

Seasonal Variation of Air Quality Index in Various Locations of Port Harcourt Metropolis, Rivers State

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Abstract

Background: Seasonal variations in Air Quality Index (AQI) is of public health importance as it provides insights into the changing air quality dynamics as influenced by climatic conditions, prevalent wind patterns, and local emission sources. This study aimed at determining the seasonal variations of AQI in various locations of Port Harcourt Metropolis, Rivers State.

Methods: The study employed a descriptive cross-sectional study design. Air quality index machine was used to measure the AQI of different locations of Port Harcourt Metropolis over a period of one year. Ethical clearance for the study was gotten from the University of Port Harcourt Research Ethics Committee with the reference number UPH/CEREMAD/REC/MM91/067. Data was analyzed using Statistical Package for Social Sciences (SPSS) version 25.

Results: Result revealed that Elekahia and Rumukurushi had unhealthy values (152 µg/m³ and 151 µg/m³) of PM₁₀ in dry season compared to 81 µg/m³ and 82 µg/m³ for rainy season respectively. Also, Rumodara had unhealthy value (151 µg/m³) of PM₁₀ in dry season compared to 94 µg/m³ for rainy season below the EPA/DPR acceptable limit, while Bori Camp had moderate acceptable values of PM₁₀ in both dry and wet seasons. Agip had unhealthy value (153 µg/m³) of PM₁₀ in dry season above the EPA/DPR acceptable limit compared to 93 µg/m³ for rainy season below the EPA/DPR acceptable limit, while Nguoba and Agip had moderate values within the acceptable values of PM₁₀ in both dry and wet seasons. Elekahia, Rumukurushi, Rumuodara, Bori Camp, and Agip had unhealthy values of Carbon Monoxide (1.0 mg/m³, 2.0 mg/m³, 6.0 mg/m³, 2.0 mg/m³, 4.0 mg/m³) respectively, while Elekahia and Rumuokwursi had unhealthy values of Relative Humidity (70.0%, 66.0%) respectively, particularly in dry seasons.

Conclusion: There are unhealthy levels of particulate matter concentrations, carbon monoxide, and relative humidity in various locations of Port Harcourt metropolis, particularly during the dry season. There is need for more public awareness campaigns and stricter regulations on how to mitigate the adverse effects of air pollution in Port Harcourt metropolis especially in dry seasons.

Keywords: Seasonal Variation, Air Quality Index, Port Harcourt Metropolis, Rivers State

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I. Introduction

Air quality has significant implications for public health and environmental integrity, particularly in urban agglomerations where anthropogenic activities are concentrated [1, 2]. The Port Harcourt Metropolis in Rivers State, Nigeria, is an area characterized by rapid industrialization, urbanization, and population growth, leading to varying degrees of air pollution [3-5]. Seasonal variations in the Air Quality Index (AQI) can provide insights into the changing air quality dynamics as influenced by climatic conditions, prevalent wind patterns, and local emission sources [6].

The Air Quality Index (AQI) serves as an effective metric for assessing and communicating air quality levels to the public [7]. It aggregates various pollutants, notably particulate matter (PM), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), carbon monoxide (CO), and ozone (O₃), into a singular value that reflects overall air quality [8]. Seasonal changes can influence the AQI due to variations in temperature, humidity, and wind patterns, which can affect pollutant dispersion and transformation [9].

Studies indicate that metropolitan regions frequently encounter increased air pollution levels during particular seasons. For example, arid periods may experience heightened particulate matter as a result of dust storms and stagnant air, whereas the wet season can decrease pollutant levels but may also enable the liberation of contaminants sequestered in the soil and surface due to augmented runoff [10]. In the context of Port Harcourt, a detailed examination of seasonal AQI variations across different locations in the metropolis can provide valuable insights into the timing and sources of air pollution, thereby informing public health interventions and environmental policies [11].

Air pollutants, including particulate matter (PM), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), and carbon monoxide (CO), are often at elevated levels during specific seasons due to factors such as increased vehicular emissions, dust from construction sites, and seasonal weather conditions [12]. Understanding the patterns of air quality across different seasons in Port Harcourt is crucial, as it allows for the identification of critical periods when air pollution poses a significant risk to public health, especially for vulnerable populations [13].

Previous studies have established that air quality varies significantly in relation to geographic and environmental factors [14-16]. For instance, urban areas may experience higher pollution levels due to concentrated traffic and industrial activities, while rural areas may benefit from relatively better air quality [17]. The AQI serves as a useful tool for assessing air quality and guiding policy decisions aimed at reducing pollution exposure [18]. By evaluating the seasonal AQI in various locations across Port Harcourt, this study seeks to contribute to the understanding of local air quality dynamics and inform stakeholders about necessary interventions for health protection and environmental management.

Air quality is a critical environmental health issue, particularly in rapidly urbanizing regions like Port Harcourt Metropolis, Rivers State, Nigeria. As a hub of oil and gas activities, this city experiences significant emissions from industrial processes, vehicular traffic, and other anthropogenic sources, which contribute to deteriorating air quality [19]. Understanding the variations in air quality across different seasons is essential for developing effective air quality management strategies and protecting public health [20, 21]. This study aims to assess the seasonal variation of the AQI in various locations within Port Harcourt Metropolis, highlighting the implications for environmental quality and public health. By identifying seasonal trends and their underlying causes, the research will contribute to a broader understanding of urban air quality dynamics in Nigeria.

II. Methodology

This research was carried out in the Port Harcourt Metropolis, Rivers State. Port Harcourt serves as a principal industrial center in Nigeria, mostly engaged in oil and gas operations, which substantially elevate its air pollution rates. The metropolis undergoes two predominant seasons: the arid season and the rainy season. It serves as the capital of Rivers State, Nigeria, and has considerable seasonal fluctuations in air quality index (AQI) attributed to its industrial operations, vehicle emissions, and geographical setting. Comprehending the seasonal fluctuations in Air Quality Index is crucial for environmental governance and public health.

A multi-tiered sampling technique was employed for this research. The regions of Port Harcourt Metropolis ultimately chosen comprise Elekahia, Rumukwursi, Rumuodara, Bori Camp, Mgbuoba, and Agip. The research apparatus comprised an air quality monitoring device utilized for assessing the air quality index. The apparatus functions as a real-time, multi-channel particle detector for aerosol characterization. The operational state of the machinery was confirmed to be satisfactory and adjusted for precise measurement. A systematic survey was employed to gather the socio-demographic attributes of the individuals.

Data gathering was conducted over the span of one (1) year. The investigator utilized the assistance of five research aides. The research aides were master's students in public health from the University of Port Harcourt, who underwent a 7-day training on questionnaire administration and data collection. These research assistants demonstrated a solid understanding of the study, research ethics, and familiarity with the subject areas. The objective of the research was elucidated to the qualified participants. The investigator utilized the assistance of five research aides. The research aides were master's students in public health from the University of Port Harcourt, who underwent a 7-day training on questionnaire administration and data collection. These research assistants demonstrated a solid understanding of the study, research ethics, and familiarity with the subject areas.

The analysis of data was conducted utilizing Statistical Package for Social Sciences (SPSS) version 25. Frequency and percentage descriptive statistics were conducted. The outcomes derived from the studied data were exhibited in tabular format.

Ethical approval was secured from the Research and Ethics Committee at the University of Port Harcourt. The acceptance letter's reference number is UPH/CEREMAD/REC/MM91/067. Authorization to carry out the research was secured from the community leaders at the location of the study. Consent was obtained from the subjects.

III. Results

Table 1: Socio-demographic Characteristics of Respondents

Variables	Frequencies (n=381)	Percentage (%)
Age (years)		
18-27	184	48.3
28-37	136	35.7
38-47	40	10.5
≥48	21	5.5
Gender		
Male	206	54.1
Female	175	45.9
Tribe		
Igbo	169	44.1
Hausa	14	3.7
Yoruba	6	1.6
Others	192	50.4
Religion		
Christianity	329	86.4
Islam	35	9.2
Others	17	4.4
Level of Education		
Primary	96	25.2
Secondary	65	17.1
Tertiary	190	49.9
None	30	7.9
Marital Status		
Single	229	60.1
Married	137	36.0
Divorced	7	1.8
Cohabiting	18	2.1
Range of income		
≤50000	164	43.0
50001-100000	98	25.7
100001-150000	35	9.2
≥150001	84	22.0
Occupation		
Employed position	70	18.4
Employed profession	118	31.0
Entrepreneur, agric	106	27.8
Middle Management	41	10.8
Student, retired	46	12.1

Table 1 delineates the socio-demographic attributes of the participants. The data indicates that the predominant age group among respondents was 18-27 years, including 184 individuals (48.3%), and those aged 48 years or above, totaling 21 individuals (5.5%), were the least represented demographic. A total of two hundred and six participants, constituting 54.1%, were male, whilst one hundred and seventy-five participants, representing 45.9%, were female. Two hundred twenty-nine participants, constituting 60.1%, were single, representing the majority of the group, while seven participants, or 1.8%, were divorced, making them the least represented. The data indicated that one hundred and ninety participants (49.9%) attained a tertiary education, whereas just thirty individuals (7.9%) lacked formal schooling. The findings indicated that three hundred twenty-nine (86.4%) of the respondents identified as Christians, while one hundred ninety-two (50.4%) belonged to other minor ethnic groups, including Ikwerre and Ijaw. The research indicated that one hundred sixty-four (43.0%) of the participants make less than or equal to 50,000, whilst just thirty-five (9.2%) earn up to 150,000. Ultimately, one hundred eighteen (31.0%) of the participants were in work, but just forty-one (10.8%) belonged to the middle management tier.

Table 2: Seasonal Variation of Air Quality Index in various locations of Port Harcourt Metropolis (Elekahia and Rumukurushi)

PARAMETER/LOCATION	COORDINATE	AQ1 ELEKAHIA N 04049'17.5" E 007001'26.6"	AQ2 RUMUKURUSHI N 04050'57.6" E 007003'13.3"	WHO/EPA/DPR Acceptable Limit	Description
		Dry Season	Wet season	Dry Season	Wet season
					(mg/m3)
SOX, (mg/m3)	0.1	<0.1	0.1	<0.1	0.02
NOX (mg/m3)	<0.1	<0.1	0.1	<0.1	5.6
					Healthy Healthy

Seasonal Variation of Air Quality Index in Various Locations of Port Harcourt ..

Carbon Monoxide, CO (mg/m3)	1.0	0.23	2.0	1.10	0.03	Unhealthy
CXHY (mg/m3)	<0.1	<0.1	1.0	0.51	-	
H2S (mg/m3)	<0.1	<0.1	<0.1	<0.1	200	Healthy
NH3(mg/m3)	0.4	0.2	0.7	0.3	27	Healthy
VOC (mg/m3)	0.013	0.035	0.5			Healthy
Ozone (mg/m3)	<0.1	<0.1	<0.1	<0.1	0.106	Healthy
Carbon Dioxide, CO2 (ppm)	593	421	583	314	9000	Healthy
Ambient Temperature (°C)	32.0	28.0	34.6	30.0	36	Moderate
Relative Humidity (%)	70.0	56	66.0	54	30-60	Unhealthy
Wind Direction (Degrees)	SW		SW	SE	SE	
Wind Speed (m/s)	0.8	0.6	0.8	0.5	13-18	Healthy
Noise Level (dBA)	62.5	57	64.2	60.0	85	Moderate
Particulate matter 1.0 (µg/m3)	11	3	20	16	6-35	Moderate
Particulate matter 2.5 (µg/m3)	37	28	35	30	35-65 µg/m3	Moderate
Particulate matter 10 (µg/m3)	152	81	93	82	150 µg/m3	Unhealthy/Healthy
Total Suspended Particulate (TSP) (µg/m3)	200	112	148	128	250 µg/m3	Healthy

Table 2 showed that Elekahia and Rumukurushi had unhealthy values of Carbon Monoxide, CO (mg/m3) above the acceptable limit. Also, Elekahia and Rumukurushi Camp had unhealthy values of Relative Humidity (%) above the acceptable limit. There were moderate Ambient Temperature (°C) and Noise Level (dBA) within the acceptable limit. The result indicated that Elekahia and Rumukurushi had moderate acceptable values of PM1.0 and PM2.5 in both dry and wet seasons. These values are below and within EPA/DPR acceptable limit. The result showed that Elekahia and Rumukurushi had unhealthy values (152 µg/m3 and 151 µg/m3) of PM10 in dry season above the EPA/DPR acceptable limit compared to (81µg/m3 and 82 µg/m3) for rainy season below the EPA/DPR acceptable limit respectively.

Table 3: Seasonal variation of air quality index in various locations in Port Harcourt (Rumodara and Bori Camp)

PARAMETER/LOCATION	RUMUODARA N 04051'37.4" E 007001'73.6" Dry Season	BORI CAMP N 04052'00.2" E 006059'59.3" Wet Season	EPA/DPR Limit	Acceptable	Description
COORDINATE			Dry Season		Wet Season
SOX, (mg/m3)	0.2	0.1	0.1	0.02	Healthy
NOX (mg/m3)	<0.1	<0.1	<0.1	5.6	Healthy
Carbon Monoxide, CO (mg/m3)	6.0	3.1	2.0	0.03	Unhealthy
CXHY (mg/m3)	<0.1	<0.1	<0.1	<0.1	-
H2S (mg/m3)	<0.1	<0.1	<0.1	200	Healthy
NH3(mg/m3)	0.2	0.2	0.1	27	Healthy
VOC (mg/m3)	0.025	0.023	0.011	0.5	Healthy
Ozone (mg/m3)	<0.1	<0.1	<0.1	0.106	Healthy
Carbon Dioxide, CO2 (ppm)	585	577	590	583	9000
Ambient Temperature (°C)	35.0	31.0	35.8	32.8	36
Relative Humidity (%)	60.0	68.0	60.0	66.0	30-60
Wind Direction (Degrees)	NE	NE	SE		SE
Wind Speed (m/s)	0.5	0.5	2.0	2.0	13-18
Noise Level (dBA)	72.3	70.2	69.3	71.1	85
Particulate matter 1.0 (µg/m3)	7	5	17	15	6-35
Particulate matter 2.5 (µg/m3)	23	18	20	17	35-65 µg/m3

Particulate matter (µg/m ³)	151	94	65	23	150 µg/m ³	Unhealthy/Healthy
Total Suspended Particulate (TSP) (µg/m ³)	181	25	102	55	250	Healthy

Table 3 revealed that Rumuodara and Bori Camp had unhealthy value of Carbon Monoxide, CO (mg/m³) above the acceptable limit. The table revealed that Rumodara and Bori Camp had unhealthy values of Relative Humidity (%) above the acceptable limit. There were moderate Ambient Temperature (°C) and Noise Level (dBA) within the acceptable limit. Also, Rumodara and Bori Camp had moderate acceptable values of PM1.0 and PM2.5 in both dry and wet seasons. These values are below and within EPA/DPR acceptable limit. The result showed that Rumodara had unhealthy value (151 µg/m³) of PM10 in dry season above the EPA/DPR acceptable limit compared to (94µg/m³) for rainy season below the EPA/DPR acceptable limit, while Bori Camp had moderate acceptable values of PM10 in both dry and wet seasons.

Table 4: Seasonal variation of air quality index in various locations in Port Harcourt (Ngbuoba and Agip)

PARAMETER/LOCATI ON	NGBUOBA N 04051'40.0" E 006057'54.0"		AGIP N 04052'00.2" E 006059'59.3"		EPA/DPR Limit	Description
COORDINATE	Dry Season		Wet Season		Dry Season	Wet Season
SOX, (mg/m ³)	<0.1	0.1	0.1	0.1	0.02	Healthy
NOX (mg/m ³)	<0.1	<0.1	0.1	<0.1	5.6	Healthy
Carbon Monoxide, CO (mg/m ³)	0.05	0.3	4	2.0	0.03	Unhealthy
CXHY (mg/m ³)	<0.1	<0.1	<0.1	<0.1	<0.1	-
H ₂ S (mg/m ³)	<0.1	<0.1	<0.1	<0.1	200	Healthy
NH ₃ (mg/m ³)	<0.1	0.2	0.3	0.1	27	Healthy
VOC (mg/m ³)	0.008	0.005	0.011	0.010	0.5	Healthy
Ozone (mg/m ³)	<0.1	<0.1	<0.1	<0.1	0.106	Healthy
Carbon Dioxide, CO ₂ (ppm)	575	567	590	573	9000	Healthy
Ambient Temperature (°C)	34.0	30.0	33.0	30.8	36	Moderate
Relative Humidity (%)	62.0	67.0	61.0	65.0	30-60	Unhealthy
Wind Direction (Degrees)	SW		NE	NE		SE
Wind Speed (m/s)	0.2	0.5	0.6	1.0	13-18	Healthy
Noise Level (dBA)	60.1	63.2	71.5	70.1	85	Moderate
Particulate matter (µg/m ³)	6	5	10	9	6-35	Moderate
Particulate matter (µg/m ³)	7	8	36	21	35-65 µg/m ³	Moderate/Healthy
Particulate matter (µg/m ³)	48	9	153	93	150 µg/m ³	Unhealthy/Healthy
Total Suspended Particulate (TSP) (µg/m ³)	61	25	199	123	250	Healthy

Table 4 showed that Ngbuoba and Agip had unhealthy value of Carbon Monoxide, CO (mg/m³) above the acceptable limit. Also, Ngbuoba and Agip had unhealthy values of Relative Humidity (%) above the acceptable limit. There were moderate Ambient Temperature (°C) and Noise Level (dBA) within the acceptable limit. The result showed that moderate acceptable values of PM1.0 in both dry and wet seasons. However, the PM2.5 values were within the EPA/DPR acceptable limit. The result showed that Agip had unhealthy value (153µg/m³) of PM10 in dry season above the EPA/DPR acceptable limit compared to (93µg/m³) for rainy season below the EPA/DPR acceptable limit, while Ngbuoba and Agip had moderate values within the acceptable values of PM10 in both dry and wet seasons.

IV. Discussion

This study investigated the seasonal variation of AQI in various locations of Port Harcourt Metropolis, Rivers State. The result revealed that Elekahia and Rumukurushi had moderate acceptable values of PM_{1.0} and PM_{2.5} in both dry and wet seasons. These values are below and within EPA/DPR acceptable limit. These findings align with broader seasonal air quality patterns reported in Port Harcourt and similar settings, where fine particulate matter (PM_{2.5}) often exceeds health-based guidelines in the dry season due to reduced wet scavenging from rainfall and enhanced re-suspension of dust and combustion products [22]. More granular local studies have documented higher PM_{2.5} and PM₁₀ during the dry season compared to the wet season in Port Harcourt schools and community sites, attributing these differences to meteorology and episodic dust intrusions (e.g., Harmattan influence) that elevate fine and coarse particles during drier months [22]. The findings from this study also indicate that both Elekahia and Rumukurushi exhibited unhealthy concentrations of PM₁₀ during the dry season, with values of 152 µg/m³ and 151 µg/m³, respectively. These values exceed the EPA/DPR acceptable threshold of 150 µg/m³ for a 24-hour period. The increased levels of PM₁₀ in these locations during the dry season can be attributed to a combination of factors, including vehicular emissions, industrial activities, and seasonal dust from nearby construction or agricultural activities. In particular, the dry season is known to exacerbate particulate pollution due to lower humidity levels, which allow dust and smoke to remain suspended in the air for longer periods [23, 24].

In contrast, during the rainy season, PM₁₀ levels in Elekahia and Rumukurushi decreased significantly to 81 µg/m³ and 82 µg/m³, respectively. These values are within the acceptable limit, as rainfall often helps to wash airborne particles from the atmosphere, improving air quality. The reduction in particulate matter during the rainy season underscores the critical role that weather conditions, particularly precipitation, can play in mitigating air pollution. The seasonal fluctuations in PM₁₀ concentrations suggest that weather conditions, local industrial activities, and traffic congestion may have significant impacts on air quality. The dry season, with its increased dust and smoke, creates conditions for the accumulation of particulate matter, whereas the rainy season helps to alleviate these conditions through natural processes like precipitation and deposition. This finding aligns with previous research in regions with similar climatic conditions, where particulate matter levels tend to spike during dry periods and decrease during the rainy season [25, 26].

The study also revealed that Rumuodara and Bori Camp exhibited unhealthy levels of carbon monoxide (CO), with concentrations exceeding the acceptable limits of 10 mg/m³ for a 24-hour period. CO concentrations in these areas could be linked to the high levels of vehicular emissions and the combustion of biomass for cooking, particularly in residential areas with limited access to cleaner energy alternatives [27]. CO is a colorless, odorless gas, and even at low concentrations, it can have detrimental effects on human health, such as headaches, dizziness, and impaired cognitive function. Prolonged exposure to higher levels can result in more severe effects, including asphyxiation and death, particularly in confined spaces. The elevated CO levels in these areas are concerning, as they not only violate air quality standards but also point to a need for stricter regulatory measures and better pollution control technologies. Urban and suburban areas with high vehicular traffic and insufficient regulation of industrial emissions often experience increased CO concentrations, especially in the absence of adequate infrastructure to mitigate these emissions [28].

Furthermore, this study found that Ngbuoba and Agip had unhealthy values of Carbon Monoxide, CO (mg/m³) above the acceptable limit. It was also revealed that Ngbuoba and Agip had unhealthy values of Relative Humidity (%) above the acceptable limit. There were moderate Ambient Temperature (°C) and Noise Level (dBA) within the acceptable limit. The result showed that there were moderate acceptable values of PM_{1.0} in both dry and wet seasons in both locations. However, the PM_{2.5} values were within the EPA/DPR acceptable limit. The result showed that Agip had unhealthy values (153µg/m³) of PM₁₀ in dry season above the EPA/DPR acceptable limit compared to (93µg/m³) for rainy season below the EPA/DPR acceptable limit, while Ngbuoba and Agip had moderate values of PM₁₀ in both dry and wet seasons which was within the acceptable limits. Similarly, U.S. NO₂ trends (2005–2013), EPA Air Quality System (AQS) data versus improved observations from the Ozone Monitoring Instrument (OMI) shows the spatial variation of the annual trend in OMI tropospheric NO₂ VCDs for the 2005-2008 and 2010-2013 periods. There are significant decreasing trends over large areas of the U.S. during 2005-2008 with an annual reduction rate of 0-12 %. Reductions are more rapid in many populated areas of the U.S.; trends in sparsely populated areas are small or insignificant. The trends are substantially weaker during 2010-2013. The spatial distribution as well as the magnitude of the two trends for both periods are generally consistent, but are less so as compared to the entire 2005-2013 period. OMI observations suggest a stronger average decrease of $4.8 \pm 1.9\%/yr$ as compared to $3.7 \pm 1.5\%/yr$ from AQS data for 2005-2008, whereas the AQS data suggest a larger reduction of $2.1 \pm 1.4\%/yr$ as compared to $1.2 \pm 1.2\%/yr$ from OMI data for 2010-2013 [29].

The current study is consistent with finding by Zhan et al. [27] in China who found that there is a distinct seasonal variation of AQI with the mean ranked in decreasing order as winter (104.0) > spring (81.9) > autumn (74.4) > summer (69.4), indicating that urban air quality in 2015 across the Chinese cities is much worse in winter, but relatively better in summer. There is similarity between finding this current study and another finding by Yan

et al., [30] in Beijing. They reported similar values of average AQI of Beijing from 2015 to 2016. There were obvious seasonal differences ($P < 0.001$) of the AQI in the two years, decreasing in winter, spring, autumn, and summer. The summer average AQI (84.12 ± 52.37) was lower than the overall average. However, the winter average AQI (125.05 ± 117.64) was significantly higher than the overall average. The average AQI of each month in 2015 to 2016 varied from 70.72 to 167.74. The AQI was higher at the beginning and end of the year and lower in the middle of the year, showing a U-shaped variation. In August, the average AQI was the lowest (70.72 ± 44.45) with high stability. In December, the average AQI was the highest (167.74 ± 160.00) and with a high discrete degree. These variations indicated that the air quality of Beijing in the summer months was generally good and stable from 2015 to 2016. The air pollution increased in spring and autumn and was the worst in winter with large fluctuations and susceptibility to high pollution weather events. There is an agreement between finding in this study finding by Kanee et al. [31] (2020) on Particulate matter-based air quality index estimate for Abuja, Nigeria who found that the air quality of the selected areas in Abuja was generally good and healthy.

V. Conclusion

There are unhealthy levels of particulate matter concentrations, carbon monoxide, and relative humidity in various locations of Port Harcourt metropolis, particularly during the dry season. There is need for more public awareness campaigns and stricter regulations on how to mitigate the adverse effects of air pollution in Port Harcourt metropolis especially in dry seasons.

Study Limitations

This study has some notable limitations. First, although several zones were studied the findings may not fully represent other areas of Port Harcourt Metropolis or nearby regions with similar pollution sources. Secondly, the study was conducted over a specific period, potentially limiting its ability to capture variations in air quality and health outcomes across different seasons and longer timeframes.

Conflict of Interest Declaration

The authors declare no conflict of interest whatsoever

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References

- [1]. Liang L, Gong P. Urban and air pollution: a multi-city study of long-term effects of urban landscape patterns on air quality trends. *Scientific reports*. 2020 Oct 29;10(1):18618.
- [2]. Feng T, Du H, Lin Z, Zuo J. Spatial spillover effects of environmental regulations on air pollution: Evidence from urban agglomerations in China. *Journal of Environmental Management*. 2020 Oct 15;272:110998.
- [3]. Yakubu OH. Particle (soot) pollution in Port Harcourt Rivers State, Nigeria—double air pollution burden? Understanding and tackling potential environmental public health impacts. *Environments*. 2017 Dec 24;5(1):2.
- [4]. Garba SZ, Shuaibu DM. Effects of Air Pollution on Human Health in Port Harcourt City, Rivers State Nigeria.
- [5]. Akinfolarin OM, Obunwo CC, Boisa N. Air quality characteristics of emerging industrial areas in Port Harcourt, Nigeria. *Journal of Chemical Society of Nigeria*. 2018 Feb 3;43(1).
- [6]. Adeyemi, A. A., Aboluwoye, O., & Fabunmi, J. Assessment of Air Quality and Its Impacts on Human Health in Port Harcourt Metropolis. *Environmental Science and Pollution Research*. 2020; 27(1), 451-462.
- [7]. Kumar P. A critical evaluation of air quality index models (1960–2021). *Environmental Monitoring and Assessment*. 2022 May;194(5):324.
- [8]. U.S. Environmental Protection Agency. Air Quality Index (AQI) Basics. 2021. Retrieved from <https://www.epa.gov/aqi/aqi-basics>.
- [9]. Olorunfemi, M. O., & Fawale, A. Influence of meteorological parameters on seasonal variations of air quality indices in urban and rural areas of Nigeria. *Journal of Environmental Management*. 2018; 223, 137-148.
- [10]. Efe, S. O., & Eshiet, A. U. (2019). Seasonal variation of air quality index in a coastal city: The case of Port Harcourt, Nigeria. *Journal of Environmental Protection*. 2019; 10(8), 1035-1047.
- [11]. Igbinsola, E. O., Igbinsola, O. I., & Osazee, S. Air quality assessment and public health implications in Port Harcourt Metropolis, Nigeria. *Environmental Monitoring and Assessment*. 2021; 193(6), 1-14.
- [12]. Nwachukwu, C., & Okorie, U. A Comprehensive Study of Air Quality and Seasonal Trends in Port Harcourt, Nigeria. *International Journal of Environmental Science and Technology*. 2021; 18(3), 849-861.
- [13]. Eke, N. A., Nwankwo, G. I., & Iwuoha, G. I. (2019). Seasonal Variation of Air Quality Index and its Implications in Urban Areas of Nigeria: A Case Study of Port Harcourt. *Nigerian Journal of Science and Environment*, 18(2), 55-64.
- [14]. Xu W, Tian Y, Liu Y, Zhao B, Liu Y, Zhang X. Understanding the spatial-temporal patterns and influential factors on air quality index: The case of north China. *International Journal of Environmental Research and Public Health*. 2019 Aug;16(16):2820.
- [15]. Bai L, Jiang L, Yang DY, Liu YB. Quantifying the spatial heterogeneity influences of natural and socioeconomic factors and their interactions on air pollution using the geographical detector method: A case study of the Yangtze River Economic Belt, China. *Journal of Cleaner Production*. 2019 Sep 20;232:692-704.
- [16]. Han X, Li H, Liu Q, Liu F, Arif A. Analysis of influential factors on air quality from global and local perspectives in China. *Environmental Pollution*. 2019 May 1;248:965-79.
- [17]. Olaniyan, J. A., Ojoye, J., & Uche, I. A. Air Quality Assessment of Urban and Rural Areas in Nigeria: A Case of Port Harcourt Metropolis. *Journal of Environmental Monitoring*. 2022; 24(5), 231-240.
- [18]. World Health Organization. Air Quality Guidelines: Global Update 2021. Geneva: World Health Organization. 2021.

- [19]. Nwachukwu, C., Akpan, E. J., & Ekere, W. Emissions from the oil and gas sector: Impacts on air quality in Port Harcourt, Nigeria. *Environmental Science and Pollution Research*. 2020; 27(10), 11300-11311.
- [20]. Sokhi RS, Moussiopoulos N, Baklanov A, Bartzis J, Coll I, Finardi S, Friedrich R, Geels C, Grönholm T, Halenka T, Ketzel M. Advances in air quality research–current and emerging challenges. *Atmospheric Chemistry and Physics Discussions*. 2021 Sep 23;2021:1-33.
- [21]. Ramírez AS, Ramondt S, Van Bogart K, Perez-Zuniga R. Public awareness of air pollution and health threats: challenges and opportunities for communication strategies to improve environmental health literacy. *Journal of Health Communication*. 2019 Jan 2;24(1):75-83.
- [22]. Nwokorie VC, Bousiotis D, Pope FD. Particulate matter monitoring and source apportionment inside and outside schools in a Global South metropolis. *Environmental Science: Atmospheres*. 2026.
- [23]. Emekwuru N, Ejohwomu O. Temperature, humidity and air pollution relationships during a period of rainy and dry seasons in Lagos, West Africa. *Climate*. 2023 May 21;11(5):113.
- [24]. Al-Thani H, Koç M, Isaifan RJ. A review on the direct effect of particulate atmospheric pollution on materials and its mitigation for sustainable cities and societies. *Environmental science and pollution research*. 2018 Oct;25(28):27839-57.
- [25]. Przybysz A, Sæbø A, Hanslin HM, Gawroński SW. Accumulation of particulate matter and trace elements on vegetation as affected by pollution level, rainfall and the passage of time. *Science of the Total Environment*. 2014 May 15;481:360-9.
- [26]. Wu Y, Liu J, Zhai J, Cong L, Wang Y, Ma W, Zhang Z, Li C. Comparison of dry and wet deposition of particulate matter in near-surface waters during summer. *PloS one*. 2018 Jun 21;13(6):e0199241.
- [27]. Zhang, Z., Wang, H., Chen, D., Li, Q., Thai, P., Gong, D., ... & Wang, B et al. Emission characteristics of volatile organic compounds and their secondary organic aerosol formation potentials from a petroleum refinery in Pearl River Delta, China. *Science of the Total Environment*; 2017; vol. 584, pp. 1162-1174.,
- [28]. Rahma R, Mariana M, Gani A, Sugiarto S, Isya M. Assessing carbon monoxide (CO) emissions from private vehicles: A pathway to cleaner urban mobility. *InIOP Conference Series: Earth and Environmental Science* 2025 Apr 1 (Vol. 1479, No. 1, p. 012001). IOP Publishing.
- [29]. Lamsal LN, Duncan BN, Yoshida Y, Krotkov NA, Pickering KE, Streets DG, Lu Z. US NO₂ trends (2005–2013): EPA Air Quality System (AQS) data versus improved observations from the Ozone Monitoring Instrument (OMI). *Atmospheric Environment*. 2015 Jun 1;110:130-43.
- [30]. Yan R, Liao J, Yang J, Sun W, Nong M, Li F. Multi-hour and multi-site air quality index forecasting in Beijing using CNN, LSTM, CNN-LSTM, and spatiotemporal clustering. *sExpert Systems with Applications*. 2021 May 1;169:114513.
- [31]. Kane RB, Adeyemi A, Edokpa DO, Ede PN. Particulate matter-based air quality index estimate for Abuja, Nigeria: Implications for health. *Journal of Geoscience and Environment Protection*. 2020 May 6;8(5):313-21.