Published by
NIGERIAN SOCIETY OF PHYSICAL SCIENCES
Available online @ https://asr.nsps.org.ng/index.php/asr

African Scientific Reports 1 (2022) 123–132

African Scientific Reports

Atmospheric Physics; Air Pollution Monitoring and Analysis Using Purple Air Data

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Abstract

Air pollution has become one of the agents that leads to the cause of life threatening diseases in our contemporary world**.** Among the major air pollutants is the Particulate Matters $PM_{2.5}$ and $PM_{10.0}$. Long-time exposure to fine particles $PM_{2.5}$ and $PM_{10.0}$ in the environment has been linked to serious respiratory and cardiovascular diseases. The purpose of this research is to find the concentration of PM in some selected areas of Lagos, Rivers and Abuja namely Lekki, Port Harcourt and Lugbe respectively using Purpleair real time data for 12 weeks duration from 1^{st} November 2021 to 31^{st} January 2022. Findings have shown that among the study areas, Port Harcourt has the highest concentration of Particulate Matters followed by Lugbe with a 12 weekly average concentration of the Standard Indoor(CF1) $PM_{2.5}$ & $PM_{10.0}$ concentration and Standard Outdoor or Atmospheric(ATM) $PM_{2.5}$ concentration to be 87.80 $\mu g/m^3$, 101.76 $\mu g/m^3$ and 63.15 $\mu g/m^3$ respectively while Abuja has an average $PM_{2.5}$_CF1, $PM_{10.0}$_CF1 and $PM_{2.5}$_ATM values of 70.51 $\mu g/m^3$, 86.21 $\mu g/m^3$ and 52.07 $\mu g/m^3$ respectively. It was also found that the relationship between $PM_{2.5}$ and $PM_{10.0}$ showed a positive correlation with r = 0.99 indicating strong linear relationship.

DOI:10.46481/asr.2022.1.2.42

Keywords: Particulate matters, PurpleAir data, Air pollution, Pollutant, Concentration

Article History :
Received: 29 June 2022
Received in revised form: 21 August 2022
Accepted for publication: 23 August 2022
Published: 29 August 2022

Communicated by: Aanuoluwapo R. Obasuyi

1. Introduction

Air pollution has become one of the agents that leads to the cause of life threatening diseases in our contemporary world. According to WHO, almost the entire global population (99%) breathes air that exceeds WHO guidelines.

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The major air pollutants according to the Environmental Protection Agency (EPA) are Ground-level ozone, Carbon monoxide, Sulfur dioxide, Nitrogen dioxide and Particulate Matter ($PM_{2.5}$ and PM_{10}). PM is a heterogeneous and complex mixture of liquid and solid particle in the ambient air having different sizes like fine $PM_{2.5}$ and coarse PM_{10} [1]. These particles are either physical or chemical particles. According to a report by the United State Environmental Protection Agency EPA; $PM_{2.5}$ are fine inhalable particles with diameters that are generally 2.5 micrometers and smaller while PM_{10} are inhalable particles, with diameters that are generally 10 micrometers and smaller. PM_{10} are coarse particles that include $PM_{2.5}$ and particles up to 10 micrometers in diameter [2]. Owing to the size of $PM_{2.5}$, they can travel far and can easily be inhaled through breathing. Hence, they are regarded to be more dangerous than the PM_{10}. According to [3], particulate matters have been divided according to their origin into natural and anthropogenic aerosols e.g. sooths from industries, sprayed insecticides or pesticides, exhausts from automobiles etc. [4, 5]. The natural sources of PM include trade dusts, smoke from annual wild fire especially in the Savanna. Studies by the EPA have shown that the size of particles is directly linked to their potential for causing health problems. However, the duration of exposure has also been confirmed to contribute to the severity of health effect Particulate Matters (PM) pose on humans. Sustained long-time exposure to fine particles $PM_{2.5}$ and sulfur oxide related air pollution in the environment has been linked to serious cardiovascular, respiratory, skin diseases, lung cancer and death among postmenopausal women [6 - 8] According to Oladapo et al., [9]; Particulate matter may cause damage by discoloring or destroying painted surfaces, corrode metals and building surfaces, soil, textiles and clothing.

In an attempt by Nathaniel et al., [2] to find the Air Quality Levels and Health Risk Assessment of Particulate Matters in Abuja Municipal Area, Nigeria with data collected BR-SMART-126 - a handheld portable smart air quality detector found out that the daily averaged concentrations of $PM_{2.5}$ varied from 15.30 μg/m^3 to 70.20 μg/m^3. Out of the 20 study locations, they found that the top four most-polluted locations fell under business/commercial locations, transport and residential areas. Alani et al., [4] found out that the $PM_{2.5}$ concentrations ranged from 6 – 14μg/m^3 in UniLag and Agege respectively. The concentration in $PM_{2.5}$ was observed to be lower than the WHO regulatory standard. Francis et al., [10] *have* provided in-depth analysis of the air quality in some states for about 5 – 7 months using NASRDA real time data. Results from this finding have revealed that the concentration of PM2.5 within this study period in FCT, Osun, Lagos and Delta are in the range 0 -1146.73 μg/m^3, 9.1 – 236.6 μg/m^3, 23.23 – 847.75 μg/m^3 and 12.11 – 487.36 μg/m^3 respectively while the concentration of $PM_{10.0}$ in these aforementioned regions are in the range of 0 - 831 μg/m^3, 9.95 – 260.68 μg/m^3, 25 – 753.8 μg/m^3 and 12.96 – 552.51 μg/m^3 respectively.

The studies presented so far provide insight on the air quality and the Particulate Matter (PM) concentration in some certain locations within Nigeria. Results obtained from the findings of Francis et al., [10] are based on data obtained from NASRDA. This paper seeks to investigate the air quality and PM concentration in some areas of Lagos, Rivers and Abuja namely; Lekki, Port Harcourt and Lugbe respectively using purple air real time data.

2. Data and Method

The data used in this paper was obtained from PurpleAir available at www.purpleair.com. The PurpleAir map is a web application that displays a network of community-owned PurpleAir sensors. Each sensor measures and upload airborne Particulate Matter (PM) data to the PurpleAir real time map database. The sensors use PMSX003 laser counters to measure particulate matter in real time, with each laser counter alternating 5 second readings averaged over 120 seconds. Each laser counter uses a fan to draw a sample of air past a laser beam. The beam from these class IIIa/3R lasers will reflect light from any present particles onto a detection plate. The reflection is measured as a pulse by the detection plate and the length of the pulse determines the size of the particle while the number of pulses determines the particle count which are then used to calculate the concentration $PM_{2.5}$ and PM_{10} for standard indoor (CF_1) and outdoor or atmospheric (ATM) particle. The average daily data was downloaded for the period of twelve weeks i.e. November 2021 to January 2022. As the magnitude of environmental pollution problem is linked to the nature of activities, quantity of automobiles and quantity of waste generated by industries, we chose highly urbanized and industrialized regions. To determine the daily variation of air pollution, we plot the graph of particulate matter $PM_{2.5}$ & $PM_{10.0}$ against the days and thereafter, we found the correlation between the variation of PM and temperature for each selected location.

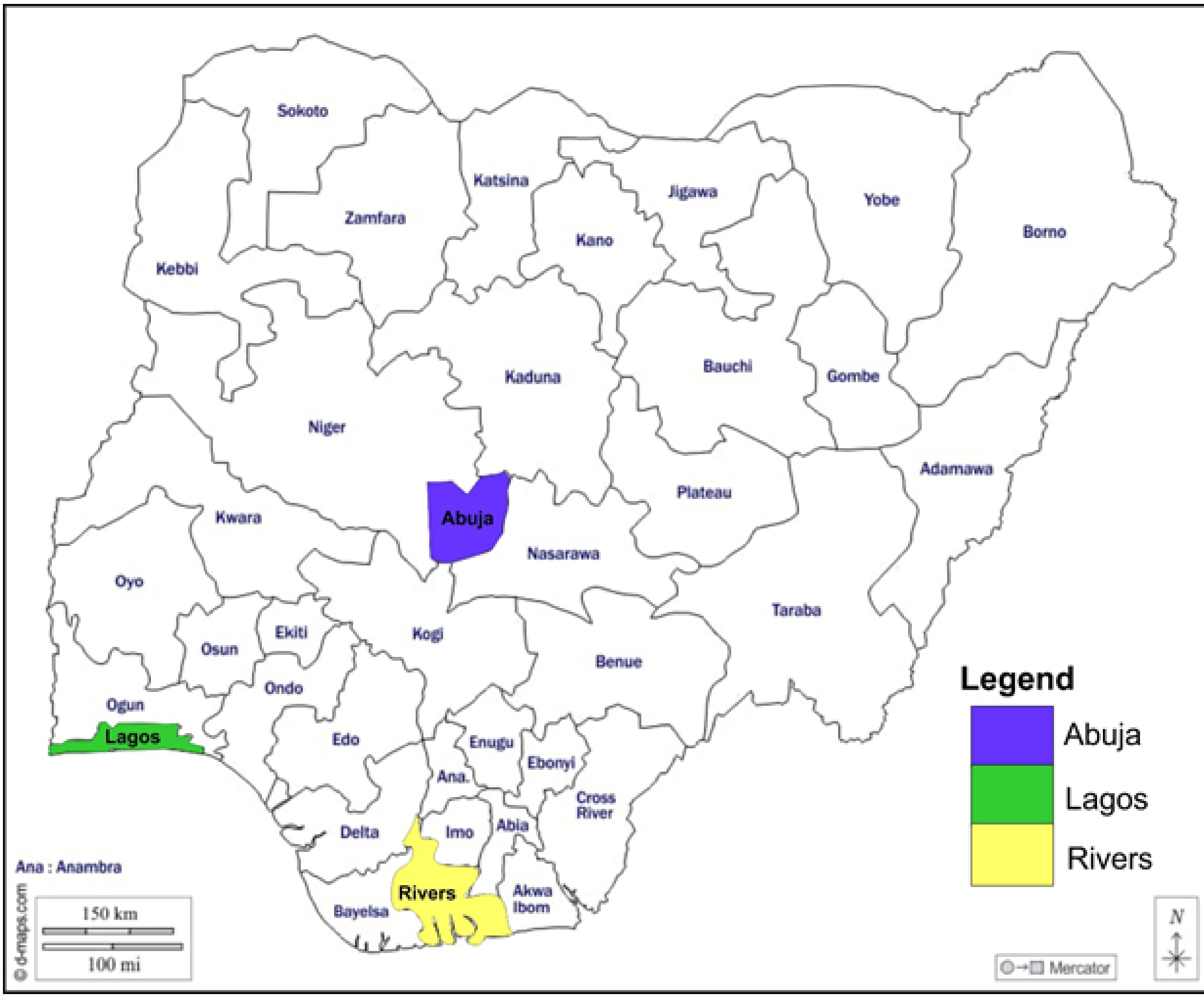

Figure 1. Map of Nigeria showing the 36 states including FCT. The colored region depicts the study area

3. Study Area

Due to the number of population and industries, we have selected some suitable areas of study from Lagos, Rivers, and Abuja namely; Lekki, PortHarcourt and Lugbe respectively.

Lagos is Nigeria also known as Èkó (in Yoruba). It is known for its numbers of industries and large population. It is the largest city in Nigeria. It has a land mass of about 1.171km^2 with an approximate population of about 23.5Million as at 2018. It is located in the South western part of Nigeria with latitude 6.465422 and longitude 3.406448. Because of its high number of industries, busy sea ports etc., the city has been described as the main economic hub of the country.

Rivers state is part of the Niger delta region of southern Nigeria with GPS coordinate of Latitude 4° 49′ 27.0012″ N and Longitude7° 2′ 0.9996″ E. It is one of the states with large deposits of crude oil. As a result, it houses one of the country's refinery and other oil related companies.

Abuja is the capital city of Nigeria. It is located in the North Central Nigeria with Latitude 9.072264 and longitude 7.491302. Abuja being the Federal Capital Territory, is a home for the major administrative institutions in Nigeria and because of this, it has accommodated a good number of people whose major means of transportation is automobiles. It is one of the Northern states faced with dry and dusty northeasterly trade wind from the Sahara especially during harmattan season.

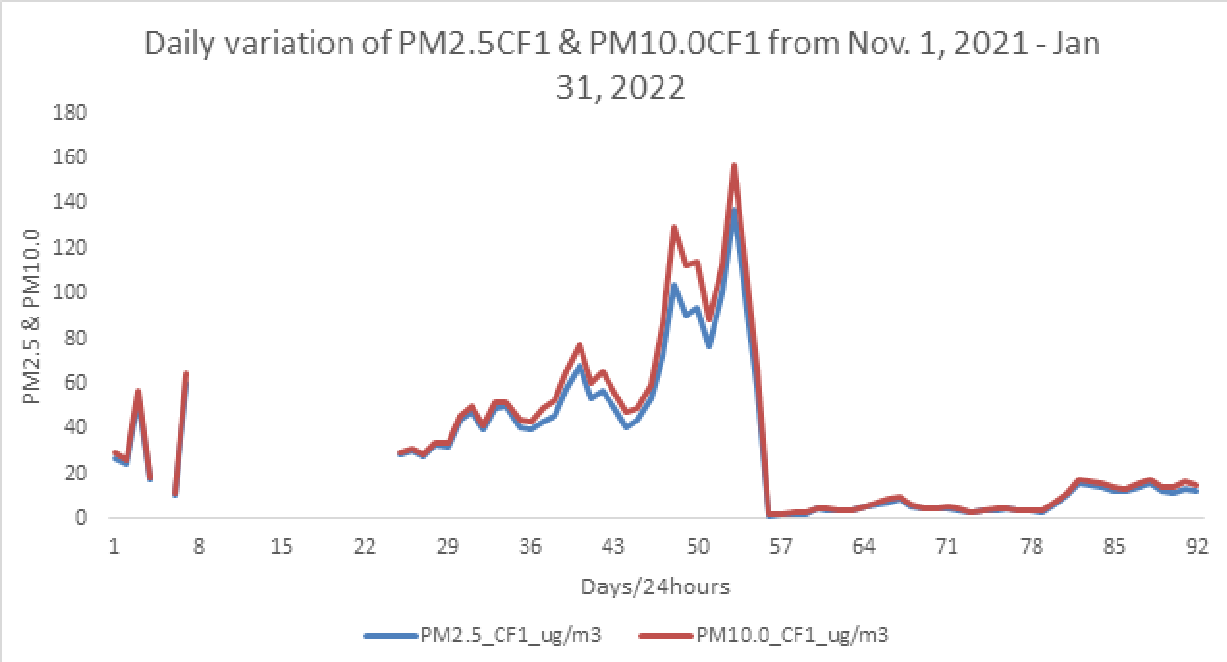

Figure 2. Daily variation of PMs_CF1(Standard Indoor concentration)

4. Results and Discussion

Air quality and concentration of particulate matter ($PM_{2.5}$, $PM_{10.0}$), Humidity and Temperature in Lekki, Port Harcourt and Lugbe. (Figure 1 above) as monitored and collected by purple air sensors over a period of 12 weeks, between November 1^{st} 2021 to January 31^{st} 2022 have been analyzed.

Figure 2 – Figure 4 shows the atmospheric data variation from Lekki, Lagos Nigeria.

Figure 5 – Figure 7 shows the data variation from Port Harcourt; Rivers state.

Figure 8 – Figure 9 shows the data variation from Lugbe, Abuja.

Figure 2 shows the daily variation of Particulate matters $PM_{2.5}$_CF1 and $PM_{10.0}$_CF1. The sensor was down from the 4^{th} to 6^{th} and 8^{th} to 24^{th} November 2021. The variation of $PM_{2.5}$_CF1 and $PM_{10.0}$_CF1 fluctuates between 29.84μg/m^3 and 53μg/m^3 from 26^{th} November to 5^{th} December 2021. The PM (2.5 & 10.0) steadily increased within the interval 14^{th} – 18^{th} December 2021 with $PM_{10.0}$_CF1 = 129.58μg/m^3 and $PM_{2.5}$_CF1 = 103.78μg/m^3. They decreased rather steadily and, on the 21st December, they started to increase steadily to reach $PM_{2.5}$_CF1***peak*** = 136.9μg/m3 and $PM_{10.0}$CF1 peak = 156.73μg/m3. $PM_{2.5}$_CF1 is seen to lag as can be observed from the plot. They decreased steadily and thereafter, show little variation for the rest of the study period.

Figure 3 shows the daily variation of $PM_{2.5}$, Temperature (F) and Humidity. The sensor was offline from the 4^{th} to 6^{th} and 8^{th} to 24^{th} November 2021. The temperature is seen to maintain almost steady mean value within the study period. $PM_{2.5}$_ATM shows great fluctuation within the interval 26^{th} November 2021 and 18^{th} December 2021. It decreased and on the 31^{st} December, $PM_{2.5}$_CF1 increased steadily reaching $PM_{2.5}$_CF1peak = 91.2μg/m^3 on the 23^{rd} of December 2021. The Relative Humidity (RH) was observed to show fairly steady variation until 16^{th} December 2021, when the humidity dropped from 59% to 41%. This decrease in humidity lasted for about three days and on the 22^{nd} of December 2021, the humidity began to increase to attain a value humidity = 61% on the 26^{th} of December. The humidity began to vary slowly until 5^{th} of January when it depressed to 40%.

Figure 4 shows the scatter diagram showing the correlation between the Particulate matters $PM_{10.0}$ and $PM_{2.5}$, The scatter diagram is seen to show a positive correlation. The Pearson correlation coefficient = 0.99 indicating a very strong correlation.

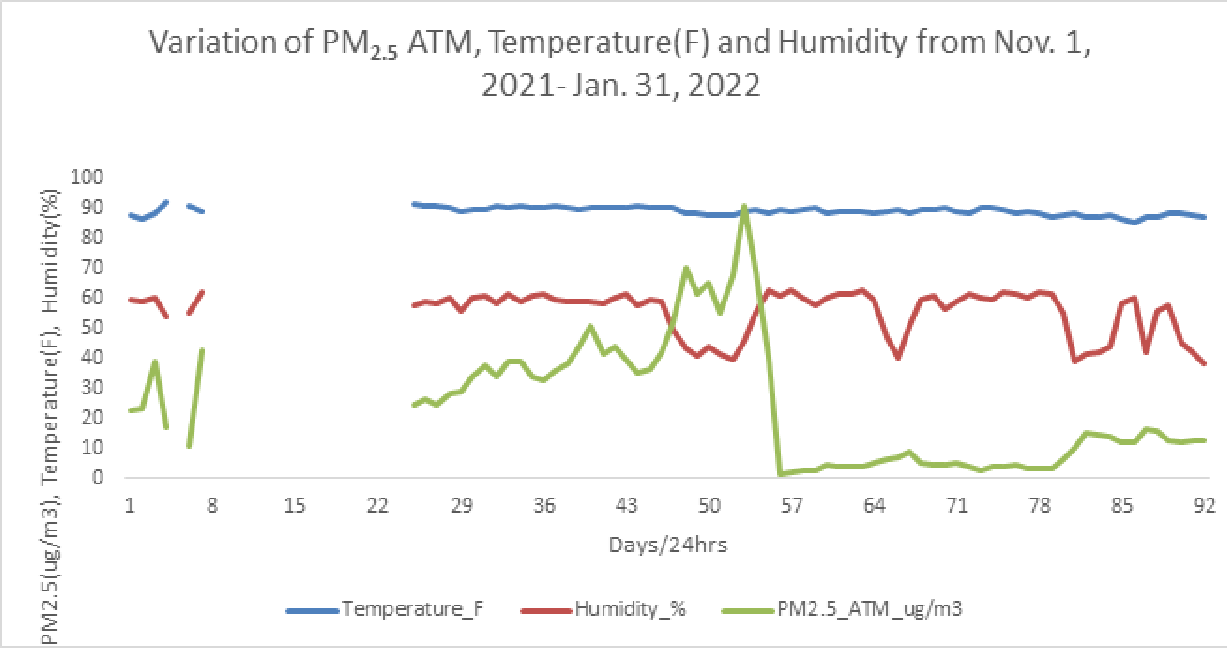

Figure 3. Daily variation of $PM_{2.5}$_ATM, Temperature (F) and Humidity (%)

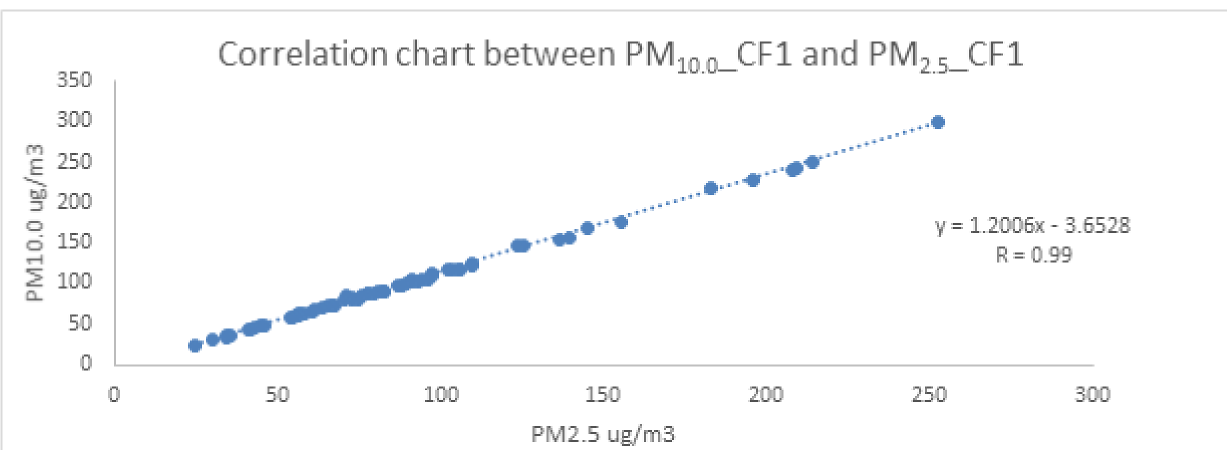

Figure 4. Scatter plot showing correlation between $PM_{10.0}$_CF1 and $PM_{2.5}$_CF1

Figure 5 shows the daily variation of $PM_{2.5}$_CF1 and $PM_{10.0}$CF_1. On the 6^{th} of November 2021, $PM_{10.0}$ = 104μg/m^3 while $PM_{2.5}$ = 90.3μg/m3. It gradually decreased from 6^{th} – 8^{th} of December to about 35.9μg/m^3 and immediately, it was seen to increase to about 93μg/m^3. The sensor was offline from 11^{th} – 15^{th}, 21^{st} – 22^{nd} November, 18^{th} – 26^{th} December 2021 and 3^{rd} – 10^{th} January 2022 and hence, no data collected within these period as can be observed in Figure 5 above. From 15^{th} – 20^{th} November, the $PM_{10.0}$ fluctuates between 108μg/m^3 to 120μg/m^3 and from the 22^{nd} while $PM_{2.5}$ fluctuates between 95μg/m^3 to 104μg/m^3. On the 24^{th}, PM10.0 = 160.17μg/m^3 while $PM_{2.5}$ = 76.39μg/m^3. It sharply decreased and immediately, $PM_{10.0}$ and $PM_{2.5}$ increased abruptly to 252.4μg/m^3 and 152.2μg/m^3 respectively on the 28^{th} December 2021. It decreased sharply to 152 and 109μg/m^3 for PM_{10} and $PM_{2.5}$ respectively and began to fluctuate between 242 to 231μg/m^3. The highest concentration recorded occurred on the 15^{th} December 2021 with a corresponding $PM_{10.0}$ and $PM_{2.5}$ values of 302.16μg/m^3 and 251μg/m^3 respectively.

Figure 6 shows the daily variation of Temperature (F), Humidity and $PM_{2.5}$_ATM. The temperature was fairly

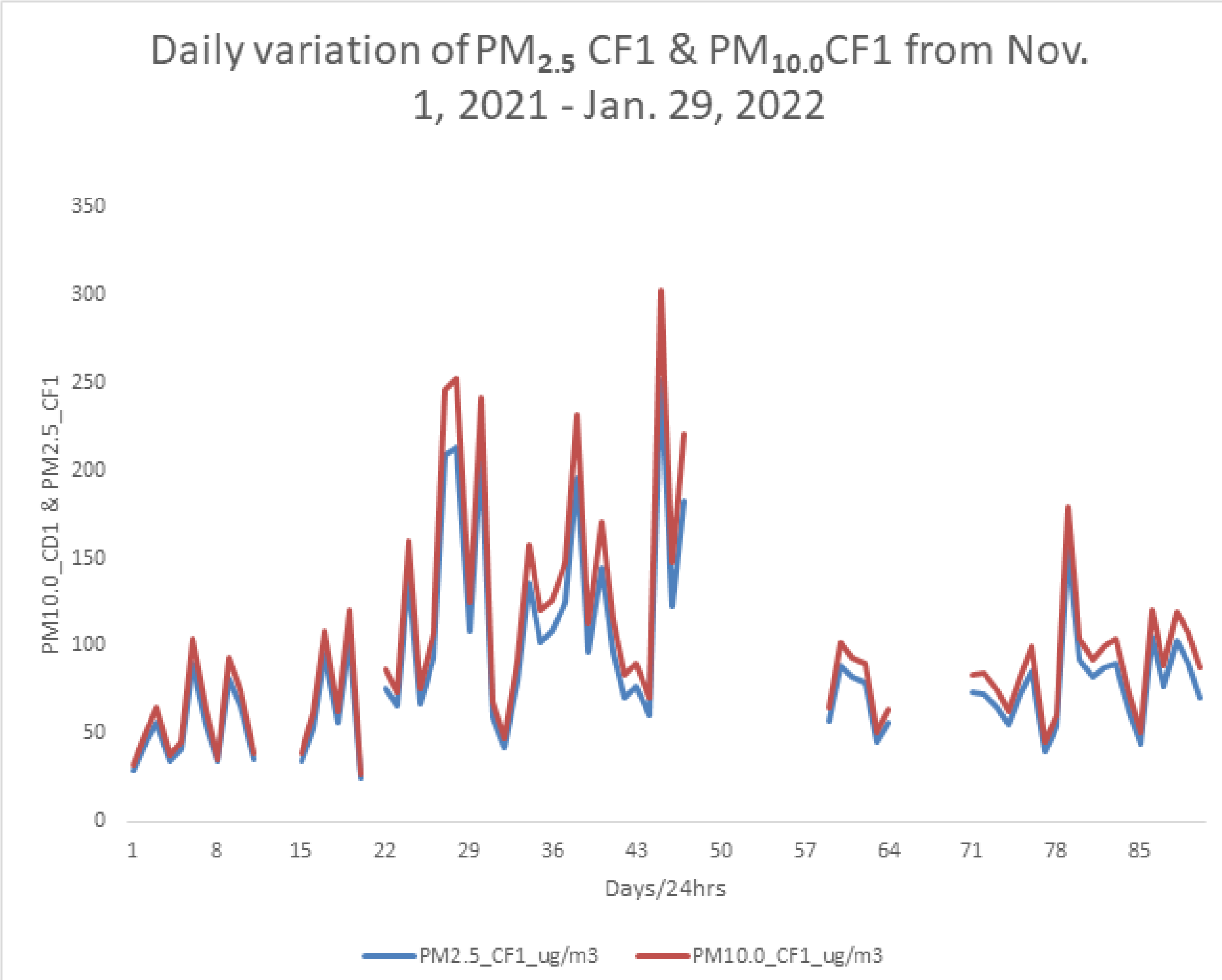

Figure 5. Daily variation of $PM_{2.5}$_CF1 & $PM_{10.0}$_CF1

steady with an average value of 89.2F within the study period. The purple air sensor was offline from 11^{th} – 15^{th}, 21^{st} – 22^{nd} November, 18^{th} – 26^{th} December 2021 and 3^{rd} – 10^{th} January 2022 thereby depriving us the daily data within these periods. $PM_{2.5}$_ATM vary between 26 – 73μg/m^3 within the interval November 1^{st} – November 19^{th}, 2021. On the 24^{th} of November, $PM_{2.5}$ = 124 μg/m^3. It sharply decreased to 49.7 and after then, steadily increased to $PM_{2.5}$ = 142.59, November 28. Thereafter, $PM_{2.5}$ showed large fluctuation until December 15^{th} when it began to increase to attain a $PM_{2.5}$ peak = 167.16 μg/m^3. The humidity showed fairly steady variation until December 16^{th} when it sharply decreased to 28% just after $PM_{2.5}$ maximum.

Figure 7 shows the correlation between the particulate matters $PM_{2.5}$CF_1 and $PM_{10.0}$_CF1. The scatter diagram shows a positive correlation. The Pearson correlation coefficient r = 0.99 indicating a very strong correlation.

Figure 8 shows the daily variation of $PM_{2.5}$_CF1 and $PM_{10.0}$_CF1 in Lugbe, Abuja Nigeria. The sensor was not active from 5^{th}-7^{th}, 27^{th}-29^{th} November, 3^{rd} – 6^{th}, 10^{th} – 12^{th}, 15^{th} – 20^{th} December 2021, 24^{th} – 28^{th} and 30^{th} December to January 2^{nd}, 2022. The PM concentration ranges between 34μg/m^3 - 213 μg/m^3 for PM10.0_CF1 and 198 μg/m^3 for $PM_{2.5}$_CF1. $PM_{2.5}$_CF1 decreased steadily from 154 μg/m^3 to 32.5 μg/m^3 January 2^{nd}. Immediately, it began to increase fairly steadily to reach $PM_{2.5}$= 190 μg/m^3 January 9 while the concentration of $PM_{10.0}$_CF1 = 213.3μg/m^3. The highest concentration of the PM (2.5_CF1 and 10.0_CF1) was recorded on the 14^{th} January 22 with a corresponding $PM_{2.5}$_CF1 = 198 μg/m^3 and $PM_{10.0}$_CF1= 220 μg/m^3. Similarly, the highest concentration of $PM_{2.5}$_ATM recorded was January 14^{th} 2022 with PM_ATM= 131.4 μg/m^3.

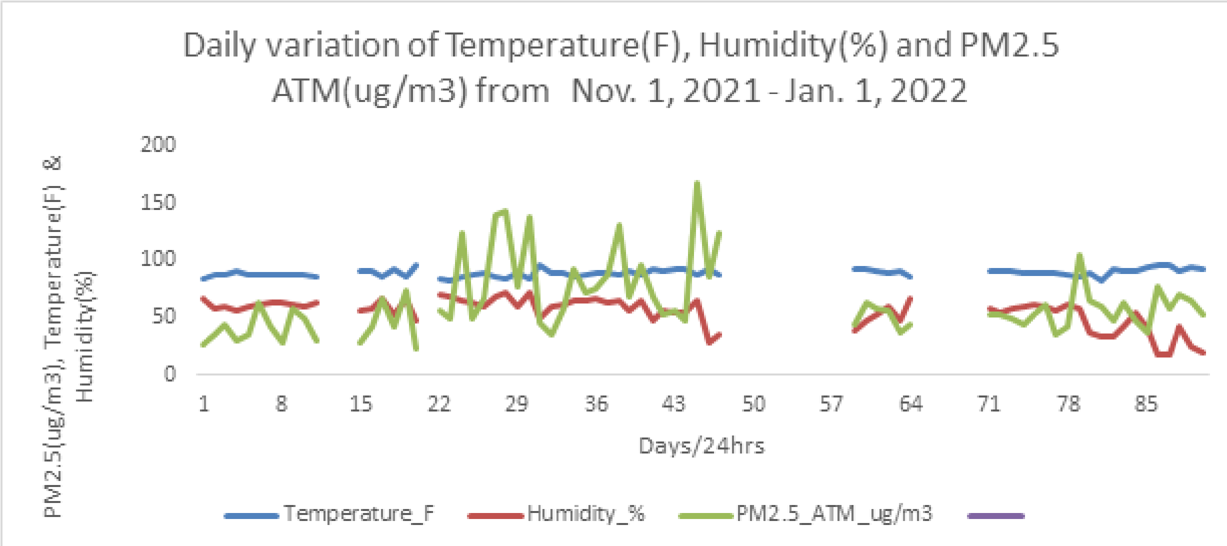

Figure 6. Daily variation of Temperature (F), Humidity and PM2.5_ATM

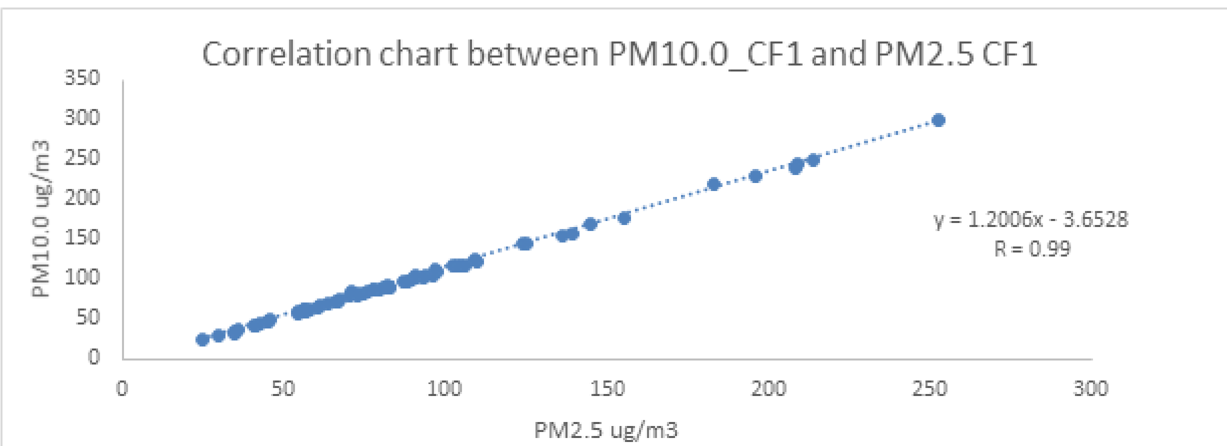

Figure 7. Scatter diagram showing the correlation of PM_{10} with $PM_{2.5}$

5. Discussion

The level of negligence on air and air quality by the majority is a matter of great concern. The unmonitored human activities and lack of compliance to preventive measures has contributed a great quota to the cause of ambient air pollution. Analysis from the data collected over a period of 12 weeks have shown that the $PM_{10.0}$ _CF1 concentration in Lekki, Port Harcourt, and Lugbe are between 11.42 – 156.73$\mu g/m^3$, 32-302 $\mu g/m^3$ and 34-213$\mu g/m^3$ respectively while $PM_{2.5}$_CF1 concentration within these locations ranges between 26 – 136.9$\mu g/m^3$, 50 - 251$\mu g/m^3$ and 34 - 198$\mu g/m^3$ respectively. River state is the most polluted area within this study period followed by Abuja. Similarly, results obtained by Oladapo et al., [9] from the assessment of atmospheric particulate matter at three emerging industrial sites in Port Harcourt indicated higher concentration of PM.

The average concentration of $PM_{2.5}$_CF, $PM_{10.0}$_CF and $PM_{2.5}$_ATM for the three weeks study period as shown in Table 1 are 30.57, 34.47 and 24.15$\mu g/m^3$ respectively. It can be observed from Figure 6 that the daily concentration of Particulate Matters $PM_{2.5}$_ATM is within the range of 35-167 $\mu g/m^3$ while $PM_{10.0}$_CF1 and $PM_{2.5}$_CF1 ranges from 32-302 $\mu g/m^3$ and 50-251 $\mu g/m^3$ respectively. These values are beyond the WHO regulation on Air Quality and Air

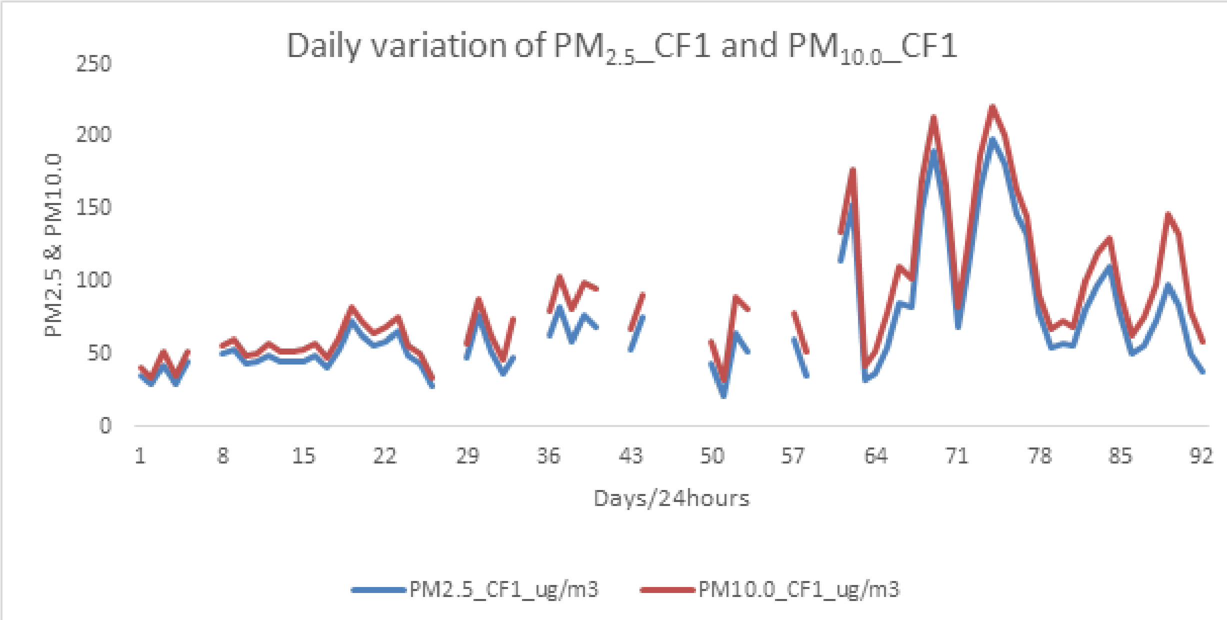

Figure 8. Daily variation of $PM_{2.5}$_CF1 and $PM_{10.0}$_CF1

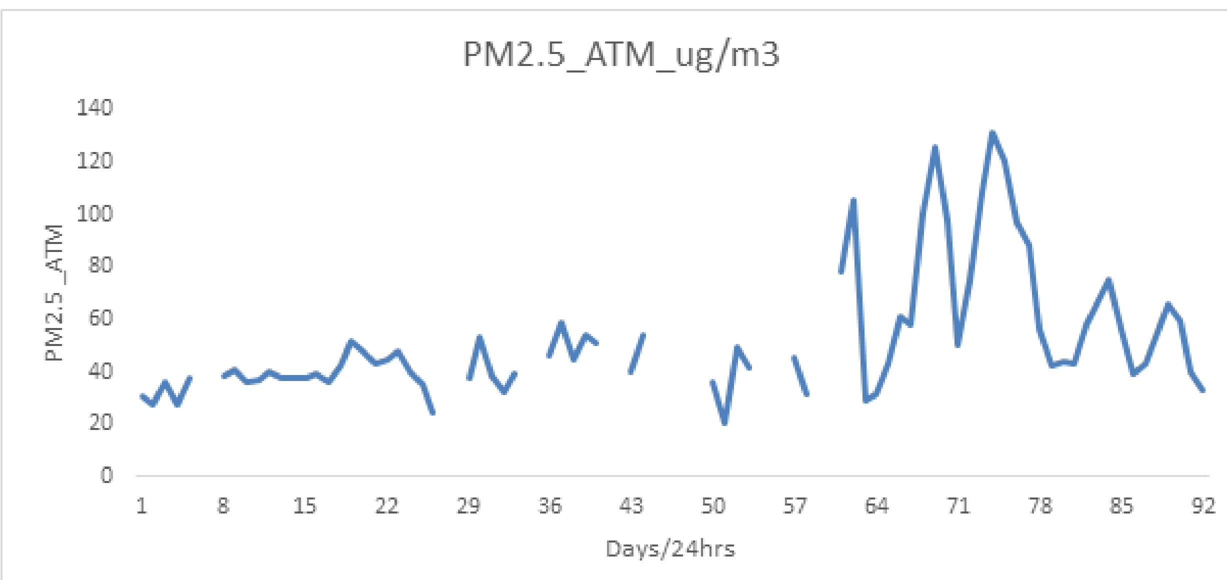

Figure 9. Daily variation of $PM_{2.5}$_ATM

Table 1. Monthly Average PM Concentration from November 2021 – January 2022

Location	$PM_{2.5}$_CF1 average(μg/m^3)	$PM_{10.0}$_CF1 average(μg/m^3)	$PM_{2.5}$_ATM average(μg/m^3)
Lekki	30.57	34.47	24.15
Port Harcourt	87.80	101.76	63.15
Abuja	70.51	86.21	52.07

Table 2. Air quality index for PM2.5 and PM10.0 (Source: [2])

AQI Value Of Index	Levels of Health Concern	$PM_{2.5}$ Conc. (μg/m³)	PM_{10} Conc. (μg/m³)	Daily AQI Color	Air Pollution Level
0–50	Good	0–12	0–54	green	Level 1
51–100	Moderate	12.1–35.4	55–154	yellow	Level 2
101–150	Unhealthy for sensitive groups	35.5–55.4	155–254	orange	Level 3
151–200	unhealthy	55.5–150.4	255–354	Red	Level 4
201–300	Very unhealthy	150.5–250.4	355–424	Purple	Level 5
301 and Higher	Hazardous	250.5–Higher	425–Higher	Maroon	Level 6

Table 3. Monthly average air quality and correlation r between $PM_{2.5}$ and meteorological factors

Study Location	Months	Average Monthly $PM_{2.5}$ Concentration (μg/m^3)	$PM_{2.5}$ & Temperature	$PM_{2.5}$ & Relative Humidity	Relative Humidity & Temperature
Lekki	November 2021	26.87	- 0.34	0.78	-0.52
	December 2021	39.19	-0.23	-0.68	0.64
	January 2022	8.05	-0.71	-0.69	0.27
Port Harcourt	November 2021	60.04	-0.49	0.61	-0.95
	December 2021	76.42	-0.61	0.16	-0.63
	January 2022	55.15	-0.12	-0.22	-0.59
Lugbe	November 2021	44.16	-0.21	0.09	-0.69
	December 2021	48.55	0.02	0.37	-0.47
	January 2022	73.73	0.46	0.77	0.39

pollution level.

It was observed from Figure 9 that the daily concentration of $PM_{2.5}$ in Lugbe fluctuates between 31 and 52 $\mu g/m^3$ within the interval 1^{st} – 18^{th} November 2022. This observed value falls within Level 2 and Level 3 (Table 2) i.e. unhealthy for sensitive group. However, an abrupt increase in $PM_{2.5}$ concentration (i.e. $PM_{2.5} \geq 59\mu$g/m^3) was observed within the interval November 11, 2021 – January 28, 2022. This PM concentration according to daily air quality standard level is classified very dangerous and thus very unhealthy for both sensitive group (e.g. Asthmatic patients) and insensitive group.

A possible explanation for the rise in the concentration of PM in industrialized area like Port Harcourt (Table 3) in the month of November and December could be as a result of increase in industrial production. It is noteworthy that the annual break for most organizations in Nigeria is usually in November or December and within these periods, most industries continuously work so as to have enough stock available during the break. However, in Lugbe - a semi-industrialized area, the highest concentration of $PM_{2.5}$ was in January. It seems possible that this increase in the concentration of $PM_{2.5}$ results from the increasing number of automobiles travelling the road of Abuja as it is the major route linking the Northern Nigeria to the Southern, Western and Eastern part of the country.

The impact of Relative Humidity (RH) on the daily average concentration of $PM_{2.5}$ as studied by Rasa et al., [11] have revealed that the RH correlated positively with the daily average $PM_{2.5}$ concentration in traffic busy areas and negative in more industrial areas. However, in this work, the correlation between the $PM_{2.5}$ and RH vary within the study areas (Table 3). This variation could be due to the variation of the climatic condition in these study locations.

6. Conclusion

In our study to find the concentration of Particulate matters (PM) in Lekki, Lugbe and Port Harcourt, results obtained from our analysis using data from purpleAir map have revealed that the most polluted of the three locations is Port Harcourt with 12 weekly average $PM_{2.5}$_CF1, $PM_{10.0}$_CF1 and $PM_{2.5}$_ATM of 87.80 $\mu g/m^3$, 101.76 $\mu g/m^3$ and 63.15 $\mu g/m^3$ respectively while Lugbe has an average $PM_{2.5}$_CF1, $PM_{10.0}$_CF1 and $PM_{2.5}$_ATM values of 70.51 $\mu g/m^3$, 86.21 $\mu g/m^3$ and 52.07 $\mu g/m^3$ respectively. The correlation coefficient **r** obtained from the linear relationship between $PM_{2.5}$ and $PM_{10.0}$ obtained from the study areas were found to be 0.99 each indicating a good positive correlation. The high concentration of PM in these affected states results from the increasing number of automobiles and industrial activities. To reduce this pollution, it is suggested that trees be planted on the edges of the road in order to trap some of these toxic gasses emitted from moving automobiles. Also, proper regulation in the disposal of industrial waste be adopted especially gas flares from refineries as this has jeopardized the health of the people living within these areas.

Acknowledgment

The data used in this research was provided for free by purpleair.com. We are very grateful for their support.

References

[1] R. K. Krishna & B. Gufran, "Influence of meterrology on particulate matter (PM) and vise-versa over two Indian metropolian cities", Open Journal of Air Pollution (2018) 244.
[2] M. W. Nathaniel & D. Xiaoli , "Air quality levels and health risk assessment of particulate matters in Abuja municipal", Atmosphere 11 (2020) 817.
[3] R. G. Barry & J. C. Richard, Atmosphere, Weather and Climate, Routledge , New York (2000).
[4] A. A. Alani , O. O. Ayejuyo, O. E. Akinrinade, G. O. Badmus, C. J. Festus, B. A. Ogunnaike & B. I. Alo, "The level of PM2.5 and the elemnetal compositions of some potential receptor locations in Nigeria", Air Quality, Atmosphere & Health (2019).
[5] J. Wang & S. Ogawa, "Effects of meteorolgical conditions on PM2.5 concentration in Nagasaki, Japan", Int. J. Environ. Res. 2 (2015) 9089.
[6] K. A. Miller, D. S. Siscovick, L. Sheppard, K. Shepherd, J. H. Sullivan, G. L. Anderson & J. D. Kaufman, "Long term exposure to air pollution and incidence of cardiovascular events in women", N Engl J Med. (2007) 447.
[7] C. Bingheng & K. Haidong, "Air pollution and population health: a global challange", Environmental Health and Preventive Medicine (2008) 94.
[8] Z. Javeria, J. Jongho, B. L. Seung & S. K. Jin, "Effects of particulate matter on human health, prevention, and imaging using PET or SPECT", Progress in Medical Physics (2018) 81.
[9] A. M. Oladapo, B. Ndokiari & O. C. Charles, "Assessment of particulate matter - based air quality index in Port Harcourt Nigeria", Journal of Environmental Analytical Chemistry 4 (2017) 224.
[10] O. A. Francis & A. A. Ifeoluwa, "Monitoring air quality in Nigeria: The case of CARNASRDA", Aerosol Science and Engineering 5 (2021) 478.
[11] Z. Rasa, L.-V. Jesus & R. Yves, "Contrasted effects of relative humidity and precipitation on urban PM2.5 pollution in high elevation urban areas", Sustainability 10 (2018) 64.