harmattan conditions from December to February, known as the NE Trade Wind. The tropical rainforest covers the inland areas of Rivers State, with mangrove swamps dominating the coastal regions along the Atlantic Ocean. This vegetation is considered one of the most lush, complex, and diverse terrestrial ecosystems on the planet (Eludoyin et al., 2013). Andoni, Ekpeye, Engenni, Etche, Ibali, and Ikwerre (Figs. 1–4).

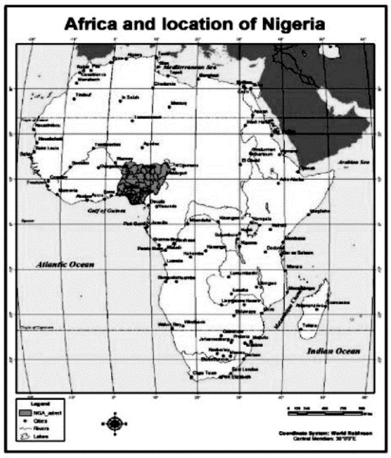

Fig. 1. Map of Africa with location of Nigeria

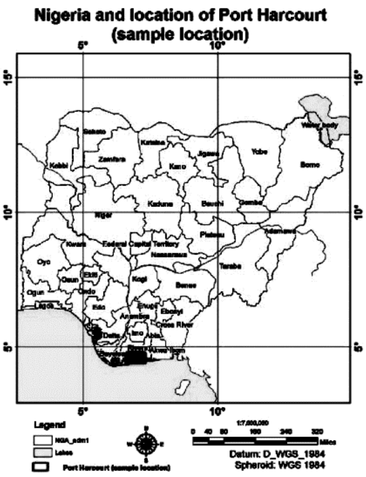

Fig. 2. Map of Nigeria and location of Port Harcourt. Source: ESRI

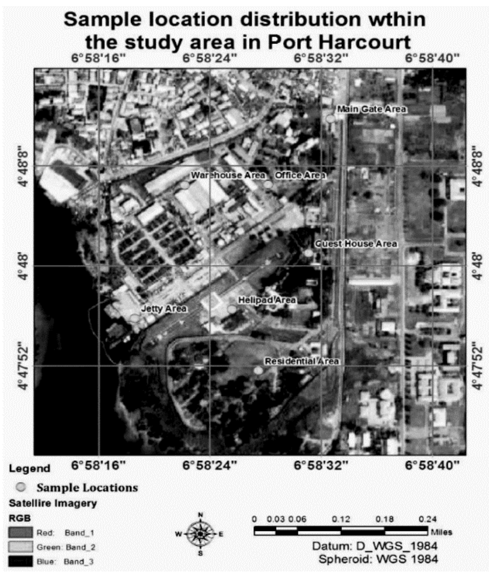

Fig. 3. Map of Rivers State

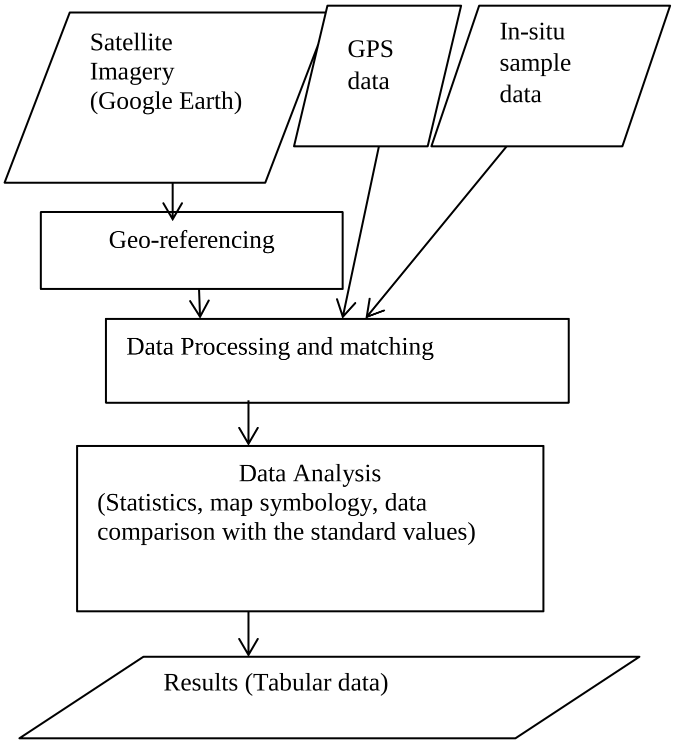

Fig. 4. Methodology Flowchart

2.2. Data collection

Within the study area, eight monitored locations were carefully chosen for the air quality study (Tabls. 1, 2).

Table 1

Site and description

S/N	Latitude	Longitude	Description
1	04°47'51.6'	006°58'27.5"	Residential Area
2	04°48'06.5"	006°58'28.2"	Office Area
3	04°47'56.5"	006°58'25.6"	Helipad Area
4	04°47'55.8"	006°58'18.6"	Jetty Area
5	04°48'06.5"	006°58'22.2"	Warehouse Area
6	04°48'01.0"	006°58'31.1"	Guest House Area
7	04°48'11.8"	006°58'32.7"	Main Gate Area

Table 2

Equipment Used

No.	Tools	Uses
1	Aeroqual Series 500	Insitu measurement for gases
2	Kestrel Weather Tracker	Meteorology measurement
3	Dwyer	Measurement of noise level
4	ToxiRae PID II meter	Measurement of VOC
5	Kanomax Model 3900	Measurement of Suspended Particulate Matter.
6	Membrane Filter	Heavy metals / Hydrocarbon determinations
7	GPS (Garmin 60csx)	Location (Co-ordinates)

2.3. Methods

Air samples were collected at different locations using various sampling devices for measurements. Gaseous pollutants were analyzed on-site using hand-held meters equipped with electrochemical sensors. The locations' coordinates were acquired through the use of a handheld GPS device (Garmin 60csx).

Air samples were collected at an approximate altitude of 1.6 meters above ground level at each designated monitoring site utilizing an Active Sampling approach for air sampling. Noise levels were measured at all sampling locations using a pre-calibrated Dwyer precision (class 2) sound level meter. The determination of Airborne Suspended Particulate Matter (PM2.5 and PM10) was conducted in accordance with ISO 14644/EPA 10-2 standards using a Kanomax 3900 Portable Counter High Volume Sampler (Andover, USA) and HoldPeak particle counter (Zhuahai, China). Particulate samples captured on air filters were extracted and analyzed using the USEPA 3550C/8015C standard method with the assistance of an Agilent 6890N GC-FID calibrated with 35 components.

The air filter particulate samples were extracted and analyzed following USEPA standards (3550C/8270D) using an Agilent 6890N/5973 GC/MS system calibrated with 16 components. BTEX analysis was done with USEPA method 8260B. VOA vials (EPA type 3) were used for Headspace-GCMS analysis of the trapped air. Tekmar 7000/Agilent 6890N/5973 Headspace/GCMS system calibrated with 6 analytes was used for analysis. ASTM methods D1971/4691 were utilized for trace metal analysis (Cd, Ni, Cr, Pb, Hg, Fe) using a Shimadzu AA-6650 atomic absorption spectrophotometer. Toxic gases (CO, NO_2, SO_2, H_2S, NH_3, VOCs) were measured with an Aeroqual 500 Series air quality sensor. Results were calculated based on ASTM D1914 – 2005 standards. Wind speed, humidity, and temperature were recorded using a Kestrel Weather Tracker (4250) and ArcGIS 10.3 was used for mapping the study area. Microsoft Excel was used for statistical analysis.

3. Results and Discussion

The Table 3 to 7 below are results and statistics on air quality, noise levels, and meteorological conditions in an industrial base located in Port Harcourt, Rivers State. The results obtained were compared with FMEnv, USEPA and WHO regulatory limits

Table 3

Air Quality, Noise and Meteorology – Residential Area

Parameters	Time Of Sampling			Mean	FMEnv	USEPA	WHO	USEPA
	7:24 am	12:15 pm	9:00 pm					(AQI)
Noise level dB (A)	50.1	51.2	50.1	50.47±0.64	90	[a]55 [b]45 [o]90	[a]55 [b]45	N.A
1	2	3	4	5	6	7	8	9
PM2.5, $\mu g/m^{-3}$	36.9	20.5	58.7	38.70±15.65	N.A.	[d]35	[d]25	[*]108
PM10, $\mu g/m^{-3}$	76.3	64.1	73.2	71.20±6.34	N.A.	[d]150	[d]70	58
SO_2, ppm	<0.1	<0.1	<0.1	<0.1	[c]0.1	[c]0.075	[c]0.03	[#]0
CO, ppm	<1.0	<1.0	<1.0	<1.0	[d]10	[d]9	[d]9	[#]4
NO_2, ppm	<0.1	<0.1	<0.1	<0.1	[d]0.04 – 0.06	[c]0.1	[d]0.04	[#]10
NH_3, ppm	<2.0	<2.0	<2.0	<2.0	N.A.	N.A.	N.A.	N.A.
H_2S, ppm	<0.012	<0.012	<0.012	<0.012	N.A.	N.A.	N.A.	N.A.
Cd, $\mu g/m^{-3}$	<0.012	<0.012	<0.012	<0.012	N.A.	[o]2.500	[f]0.005	N.A.
Ni, $\mu g/m^{-3}$	0.141	0.188	0.13	0.153±0.025	N.A.	[o]1000.0	[f]0.01	N.A.
Cr, $\mu g/m^{-3}$	0.178	0.236	0.153	0.189±0.035	N.A.	[o]5.000	[f]0.02	N.A.
Pb, $\mu g/m^{-3}$	<0.012	<0.012	<0.012	<0.012	N.A.	[o]50.00	[e]1.5	N.A.

Continuation of Table 3

1	2	3	4	5	6	7	8	9
Hg, μg/m^{-3}	<0.012	<0.012	<0.012	<0.012	N.A.	[o]100.00	[f]0.014	N.A.
VOC, μg/m^{-3}	<0.012	<0.012	<0.012	<0.012	N.A.	N.A.	N.A.	N.A.
Aliphatic Hydrocarbon, μg/m^{-3}	<0.118	<0.118	<0.118	<0.118	N.A.	N.A.	N.A.	N.A.
BTEX, μg/m^{-3}	<0.118	<0.118	<0.118	<0.118	N.A.	N.A.	N.A.	N.A.
Temperature, °C	28.7	32.5	27.1	29.43±2.77	N.A.	N.A.	N.A.	N.A.
Humidity, % RH	83	68.7	80.1	77.27±7.56	N.A.	N.A.	N.A.	N.A.
Wind Speed, m/s	0.6	3.2	0.6	1.47±1.50	N.A.	N.A.	N.A.	N.A.

N.A. = Not Available; [a] = Daytime residential limit; [b] = Night time residential limit; [c] = hourly limit; [d] = daily limit; [e] = quarterly limit; [f] = Annual limit; [o] = occupational exposure threshold limit.

Table 4

Air quality, noise and meteorology – industrial area

Parameters	Time of sampling			Mean	FMEnv	USEPA	WHO	USEPA
	8:00 am	3:45 pm	9:45 pm					AQI
Noise level, dB(A)	41.2	60.9	51.9	58.87±3.35	90	[a]55 [b]45 [o]90	[a]55 [b]45	N.A
1	2	3	4	5	6	7	8	9
PM2.5, μg/m^{-3}	36.6	14.2	32.4	27.73±9.72	N.A.	[d]35	[d]25	83
PM10, μg/m^{-3}	71.6	59.9	64.4	65.30±5.90	N.A.	[d]150	[d]70	55
SO_2, ppm	<0.1	<0.1	<0.1	<0.1	[c]0.1	[c]0.075	[c]0.03	0
CO, ppm	<1.0	<1.0	<1.0	<1.0	[d]10	[d]9	[d]9	4
NO_2, ppm	<0.1	<0.1	<0.1	<0.1	[d]0.04 – 0.06	[c]0.1	[d]0.04	10
NH_3, ppm	<2.0	<2.0	<2.0	<2.0	N.A.	N.A.	N.A.	N.A.
H_2S, ppm	<0.012	<0.012	<0.012	<0.012	N.A.	N.A.	N.A.	N.A.
Cd, μg/m^{-3}	0.059	0.153	0.094	0.102±0.039	N.A.	[o]2.500	[f]0.005	N.A.
Ni, μg/m^{-3}	0.165	0.2	0.13	0.165±0.029	N.A.	[o]1000.0	[f]0.01	N.A.
Cr, μg/m^{-3}	0.165	0.236	0.212	0.204±0.029	N.A.	[o]5.000	[f]0.02	N.A.
Pb, μg/m^{-3}	0.188	0.259	0.224	0.224±0.029	N.A.	[o]50.00	[e]1.5	N.A.
Hg, μg/m^{-3}	<0.012	<0.012	<0.012	<0.012	N.A.	[o]100.00	[f]0.014	N.A.

Continuation of Table 4

1	2	3	4	5	6	7	8	9
VOC, µg/m^{-3}	<0.012	<0.012	<0.012	<0.012	N.A.	N.A.	N.A.	N.A.
Aliphatic Hydrocarbon, µg/m^{-3}	<0.118	<0.118	<0.118	<0.118	N.A.	N.A.	N.A.	N.A.
BTEX, µg/m^{-3}	<0.118	<0.118	<0.118	<0.118	N.A.	N.A.	N.A.	N.A.
Temperature, °C	29.2	29.5	28.2	28.97±0.68	N.A.	N.A.	N.A.	N.A.
Humidity, % RH	78.1	73	81.9	77.67±4.47	N.A.	N.A.	N.A.	N.A.
Wind Speed, m/s	0.8	6.9	1.3	3.00±3.39	N.A.	N.A.	N.A.	N.A.

N.A. = Not Available; a = Daytime residential limit; b = Night time residential limit; c = hourly limit; d = daily limit; e = quarterly limit; f = Annual limit; o = occupational exposure threshold limit.

Table 5

Diurnal concentrations of 16 USEPA PAHs for sites

Parameter	Residential Area			Office Area			Helipad Area			Jetty Area		
	M	A	N	M	A	N	M	A	N	M	A	N
Naphthalene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	1.67	<0.177	1.67	1.67	1.67
Acenaphthalene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Acenaphthene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Fluorene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Phenathrene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Anthracene	<0.177	<0.177	<0.177	<0.177	1.67	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Fluoranthene	<0.177	<0.177	<0.177	<0.177	1.67	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Pyrene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Benzo(a)anthracene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Chrysene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Benzo(b)fluoranthrene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Benzo(a)pyrene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Benzo(k)fluoranthrene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Indeno(1,2,3 cd) perylene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Dibenzo(a,h)anthracene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Benzo(g,h,i) perylene	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177	<0.177
Total, ug/m^3	<0.177	<0.177	<0.177	<0.177	3.34	<0.177	<0.177	1.67	<0.177	1.67	1.67	1.67

Table 6

Correlation between quantifiable pollutants and site meteorology

		Noise level, dB (A)	$PM_{2.5}$, µg/m^{-3}	PM_{10}, µg/m^{-3}	Cd, ppm	Ni, ppm	Cr, ppm	Pb, ppm	Temp., °C	Humidity, % RH	Wind Speed, m/s
Noise level, dB(A)	Pearson Correlation	1	–.536*	–.254	.494	.578**	.179	.308	.207	–.492*	.232
	Sig. (2-tailed)		.012	.266	.102	.006	.437	.284	.369	.023	.312
	N	21	21	21	12	21	21	14	21	21	21
PM2.5, µg/m^{-3}	Pearson Correlation	–.536*	1	.099	–.248	–.172	–.312	–.043	–.385	.758**	–.417
	Sig. (2-tailed)	.012		.671	.437	.455	.168	.884	.085	.000	.060
	N	21	21	21	12	21	21	14	21	21	21
PM10, µg/m^{-3}	Pearson Correlation	–.254	.099	1	–.158	–.155	–.046	–.115	–.144	.083	–.067
	Sig. (2-tailed)	.266	.671		.623	.503	.842	.694	.532	.722	.773
	N	21	21	21	12	21	21	14	21	21	21
Cd, ppm	Pearson Correlation	.494	–.248	–.158	1	.799**	.526	.384	–.284	–.331	–.128
	Sig. (2-tailed)	.102	.437	.623		.002	.079	.218	.371	.293	.692
	N	12	12	12	12	12	12	12	12	12	12
Ni, ppm	Pearson Correlation	.578**	–.172	–.155	.799**	1	.249	.243	–.083	–.205	.072
	Sig. (2-tailed)	.006	.455	.503	.002		.277	.403	.721	.374	.755
	N	21	21	21	12	21	21	14	21	21	21
Cr, ppm	Pearson Correlation	.179	–.312	–.046	.526	.249	1	.596*	.101	–.312	.265
	Sig. (2-tailed)	.437	.168	.842	.079	.277		.025	.663	.168	.245
	N	21	21	21	12	21	21	14	21	21	21
Pb, ppm	Pearson Correlation	.308	–.043	–.115	.384	.243	.596*	1	.297	–.466	.348
	Sig. (2-tailed)	.284	.884	.694	.218	.403	.025		.302	.093	.223
	N	14	14	14	12	14	14	14	14	14	14
Temperatu-re , °C	Pearson Correlation	.207	–.385	–.144	–.284	–.083	.101	.297	1	–.542*	.533*
	Sig. (2-tailed)	.369	.085	.532	.371	.721	.663	.302		.011	.013
	N	21	21	21	12	21	21	14	21	21	21
Humidity, % RH	Pearson Correlation	–.492*	.758**	.083	–.331	–.205	–.312	–.466	–.542*	1	–.508*
	Sig. (2-tailed)	.023	.000	.722	.293	.374	.168	.093	.011		.019
	N	21	21	21	12	21	21	14	21	21	21
Wind Speed, m/s	Pearson Correlation	.232	–.417	–.067	–.128	.072	.265	.348	.533*	–.508*	1
	Sig. (2-tailed)	.312	.060	.773	.692	.755	.245	.223	.013	.019	
	N	21	21	21	12	21	21	14	21	21	21

*. The correlation is statistically significant at $p < 0.05$ (two-tailed).
**. The correlation is statistically significant at the 0.01 level for a two-tailed test.

Table 7

Analysis of variance of quantifiable pollutants across all evaluated sites

Parameter	*F* Statistics	Significance
Noise level, dB(A)	1.840	0.163
PM2.5, µg/m^3	2.041	0.127
PM10, µg/m^3	0.412	0.859
Cd, ppm	54.381	0.000
Ni, ppm	7.897	0.001
Cr, ppm	0.878	0.536
Pb, ppm	69.822	0.000
Temperature, °C	0.659	0.684
Humidity, % RH	0.687	0.664
Wind Speed, m/s	1.353	0.299

Table 3 shows noise level around residential area was mostly constant at mean of (50.47±0.64) dB(A). It's within FMEnv regulatory limit of 90 dB(A). Night value of 50.1 dB(A) was above WHO AND USEPA limit of 45 dB(A) for residential areas at night. Further indoor noise study in residential area may be needed to check for night violations of WHO and USEPA standards. Noise mapping needed to find source of elevated night noise.

Mean PM2.5 concentration, (38.70±15.65) µg/m^{-3}, exceeded WHO and USEPA limits of 35 and 25 µg/m^{-3}, primarily from fossil fuel combustion in engines. Reducing vehicular usage can help cut PM2.5 levels. Continued monitoring can refine mitigation strategies. Mean PM10 concentration, (71.20±6.34) µg/m^{-3}, complies with the EPA's 150 µg/m^{-3} limit, but exceeds the WHO's 70 µg/m^{-3} limit due to road dust resuspension. Wetting ground surfaces may aid PM10 control, particularly in dry seasons.

Toxic gases, BTEX, VOCs, Aliphatic hydrocarbons, and PAHs checked were below detection limits in the residential area. Trace metals Cd, Ni, Cr, Pb, Hg, were well below OSHA permissible limits. PM2.5 concerns air quality, especially for those with respiratory issues. They should limit outdoor time and exertion. Measures to reduce PM2.5 can improve AQI.

In the Office Area, noise values were within regulatory limits. Mean noise level: (50.83±6.46) dB(A). The mean PM2.5 concentration was within the USEPA daily limit of 35 µg/m^{-3} but exceeded the WHO limit of 25 µg/m^{-3}. Continued monitoring is necessary to track trends and suggest better mitigation strategies to enhance air quality. Concentrations of PM10 had a mean concentration of (60.57±10.37) µg/m^{-3} across the day. This mean value fell within the USEPA and WHO regulatory limits of 150 and 70 µg/m^{-3} respectively. Toxic gases, BTEX, VOCs, and Aliphatic hydrocarbons in this study were mostly undetectable. Among 16 USEPA PAHs in the particles, only fluorene and anthracene were detected above limits at (0.56±0.78) µg/m^{-3} each. The main regulated PAH is Benzo(a)pyrene, with a 0.005 µg/m^{-3} daily exposure limit. Toxic gases, BTEX, VOCs, and Aliphatic hydrocarbons in this study were mostly undetectable. Among 16 USEPA PAHs in the particles, only fluorene and anthracene were detected above limits at (0.56±0.78) µg/m^{-3} each. The main regulated PAH is Benzo(a)pyrene, with a 0.005 µg/m^{-3} daily exposure limit.

The noise level at Helipad Area was (58.87± ±3.35) dB(A). Daytime exposure limit of 55 dB(A) was exceeded with a noise level of 60.9 dB(A) during afternoon sampling. The values are within the occupational exposure limit of 90 dB(A) for work areas.

For airborne particulates, mean PM2.5 and PM10 were respectively (27.73±9.72) and (65.30±5.90) µg/m^{-3}. The PM10 concentration fell well within the USEPA and WHO regulatory limit. Toxic gases, BTEX, VOCs, and Aliphatic hydrocarbons were all below detection limits in the study. Naphthalene was the only PAH detected with a mean concentration of (0.56±0.78) µg/m^{-3}, below the OSHA limit of 525.2 µg/m^{-3}.

Mean concentrations for Cd, Ni, Cr, and Pb: (0.102±0.039), (0.165±0.029), (0.204±0.029), and (0.224±0.029) µg/m^{-3}. All values within OSHA limits. Mercury below detection limit. AQI indicates air quality as "Good" and "Moderate" for toxic gases and particulates (PM2.5 and PM10). Mitigation measures can further improve air quality.

In this area, the average noise level falls within regulatory limits set by USEPA and WHO (90 dB(A)). PM2.5 concentration was below USEPA but exceeded WHO limit, while PM10 was within limits. Trace metals were mostly high except Hg, which was undetectable.

Metal concentrations met OSHA limits. Toxic gases, BTEX, VOCs, and Aliphatic hydrocarbons were undetectable. Naphthalene was below OSHA limit. The air quality had a moderate AQI.

Mean noise level in Warehouse Area is (66.83±10.96) dB(A), falling within USEPA's 90 dB(A) limit for industrial areas. Personnel can wear ear protective equipment to lower exposure. Conduct noise audit to assess noise pattern and sources for further reduction. PM2.5 in the area has a mean of (42.20± ±10.19) μg/m^{-3}, exceeding USEPA and WHO limits of 35 and 25 μg/m^{-3}. Reduce automobile use, especially high-emission vehicles, to lower fine particulate levels. Recommend air quality audit to assess PM2.5 sources and emission patterns in the area.

Concentrations of Cd, Ni, Cr, and Pb were below OSHA limits. Metal levels higher in this area than others. AQI: 117 for PM2.5 and 54 for PM10, toxic gases scored well. PM2.5 AQI lowest in study, concerning health impacts. Air audit needed to find sources. Smelting, fuel combustion possible sources. Workers near should wear masks for PM2.5.

Guest house area had mean noise level of (56.20±8.88) dB(A), violating daytime 55 dB(A) limit by USEPA and WHO. Night time value also exceeded 45 dB(A) limit. Noise survey recommended. PM2.5 concentration was low with mean of (23.10±3.96) μg/m^{-3}, below USEPA and WHO limits. PM10 mean concentration was (70.83±20.74) μg/m^{-3}. Toxic gases, BTEX, VOCs, Aliphatic hydrocarbons, and PAHs were below detection limits. Ni, Cr, and Pb were detected with mean concentrations of (0.204±0.062), (0.212±0.020), and (0.106±0.079) μg/m^{-3} respectively, all below limits.

Range of noise: 55.0–70.6 dB(A) with mean of (60.53±8.730 μg/m^{-3}. Values exceed residential limit but within work exposure limit. Workers can use ear protection. PM2.5 and PM10 near gate: (23.43±1.67) and (63.07±10.82) μg/m^{-3}, within USEPA and WHO limits. Toxic gases, BTEX, VOCs, aliphatic hydrocarbons, and PAHs not detected. Trace metals tested: Cd, Ni, Cr, Pb, Hg, below OSHA limits. AQI: moderate and good for particulates and toxic gases. Data for air quality parameters underwent 1-way Analysis of Variance to assess spatial variation across 7 sites. See Table 6 for results.

The *p*-value at 95 % confidence level shows significant variation for Cd, Ni, and Pb across 7 sites, indicating local metal sources. Cd sources might be near Helipad, Jetty, Warehouse, and Main Gate. Noise, PM2.5, PM10, and Chromium had no significant variation. Table 14 displays Pearson's correlation between air and meteorology parameters at 7 sites. PM10 had a strong positive correlation with humidity (r = 0.758 at 99 % Confidence Level) compared to PM2.5 and humidity (r = 0.215 at 99 % Confidence Level), suggesting humid air favors the aggregation of fine particulates into larger ones.

The correlation between airborne PM (PM2.5 and PM10) and wind speed was weak but negative: –0.251 and –0.417 respectively. Stagnant air promotes particulate buildup in the NAOC base troposphere. The Pearson's correlation coefficient for Ni and Cd is 0.800, indicating a strong positive correlation possibly from a common source.

4. Conclusions

This study shows air quality indices in the industrial Base, Port Harcourt, Nigeria. PM2.5 most affected AQI. Mean PM2.5 concentrations were (38.70±15.65) μg/m^{-3} in residential areas and (42.20±10.19) μg/m^{-3} in warehouses, both violating USEPA and WHO limits. PM10 levels met USEPA limits at all 7 locations, but exceeded WHO limits at residential and guesthouse areas. Noise data for work areas met FMEnv, USEPA, and WHO standards of 90 dB(A). Nighttime noise levels surpassed 45 dB(A) limit. Gases were undetectable at all locations. Polycyclic aromatic hydrocarbons (PAHs) found in 3 of 7 sites. Only 3 of 16 USEPA PAHs detected: Naphthalene, Fluorene, Anthracene. Trace metals concentrations below USEPA OSHA limits. More detailed air quality monitoring may be needed to validate study findings.Noise mapping indoors and outdoors in residential and guesthouse areas is advised. Continuous measurement over time is needed to confirm PM2.5 levels. Workers may wear masks filtering PM2.5 dust. A 24-hour sampling survey is necessary to compare particulates with the W.H.O daily limit of 5 ng/m^3 for Benzo(a)pyrene.

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