BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Journal of Geographical Research
https://ojs.bilpublishing.com/index.php/jgr

ARTICLE

Distribution of Respiratory Tract Infectious Diseases in Relation to Particulate Matter ($PM_{2.5}$) Concentration in Selected Urban Centres in Niger Delta Region of Nigeria

Tamuno-owunari Perri[1*] Vincent Ezikornwor Weli[2] Bright Poronakie[1] Tombari Bodo[3]

1. Department of Geography and Environmental Studies, Ignatius Ajuru University of Education, Rumulumini, Rivers state, Nigeria
2. Department of Geography and Environmental Management, University of Port Harcourt, Nigeria
3. Department of Flood, Erosion Control and Coastal Zone Management, Rivers State Ministry of Environment, Rivers State, Nigeria

ARTICLE INFO

Article history
Received: 13 September 2021
Revised: 01 November 2021
Accepted: 09 November 2021
Published Online: 01 December 2021

Keywords:
Soot
Particulate matter and respiratory tract infections
Diseases

ABSTRACT

Due to the visibility of soot in the environment of the Niger Delta especially Rivers State has led to the increase of Respiratory Tract Infections (RTIs) in the region, this study was undertaken to determine the relationship between Particulate Matter ($PM_{2.5}$) concentration and the incident of Respiratory Tract Infections (RTIs) in selected urban centres of the Niger Delta. Data on RTIs were collected from the Hospital Management Boards of the Ministries of Health of Rivers, Bayelsa and Delta States and the data for $PM_{2.5}$ were remotely sensed from 2016 to 2019, and subsequently analyzed with ANOVA and Spearman's rank correlation statistics. The findings of this study revealed that there was significant variation in the occurrence of $PM_{2.5}$ across the selected urban centres in the Niger Delta Region. The $PM_{2.5}$ for the reviewed years was far above the World Health Organization's (WHO) annual permissible limit of 10 $\mu g/m^3$ thereby exacerbating Respiratory Tract Infections (RTIs). The epidemiology of the RTIs showed that there are basically four (4) prominent RTI diseases: Asthma, Tuberculosis, Pneumonia and Chronic Obstructive Pulmonary Disease (COPD). The result of this study showed that the concentration of $PM_{2.5}$ varies in all the selected cities, and the mean monthly variation (2016-2019) showed that Port Harcourt had 47.27 $\mu g/m^3$ for January while Yenagoa and Asaba had 46 $\mu g/m^3$ and 47.51 $\mu g/m^3$ respectively for January; while the lowest mean value in the cities was seen within the month of September and October, which also had a strong seasonal influence on the concentration of $PM_{2.5}$. The concentration of $PM_{2.5}$ and the number of RTIs also gradually increases in the study areas from 2016 to 2019. The study recommends that the necessary regulatory bodies should closely monitor the activities of the companies likely to cause such pollution; guild them through their operations and give prompt sanctions and heavy fines to defaulters of the accepted standards.

*Corresponding Author:
Tamuno-owunari Perri,
Department of Geography and Environmental Studies, Ignatius Ajuru University of Education, Rumulumini, Rivers state, Nigeria;
Email: tombarib@gmail.com

DOI: https://doi.org/10.30564/jgr.v5i1.3710

1. Introduction

The atmosphere is the gaseous envelope that surrounds the earth and makes the transition between its surface and the vacuum of space [1,12]. Unfortunately, the atmosphere also contains pollutants that affect health [8]. Pollution is generally the introduction by mankind into the environment substances liable to cause hazards to human health, harm to the living organism and ecological system [1,9], damage to the structure or interfere with the legitimate uses of the environment [32,34,35]. Air pollution is on the increase especially in highly urbanized and industrialized cities [4,16,25]. The major air pollutants in the urban environment includes: oxides of sulphur (SO_2, SO_x); Oxides of nitrogen (NOx); carbon monoxide (CO); volatile organic compounds (VOCs); ozone (O_3); suspended Particulate Matter ($PM_{2.5}$ and PM_{10}) and Lead (Pb) [22,31]. Air pollutants can be in the form of solid particles, liquid droplets, or gases [32,36]. In addition, they may be natural or anthropogenic [19].

Particulate Matter is a complex combination of anthropogenic and biophysical materials suspended as aerosol particles in the atmosphere with major constituents like sulphate, nitrate, ammonium, organic carbon, elemental carbon, sea salt, and dust. Particulate Matter is a major air pollutant and includes all solid particles, soot and lead [23,30,37]. In other words, it is a combination of varying physical and chemical characteristics varying by location. Common chemical constituents of Particulate Matter include sulphate, nitrate, ammonium, other inorganic ions like ions of sodium, potassium, calcium, magnesium and chloride, organic and elemental carbon, crustal materials, particle-bound water, metals (including cadmium, copper, nickel, vanadium, and zinc) and polycyclic aromatic hydrocarbons (PAH) [38,39,40]. Fine Particulate Matter has become a major public health concern because of their adverse health effects [7] and the lungs are considered to be the primary or main organ affected, as $PM_{2.5}$ can penetrate deep into the respiratory tract and reach the alveoli ducts.

The health effect of air pollution on humans includes carcinogenicity, pulmonary tuberculosis, cerebrospinal meningitis, pneumonia, whooping cough and measles [8,9]. Particulate Matter can also comprise toxic pollutants, such as heavy metals, polycyclic aromatic hydrocarbons (PAHs), and other particle-bound organic compounds, which may be responsible for activating local lung damage particularly when the particles deposit on the epithelial surfaces [24]. Bio-distribution studies suggest translocations of Particulate Matter from the respiratory system to other organs including the liver, heart and central nervous system, which can cause serious health effects [1,28].

Based on known health effects, both short-term (24-hour) and long-term (annual mean) guidelines were provided by the World Health Organisation (WHO) for $PM_{2.5}$ and PM_{10} pollutions as shown in Table 1a below, with $PM_{2.5}$ value preferred for usage over PM_{10} [49,50].

Table 1a. WHO Air Quality Guidelines and Interim Targets for Particulate Matter: Annual Mean Concentrations

	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	Basis for the selected level
Interim target-1 (IT-1)	70	35	These levels are associated with about a 15% higher long-term mortality risk relative to the AQG level.
Interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower the risk of premature mortality by approximately 6% [2–11%] relative to theIT-1 level.
Interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce the mortality risk by approximately 6% [2-11%] relative to the -IT-2 level.
Air quality guideline (AQG)	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to $PM_{2.5}$.

Source: WHO, 2006.

One of the major environmental problems facing the Niger Delta area is air pollution consequent on complex industrial activities such as oil and gas exploitation and flaring [5,25]. There have been complaints by the city dwellers about black particles settling on their cars and black dirt in their nostrils when cleaned up with a handkerchief in which cloths got stained, and a high rate of respiratory problems leading to wheezing and sneezing [9,10]. The rapid rate of urbanization in the Niger Delta Region through various activities such as industrialization, on-going construction works and vehicular movements have led to the constant discharge of dangerous pollutants into the atmosphere without taking proper protection and good operational methods as approved by the relevant authorities [4,15]. This implies that ambient air quality is one of the key environmental problems experienced by the inhabitants of towns and villages in the Niger Delta Region. In recent times, the occurrence of pollutants in the air space of the Niger Delta Region of Nigeria and beyond has been very worrisome because of natural and man induced changes and transformation without regard to its consequences on people wellbeing [22,44,45].

In the Niger Delta region, anthropogenic activities such as bush burning, refuse burning, traffic emission, industrial emission, chemical fertilizers industry, refinery and petrochemical complexes, gas flaring and pipeline explosion release a barrage of substances including Particulate Matter which pollute the atmosphere and have local and regional effects on materials and artefacts [12,44]. In a research on the contamination and health risk assessment of particulate matter in Uyo; it was reported that there was no significant contamination of the particulate matter and measurable health risk associated with particulate matter at the time of the study but suggest continued monitoring as urbanization and population increases in the city [18].

Many studies have been conducted on Particulate Matter (PM) pollutants generation, concentration, spread and its effects in the region [10,11,14]; however, the missing link in these studies is the dearth of research on the spatial pattern of Particulate Matter pollution and the emergence of Respiratory Tract Infectious diseases in specific selected urban centres of the Niger Delta Region. Existing literature shows pieces of evidence of pollution-related diseases but the extent of spread and distribution in specific cities and the consequent health impact as it concerns Respiratory Tract Infections (RTIs) in the region is lacking. This study is focus on determining the distribution of Particulate Matter (PM) in the specific urban centres of Port Harcourt, Nchia, Yenagoa, Brass, Asaba and Effurun; looking at the correlation between PM concentration and the incidence of Respiratory Tract Infections (RTIs) in these selected urban centres.

2. Study Area

The Niger Delta is the home to about 31 million people, which is defined officially by the Nigerian government to cover over about 70,000 km^2 (27,000 sq mi) and makes up 7.5% of Nigeria's land mass [4]. It is typically considered to be located within nine coastal southern Nigerian states, which include: all six states from the South-South zone, one state (Ondo) from the South-West and two states (Abia and Imo) from the South-East; and of all the states that the region covers, only Cross River State is not an oil-producing state [3]. The Niger Delta lies between latitudes 4^0 and 6^0 north of the equator and longitudes 5^0 and 9^0 east of the Greenwich Meridian [42, 45].

In this study, Port Harcourt, Nchia, Yenagoa, Brass, Asaba and Effurn were purposively selected from the three Niger Delta States of Rivers, Bayelsa and Delta States. The urban centres (Port Harcourt, Yenagoa and Asaba) were selected because of their status as state capitals and the other three urban centres (Nchia, Brass and Effurun) are oil-bearing communities.

3. Methodology

The monthly Particulate Matter ($PM_{2.5}$) data covering 2016 to December 2019 were derived from the Satellite-Based Aerosol Optical Depth (AOD) at 550 Nanometer

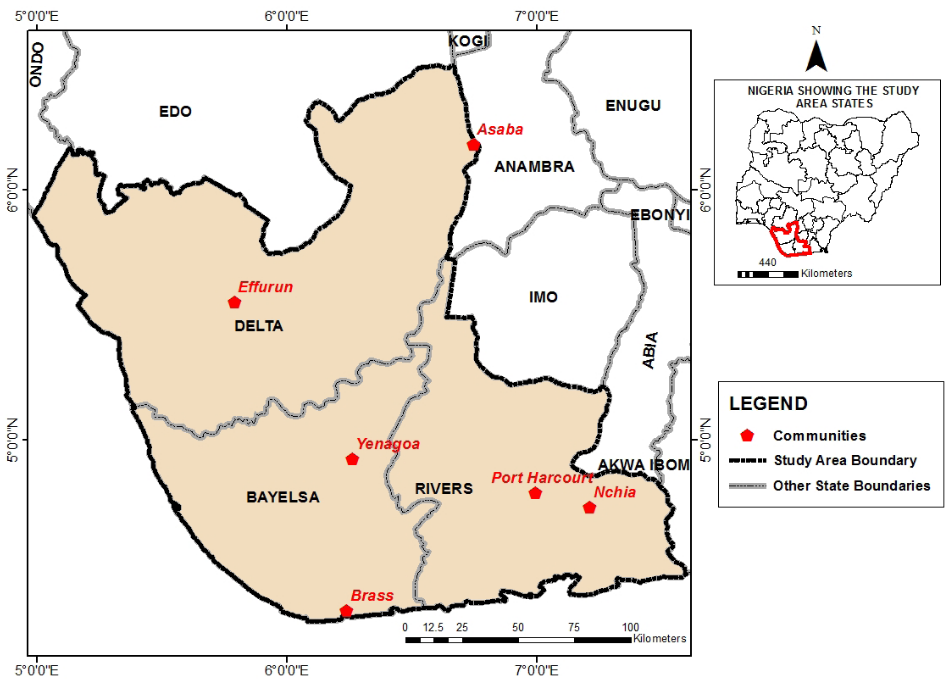

Figure 1. A Section of the Map of Nigeria showing the Study Locations (Source: Fieldwork, 2020)

(nm). The rationale for using AOD in deriving $PM_{2.5}$ was due to the unavailability of ground-based data as well as fine resolution current reanalysis estimate of $PM_{2.5}$ at the global level [6,7]. Thus, the AOD covering January 2016 to December 2019 was sourced from the Copernnicus Atmosphere Monitoring Service (CAM) Emission of Atmospheric Compound and Compilation of Ancillary Data (ECCAD) website. The AOD data consists of a collection of gridded monthly emission temporal profiles from anthropogenic pollution sources categories namely energy industry, residential combustion, manufacturing industry, road transport and agriculture with guaranteed data quality and consistency [47].

The griddled AOD data which came in interoperable NETcdf format were converted to a raster layer and numerical values were extracted with the aid of x,y coordinates of the sampled locations in ARC GIS 10.1 environment. The extracted values are subsequently exported into Microsoft Excel where the $PM_{2.5}$ were computed using the formula in Equation (1).

$$PM_{2.5}=AOD*46.7+7.3 \quad (1)$$

Where 46.7 and 7.13 are statistical constants for approximation [34,46].

For RTIs

The research covers 4 years (2016-2019) in selected cities of Bayelsa, Delta and Rivers states. Epidemiological data of those treated for air-borne related diseases in the respiratory clinic of government hospitals for 2016, 2017, 2018 and 2019 were collected from the health management board of each of the state Ministry of Health in the states, of which the chosen towns (Port Harcourt, Nchia, Yenagoa, Brass, Asaba and Effurun) were purposively selected because they are urban towns with industrial activities as shown on Table 1b.

4. Data Analysis and Interpretation

Table 2 shows the value of $PM_{2.5}$ in each month for the years under study for the selected urban cities in the Niger Delta States. The tables for the years (2016-2019) revealed that January has the highest concentration level followed by February in all the six selected cities and October has the least value for concentration in all the selected cities too. Seasonality must have played a major part in the trend of $PM_{2.5}$ concentration because January and February are within the dry season. The selected urban cities in Rivers state have the highest concentration in most the months of the year; this might be a result of its high industrialization status, urbanization and high population density as compared to the selected cities in Bayelsa and Delta States.

As seen in Table 3, January and February have the highest mean value of 42.16 μg/m^3 and 47.43 μg/m^3 respectively indicating the concentration of Particulate Matter for the city of Port Harcourt while October with a minimum value of 14.28 μg/m^3 has the lowest data. This high level of concentration of particulate matter in January and February might be a result of the fact that these months are within the dry season where meteorological impacts on the particulate matter is minimal as corroborated by Weli and Emenike [33]. Also, the column for Nchia shows that January and February over the years (2016-2019) have the highest concentration level of Particulate Matter while its lowest concentration falls within August and September. The very high concentration in those months might be a result of the increased gas flaring activities during the dry season by the multiple companies such as the Port Harcourt refinery, Indorama petrochemicals and Notore fertilizers situated in Nchia; and the PM concentration was relatively low during in the August and September during the dry season for the years under review.

Table 2 and table 3 prove that the three states of the Niger Delta are all burdened with high particulate matter concentration which is above the Department of Petroleum Resources (DPR) and World Health Organisation (WHO) annual permissible limits. The months of January and February still have the highest concentration level with maximum concentrations of 53.64 μg/m^3 and 43.00 μg/m^3 respectively while the least concentration level months are September and October with values of 13.40 μg/m^3. The particulate matter concentration in the six selected cities of the Niger Delta states of Rivers, Bayelsa and Delta has shown similar trends where the highest concentration level is found in January and February while the lowest concentration levels are also seen in the months of September and October of the years under review (2016-2019). This trend aligned with previous studies undertaken in other parts of the world and also in Nigeria [16,17,33]. All these studies show the relationship between seasonality and atmospheric pollutants which particulate matter is a major contributor. They all proved meteorological effects and seasonality impacts on the concentration levels of the pollutants of the six cities studied in the Niger Delta where the concentration is at its peak in January and February while the lowest concentration was recorded in September and October in the studied years of 2016-2019.

Table 4 shows the 2016 particulate matter pollution amongst the selected six centres of the Niger Delta States

Table1b. Sample Size of Respiratory Tract Infection Patients in the State of the Niger Delta.

S/NO	Niger Delta States	Sampled Cities	Sampled Health Institutions	Sampled Respiratory Disease patients	Total Cases
1	Delta	Asaba	FMC, Asaba	6,001	12,341
		Effurum	General Hospital, Effurum	6,340	
2	Bayelsa	Yenagoa	FMC,Yenagoa	5,175	10,275
		Brass	General Hospital , Brass	5,100	
3	Rivers	Port Harcourt	RSUTH, Port Harcourt	17,000	27,144
		Nchia	General Hospital ,Nchia	10,144	

Source: Fieldwork, 2020

Table 2. Spatio-Temporal Concentration of $PM_{2.5}$ in the selected urban centre of the Niger Delta.

2016.

Cities	Jan	Feb	March	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Harcourt	52.30	49.50	48.20	40.60	20.20	16.90	17.50	13.90	14.30	14.60	26.50	48.90
Nchia	43.20	49.10	30.20	20.00	20.10	20.30	18.02	14.70	13.10	20.60	28.50	30.10
Yenagoa	41.75	47.86	32.10	26.60	17.10	17.50	18.20	13.06	13.67	12.21	19.60	27.70
Brass	50.22	38.90	27.10	25.70	17.40	18.90	19.60	17.40	12.70	12.50	19.70	27.90
Asaba	52.50	42.60	31.60	35.10	24.10	21.70	17.10	15.60	13.40	16.40	21.60	24.10
Effurun	52.40	40.10	29.40	31.80	23.10	21.01	18.10	17.90	13.40	17.50	21.90	28.90

Source: Satellite-based Aerosol Optical Depth at 550nm (2019).

2017.

Cities	Jan	Feb	March	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Harcourt	42.90	49.10	33.60	26.70	19.60	19.80	19.20	40.50	15.10	13.50	20.70	29.80
Nchia	50.01	41.50	30.26	30.10	20.00	20.10	20.30	18.02	14.70	13.10	20.60	28.50
Yenagoa	50.40	45.60	30.70	24.40	16.70	15.40	16.10	11.10	11.40	10.80	17.42	25.80
Brass	40.70	46.70	32.10	26.10	18.10	19.70	21.02	15.70	14.80	12.90	19.70	28.40
Asaba	42.30	48.10	35.70	31,40	21.10	19.10	17.60	14.65	15.80	14.90	21.20	26.10
Effurun	43.00	50.70	34.50	32.10	20.40	19.10	18.60	15.30	14.51	13.40	22.20	28.80

Source: Satellite-based Aerosol Optical Depth at 550nm (2019).

2018.

Cities	Jan	Feb	March	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Harcourt	50.03	41.64	30.48	30.20	20.03	20.20	20.47	18.17	14.30	15.64	22.83	28.87
Nchia	52.88	41.48	30.25	29.34	19.75	20.28	20.75	18.33	14.32	15.44	22.75	29.30
Yenagoa	52.76	40.82	29.54	31.27	20.10	20.00	20.28	18.50	14.08	15.41	22.50	28.60
Brass	51.42	39.86	28.04	27.95	19.04	20.13	21.65	19.74	14.25	14.55	21.85	29.55
Asaba	51.74	41.74	32.71	36.10	24.48	20.62	18.48	16.87	14.55	17.54	22.51	25.74
Effurun	53.64	41.33	31.47	34.84	21.31	20.35	19.32	17.88	14.34	16.47	22.90	27.74

Source: Satellite-based Aerosol Optical Depth at 550nm (2019).

2019.

Cities	Jan	Feb	March	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Harcourt	43.41	49.49	33.61	27.19	18.34	18.34	18.75	14.30	14.92	13.36	20.80	28.87
Nchia	42.99	49.20	33.03	26.52	18.09	19.22	18.81	14.32	14.90	13.22	20.37	29.30
Yenagoa	42.85	48.96	33.28	27.71	18.29	18.75	19.31	14.08	14.97	13.31	20.78	28.60
Brass	41.08	47.14	30.89	25.19	17.27	19.86	20.23	14.25	15.16	18.88	19.20	29.55
Asaba	43.84	50.04	36.61	33.34	20.47	18.05	18.62	14.55	15.76	14.61	20.96	25.74
Effurun	44.00	50.68	35.55	31.19	19.46	18.32	19.16	14.34	15.51	14.04	21.19	27.74

Source: Satellite-based Aerosol Optical Depth at 550nm (2019).

Table 3. Mean Monthly of $PM_{2.5}$ μg/m^3 across the selected urban centres of the Niger Delta (2016-2019).

Months	Yenagoa and Brass	Asaba and Effurun	Port-Harcourt and Nchia
Jan	46.39	47.88	47.22
Feb	44.48	45.65	46.37
March	30.47	33.44	33.70
April	26.87	33.23	30.09
May	18.00	21.80	19.50
June	18.78	19.78	19.31
July	19.55	18.37	19.41
Aug	15.48	18.37	19.41
Sept	13.88	14.66	14.68
Oct	13.07	15.60	14.26
Nov	20.09	21.80	22.00
Dec	28.26	26.86	31.42

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

Table 4. Temporal Variation of $PM_{2.5}$ within the six centres in the Study Area between 2016 – 2019

	2016		**2017**		**2018**		**2019**	
STUDY LOCATION	MIN – MAX	MEAN ± SD	MIN – MAX	MEAN ± SD	MIN – MAX	MEAN ± SD	MIN – MAX	MEAN ± SD
BRASS	12.50 -50.38	21.28 ± 54.12	12.90 – 46.70	24.66 ± 35.42	14.25 – 51.42	25.33 ± 35.79	12.88 -47.14	24.43 ± 36.05
YENEGOA	12.21 – 47.86	23.95 ± 38.45	10.80 – 50.40	22.99 ± 43.93	14.08 – 52.70	26.16 ± 26.48	13.31 – 48.96	25.07 ± 35.47
ASABA	13.40 – 52.50	26.32 ± 39.68	14.65 – 58.01	25.91 ± 37.07	14.55 – 51.74	27.76 ± 38.19	14.55 – 50.04	26.02 ± 38.20
EFFURUN	13.40 – 54.40	24.46 ± 38.90	13.40 – 40.70	26.06 ± 39.63	14.34 – 53.64	26.80 ± 38.77	14.30 - 50.68	26.02 ± 40.19
PORT HARCORT	13.90 -52.60	30.28 ± 53.73	13.50 – 49.10	25.35 ± 4.72	14.30 – 50.03	26.12 ± 36.48	13.22 – 49.20	25.17 ± 38.98
NCHIA	13.10 – 49.10	25.66 ± 36.86	14.90 – 50.01	25.64 ± 30.06	14.90 – 52.88	25.88 ± 38.25	13.20 – 49.20	24.83 ± 38.61

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

of Rivers, Bayelsa and Delta with its maximum and minimum concentration with calculated mean value and standard deviation. The data show that Port Harcourt has the highest concentration level (54.40 μg/m^3) in 2016 among the cities while Yenagoa has the lowest recorded concentration level (12.21 μg/m^3) in 2016. The reasons will not be far-fetched to the level of industrialization, population density and also the number of vehicular movements which all contribute to the level of air pollution in the cities between Port Harcourt and Yenagoa.

Also, the data in table 4 show that in 2017 the city of Yenagoa (10.80 μg/m^3) has the least concentration of particulate matter as compared to Brass (12.90 μg/m^3), Effurun (13.40 μg/m^3), Asaba (14.65 μg/m^3) and Port Harcourt (13.50 μg/m^3) while Nchia had the maximum cumulative concentration of particulate matter in 2017, this might be as a result of the industrial activities of the refinery in Alesa Eleme, the Notore Fertiliser plant and the Eleme petrochemical plants both in Onne and Agbonchia, Aleto and Akpajo. Nchia also hosts multiple marine companies, oil and gas servicing companies plus a population that is overwhelming with its corresponding vehicular movements. The cumulative effect of this pollution in recent times is seen in the occurrences of soot which affected residents of the Niger Delta states especially the Port Harcourt metropolis, with the first observation reported in November 2016.

The wet season is relatively longer, lasts between seven and eight months of the year, i.e. from March/April to October/November. There is usually a short break around August, otherwise termed "August Break" The August break is usually a period of the high sun with a break in precipitation in the middle of the rainy rainfall regimes or double maxima or double peaks. The analyzed data shows that at the onset of the wet season in April the concentration level is still high (180.40) because the effects of precipitation are not fully in effect, the $PM_{2.5}$ concentration begins to reduce till it gets to the peak of the wet season which is September was the concentration gets to its minimum (86.45) and after which it begins to pick up as the dry season set in. This gradual drop in concentration level is due to the washing effects of the rain as vehicular activities and industrial emissions are reduced within this period compared to the dry season.

Table 5. Seasonality of Particulate Matter ($PM_{2.5}$)Pollution in the Study Area

	WET SEASON		DRY SEASON	
STUDY LOCATIONS	MIN – MAX	MEAN ± SD	MIN – MAX	MEAN ± SD
BRASS	17.74 – 19.62	18.34	32.76 – 34.14	33.56
YENEGOA	15.13 – 19.95	17.51	33.80 – 38.84	35.38
ASABA	19.34 – 20.95	20.11	34.48 – 36.09	35.15
EFFURUN	18.86 – 20.64	19.74	34.42 – 35.97	35.20
PORT HARC5URT	16.15 – 21.71	19.03	34.77 – 45.08	37.75
NCHIA	15.90 – 21.47	17.30	28.47 – 29.44	28.92

Source: Statistical analysis from data derived from Satellite-Based Aerosol Optical Depth at 550nm (2019).

Weli and Emenike [33] validated this finding in their research on *Atmospheric Aerosol Loading Over the Urban Canopy of Port Harcourt City* which revealed that Particulate Matter has the highest contribution during the dry season and the lowest contribution during the wet season. It is also revealed that wet deposition can reduce air pollution by removing particulate matter and other atmospheric pollutants [27,29]. The dry simply denotes a region lacking in humidity. The dry season in the Niger Delta lasts for about five months from November to March. During the dry season, the Northeast trade wind, otherwise known as the tropical continental (ct), blowing over the Sahara Desert extends its dehydrating influence progressively towards the equator, reaching the southern coasts of Nigeria in late December or early January. The period is known as the "Harmattan" which is more noticeable in some years than others. The analysed data in Table 4 show that in November the metrological factors of the urban environment have much influence on atmospheric pollution but the concentration is much higher during the dry season. The onset of the dry season witness a remarkable increase in concentration (127.83) but the concentration gets to its maximum during the peak of the dry season which is January (283.00) followed by February (271.37); after these two months the concentration of Particulate Matter begins to reduce as the wet season begins to set.

Incidence of Respiratory Tract Infections in the Study Area

Table 6 shows the epidemiology of respiratory tract infection for the years under review (2016 – 2019) for Asaba and Effurun in Delta State for 10,275 patients with pneumonia accounted for 6.445 patients (62.7%), followed by tuberculosis with 1,697 patients (16.5%) while COPD had a cumulative 1,114 patients (10.8%) and the least was Asthma with 1,019 patients (9.9%). Table 2 and 3 show that Asaba and Effurun has an annual mean $PM_{2.5}$ concentration of 26.01ug/m^3 and 25.93ug/m^3 respectively which are both above the DRR and WHO standards. This high $PM_{2.5}$ concentration strongly indicates that atmospheric pollution has both environmental and health impacts; this finding is corroborated by other studies. They established a strong relationship between air pollutants including particulate matter with morbidities sources such as respiratory diseases. Zhang and Kondragunta [46] found that high $PM_{2.5}$ concentration was associated with an increase in emergency department and out-patient units visit for respiratory diseases in children which is in uniform with the findings of this study.

Table 7 shows the occurrence of the different diseases of respiratory tract infection for the years under review (2016-2019) in Yenagoa and Brass. There was a total of 12,341 patients with pneumonia accounting for the highest at 63% followed by tuberculosis at 15% while COPD accounted for 11% and Asthma contributed the least number of patients at 10%. Apart from the environmental impact, the high concentration of Particulate Matter in the two urban centres which are above the WHO Limit as shown in table 2 and 3 and will also lead to serious health implications such as respiratory diseases like asthma, COPD and pneumonia. This result is validated by Nwachukwu, Chukwuocha and Igbudu [20] that listed respiratory diseases as some of the human impacts of atmospheric pollution. In other studies, it was said that Particulate Matter exposure leads to respiratory diseases [10,13]. Also, Zhang and Kondragunta [46] concluded that higher $PM_{2.5}$ concentration was associated with an increase in the emergency department and out-patient units visits for respiratory diseases, while Weli and Emeneke [33] concluded that residents in Port Harcourt which are sensitive to $PM_{2.5}$ especially those with respiratory diseases like COPD must not be allowed to spend longer hours or reside in those part of the city.

Table 8 shows the occurrence of the different froms of the RTIs from 2016-2019 in the two government hospitals that were purposively selected; there were a total of 27,144 patients in the years under review. Pneumonia

19,233 making 70.86% followed by TB with a patient 3,229 making 11.89% COPD accounts for a total of 2,789 (10.27%) while Asthma accounted for the least number of patients 1893 (6.97%) for the years under review (2016-2019.). Table 2 and 3 show that Port Harcourt and Nchia for the period under investigation has PM concentration beyond the WHO standards which will lead to negative health challenges such as respiratory tract infections as shown in table 8, which corroborate with the studies of other researchers [26,34].

The pollution of Port Harcourt and Nchia is also a result of other mixed pollutants, and when particulate matter acts in synergy with other pollutants, it can cause serious health impacts especially respiratory diseases. This observation is corroborated by the study of Nwokocha, Edebeatu and Okujagu [21] which listed pulmonary tuberculosis, pneumonia and whooping cough as human health effects due to air pollutants. The study by Ciencewicki and Jasper [48] also suggested a potential link between atmospheric pollutants the adverse health effects such as respiratory diseases.

The ANOVA table result shows that there is a significant variation in the distribution of Particulate Matter ($PM_{2.5}$) among the six (6) cities in the study area. The F-ratio statistic between and within the cities is 2.056 with a p-value of 0.002 which is less than 0.05 (5%) level of significance. Consequently, the result of the descriptive statistics emanating from this analysis reveals that Port Harcourt city (2016) has a very high variation, followed by Yenagoa (2017) with 16.11 and 13.20 respectively. Similarly, Effurun (2019) and Asaba (2019) have a 12.02 standard deviation each while the rest cities' location with 10.06-11.91 ranges of spread.

Table 10. Summary Spearman's Rank Correlation Statistics

		Rivers	Bayelsa	Delta
COPD	Correlation Coefficient	0.400	-0.400	0.000
	Sig. (2-tailed)	0.600	0.600	1.000
	N	4	4	4
Asthma	Correlation Coefficient	-0.200	0.000	-0.600
	Sig. (2-tailed)	0.800	1.000	0.400
	N	4	4	4
Tuberculosis	Correlation Coefficient	-0.600	0.800	0.400
	Sig. (2-tailed)	0.400	0.200	0.600
	N	4	4	4
Pneumonia	Correlation Coefficient	-1.000**	0.800	0.000
	Sig. (2-tailed)	0.000	0.200	1.000
	N	4	4	4

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Fieldwork (2019).

Spearman's correlation statistics show that there is no significant relationship between RTIs and $PM_{2.5}$ in the selected urban centres of the Niger Delta. In Rivers State, $PM_{2.5}$ was positively correlated with COPD (r=0.400) but negatively correlated with Asthma, Tuberculosis and Pneumonia. The correlation was significant in Pneumonia (r=1.000).

In Bayelsa State, $PM_{2.5}$ was positively correlated with RTIs except for COPD which had a negative correlation. None of the correlations was significant. Similarly, in

Table 6. Cumulative Number of RTIs Patients in Asaba and Effurun (2016-2019).

YEAR	COPD	ASTHMA	TUBECULOSIS	PREUMONIA	TOTAL
2016	240	234	337	1,371	2,182
2017	274	268	376	1,553	2,471
2018	290	237	574	1,671	2,776
2019	310	280	406	1,850	2,846
TOTAL	**1,114**	**1,019**	**1,697**	**6,445**	**10,275**

Source: Delta State Hospital Management Board (2019).

Table 7. Cumulative RTIs Patients in Yenagoa and Brass from 2016-2019.

YEAR	COPD	ASTHMA	TUBECULOSIS	PREUMONIA	TOTAL
2016	312	278	341	1,782	2,713
2017	369	329	404	1,733	2,835
2018	331	292	672	2,049	3,344
2019	355	368	474	2,252	3,449
TOTAL	**1,367**	**1,267**	**1,891**	**7,816**	**12,341**

Source: Computed from data derived from the Bayelsa State Hospital Management Board (2019).

Table 8. Cumulative Number of RTIs Patients in Port Harcourt and Nchia from 2016-2019.

YEAR	COPD	ASTHMA	TUBERCULOSIS	PNEUMONIA	TOTAL
2016	841	552	779	4,227	5,339
2017	656	449	678	4,486	6,269
2018	634	235	899	4,877	6,445
2019	657	873	873	5843	8,031
TOTAL	**2,789**	**1,893**	**3,229**	**19,233**	**27,144**

Source: Rivers State Hospital Management Board (2019).

Table 9. Summary Table of the One-Way ANOVA

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					

Source: Fieldwork (2019).

Delta State, there was a positive correlation with RTIs except for Asthma which was negative. However, none of the correlations was significant.

5. Conclusions

The distribution of Particulate Matter across the Niger Delta region is far beyond the WHO standard and therefore comes with corresponding health challenges such as Respiratory Tract Infections. It is clear from the study that $PM_{2.5}$ pollution has adverse effects on the people and the Niger Delta environment. To a larger extent the study has established that particulate matter ($PM_{2.5}$) is an exacerbating or risk factor for Respiratory Tract Infection as it triggers an episode of these infections such as frequent asthma attacks when asthmatic patients are exposed to high concentrations of particulate matter in the atmosphere. The necessary regulatory bodies should closely monitor the activities of the companies likely to cause such pollution; guild them through their operation and give prompt sanctions and heavy fines to defaulters of the accepted standards.

References

[1] Ali, M., Ather, M., 2008. Air pollution due to traffic air quality monitoring along three sections of National Highway, N-5. Pakistan. Environ. Health Prev. Med. 13, 219-226.

[2] Aniefiok, E., Udo, J., Margaret, U., Sunday, W., 2013. Petroleum Exploration and Production: Past and Present Environmental Issues in the Nigeria's Niger Delta. American Journal of Environmental Protection. 1(4), 78-90.

[3] Asanebi, 2016. A concise view of Niger Delta Region of Nigeria: An interpretation of a Nigerian Historian. International Research Journal of Interdisciplinary and Multidisciplinary Studies. 2(10), 56-63.

[4] Bodo, T., 2019. Deep Issues behind the Crisis in the Niger Delta Region: The Case of Oil Exploration in Ogoniland, Rivers State, Nigeria. Asian Journal of Geographical Research. 2(1), 1-12.

[5] Bodo, T., David, L.K., 2018. The petroleum exploitation and pollution in Ogoni, Rivers State, Nigeria: The community perspective. European Scientific Journal. 14(32), 197- 212.

[6] Brauel, M., Greg, F., Joseph, F., Aaron, V., 2016. Ambient air pollution exposure estimation for the global burden of disease 2013. Environ. Sci. Tech. 50, 79-88.

[7] Chen, A., 2015. Carboneceous Aerosols and Climate change. National Laboratory Review. 2(3), 66-68.

[8] David L.T., Bodo, T., 2019. Environmental Pollution and Health Challenges of the Ogoni People, Rivers State, Nigeria. International Journal of Advanced Research and Publication. 2(2), 28-32.

[9] David, L.K., Bodo, T., Gimah, B.G., 2019. Petroleum pollution and decrease neuroplasticity in brain development of the Ogoni children in Rivers State, Nigeria. Journal of Advances in Medicine and Medical Research. 29, 1-13.

[10] Ede. P.N., Edokpa, D.O., 2017. Regional air quality of Nigeria's Niger Delta. Open Journal of Air Pollution. 4, 7-15.

[11] Ezekwe, C.I., Agbakoba, C., Igbagara, P.W., 2016. Source Gas Emission and Ambient Air Quality around Eneke co-disposed landfill in Port-Harcourt, Nigeria. International Journal of Applied Chemistry and Industrial Sciences. 2(1), 11-23.

[12] FEPA, 1999. National Guidelines and standards for Industrial Effluence, Gaseous Emissions and Hazard-

ous Waste Management in Nigeria, Abuja. Federal Environmental Protection Agency.

[13] Hwang, B.F., Chen, Y.H., Lin, Y.T., Wu, X.T., Leo, L.Y., 2015. Relationship between exposure to fine particulates and ozone and reduced lung function in children. Environ Res. 137, 382-390.
DOI: https://doi.org/10.1016/j.envres.2015.01.009.

[14] Ibe, F.C., Opara, A.I., Njoku, P.C., Alinor, J.I., 2017. Ambient Air Quality Assessment of Orlu, South-eastern Nigeria. Nigeria Journal of Applied Science. 17(3), 442-457.

[15] Igbara, S.A., 2016. Study of Dumpsite and rental value of residential properties in Rumuolumeni Community in Port Harcourt Metropolis. Unpublished M.Sc Thesis, Department of Estate Management, Faculty of Environmental Studies, Abia State University, Uturu.

[16] Kelly, C.B., James, F.P., 2004. Thermodynamics of the Formation of Atmospheric Organic Particulate Matter by Accretion Reaction –Part 1. Atmospheric Environment. 38(26), 4371-4382.

[17] Kayes, I., Shahriar, S., Hansan, K., 2019. The relationship between meteorological parameters and air pollutants in an urban environment. Global Journal on Environmental Science and Management. 5(3), 265-278.

[18] Moses, Urok, 2016. Propelling Reform in Cross Rivers State, Nigeria. www.hfgproject.org.

[19] Narayanan. P., 2014. Environmental Pollution Principles, Analysis and Control. New Delhii. CBS Publishers.

[20] 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.

[21] 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 (IJARPS). 2, 19-25.

[22] Obafemi, A. A., Diagi, B., 2012. Effects of Waste dumps location on the property values in Benin City: Implication for Urban Environmental Management. African Science and Technology Journal. 5(2), 73-88.

[23] Oladapo, M.A., Idokiari, B., Obunwo, C.C., 2017. Assessment of particulate matter-based air quality index in Port Harcourt, Nigeria. J Environ Ana Chem. 4(4), 224.

[24] Ostro, B.D., Lipsett, M.J., Mann, J.K., 1991. Ambient air pollution and hospitalisation for respiratory causes in Minneapolis- St Paul and Birmingham. Epidemiology. 8, 364-370.

[25] Poronakie, N.B., 2007. Industrial Development of the Niger Delta. In D.R.T.Ukpere, U.D Agumagu, G.N Naluba& C.O Oteh (eds). Perspectives on the Niger Delta Environment, Port Harcourt. Emma Publishing Company.

[26] Sinclair, A.M., Tolsma, D., 2004. Association and Lags between air pollution and acute respiratory visits in ambulatory care setting: 25-month result from the aerosol research and inhalation epidemiological study. Journal of the Air and Waste Management Association. 54(9), 1212-8.

[27] Tawari, C.C., Abowei, J.F.N., 2012. Air pollution in the Niger Delta area of Nigeria. International Journal of Fisheries and Aquatic Sciences. 1(2), 92-117.

[28] Trenga, C.A., Sullivan, J.H., Schildcrout, J.S., Shepherd, K.P., Kaufma, J.D., Koenig, J.E., 2006. Effects of particulate air pollution on lungs functions in adult and pediatric subjects in a Seattle panel study. 129, 1614-1622.

[29] Ukonta, I.U., Ubong, U.U., Ubong, U.E., Ukonta, R., Ishmeal, D., 2015. Distribution of particulate matter in Cawthornr Channel Air Basin in Nigeria. Environmental Pollution. 4, 19-22.

[30] United State Environmental Protection Agency (UNSPA), 2014. Air Quality Index: A guide to Air Quality and Your Health. Research Triangle Park. New York City.

[31] Weli, V.E., 2014a. Atmospheric concentration of Particulates in its implication for Respiratory Health Hazard Management in Port Harcourt Metropolis, Nigeria. Journal of Civil and Environmental Research. 6(5), 11-17.

[32] Weli, V.E., Adekunle, O., 2014. Air quality in the vicinity of Landfill site in Rumuolumeni, Port Harcourt, Nigeria. Journal of Environment and Earth Science. 4(10), 1-9.

[33] 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 Journals of Environment and Pollution Research. 5(1), 52-69.

[34] Weli, V.E., 2014b. Spatial and Seasonal Influence of meteorological parameters on the concentration of suspended particulate matter on the industrial city of Port Harcourt, Nigeria. Journal of Developing Country Studies. 4 (10), 1-10.

[35] Weli,V.E., Adegoke, J.O., 2016. The Influence of Meteorological Parameters and Land use on the Sea-

sonal Concentration of Carbon Monoxide (CO) in the Industrial Coastal City of Port Harcourt. Nigeria. J. Pollut. Eff. Cont. 4, 171.
DOI: https://doi.org/10.4172/2375-4397.1000171.

[36] Weli, V.E., Kobah, E., 2014. The Air Quality Implications of the SPDC-Bomu Manifold Fire Explosion in K-Dere, Gokana LGA of Rivers State, Nigeria. Maxwell Sciences Research Journal of Environmental and Earth Sciences. 6(1), 769-777.

[37] World Health Organisation (WHO): Regional Office for Europe, 2017. Health Relevance of Particulate Matter from Various Sources. Report on a WHO Workshop. Copenhagen.

[38] World Health Organisation Global Health Observation, 2012. Recent Data on Air Quality.

[39] World Health Organisation Report, 2013. On Air Pollution Across the World.

[40] World Health Organisation Report, 2014. Death Related Cases of Air Pollution. http://www.epa.gov/aircompare/.

[41] Weli,V.E., Emenike, G.C., 2017. Atmospheric Aerosol Loading over the Urban Canopy of Port Harcourt City and its Implications for the Incidence of Chronic Obstructive Pulmonary Diseases. International Journal of Environment and Pollution Research. 5(1), 55-69.

[42] Akpomuvie, O. B., 2011. Tragedy of commons: Analysis of oil spillage, gas flaring and sustainable development of the Niger Delta of Nigeria. Journal of Sustainable Development. 4(2), 200-210.

[43] Bodo, T., 2019. Rapid Urbanisation Problems and Coping Strategies of Port Harcourt Metropolis, Rivers State, Nigeria. Annals of Geographical Studies. 2(3), 32-45.

[44] Bodo, T., Gimah, G.B. Seomoni, K.E., 2021. Deforestation and Habitat Loss: Human Causes, Consequences and Possible Solution. Journal of Geographical Research. 4(2), 1-9.

[45] Bodo, T. Gimah, G.B., 2020. The destruction of the Niger Delta Ecosystem in Nigeria: Who is to be blamed? European Scientific Journal. 16(5), 161-182.

[46] Zhang, H. Kondragunta, S., 2018. Daily and Hourly Surface PM2.5 Estimation from satellite AOD.
DOI: https://doi.org/10.1029/2020EA001599.

[47] Klimont, Z., Smith, S. J., Cofala, J., 2013. The last decade of global anthropogenic sulfur dioxide: 2000-2011 emissions. Environmental Research Letters. 8(1), 1-10.

[48] Ciencewicki, J., Brighton, L., Wu, W., Madden., M, Jasper, I., 2007. Diesel exhaust enhance virus poly(i:c) induced Toll like receptor 3 expression and signaling in respiratory epithelia cells. American Journal of physiology-lungs cellular and Molecular physiology. 29(6), 1-10.

[49] WHO, 2006. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide Global update 2005. Summary of risk assessment.

[50] DPR, 2002. Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) Issued by The Department of Petroleum Resources Lagos 1991 Revised.