Journal of Scientific Research & Reports

25(2): 1-9, 2019; Article no.JSRR.52831
ISSN: 2320-0227

Analysis of Particle Pollution in Residential Urban Area of Port Harcourt, Nigeria

Christopher U. Onuorah[1*], T. G. Leton[1] and O. L. Y. Momoh[2]

[1]Centre for Occupational Health, Safety and Environment, University of Port-Harcourt, Nigeria.
[2]Department of Civil and Environmental Engineering, University of Port-Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author CUO designed the study, wrote the protocol and wrote the first draft of the manuscript, which was approved by his supervisors. Authors CUO, TGL and OLYM equally collected field samples and carried out laboratory analyses. Author TGL guided literature searches and field sampling while Author OLYM guided the statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2019/v25i230187
Editor(s):
(1) Prof. Mohamed Abd El-moneim Ramadan, Department of Pretreatment and Finishing of Cellulosic Fibres, Textile Research Division –NRC- Egypt.
Reviewers:
(1) Mandadapu S. V. K. V. Prasad, Swarnandhra College of Engineering and Technology (autonomous), India.
(2) Hanns Moshammer, Medical University of Vienna, Austria.
(3) Nádia Hortense Torres Romanholo Ferreira, Tiradentes University, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/52831

Original Research Article

Received 18 August 2019
Accepted 23 October 2019
Published 25 October 2019

ABSTRACT

Particle pollution poses serious public health concern because of its potential to find its route into human lungs thereby causing respiratory diseases and cancer. This paper analyses various aspect of particulate matter including seasonal variation, Particulate matter based AQI, particulate matter exceedances and empirical modelling for seasonal prediction of $PM_{2.5}$ and PM_{10} concentration. The study was carried out in Woji, a residential urban area of Port Harcourt, Nigeria, between May and December 2018. The Particulate matter concentrations were monitored with particulate monitor while meteorological variables were also monitored with Misol weather station. The 24-hour average PM_{10} concentration for dry and wet seasons were 139.6 µg/m³ and 97 µg/m³ respectively. These concentrations are below USEPA 24-hr standard (PM_{10} = 150 µg/m³) while the 24-hour average $PM_{2.5}$ concentrations of 46.1µg/m³ for dry season exceeded daily limit ($PM_{2.5}$ = 35 µg/m³) but was below the limit in wet season with concentration of 29.1 µg/m³. The study area experienced daily $PM_{2.5}$ and PM_{10} exceedances of 33.3% and 19.7% respectively for the study period. Also, the

**Corresponding author: E-mail: ugothorax@yahoo.com;*

PM based AQI were unhealthy to all residents for 13%, unhealthy to the sensitive group for 20%, moderate for 62% and good for 5% of the monitoring period. $PM_{2.5}$ and PM_{10} pollution prediction model were developed for dry and wet season with a high correlation coefficient of 0.98 and 0.97 respectively at (*P < 0.001).*The seasonal variation of PM concentration revealed that PM_{10} and $PM_{2.5}$ concentration varied from season to season, with significantly higher concentration in dry season than in wet season. The air quality of Woji Port Harcourt was better in wet season than in dry season due to the scavenging mechanism of rainfall. Also, PM exceedances were higher in dry season than wet season due to high atmospheric stability associated with low wind speed in dry season.

Keywords: $PM_{2.5}$; PM_{10}; particle pollution; particulate matter; air quality index; Port Harcourt Nigeria.

1. INTRODUCTION

Particle pollution is a mixture of liquid, solid or combination of both particles suspended in the air [1]. These particles which are part of the criteria air pollutants seriously affect human health and the environment [2]. These pollutants known as particulate matter ($PM_{2.5}$ and PM_{10}) are usually released into the atmosphere either by natural or anthropogenic means such as fuel burning, vehicular emissions, road and building construction, industrial processes or through chemical transformation of gases [3,4].They are classified in relation to their nature and size, known as aerodynamic diameter. Fine particles are usually smaller than 2.5 µm in diameter while coarse particles (PM_{10}) are lower than 10 micrometers (µm) in diameter [5]. With respect to their nature, combustion particles such as smoke and soot belongs to $PM_{2.5}$ while pollen, dust, mold, mist and fungi belongs to PM_{10} fraction [6]. The Air quality life index study carried out by University of Chicago revealed that the global life expectancy is being reduced by particle pollution by an average of 1.8 years per person [7]. Their main chemical components which are probable human carcinogen include heavy metals, ionic species, and PAHs. At elevated concentration, these components can find their way into human blood stream and lungs, thereby causing respiratory diseases, heart attack and cancer [8-11,12]. Approximately 30% of respiratory diseases are connected to personal exposure to elevated particulate matter concentrations [10]. According to global burden of disease report, 3.22 million deaths globally were recorded in 2010 as a result of particulate matter pollution [13]. Some studies have been done to show how Particulate matter level varies with season [10-14]. However, not much has been done with regards to seasonal air quality index based on particulate matter (PM), determination of hourly PM exceedances and seasonal prediction of PM in Port Harcourt, Nigeria. The particle pollution is threatening Port Harcourt urban air quality due to the impact of industrialization, rapid urbanization and population growth [2]. This study attempts to analyze the variability of particulate matter ($PM_{2.5}$ and PM_{10}) concentration with season in the study area, develop particle pollution prediction model for the seasons, analyze PM exceedances for the study period, and its impacts on the air quality of Woji Port Harcourt, Nigeria.

2. METHODOLOGY

2.1 Study Area

The monitoring location for the study was at Woji urban residential area of Port Harcourt in River state Nigeria as shown in Fig 1. The metropolis which is located between Latitude 4º49' 53.80'' N and Longitude 7º3' 30.94'' E is rapidly undergoing development and urbanization with massive population growth. It is bordered by Rumurolu, Trans-Amadi, Rumuibekwe and Rumuomasi communities with a total aerial of 5.53 square kilometers.

The climate is tropical with two seasons' namely wet season (April to October) and dry season (November to March) for the year [1]. The wet season average monthly rainfall varies from 20.7 mm–434 mm with the peak in July and September while December is the peak of the dry season being the driest month of the year. Average temperatures are usually between 25ºC-30ºC with 55% relative humidity in dry season and 96% in wet season. The town is a fast growing urban centre with numerous industries such as Indorama Eleme Fertilizer and Chemicals Limited, Indorama Eleme Petrochemicals Limited, Shell Petroleum and Development Company and other industries.

2.2 Data Collection

The $PM_{2.5}$ and PM_{10} concentration were monitored at Woji monitoring location using Aerocet 531 handheld particulate matter monitor.

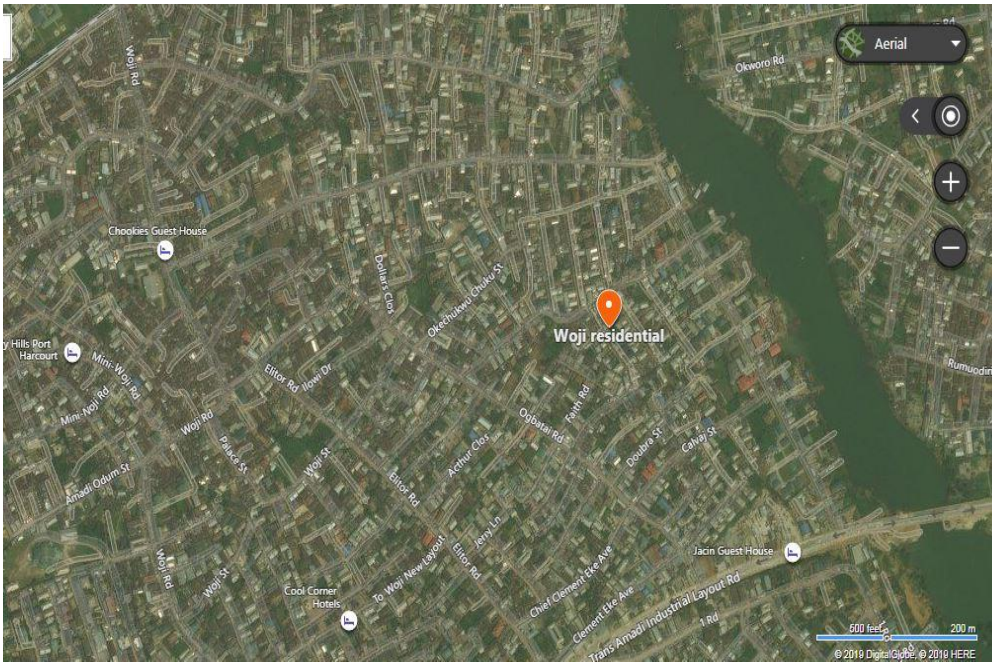

Fig. 1. Location map of study area

The monitor has an optical laser sensor for measuring and detecting particulate matter concentration of 0-1 mg/m^3 which was calibrated prior deployment to ensure accuracy of monitored data. The particulate matter concentration was monitored for wet and dry season on one hourly interval for 24 hours duration covering eight (8) months from May to December 2018. The sampler displays real time reading of PM concentration in µg/m^3 at a height of 1.5 m above ground level. The meteorological parameters were collected from a Misol weather station mounted 10 m above the ground. The wind speed, wind direction, relative humidity, ambient temperature and rainfall were detected by the weather station sensor and transmitted to the indoor console which was downloaded at the end of the monitoring period for analysis.

2.3 Method of Data Analysis

R-Programming and its application package "Openair" was used for the polar plot and polar frequency plot in determination of seasonal particulate matter concentration and wind direction contribution to overall PM concentration respectively. Excel stat was used for Weibull plot in determination of Particulate matter exceedances while SPSS version 20 was used for empirical modelling of $PM_{2.5}$ and PM_{10}.

3. RESULTS AND DISCUSSION

3.1 Seasonal Variation of $PM_{2.5}$ & PM_{10} Concentration in the Study Area

Fig. 2 presents a seasonal $PM_{2.5}$ & PM_{10} mean concentration as against wind speed and direction. The first two upper plots shows the daily mean concentration of PM_{10} for wet and dry season while the plots below presents the mean concentration of $PM_{2.5}$ for wet and dry season. The figure showed that the 24- hour average seasonal $PM_{2.5}$ concentrations were 46.1µg/m^3 & 29.1 µg/m^3 for dry & wet season respectively while mean PM_{10} level for dry and wet season were 139.6 µg/m^3 and 97 µg/m^3 respectively. The wet and dry season average daily PM_{10} concentration were below USEPA 24-hr standard (PM_{10} = 150 µg/m^3) while the dry season $PM_{2.5}$ mean concentration was above the standard concentration ($PM_{2.5}$ = 35 µg/m^3). The dry season had the highest daily $PM_{2.5}$ & PM_{10} level of 110 and 263 µg/m^3 respectively which occurred on the 21st of December while the wet season had the maximum diurnal PM_{10} concentration of 257 µg/m^3 on the 26th of July and 83 µg/m^3 on 24th of August for the wet season. Fig. 3 revealed that the concentrations of Particulate matter at the study location during wet season was totally dominated by the south west wind at a mean wind speed of 1.7 m/s while the North wind direction dominated the concentration of Particle concentration in dry season at a mean wind speed of 1.4 m/s. In wet season at greater wind speed, the south easterly wind tends to contribute high PM concentration.

3.2 $PM_{2.5}$ - AQI for Determination of Health Impact at the Study Area

Fig. 4 presents $PM_{2.5}$ - AQI for wet season and dry season which is a sub-index of the general AQI use to estimate how healthy or unhealthy the air is to the population exposed to the particle pollution. The figure presents percentage of time air quality at Woji Port Harcourt is healthy or unhealthy with respect to particle pollution. The results of $PM_{2.5}$ -AQI for wet season in Fig. 4 revealed that air quality at Woji was good for 6%, moderate for 69%, unhealthy for sensitive group of persons for 17% and unhealthy for every resident for 8% of the study period. This implies that average daily $PM_{2.5}$ concentrations during wet season were below the USEPA 24 hour standard (AQI<100) for 75% of sampling period. On the other hand, Fig. 4 also shows that $PM_{2.5}$ concentrations during dry season were below the USEPA standard (AQI<100) for 44% of sampling period. Generally, the Air quality at Woji Port Harcourt from May to December 2018 was unhealthy for 29 days for everyone living in that town and unhealthy for sensitive group for 47 days.

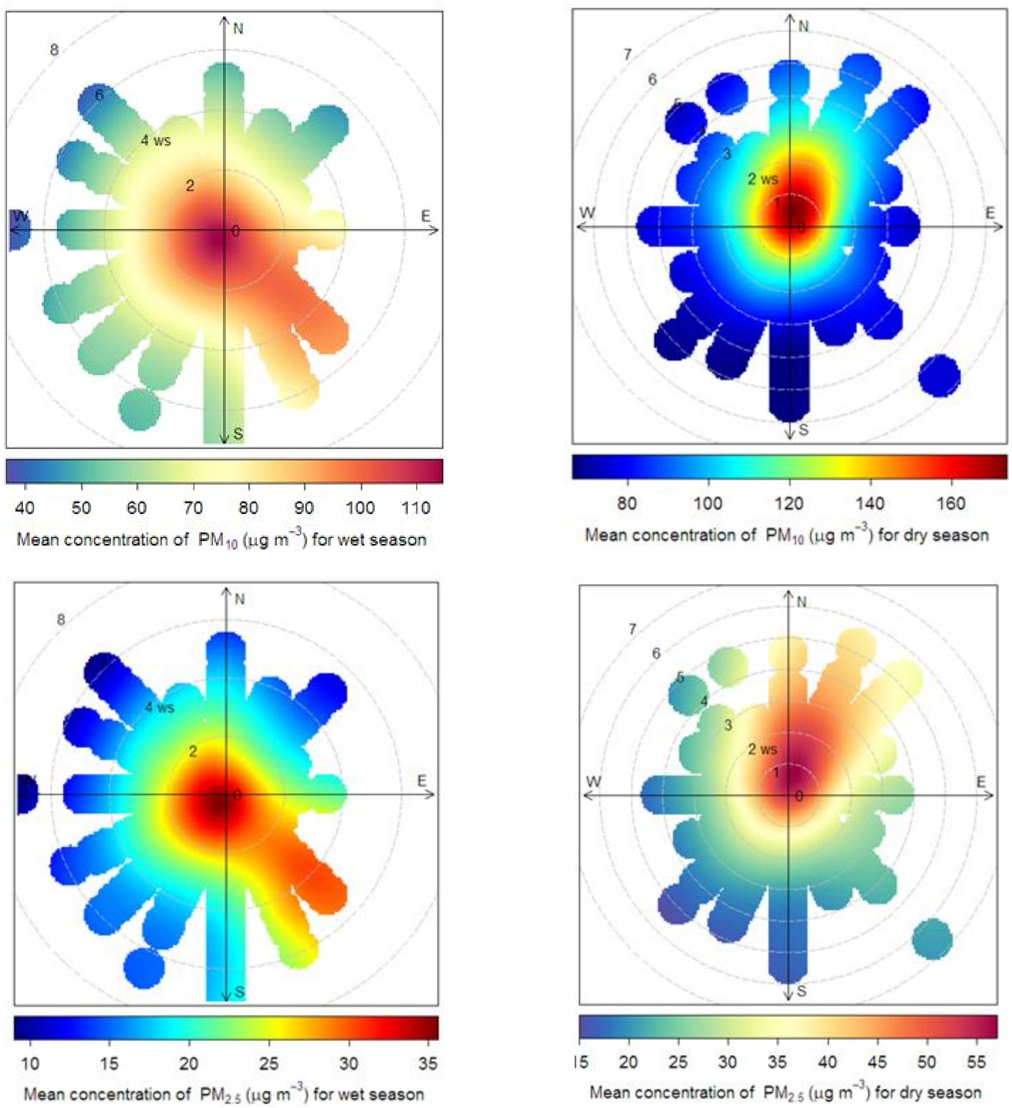

Fig. 2. Polar plot showing seasonal mean concentration for $PM_{2.5}$ & PM_{10}

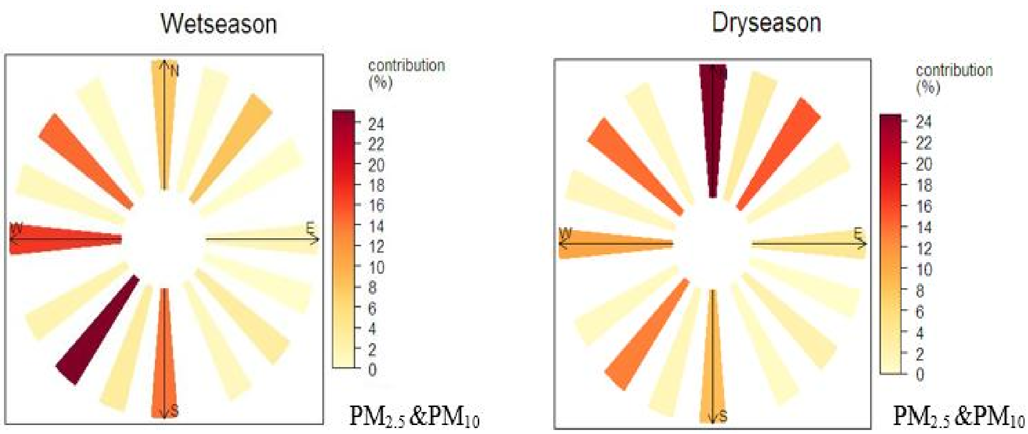

Fig. 3. The percentage contribution of wind direction to overall mean concentrations of $PM_{2.5}$ & PM_{10} at Woji, Port Harcourt for Wet season and Dry season

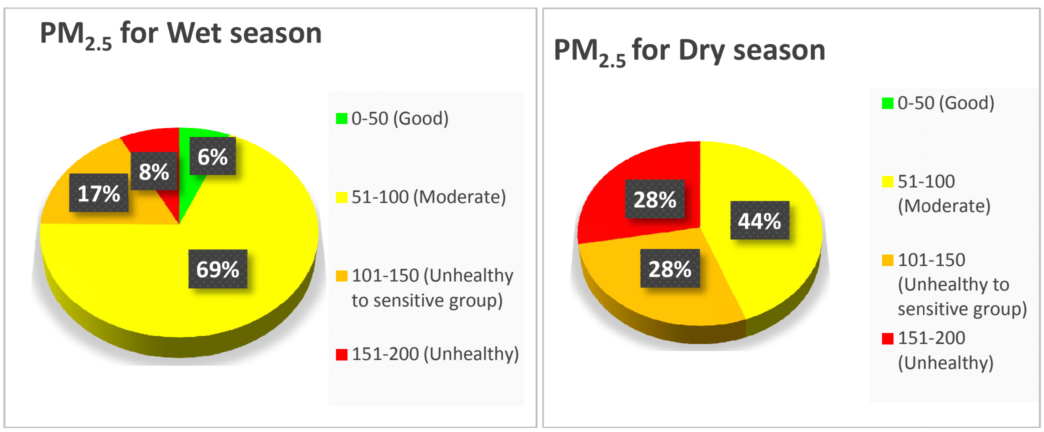

Fig. 4. $PM_{2.5}$ –AQI for wet and dry season

3.3 Particulate Matter Exceedances at the Study Area

The objective of investigating the air particulate pollution episode (PM exceedances) is to make known those days that USEPA NAAQS 24 hour guidelines for PM_{10} & $PM_{2.5}$ were exceeded. The guidelines states that standard limit for $PM_{2.5}$ & PM_{10} must never be exceeded three days in a year to protect the health of the public. USEPA NAAQS sets a 24 hour target for PM ($PM_{2.5}$ = 35 µg/m^3, PM_{10} = 150µg/m^3). The Weibull plot in Fig. 5 revealed that $PM_{2.5}$ concentrations exceeded USEPA NAAQS 24–hour exposure limit for 33.3% of the study period. It means that the period of May to December experienced $PM_{2.5}$ exceedances of 33.3% which translates to 80 days with the heaviest $PM_{2.5}$ episode observed in the month of December. Also Fig. 6 clearly highlight the percentage of time the PM_{10} level exceeded USEPA NAAQS 24 hours limit of 150 µg/m^3. It shows that PM_{10} concentration exceeded USEPA Standard limit for 19.7% of the study period bringing the total PM_{10} exceedances to 46 days. Therefore, the result demonstrated 33.3% and 19.7% of $PM_{2.5}$ and PM_{10} exceedances respectively for the study period.

3.4 Prediction Model for Particle Pollution

Table 1 presents the summary of the empirical model developed for the $PM_{2.5}$ and PM_{10} pollution prediction using multiple linear regression and over 3900 data points of monitored data for the combined season, wet season and dry season differently. The table also presents the R^2 for model development and verification as well as correlation coefficient and P-value to show significance. The coefficient of determination, R^2 explains the goodness of fit for the model.

3.4.1 Model performance for particulate matter prediction

The model performance was ascertained by visual examination of scatter plot of predicted and observed $PM_{2.5}$ & PM_{10} (See Figs. 7, 8 & 9). The model performance was verified considering the conditions below:

1. From the predictive model developed for all season, a very high goodness of fit, R^2 were attained. From Table 1 & Fig. 7, the R^2 for $PM_{2.5}$ & PM_{10} were 0.95 and 0.94 respectively with a very strong correlation (r=0.97). For wet season (Fig. 8), the $PM_{2.5}$ & PM_{10} predictive models have a very high R^2 value (0.94) for the regression analysis and correlation coefficient of 0.97. While dry season (Fig. 9) also reveals high (R^2=0.96) with correlation coefficient of 0.98. The high goodness of fit, R^2 and strong positive correlation is a performance indicator for good model.
2. The assumptions of normality and constant variance in errors was verified by plotting residuals (error) against computed values of $PM_{2.5}$ & $PM_{10,}$ errors being normally distributed.
3. ANOVA and F-test were used to ascertain the significant of regression equation. The result confirms a very large value of *F*, that is significant at p <.001. Hence we can conclude that our regression equations is a significantly better predictor of $PM_{2.5}$ & PM_{10}.

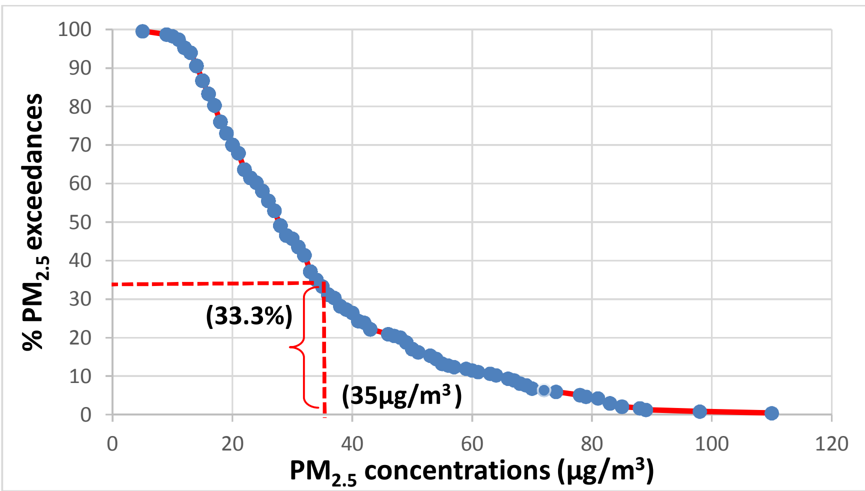

Fig. 5. Plot showing percentage $PM_{2.5}$ exceedances for the study period at Woji

Table 1. Summary of developed particle pollution ($PM_{2.5}$ & PM_{10}) model

Season	Particle pollution model	Goodness of fit, R^2 on development	Goodness of fit, R^2 on verification	Correlation coefficient	P- Value
General (All season)	$PM_{2.5}$ = 65.6 + 0.36PM_{10} – 1.6Tp – 0.35RH	0.945	0.95	0.97	*P*< .001
	PM_{10} = -137.3 + 2.58$PM_{2.5}$ + 3.53Tp + 0.82RH – 1.22Ws	0.944	0.94	0.97	*P*< .001
Wet Season	$PM_{2.5}$ = 17.4 + 0.36PM_{10} – 0.55Tp – 0.1RH	0.936	0.94	0.97	*P*< .001
	PM_{10} = -56.2 + 2.62$PM_{2.5}$ + 1.76Tp + 0.39RH – 0.69Ws	0.936	0.94	0.97	*P*< .001
Dry Season	$PM_{2.5}$ = 59.7 + 0.38PM_{10} + 0.78Ws -1.49Tp - 0.37RH	0.960	0.96	0.98	*P*< .001
	PM_{10} = -97.1 + 2.47$PM_{2.5}$ + 2.52Tp + 0.8RH – 3.0Ws	0.959	0.96	0.98	*P*< .001

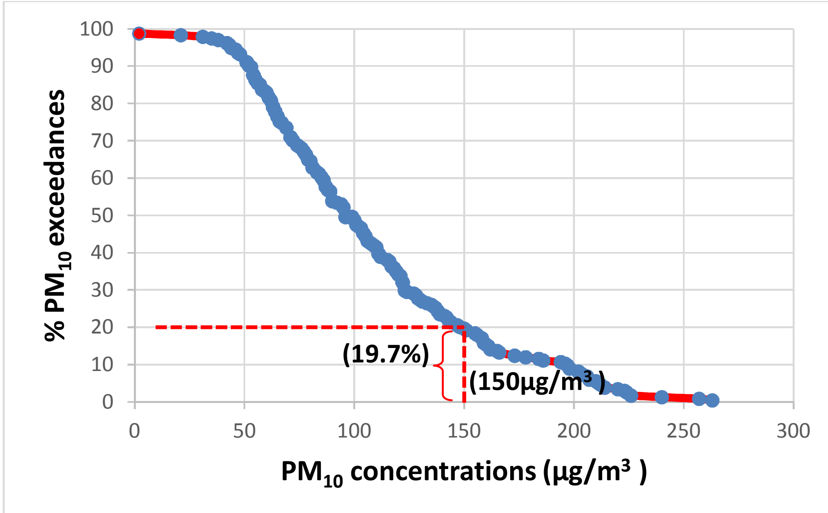

Fig. 6. Plot showing percentage PM_{10} exceedances for the study period at Woji

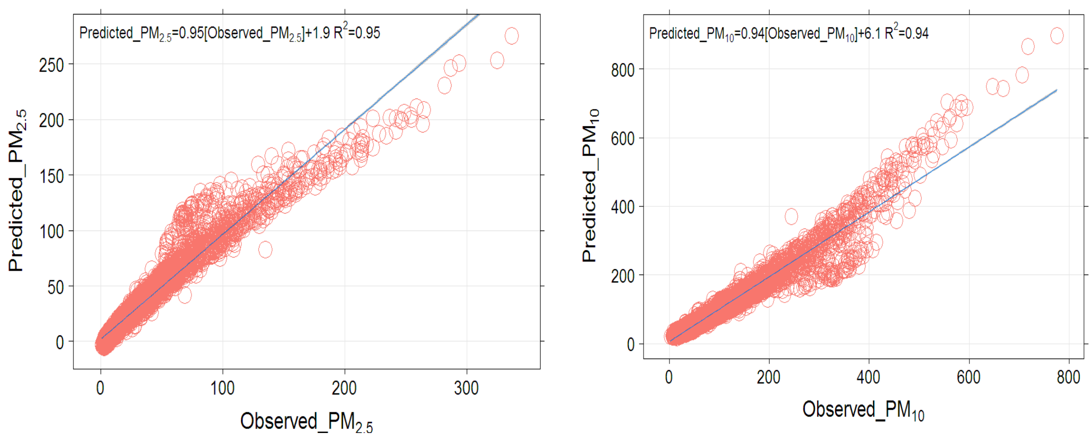

Fig. 7. Scatter plot for model verification of predicted versus measured $PM_{2.5}$ & PM_{10}

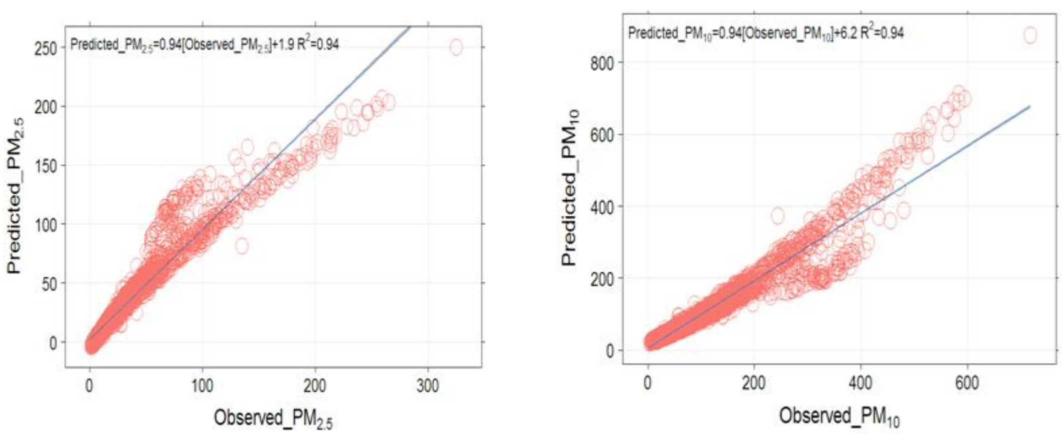

Fig. 8. Scatter plot of model computed & actual $PM_{2.5}$ & PM_{10} levels for wet season

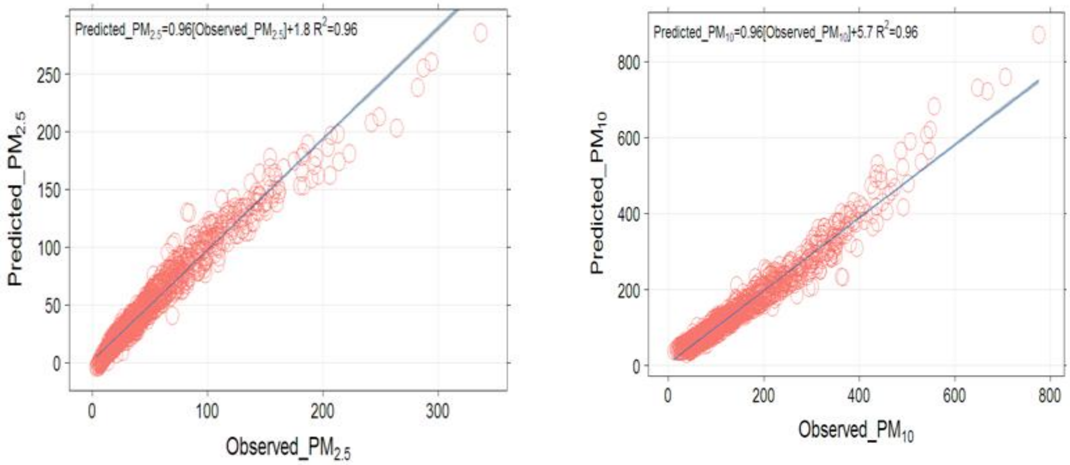

Fig. 9. Scatter plot of model computed and actual $PM_{2.5}$ & PM_{10} levels for dry season

3.4.2. Model applicability

The model was discovered to be statistically significant and the performance verified with monitored data set. Although, the model may have limitation in utility considering the fact that data was not spatially distributed .However, the model can be deployed for reconnaissance survey to predict $PM_{2.5}$ Concentration if PM_{10} level is known or the other way round.

4. CONCLUSION

The following conclusions can be drawn from this study:

1) The seasonal variation of PM concentration observed revealed that PM_{10} and $PM_{2.5}$ concentration varied from season to season, with significantly higher concentration in the dry season than in the wet season.
2) The average daily $PM_{2.5}$ concentration for the wet season was below the USEPA daily permissible limit but above these internationalstandard in dry season. However, the average daily PM_{10} concentration for the wet season and dry season were below USEPA National Ambient Air Quality standard daily limit.
3) The investigation of particle pollution exceedances, concludes that Woji, Port Harcourt experienced 33.3% and 19.7% of $PM_{2.5}$ and PM_{10} exceedances respectively with reference to USEPA 24-hour permissible exposure limit for the study period.
4) Also, we conclude that air quality of Woji Port Harcourt was better in wet season than in the dry season due to the fact that wet season Particulate matter air quality index was satisfactory for 75% of the season while in dry season it was only satisfactory for 38% of the time.
5) The empirical model developed will be a good predictor of particle pollution which can be deployed for reconnaissance survey when other parameters are known.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dockery DW, Pope CA III. Outdoor air I: particulates. In: Steenland K., Savitz DA., eds., Topics in environmental epidemiology, Oxford University Press,Oxford; 1997.
2. Onuorah CU, Leton TG, Momoh YOL. Influence of meteorological parameters on particle pollution (PM2.5 and PM10) in the Tropical Climate of Port Harcourt, Nigeria. Archives of Current Research International. 2019;19(1):1-12. Available:https://doi.org/10.9734/acri/2019/v19i130149
3. Seinfeld JH, Pandis SN. Atmospheric chemistry and physics: From air pollution to climate change, 2nd ed., John Wiley and Sons, Inc. Hoboken, New Jersey; 2006.
4. Plainiotis S, Pericleous KA, Fisher BEA, Shier L. Application of lagrangian particle

dispersion models to air quality assessment in the Trans-Manche region of Nord-Pas-de-Calais (France) and Kent (Great Britain). International Journal of Environment and Pollution (IJEM). 2010;40(1/2/3):160–174.
DOI:10.1504/IJEP.2010.030891

5. EPA US, OAR. Particulate Matter (PM) Basics. US EPA; 2016.
(Retrieved 5 October 2019)
6. US EPA, United States environmental protection agency. Revised air quality standards for particle pollution and updates to the air quality index (AQI); 2012.
(Accessed 14 November 2018)
Available:www.epa.gov/airquality/particlepollution/2012/decfsstandards.pdf
7. Energy Policy Institute, EPIC. the air quality life index, University of Chicago; 2018.
(Accessed 18 March 2019)
8. Turaliog˘lu FS, Nuhog˘lu A, Bayraktar H. Impacts of some meteorological parameters on SO2 and TSP concentrations in Erzurum, Turkey. Chemosphere. 2005;59:1633-1642.
9. World Health Organization (WHO). Air quality guidelines for Europe. WHO Regional Publications, European Series No.91, WHO Regional Office for Europe, Copenhagen, 2000.
10. Weli VE. Spatial and seasonal influence of meteorological parameters on the concentration of suspended particulate matter in an industrial city of Port Harcourt, Nigeria. Developing Country Studies www.iiste.org. ISSN 2224-607X (Paper) ISSN 2225-0565 (Online), 2014:4(10): 112-120.
11. Kumar SD, Dash A. Seasonal variation of air quality index and assessment. Global. J. Environ. Sci. Manage. 2018;4(4):483-492.
DOI: 10.22034/gjesm.2018.04.008
12. US EPA, OAR. Health and environmental effects of Particulate Matter (PM). US EPA; 2016.
(Retrieved 5 October 2019)
13. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani HA. Comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: A systematic analysis for the Global Burden of Disease Study 2010. The Lancet. 2012; 380(9859):2224–2260.
DOI:10.1016/s0140-6736(12)61766-8
14. Abali H. Seasonal particulate pollution in Port Harcourt Nigeria. Journal of Environment Pollution and Human Health. 2018;6(1):20-25.
DOI: 10.12691/jephh-6-1-3

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/52831