The Impact of Particulate Matter (PM2.5) Pollution on Respiratory Health in Eleme and Port-Harcourt Local Government Areas of Rivers State from 2015-2019

[1]Perri, Tamuno-owunari, [2]Nimi Ngo Briggs, [3]Osadolor Ebhuoma, [4]Ese Ebhuoma

[1]Department of Environmental Management, Rivers State University, Port Harcourt

[2]Department of Obstetrics and Gynecology, Rivers State University Teaching Hospital, Port Harcourt

[3]Geospatial Provincial Centre, Government of Alberta, Edmonton

[4]Department of Life Science, University of Bedfordshire, Luton

DOI: https://doi.org/10.51244/IJRSI.2024.11120031

Received: 03 December 2024; Accepted: 13 December 2024; Published: 10 January 2025

ABSTRACT

Inspired by the noticeable presence of soot in the environment, particularly in the Port Harcourt metropolis, this study sought to examine the correlation between particulate matter (PM2.5) levels and the prevalence of respiratory diseases in the Port Harcourt and Eleme Local Government Areas (LGAs) of Rivers State, Nigeria. The study period spanned from 2016 to 2019, with data on respiratory tract infections (RTIs) obtained from the Rivers State University Teaching Hospital and the General Hospital Ogale, while data were $PM_{2.5}$ are remotely sensed. The RTI and PM2.5 data were analysed using ANOVA and Spearman's rank correlation statistics. The research findings revealed significant variations in $PM_{2.5}$ concentrations across the study areas. During the study period, $PM_{2.5}$ levels consistently exceeded the World Health Organization's (WHO) annual permissible threshold of 10 µg/m³, thereby exacerbating cases of respiratory tract infections (RTIs). The epidemiological profile of RTIs identified four primary diseases: Asthma, Tuberculosis, Pneumonia, and Chronic Obstructive Pulmonary Disease (COPD). The results showed a marked difference in PM2.5 concentrations between the two LGAs. The mean monthly variation from 2016 to 2019 indicated that Port Harcourt recorded a January level of 47.27 µg/m³, while Eleme recorded 47.16 µg/m³. The lowest mean values for both locations occurred in September and October, highlighting a significant seasonal influence on $PM_{2.5}$ concentration. Both $PM_{2.5}$ levels and the incidence of RTIs increased steadily in the study areas from 2016 to 2019. This research underscores the need for regulatory authorities to rigorously monitor the operations of companies potentially contributing to atmospheric pollution, provide clear guidance for compliance, and enforce strict sanctions and substantial fines for violations of established environmental standards to mitigate air pollution.

Key words: Particulate Matter, Respiratory Tract Infection, Air Pollution, Rivers State

INTRODUCTION

Air pollution refers to the presence of harmful gaseous or particulate pollutants in the atmosphere—both indoors and outdoors—that occur at concentrations, durations, and properties detrimental to human, plant, or animal health, or that interfere with the reasonable enjoyment of life and property (Lelieveld, 2023; Mannucci & Franchini, 2017). Clean air is a fundamental necessity for human health and well-being. However, as global economic development progresses, air pollution has become an increasingly significant health risk Fotourehchi, 2016; McGranahan & Murray, 2012). Major contributors to air pollution include urbanization, transportation, and industrial activities, including fossil fuel combustion (Boston University School of Public Health, 2023; Lelieveld, 2023; Usmani, 2020). According to the World Health Organization (WHO, 2017), air

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue XII December 2024

pollution is the leading environmental risk factor, contributing to approximately 3 million deaths globally due to outdoor exposure to atmospheric pollutants.

In 2012, outdoor air pollution was responsible for 94% of the primary environmental health risks, with exposure to such pollution linked to nearly 3 million deaths worldwide. Alarmingly, 94% of these deaths occurred in low- and middle-income countries, such as Nigeria, where non-communicable diseases like lung cancer, chronic obstructive pulmonary disease (COPD), and cardiovascular disorders are major causes of mortality (WHO, 2017).

Particulate matter (PM), a complex mixture of naturally occurring and anthropogenic substances suspended in the atmosphere, is a key air contaminant. PM includes a range of components, such as dust, sulfate, nitrate, organic and elemental carbon, and metals like cadmium, copper, and zinc (Schlesinger, 2007). Among the various types of particulate matter, fine particulate matter ($PM_{2.5}$) poses a particularly critical health risk due to its ability to penetrate deep into the respiratory system and reach the alveolar ducts, where it can cause serious health problems, particularly related to lung function (Sharma et al, 2024). Studies have shown that exposure to $PM_{2.5}$ is associated with a wide range of adverse health effects, including respiratory and cardiovascular diseases, as well as lung cancer (Basith et al, 2022; Sharma et al, 2024). Additionally, the harmful effects of particulate matter are exacerbated by the presence of toxic pollutants, such as polycyclic aromatic hydrocarbons (PAHs), heavy metals, and organic compounds, which can cause localized lung damage (Ostro et al., 1991; Trenga et al., 2006).

In regions such as Port Harcourt and Eleme in Rivers State, Nigeria, air pollution, particularly from industrial activities such as oil and gas extraction, has become an urgent environmental and public health issue (Yakubu, 2017). In Port Harcourt, residents have reported the deposition of black soot on vehicles, as well as an increase in respiratory issues such as wheezing and sneezing, which are commonly associated with exposure to particulate matter (Perri et al., 2022; Yakubu, 2017). The growing concentration of particulate matter, especially PM2.5, in the Niger Delta region is particularly concerning, given its links to a range of health problems, including respiratory diseases and premature mortality (Oladapo et al., 2017; Perri et al., 2022).

Given these concerns, epidemiological studies are essential for assessing the health risks associated with air pollution, as they provide evidence that influences policy formulation, public health decisions, and environmental regulations (WHO, 20018). Recent studies have demonstrated a positive correlation between particulate matter and respiratory diseases in various regions, including the Niger Delta (Perri et al., 2022; Nwachukwu et al., 2012; Yakubu, 2017). In this context, the aim of this research is to investigate the correlation between particulate matter ($PM_{2.5}$) levels and the prevalence of respiratory tract infections (RTIs) in the Port Harcourt and Eleme Local Government Areas (LGAs) of Rivers State, Nigeria. This study seeks to provide valuable insights into the health impacts of air pollution in these regions and to inform the development of public health interventions and regulatory policies aimed at mitigating the effects of air pollution.

Study Area

Port Harcourt is the capital city of Rivers State, which is rich in oil and gas resources. Located in the South-South geopolitical zone, it is part of the Niger Delta region of Nigeria. The city's geographical coordinates are Latitude: 4.77°N (4°46' N) and Longitude: 7.00°E (7° E). Port Harcourt is bounded to the north by Oyigbo Local Government Area (LGA), to the south by Bonny LGA, to the east by Eleme LGA, and to the west by Ikwerre LGA (See Figure 1).

Eleme LGA is situated in the western part of Rivers State, Nigeria, with geographical coordinates of Latitude: 4.7333°N (4°44' N) and Longitude: 7.1667°E (7°10' E). It is one of the most industrialized LGAs in the Niger Delta region, hosting numerous oil and gas companies, as well as fertilizer and marine industries. Notable multinational companies in the area include Indorama Petrochemical and Fertilizer Company, Notore Fertilizer Company, and the Port Harcourt Refinery. Eleme LGA is bordered by Port Harcourt LGA to the north, Oyigbo to the east, Akuku-Toru to the south, and Okrika LGA to the west (See Figure 2).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue XII December 2024

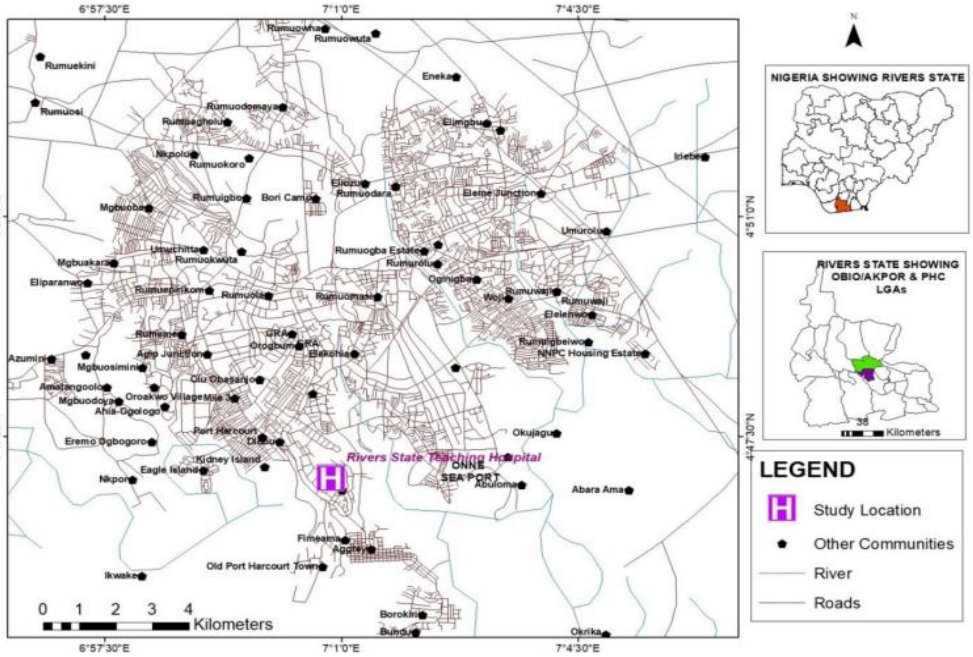

Figure 1: Map showing the location of Rivers State Teaching Hospital, Rivers State, Nigeria

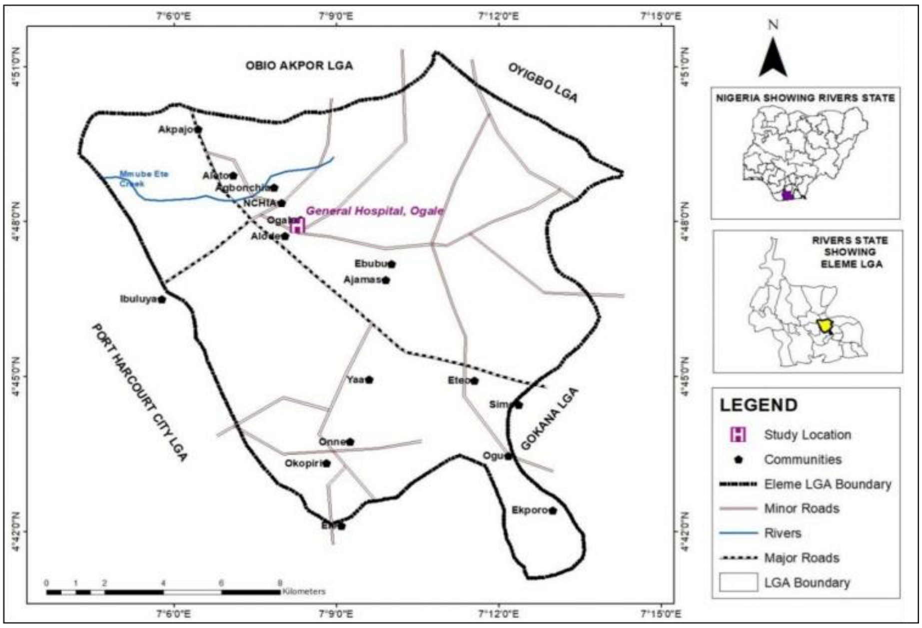

Figure 2: Map showing the location of General Hospital, Ogale, Rivers State, Nigeria

METHODOLOGY

From 2016 to 2019, the monthly PM2.5 particle matter data was obtained using the Satellite- Based Aerosol Optical Depth (AOD) at 550 Nanometres (nm). The justification for employing AOD in the estimation of PM2.5 stemmed from the lack of ground-based data and the high-resolution contemporary re-analysis estimates of PM2.5 on a global scale. Aerosol Optical Depth (AOD) data were collected from January 2016 to December 2019 using the Copernicus Atmosphere Monitoring Service (CAM) Emission of Atmospheric Compound and Compilation of Ancillary Data (ECCAD) website. In order to ensure data quality and consistency, the AOD data is a compilation of gridded monthly emission temporal profiles from anthropogenic pollution sources, such as the energy industry, domestic combustion, manufacturing, road transport, and agricultural. The gridded AOD data, which were provided in an interoperable NETcdf format, were transformed into a raster layer using the ARC GIS 10.1 environment's x,y coordinates to extract numerical values from the sampled sites. The collected numbers are then exported to Microsoft Excel, where the formula in equation (1) is used to calculate the PM2.5 levels.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue XII December 2024

PM2.5 =AOD46.7+7.3. (1)

Where 46.7 and 7.13 are statistical constants for approximation (Weli, 2014b; Zhang and Kondragunta, 2018).

The epidemiological data on RTIs were obtained from individuals treated for airborne diseases at the outpatient clinics of the Rivers State University Teaching Hospital in Port Harcourt and the General Hospital, Ogale in Nchia, Eleme from 2016 to 2019 (See Figures 1 and 2). These hospitals were purposively selected because they are tertiary and secondary health institutions in the study areas, equipped with the necessary facilities and experienced personnel to manage respiratory tract diseases. Additionally, the locations of these hospitals are in modern towns with secondary and tertiary industries, as highlighted in Table 1.

Table1: Counts of Respiratory Tract Infection in Port-Harcourt and Eleme

S/No	Study Area	Health Institution	Patients with Respiratory Disease
1	Port Harcourt	RSUTH, Port-Harcourt	17,000
2	Eleme	General Hospital, Ogale, Nchia	10,144

Data Analysis and Interpretation

Table 2: Monthly Spatio-Temporal Concentration of $PM_{2.5}$ $\mu g/m^3$ in Port-Harcourt and Nchia from 2016 to 2019

	Port Harcourt				Eleme			
Month	**2016**	**2017**	**2018**	**2019**	**2016**	**2017**	**2018**	**2019**
January	52.20	42.80	50.13	43.51	43.30	50.11	52.78	42.98
February	49.60	49.20	41.54	49.59	49.20	41.40	41.58	49.22
March	48.30	33.50	30.58	33.51	30.10	30.16	30.45	33.13
April	40.50	26.80	30.10	27.29	20.10	30.20	29.44	26.62
May	20.30	19.70	20.13	18.44	20.00	20.10	19.65	18.07
June	16.80	19.70	20.10	18.54	20.40	20.20	20.38	19.25
July	17.40	19.30	20.57	18.65	18.00	20.40	20.65	18.83
August	13.80	40.40	18.27	14.40	14.68	18.12	18.23	14.31
September	14.5	15.2	14.4	14.82	13.20	14.60	14.22	14.92
October	14.5	13.4	15.54	13.46	20.50	13.20	15.54	13.24
November	26.4	20.8	22.73	20.90	28.40	20.40	22.65	20.35
December	48.8	29.9	28.77	28.77	30.20	28.55	29.25	29.37

Source: Satellite-based aerosol optical depth at 550nm (2019)

Table 3: Mean Monthly Difference of $PM_{2.5}$($\mu g/m^3$) in Port-Harcourt and Nchiabetween 2016 and 2019

	Port Harcourt		NCHIA		Total Mean
Month	**Min – Max**	**Mean ± SD**	**Min – Max**	**Mean ± SD**	
January	42.16 – 52.03	47.16 ± 4.72	47.27 – 52.88	47.27 ± 4.96	47.22

February	47.43 – 49.50	45.32±49.20	45.32 – 49.20	45.32 ± 4.42	46.37
March	36.47 – 42.80	45.50 ± 4.10	23.37 – 33.03	36.47 ±7.96	33.70
April	31.17 – 40.60	31.17 ± 6.47	29.01 – 30.10	29.02 ± 1.70	30.09
May	19.54 – 20.20	19.54 ± 0.84	19.46 – 20.00	19.46 ± 0.92	19.50
June	18.99 – 20.20	18.99 ± 1.47	19.83 – 20.78	19.83 ±0.47	19.31
July	18.98 – 20.47	18.98 ± 1.23	19.84 – 20.75	19.84 ± 0.86	19.41
August	15.22 – 18.17	15.22 ± 1.98	16.96 – 18.33	16.96 ± 1.83	19.41
September	14.66 – 15.10	14.68 ± 0.39	10.98 – 14.90	14.71 ± 0.27	14.68
October	14.28 – 15.64	14.28 ± 1.07	14.24 – 14.90	14.24 ± 1.25	14.28
November	22.71 – 26.50	22.71 ± 2.71	21.31 – 22.75	21.31 ± 1.08	22.00
December	34.11 – 48.90	34.11 ± 9.87	28.74 – 29.30	28.74 ± 0.69	31.42

Source: Computed from data derived from Satellite-based aerosol optical depth at 550nm (2019)

Table 2 and 3 illustrates that January and February exhibit the highest mean concentrations of Particulate Matter in Port Harcourt, at 47.22µg/m3 and 47.43µg/m3, respectively, while October records the lowest concentration at 14.28µg/m3. The increased levels of particulate matter in the first two months of the year (Jan and Feb) can be ascribed to these months occurring in the dry season, when meteorological effects on particulate matter are minimal. This is corroborated by researchers such as Abali et al. (2018) and Weli and Emenike (2017), who concluded in their respective studies that particulate matter concentrations are predominantly the peak during the dry season, particularly peaking in January and February, with lower concentrations observed in the wet season. The data for Nchia indicates that February exhibits the highest concentration of Particulate Matter at 52.88µg/m3, while the lowest concentration, recorded in September and October, is 14.32µg/m3. Consequently, the mean values for these months are 47.27µg/m3 and 10.98µg/m3, respectively. The elevated concentration may stem from the presence of several companies, including the Port Harcourt refinery, Indorama Petrochemicals and Fertilisers, Notore Fertilisers, and other enterprises located in Nchia and its surroundings.

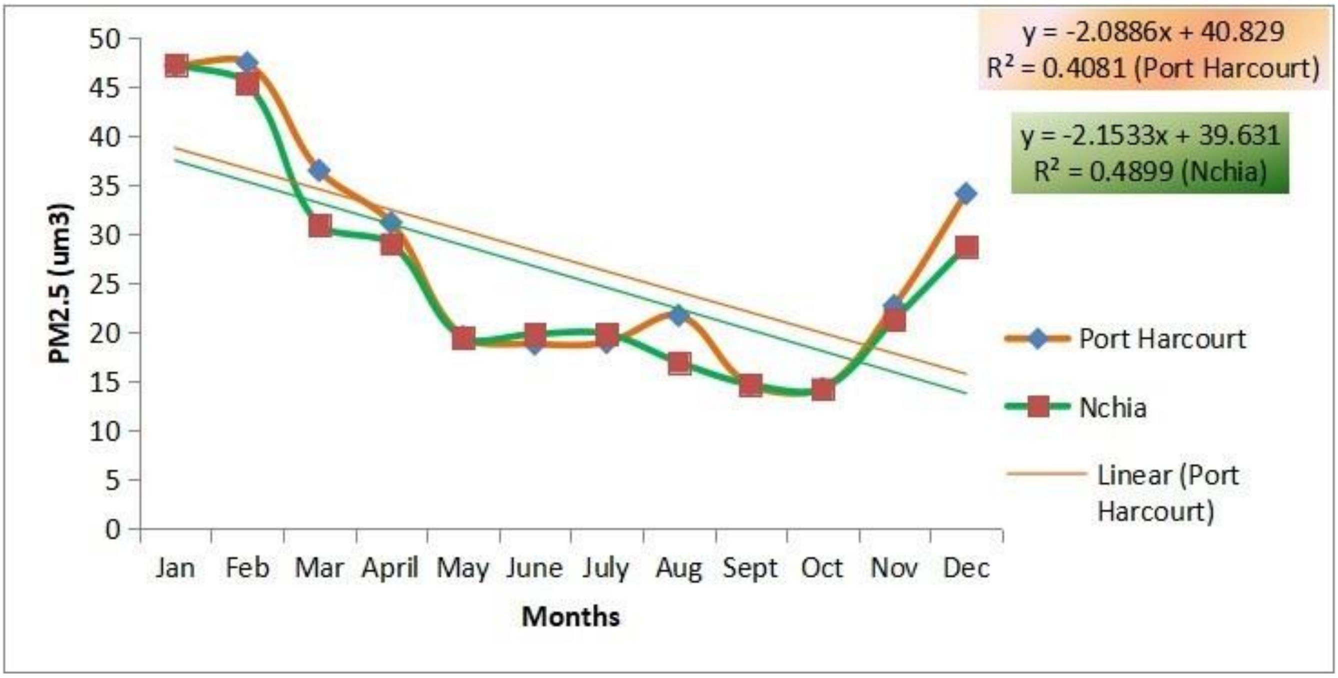

Figure 3: Monthly Average Concentration of $PM_{2.5}$ µg/m^3 in Port Harcourt and Nchia (2016-2019)

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue XII December 2024

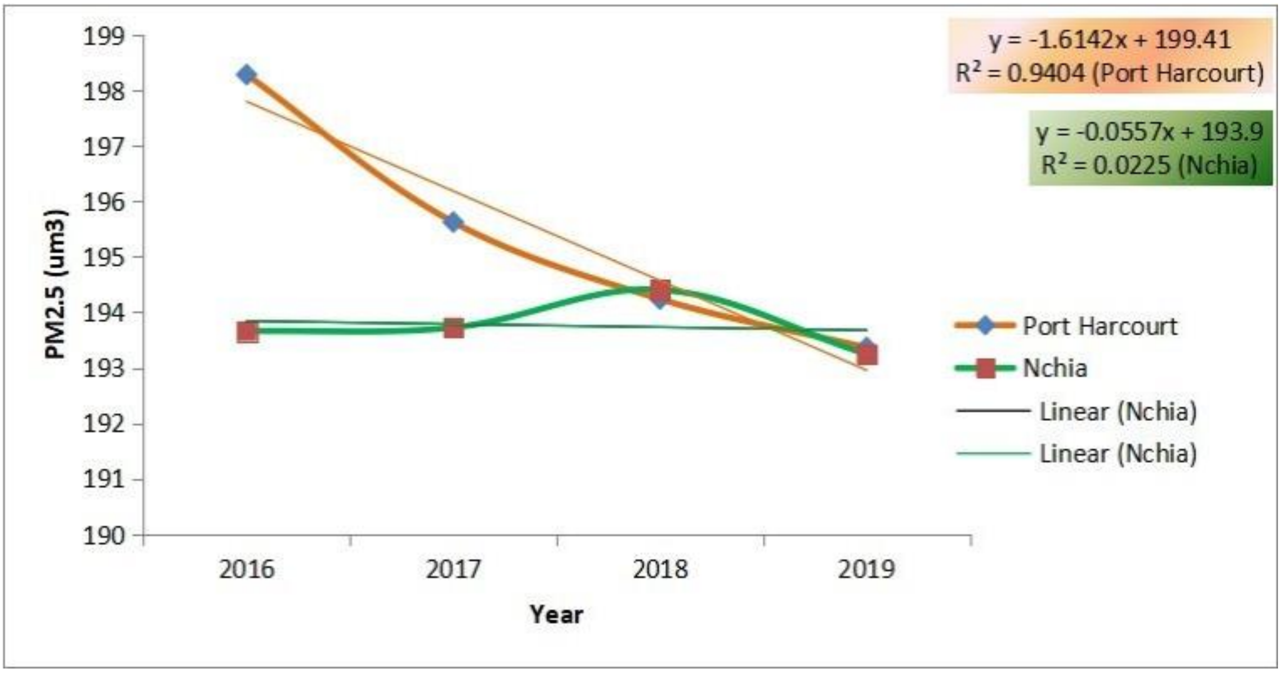

Figure 4: Yearly Mean of $PM_{2.5}$ μg/m^3 in Port Harcourt and Nchia (2016-2019)

In Figure 3, it is observed that the monthly mean trend of $PM_{2.5}$ was decreasing from January to December by 2.09 μg/m^3 in Port Harcourt and 2.15 μg/m^3 in Nchia. The coefficient of determination of $PM_{2.5}$ for the monthly analysis in Port Harcourt was 0.41μg/m^3 and 0.49μg/m^3 in Nchia. The yearly trend analysis of $PM_{2.5}$ in Port Harcourt and Nchia over the years (2016-2019) (Figure 4) were also decreasing by 1.61μg/m^3 and 0.06μg/m^3 respectively; and the coefficient of determination for the yearly trend in Port Harcourt was 0.94μg/m^{3}while that of Nchia was 0.02μg/m^3.

Prevalence of Respiratory Tract Infections in the Port Harcourt and Eleme LGA

Table 4: Summary of RTIs Patients Hospitalized in Eleme and Port Harcourt, 2016.

Diseases	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
COPD	40	126[1]	63	30	21	50	41	77	41	74	26	69	656
Tuberculosis	42	79	51	28	19	21	18	47	14	62	17	51	449
Asthma	58[1]	46	51	48	69	85	42	56	61	48	43	71	678
Pneumonia	295	288	342	376	397	354	455	339[1]	401	325	362[1]	550	4,486

Source: RSUTH and General Hospital Ogale (2019)

Table 4 shows that there was a total of 6,269 patients that needed medical intervention in the two hospitals in 2017 for one form of respiratory tract infections. Pneumonia accounted for 4786 (71.56%) Tuberculosis had 678 (10.82%), Asthma patients accounted for 449(7.16%) and COPD had 656 patients which is 10.46%. Also, table 3 showing the $PM_{2.5}$ concentration reveal that in 2016, Port Harcourt and Nchia has a yearly mean of 27.54μg/m^3 and 25.64μg/m^3 which are far beyond the WHO annual permissible level (WHO, 2012) therefore implying that the two towns are highly polluted with $PM_{2.5}$.

Table 5: Summary of RTIs Patients Hospitalized in Eleme and Port Harcourt in 2017.

Diseases	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
COPD	1142	78	83[1]	76	65	42	38	65	41	107	63	69	841

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue XII December 2024

Asthma	54	48	23[1]	41	57	29	18	73[3]	18	92	52	47	552
Tuberculosis	87	72	49	66	69[1]	32	59	54	65	75	70	61	779
Pneumonia	2351	350	290	393	380	372	4622	472	273	306	353	3471	6,399

Source: RSUTH and General Hospital, Ogale (2019)

Table 5 Indicates that in the year 2018, a total of 6,399 patients presented themselves for treatments of respiratory infection in the two hospitals. 841 (13.14%) were diagnosed of Chronic Obstructive Pulmonary Disease, 779 (12.49%) were treated of tuberculosis while 552 (8.63%) were treated for Asthma and Pneumonia accounted for 4,227 (66.06%). Also, the particulate matter concentration for 2017 in the both LGAs have an annual mean of Port Harcourt (26.07ug/m^3) and Nchia (23.70ug/m^3) which is above the World Health Organization WHO annual mean limit of 10ug/m^3 (WHO, 2012).

Table 6: RTIs Patients Summary Hospitalized in Port Harcourt and Nchia, 2018.

Diseases	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
COPD	43	128[1]	66	32	23	30	34	81[4]	28	75	26	68	634
Asthma	31	18	40[1]	29	17	9	11	21	17	8	13	21	235
Tuberculosis	72[4]	66	57[1]	52	92	91	102	95[2]	84[3]	61	59	68	899
Pneumonia	291[1]	313	325	286	332[3]	501[1]	503[1]	453	596	420[2]	392	265	4,677

Source: RSUTH and General Hospital, Ogale (2019)

Table 6 reveal that in the year 2018 in the Rivers State University Teaching Hospital and the General Hospital Ogale, Nchia 6,445 patients needed medical intervention for one form of respiratory disease. 634 (9.83%) were diagnosed with chronic Obstructive Pulmonary Disease (COPD) which is a respiratory disease of adulthood while Asthma accounted for 233 patients (3.6%), Tuberculosis accounted for 899 patient (13.95%) and Pneumonia patients were 4,677 patients (72.57%).

Table 7: Summary of RTIs Patients in Hospitals admitted in Port Harcourt and Nchia, 2019.

Disease	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
COPD	85[1]	69[1]	68	72	54	42	71	66	46	30	41	14	658
Asthma	71[1]	62	59	48	50	69	37	48	29	41	59	82	657
Tuberculosis	75	49	71	69[1]	80	72	125	53	64	57	82	76	873
Pneumonia	319	406	335	467	478	681	463	669	704	462	448	411	5,843

Source: RSUTH and General Hospital, Ogale (2019)

Table 7 review a record of 8,031 patients in 2019 seeking medical intervention for one form of respiratory tract infection. 658 (8.19%) were treated for COPD, 657 (8.18%) treated for Asthma, while 837 (10.87%) were for tuberculosis and 5,843 (72.76%) were treated for Pneumonia.

Table 8: Summation of RTIs Patients in the Study Area from 2016-2019.

YEAR	COPD	ASTHMA	TUBERCULOSIS	PNEUMONIA	TOTAL
2016	842	553	778	4,226	5,699

2017	657	448	677	4,488	6,270
2018	635	234	898	4,878	6,645
2019	656	874	874	5844	8,248
TOTAL	**2,782**	**2,109**	**3,227**	**19,436**	**26,862**

Source: RSUTH and General Hospital, Ogale (2019)

Table 8 presents the incidence of various forms of respiratory tract infections from 2016 to 2019 across the two hospitals, encompassing a total of 26,862 patients during the specified years. Pneumonia accounted for 19,436 cases, representing 70.86%, followed by tuberculosis with 3,227 cases (11.89%). Chronic obstructive pulmonary disease (COPD) comprised 2,782 cases (10.27%), while asthma had the fewest cases at 2,109 (6.97%) during the review period from 2016 to 2019.

The research findings demonstrate that increased concentrations of $PM_{2.5}$ in Port Harcourt and Eleme correlate with a greater prevalence of respiratory diseases in these areas. The research by Tam et al. (2014), which looked into the connection between air pollution and outpatient clinic visits for upper respiratory tract infections in Hong Kong, supports this finding. Significant relationships were found between the frequency of respiratory tract infection consultations per day and air pollution levels, particularly PM2.5. These findings imply that high concentration of particulate has a significant impact on morbidity and increases the burden on primary care services. Sinclair and Tolsma (2004) identified a weak yet significant correlation between particulate matter and asthma.

Zhang and Kondragunta (2018) found a correlation between higher levels of PM2.5 and more visits to emergency rooms and outpatient clinics for respiratory conditions. Conversely, Weli and Emeneke (2017) asserted that residents of Port Harcourt, particularly those with respiratory conditions such as COPD, should not be permitted to spend extended periods or reside in areas with high $PM_{2.5}$ exposure. Table 8 illustrates the incidence of various forms 26,862 of RTIs from 2016 to 2019 in the two purposively selected government hospitals, encompassing a total of patients during the specified years. Pneumonia accounted for 19,436 cases, representing 70.86%, followed by tuberculosis with 3,227 cases (11.89%). Chronic obstructive pulmonary disease (COPD) comprised 2,782 cases (10.27%), while asthma had the fewest cases at 1,893 (6.97%) during the review period from 2016 to 2019. Tables 2 and 3 indicate that Port Harcourt and Nchia exhibited PM concentrations exceeding WHO standards during the investigated period, potentially resulting in adverse health issues, such as infections of the respiratory tract, as Table 8 illustrates. These results are consistent with those of other studies, such as Sinclair & Tolsma (2004) and Weli (2014). The pollution in Port Harcourt and Nchia arises from diverse mixed pollutants, and the synergistic interaction of particulate matter with other pollutants can result in severe health repercussions, especially respiratory ailments. This finding is supported by research conducted by Nwokocha et al., (2015), which names whooping cough, pneumonia, and pulmonary tuberculosis as health impacts of air pollution. According to Ciencewicki et al., 2007), there may be a connection between air pollution and unfavourable health consequences, especially respiratory disorders.

The distribution of particulate matter ($PM_{2.5}$) in the two cities under study differs significantly, as the ANOVA table shows. For the intercity and intracity comparisons, the F- ratio statistic is 2.056, and the p-value is 0.002, which is less significant than the 0.05 (5%) cutoff. Port Harcourt city is indicated by the descriptive data that this analysis produced (2016).

Table 9: One-Way ANOVA Table Summary

Sources of Variance	Sum of Square	DF	F-Ratio Calculated	F-Ratio Table	Alpha level	Result	Decision
BSS WSS	770.332 69.667	242 45	2.056	0.002	0.005	Significant	H_o Rejected
Total	840.000	287					

Table 10: Summary Spearman's Rank Correlation Statistics

		Port-Harcourt	Eleme
COPD	CorrelationCoefficient	0.400	-0.400
	Sig. (2-tailed)	0.600	0.600
	N	4	4
Asthma	CorrelationCoefficient	-0.200	0.000
	Sig. (2-tailed)	0.800	1.000
	N	4	4
Tuberculosis	CorrelationCoefficient	-0.600	0.800
	Sig. (2-tailed)	0.400	0.200
	N	4	4
Pneumonia	CorrelationCoefficient	-1.000	0.800
	Sig. (2-tailed)	0.000	0.200
	N	4	4

According to the Spearman correlation statistics in Table 10, there isn't a meaningful connection between RTIs and PM2.5 in this investigation. Additionally, there was a negative association (r=0.400) between $PM_{2.5}$ and Asthma, Tuberculosis, and Pneumonia, and a positive correlation (r=0.400) with COPD. Pneumonia showed a strong connection (r=1.000).

CONCLUSIONS

In conclusion, this study highlights the temporal trends in $PM_{2.5}$ concentration and respiratory diseases in Port Harcourt and Eleme local government areas in Rivers State. The findings suggest a significant increase in $PM_{2.5}$ concentration over the years, which is positively correlated with the prevalence of respiratory diseases. The study clearly indicates that $PM_{2.5}$ pollution adversely affects the indigents and residents of the study areas. The study has determined that particulate matter ($PM_{2.5}$) significantly exacerbates Respiratory Tract Infections, triggering episodes such as recurrent episodes of asthma in people who are subjected to high environmental particulate matter concentrations.

Urgent action is needed to improve air quality in these areas and protect the health of residents. It is advisable for government regulatory agencies at multiple levels to collaborate and oversee industrial activities that may result in atmospheric pollution, imposing substantial sanctions and fines on violators when necessary.

REFERENCES

1. Abali, H., Etebu, O. M., & Leton, T. G. (2018). Seasonal particulate pollution in port Harcourt Nigeria. Journal of Environment Pollution and Human Health, 6(1), 20-25.
2. Basith, S., Manavalan, B., Shin, T. H., Park, C. B., Lee, W. S., Kim, J., & Lee, G. (2022). The impact of fine particulate matter 2.5 on the cardiovascular system: a review of the invisible killer. Nanomaterials, 12(15), 2656.
3. Boston University School of Public Health. (2023). Air pollution from oil and gas production contributes to thousands of early deaths and childhood asthma cases nationwide. Boston University. Retrieved from [website URL].
4. Ciencewicki, J., Brighton, L., Wu, W., Madden, M., & Jasper, I. (2007). Diesel exhaust enhances virus

poly (I:C)-induced Toll-like receptor 3 expression and signaling in respiratory epithelial cells. American Journal of Physiology-Lung Cellular and Molecular Physiology, 29(6)

5. Fotourehchi, Z. (2016). Health effects of air pollution: An empirical analysis for developing countries. Atmospheric Pollution Research, 7(1), 201-206.
6. Lelieveld, J. (2023). Global air pollution trends and impacts. Environmental Science & Technology, 57(10), 6425-6432.
7. Mannucci, P. M., & Franchini, M. (2017). Health effects of ambient air pollution in developing countries. International journal of environmental research and public health, 14(9), 1048.
8. McGranahan, G., & Murray, F. (Eds.). (2012). Air pollution and health in rapidly developing countries. Routledge.
9. Nagar, J. K., Akolkar, A. B., & Kumar, R. (2014). A review on airborne particulate matter and its sources, chemical composition and impact on human respiratory system. International Journal of Environmental Sciences, 5(2), 447-463.
10. Nwachukwu, A. N., Chukwuocha, E. O., & Igbudu, O. A. (2012). A survey on the effects of air pollution on disease of the people of Rivers State, Nigeria. African Journal of Environmental Science and Technology, 16(10), 371–379.
11. Nwokocha, C. O., Edebeatu, C. C., & Okujagu, C. U. (2015). Measuring survey and assessment of air quality in Port Harcourt, South-South Nigeria. International Journal of Advanced Research in Physical Science, 2, 19–25.
12. Oladapo, M. A., Idokiari, B., & Obunwo, C. C. (2017). Assessment of particulate matter-based air quality index in Port Harcourt, Nigeria. Journal of Environmental Analytical Chemistry, 4(4), 224.
13. Ostro, B. D., Lipsett, M. J., & Mann, J. K. (1991). Ambient air pollution and hospitalization for respiratory causes in Minneapolis-St Paul and Birmingham. Epidemiology, 8, 364–370.
14. Perri, T. O., Weli, V. E., Poronakie, B., & Bodo, T. (2022). Distribution of Respiratory Tract Infectious Diseases in Relation to Particulate Matter (PM2. 5) Concentration in Selected Urban Centres in Niger Delta Region of Nigeria. Journal of Geographical Research, 5(1), 1-11.
15. Schlesinger, R. B. (2007). The health impact of common inorganic components of fine particulate matter (PM2. 5) in ambient air: a critical review. Inhalation toxicology, 19(10), 811-832.
16. Sharma, R., Kurmi, O. P., Hariprasad, P., & Tyagi, S. K. (2024). Health implications due to exposure to fine and ultra-fine particulate matters: a short review. International Journal of Ambient Energy, 45(1), 2314256.
17. Sinclair, A. M., & Tolsma, D. (2004). Association and lags between air pollution and acute respiratory visits in ambulatory care settings: 25-month result from the aerosol research and inhalation epidemiological study. Journal of the Air and Waste Management Association, 54(9), 1212–1218.
18. Tam, W. W., Wong, T. W., Ng, L., Wong, S. Y., Kung, K. K., & Wong, A. H. (2014). Association between air pollution and general outpatient clinic consultations for upper respiratory tract infections in Hong Kong. PLoS One, 9(1), e86913.
19. Trenga, C. A., Sullivan, J. H., Schildcrout, J. S., Shepherd, K. P., Kaufman, J. D., & Koenig, J. E. (2006). Effects of particulate air pollution on lungs functions in adult and pediatric subjects in a Seattle panel study. American Journal of Respiratory and Critical Care Medicine, 129(12), 1614–1622.
20. Usmani, R. S. A., Saeed, A., Abdullahi, A. M., Pillai, T. R., Jhanjhi, N. Z., & Hashem, I. A. T. (2020). Air pollution and its health impacts in Malaysia: a review. Air Quality, Atmosphere & Health, 13, 1093-1118.
21. Weli, V. E. (2014). Spatial and seasonal influence of meteorological parameters on the concentration of suspended particulate matter in the industrial city of Port Harcourt, Nigeria. Journal of Developing Country Studies, 4(10), 1–10.
22. Weli, V. E., & Emenike, G. C. (2017). Atmospheric aerosol loading over the urban canopy of Port Harcourt city and its implication for the incidence of obstructive pulmonary diseases. International Journal of Environment and Pollution Research, 5(1), 52–69.
23. World Health Organization (WHO) Global Health Observatory. (2012). Recent data on air quality.
24. World Health Organization (WHO) Regional Office for Europe. (2017). Health relevance of particulate matter from various sources: Report on a WHO workshop. WHO.
25. World Health Organization (WHO). (2018). Preventing disease through healthy environments: A

global assessment of the burden of disease from environmental risk. World Health Organization. Retrieved from https://www.who.int/publications/i/item/9789241565196

26. Yakubu, O. H. (2017). Particle (soot) pollution in Port Harcourt Rivers State, Nigeria—double air pollution burden? Understanding and tackling potential environmental public health impacts. Environments, 5(1), 2.
27. Zhang, H., & Kondragunta, S. (2018). Daily and hourly surface PM2.5 estimation from satellite AOD. Earth and Space Science, 5(1), 1–10.