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Temporal Variability of Particulate Matter in Urban Area of Port Harcourt, Nigeria

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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.

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ABSTRACT

Particulate matter pollution poses serious health concern to public health in Nigeria especially at elevated concentration. Its size is very vital in determination of its long stay in the atmosphere as well as its deposition in human respiratory system. This study analyzes the temporal variation of particulate matter (PM_{10} and $PM_{2.5}$) concentrations and its ratio in urban area of Port Harcourt. The study was carried out in Woji, area of Port Harcourt, Nigeria, from May to December 2018 using Aerocet 531 particulate monitor while meteorological variables were monitored via Misol wireless weather station mounted 10 m above the ground level. The highest particle pollution occurred in the month of December with an average daily $PM_{2.5}$ concentration of 58.8 μgm^{-3} and PM_{10} concentration of 164.5 μgm^{-3}, which exceeds WHO and USEPA daily threshold. These particle pollution exceedances recorded the dry season month of December was due to high atmospheric stability with dry dusty north east trade wind associated with harmattan. Also, Particulate matter concentration are usually lower during the weekends than weekdays with high PM level occurring

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at night from 8:00 PM to 9:00 AM in the morning with the peak at 8.00 AM. This shows that the weekdays experienced elevated PM level than weekend as a result of high industrial, commercial and traffic activities emitting particles within the weekdays. Also the average $PM_{2.5}/PM_{10}$ ratio for wet and dry season was 0.3 respectively. This shows that the town is town is predominated by coarse particle.

Keywords: $PM_{2.5}$; PM_{10}; particulate matter; temporal variation; $PM_{2.5}/PM_{10}$ ratio; Woji; Port Harcourt Nigeria.

1. INTRODUCTION

The urban air quality in Nigeria, particularly Port Harcourt is deteriorating seriously because of rapid industrialization, urbanization and population growth [1]. These particles which are part of the criteria air pollutant extremely affect human respiratory system at higher concentrations [2].

They are found suspended in the atmosphere via natural or man-made activities such as building construction, fuel burning, vehicular emission, e.t.c [3]. An increased level of particulate matter in urban areas is responsible for pulmonary dysfunctions, neurobehavioral effects, cardio-vascular disease and mortality [4-6]. It has been a growing public concern owing to its serious health impacts and reduction of visibility [7]. The impact of particulate matter on human health varies with season which is the reason why seasonality is always considered a factor in determination of particle pollution level in the atmosphere [8]. Most importantly the size of particles has a direct link with its potential to cause health challenges which is the reason why the determination of the nature of particle through particulate matter ratio is essential [9]. This is because it is an important factor in determining the resident time of the particulate in the atmosphere and its place of deposition in human respiratory tract [10]. The ratio of $PM_{2.5}/PM_{10}$ is very vital to the identification of emission sources of Particulate matter. High PM ratios attributes particle pollution to combustion processes like vehicle emission, emissions from engine exhausts and secondary particle formed by gases in the atmosphere. Alternatively, lower ratios are ascribed to re-suspended and windblown dust which falls within coarse particulate range. In line with WHO guideline, $PM_{2.5}$ / PM_{10} ratios which range from 0.5 – 0.8 indicate predominance of $PM_{2.5}$ fraction whereas ratios under the range imply predominance of PM_{10} fraction. The challenge of $PM_{2.5}$ is because these tiny particles could cause adverse health effects based on its potential to reach the thoracic or lower regions of the respiratory zone. A $PM_{2.5}/PM_{10}$ ratio of 0.5 is typical of developing country urban areas [11-12]. This study therefore investigates how the particulate matter concentration varies with season, months, weeks days and hour. It also identified the nature of particulate matter at the study location using $PM_{2.5}/PM_{10}$ ratio.

2. METHODOLOGY

2.1 Study Area

The monitoring location for the study was at Woji urban area of Port Harcourt in River state Nigeria as revealed in Fig. 1. The town which is located between Latitude 4°49'53.80"N and Longitude 7°3'30.94" E is fast undergoing development and urbanization with great population growth. It is surrounded by Rumuomasi, Rumurolu, Trans-Amadi and Rumuibekwe communities with a total aerial of 5.5 square kilometers.

The climate is tropical with two seasons' specifically wet season (April to October) and dry season (November to March) for the year [1]. The town is a fast growing with many industries such as Indorama Eleme Fertilizer and Chemicals Limited, Indorama Eleme Petrochemicals Limited, Shell Petroleum and Development Company and host of other industries.

2.2 Data Collection

The particulate matter concentrations were monitored at Woji monitoring location using handheld Aerocet 531 particulate monitor for wet and dry season at a height of 1.5 m above ground level. The measurement was on one hourly basis for 24 hours duration from May to December 2018. The monitor has an optical laser sensor for measuring and detecting particulate matter concentration of 0-1 mg/m^3 which was pre-calibrated to ensure accuracy of monitored data. The Misol professional weather stations records and stores the meteorological data in the indoor console.

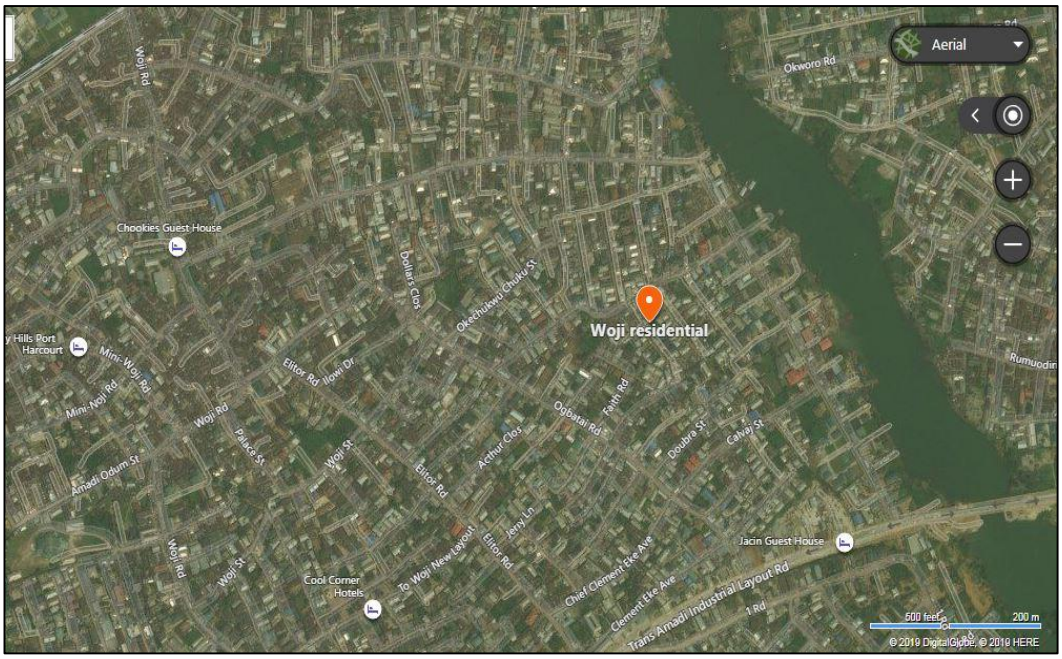


Fig. 1. Location map of study area

2.3 Method of Data Analysis

R-Programming software and its Openair application package was used for the time variation plot and polar plot in determination of temporal variability of $PM_{2.5}$ and PM_{10} concentration as well as $PM_{2.5}$ /PM_{10} ratio in the study area.

3. RESULTS AND DISCUSSION

3.1 Temporal Variation of $PM_{2.5}$ & PM_{10} Concentration

Fig. 2 presents variation of different temporal components (hour of day, day of the week and month of the year) for PM_{10} and $PM_{2.5}$ concentration at Woji Port Harcourt. The blue lines indicates PM_{10} variation while the red represents $PM_{2.5}$ variation for different periods of the year. The result in Fig. 2c revealed that highest particle pollution occurred in the month of December with an average $PM_{2.5}$ concentration of 58.8 μgm^{-3} and PM_{10} concentration of 164.5 μgm^{-3}, this concentration exceeds WHO and USEPA daily threshold, which can be attributed to north east trade wind associated with harmattan season(cold-dry dusty season in Sub Saharan Africa) while October month experienced the lowest particle pollution with mean concentration of 22.6 μgm^{-3} and 76 μgm^{-3} for $PM_{2.5}$ and PM_{10} respectively. The weekday – weekend PM variation as shown in Fig. 2d also revealed that $PM_{2.5}$ and PM_{10} concentration during the weekend are usually lower than concentration on weekdays. This can be attributed to high vehicular movement, industrial and commercial activities during the weekdays. The day of the week that experienced the highest PM concentration for the study period was Tuesdays while Sundays experienced the least due to less Particulate matter generating activities as shown in Fig. 2a & 2d. The hourly variation of $PM_{2.5}$ and PM_{10} concentration as shown in Fig. 2b & Fig 3 usually increase at night from 8:00 PM to 9:00 AM in the morning with the highest PM concentration always observed at 8:00 AM in the morning. It can equally be seen from polar plot in Fig. 3 that PM concentrations are usually low in the afternoon and remain high in the night up till the morning hours.

3.2 Temporal Variation of $PM_{2.5}$/PM_{10} Ratio

Fig. 4 presents a polar plot binned by wind speed and wind direction at Woji which shows the $PM_{2.5}$/PM_{10} ratio for wet and dry season at different wind speed and direction. While Fig. 5 presents a time variation plots that shows the average diurnal, weekly and monthly cycles of $PM_{2.5}$/PM_{10} ratio.

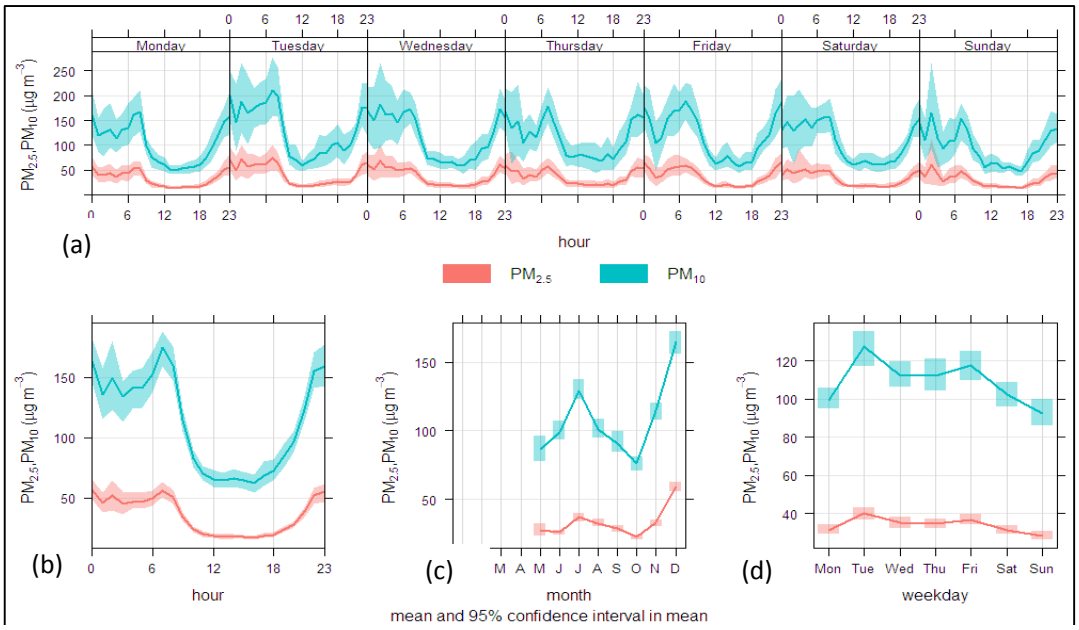
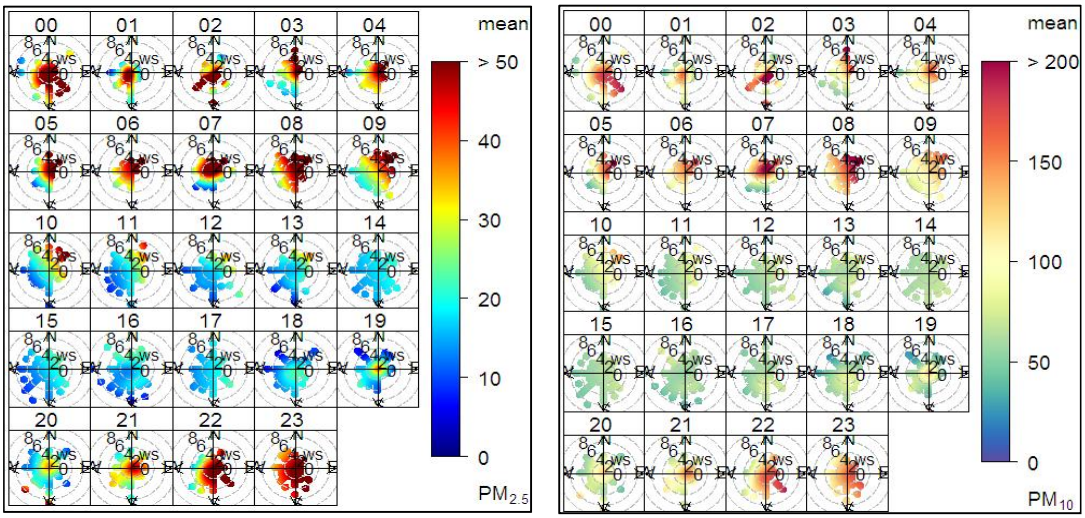


Fig. 2. Hourly, weekly and monthly variation of $PM_{2.5}$ & PM_{10} concentration



(a) Hourly mean $PM_{2.5}$ concentration **(b) Hourly mean PM_{10} concentration**

Fig. 3. Hourly mean concentration of $PM_{2.5}$ & PM_{10}

Fig. 4 revealed that $PM_{2.5}$ /PM_{10} ratios for wet season and dry season respectively range from 0.2 to 0.6 with an average ratio of 0.3 for each season. This shows that the average $PM_{2.5}$/PM_{10} ratio for the study period was 0.3 which indicates that the nature of particulate matter in Woji Port Harcourt is predominantly coarse particle.

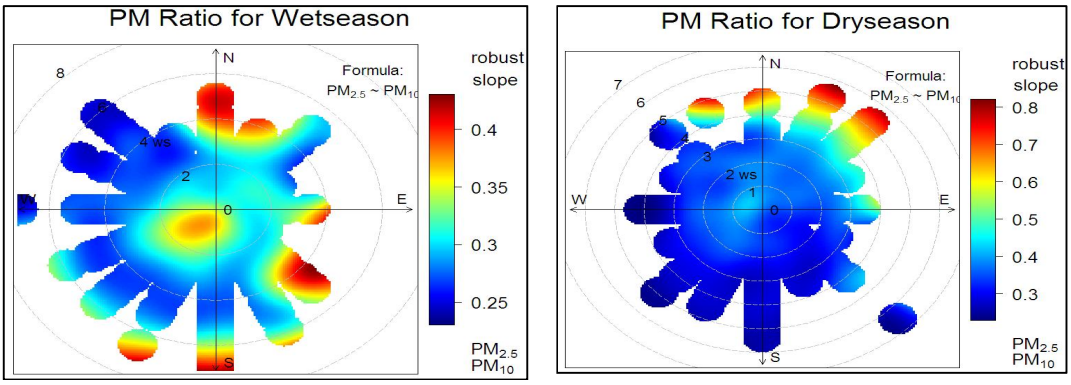
Fig. 4a which is the plot for wet season revealed that at low wind speed of 0-2 m/s, the $PM_{2.5}$ /PM_{10} ratio at the south west direction was 0.36 which is an indication of local source. The figure also revealed an increase in PM ratio at the north, south and south east wind direction at higher wind speed near and above 4 m/s. Also for dry season, Fig. 4b revealed a higher $PM_{2.5}$ /PM_{10} ratios above 0.5 at North and North east direction signifying predominance of $PM_{2.5}$ at higher wind speed at the northern axis. The monthly variation plot in Fig. 5c, presents December as the month with the highest mean

$PM_{2.5}$ / PM_{10} of 0.35 while the lowest mean ratio of 0.26 was in the month of June for the study period. The weekday-weekend variation, in Fig. 5d shows that weekdays experienced higher PM ratio than the weekend with the highest ratio occurring on Tuesdays and lowest on Sundays. The hourly variation in Fig. 5b revealed that $PM_{2.5}$ / PM_{10} ratio is usually higher in the evening through the night to morning hours and lower in the afternoon hours to 6:00 PM. The peak $PM_{2.5}$ / PM_{10} ratio occurs at 12:00 PM midnight and starts to decline till 6:00 PM. Therefore, December month experienced the highest $PM_{2.5}$ / PM_{10} level which is usually experienced from 7PM in the night to the morning hours.

The result of this study however, agreed with the work of these other researchers in Nigeria with a $PM_{2.5}/PM_{10}$ ratio below 0.5 [13-17].

The result of the study also shows that the average hourly, daily, weekly and seasonal $PM_{2.5}$ /PM_{10} ratios were below WHO ratio of 0.5 for typical developing urban area which is an indication that the particulate matter in Woji Port Harcourt was predominated by coarse particles.

The high $PM_{2.5}$ /PM_{10} ratios above 0.5 at the North and North east wind direction was as a result of long range transport dominated by $PM_{2.5}$ at higher wind speed at the northern axis.



(a) **(b)**

Fig. 4. $PM_{2.5}/PM_{10}$ ratio for (a) Dry & (b) Wet season at Woji

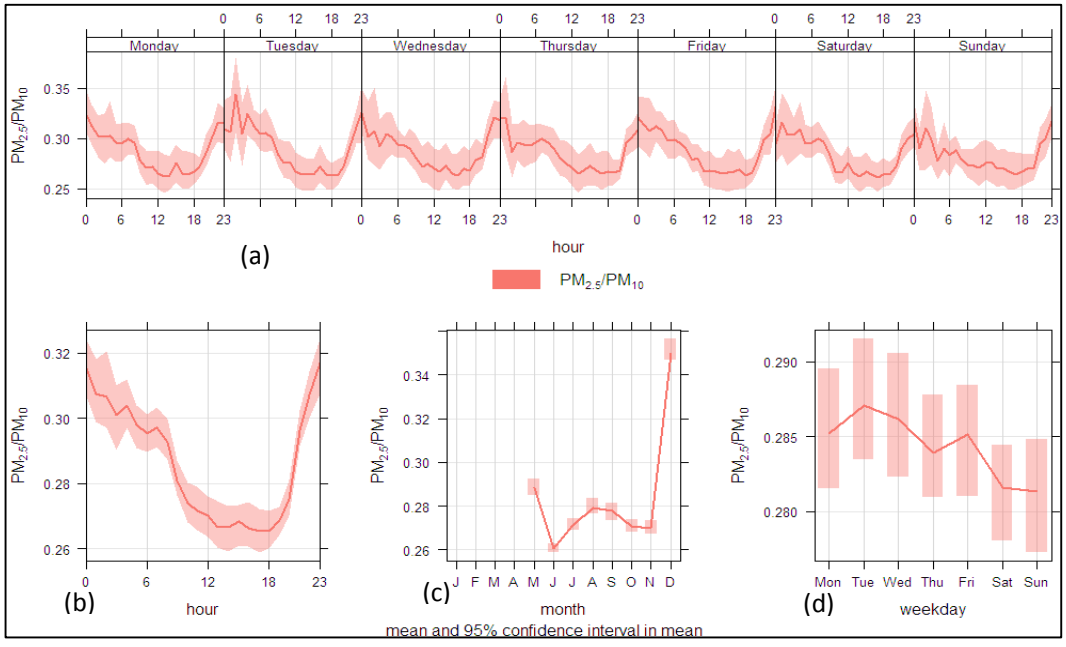


Fig. 5. Time variations of $PM_{2.5}/PM_{10}$ ratio at Woji

4. CONCLUSION

The following conclusions can be drawn from this study:

1) The maximum Particulate matter concentration was in December (dry season) owing to high atmospheric stability with dry dusty north east trade wind which was liable for particle pollution exceedances in the month. The weekdays experienced elevated PM level than weekend which can be attributed to high industrial, commercial and traffic activities emitting particles within the weekdays. It also revealed that maximum PM concentration occurred on Tuesdays with the lowest on Sundays. The time variation concludes that higher PM levels were observed daily from 8:00 PM to 9:00 AM with the peak at 8:00 AM.
2) The average $PM_{2.5}/PM_{10}$ ratio of 0.3 gotten from Woji Port Harcourt revealed that the town is predominated by coarse particle.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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