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Climate Parameters and Particulate Matter (PM2.5): Implication for Air Quality Index of Port Harcourt, Minna and Maiduguri of Nigeria

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ABSTRACT

This study, climate parameters and Particulate Matter (PM2.5) and their implications to Air Quality Index (AQI) of Port Harcourt, Minna and Maiduguri of Nigeria has revealed the pattern of climatic variables and the pollution characteristics of the three cities in Nigeria. Secondary source of data was used in this research. The data were sourced from IQ Air Earth (https://www.iqair.com/earth?nav) air quality monitoring database. Air quality data were gathered through multi-sources, validation and visualization of real-time data from governments, sensors operated by individuals and organizations. Data were acquired from ground-based air quality monitoring stations with high data availability and unprecedented accuracy of temperature, humidity, pressure, wind flow and $PM_{2.5}$ measurements. The result showed that the mean AQI index of Port Harcourt (87.1) had the highest particulate matter pollution, followed by Maiduguri (64) and the least was Minna (43) in the particulate matter air contamination. Port Harcourt had wind pressure of 1012mb and Minna (1012mb) as characterized in their Humid and Sub-Humid zones. Maiduguri had the lowest pressure value of 1009mb due to the low moisture in the air. Port Harcourt with $PM_{2.5}$ recorded 29μg/m², Minna had 11.4μg/m² and Maiduguri recorded 18.5μg/m² indicating that Port Harcourt had the highest particulate matter contamination. It was recommended that massive tree planting should be implemented and $PM_{2.5}$ emission sources should be nipped in the bud without further delay.

Keywords: Climate, Particulate Matter, Air Quality Index

1. INTRODUCTION

Air Quality (AQ) is a measure of the cleanliness or pollution the air is at a particular time. It is pertinent to monitor air quality as bad air is hazardous to life and the environment. The unit for measuring air quality is the Air Quality Index (AQI). The World Health Organization (WHO) has estimated that nine (9) out of

every ten (10) persons worldwide are breathing bad and unsafe air [1]. World Air Quality Report [WAQR], 2018 states that in the 3000 cities studied across the world, 64% of the cities' air exceed the WHO recommended annual exposure guideline for particulate matter ($PM_{2.5}$). The measured cities show that Middle East and Africa have 100% of their cities exceeding the recommended WHO threshold, South Asia has 99%, cities in Southeast Asia has 95% and East Asia has 89% respectively. These measurements show that the air quality across the cities of the world has serious damage to human health and those of plant and animal species.

Air pollution can be induced by Sulphur Oxides (SOx), Carbon Oxide (CO), Nitrogen Oxides (NOx), Particulate Matter (PM), Volatile Organic Compounds (VOC), Others are Chlorofluorocarbons (CFCs), persistent free radicals, toxic metals such as lead and mercury, Ammonia (NH_3). Air pollution can be generated from odors from garbage odor, waste from industries and pollutants from radioactive facilities as they are produced by nuclear explosions. Also, air pollution can be induced by photochemical smog, ground level ozone (O_3) produced from NOx and VOCs [2, 12, 13]. Air pollution can cause intense health hazards to humans in the form of difficulty in breathing, sneezing, coughing, cardiac discomfort, wheezing and other respiratory health challenges as well as death of many.

The impact of air pollution can be seen on the traces of plant and animal species. Some of the air pollution can be seen in the genetic composition of plant and animal species [3]. The reaction of different air pollution can result to acid rain and ground ozone. The product of these reactions are capable of destroying flora and fauna species including damage to human urban pavement materials such as roofing sheets. Other damages caused by such air pollution reactions are death of trees, farm crops and livestock at very large quantities [4]. Toxic air on reaching the ground surface can cause great damage to human, plants, animals as well as water bodies thereby causing great damage to the economy of the people. Damages caused by air pollution could make people's productive energy to drop due to associated ailments [5] [6]. The characterization of temperature, humidity, pressure, wind flow has great influence of the spread and distribution of $PM_{2.5}$ in the atmosphere of various cities of the world [7]. In this vein, the AQI of Nigeria cities has limited studies thereby making the literature in this area of study very scanty. However, this study is intended to fill the literature gag in the area of climate parameters and particulate matter ($PM_{2.5}$): implication for air quality index of Port Harcourt, Minna and Maiduguri of Nigeria

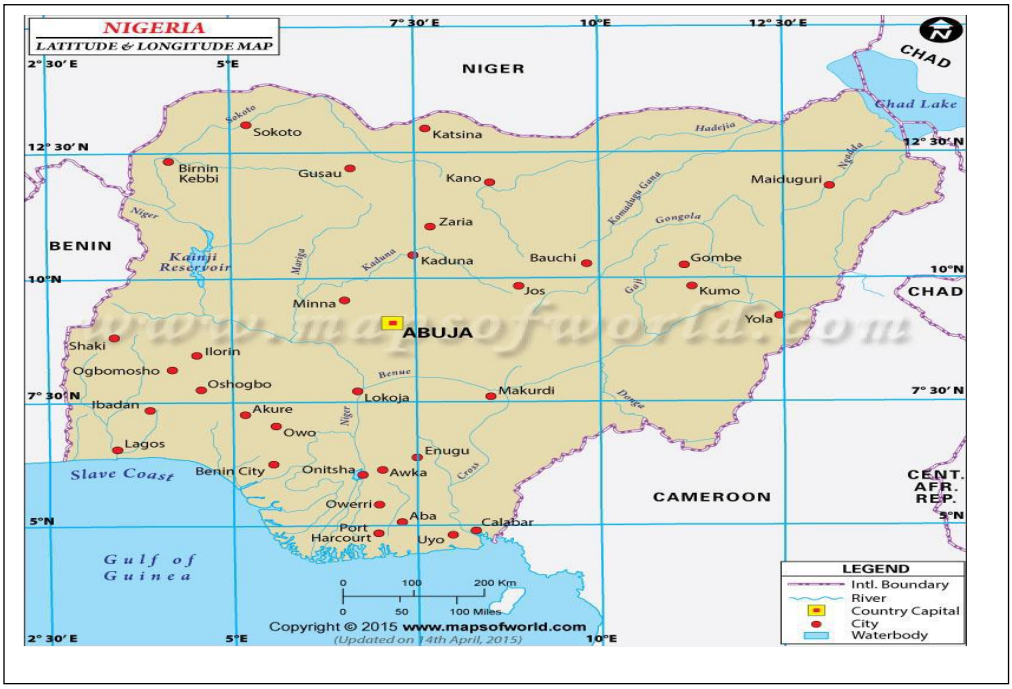

Figure 2.1: Location of Port Harcourt, Minna and Maiduguri in Nigeria (Source: World Maps)

2. STUDY AREA

The study covers the cities of Port Harcourt, Minna and Maiduguri in Nigeria. Nigeria has the area coverage of 923,768km2 with land area of 910,768 km^2 and water covering 13,000 km^2 of the total landmass [8], as in (Figure 2.1). Nigeria is occupying the Humid, Sub-Humid, Semi-Arid and Arid zones respectively (Figure 2.2). Port Harcourt is located in Rivers State of the Humid zone of the south-south part of Nigeria having boundary with the Atlantic Ocean. Minna is located in Niger State of the Sub-Humid zone, very close to the Nigeria capital city of Abuja. Maiduguri is located in Borno State of the Semi-Arid zone near the Chad basing. However,

the northern segment of Nigeria recorded mean maximum temperature between 32°C and 41°C and the mean maximum temperature in the south is between 21°C and 30°C respectively. The country recorded general mean temperature of 27°C [9]. In the Southern part, minimum rainfall is 2,500mm and maximum of 400mm in the extreme northern part such as Maiduguri [10]. The study area is characterized by tropical climates which are of raining and dry seasons respectively. The southern part experience wet season from the month of March to November and from May to October in the northern segment [10]. This indicates that rainfall is more in the southern segment than the northern part making the appearance of water bodies more in the southern region for atmospheric air quality moderation.

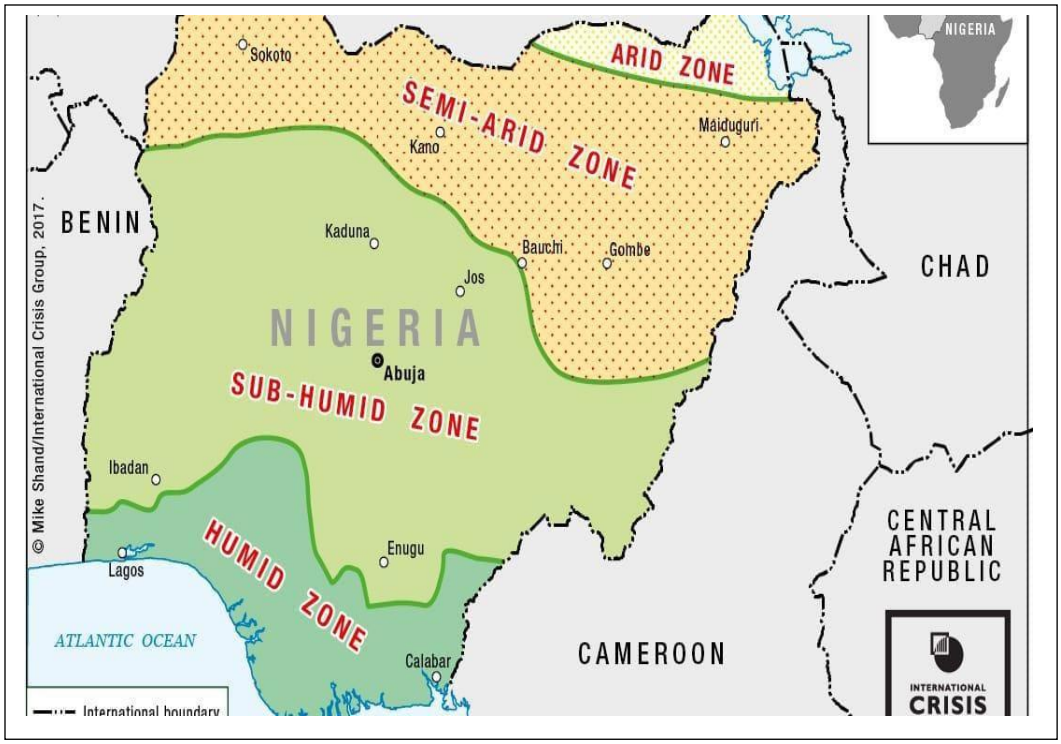

Figure 2.2: Nigeria Climate Zones

3. MATERIALS AND METHOD

Secondary source of data was used in this research. The data were sourced from IQ Air Earth (https://www.iqair.com/earth?nav) air quality monitoring database. Air quality data were gathered through multi-sources, validation and visualization of real-time data from governments, sensors operated by individuals and organizations. Data were acquired from ground-based air quality monitoring stations with high data availability and unprecedented accuracy. Some of the source locations were additionally given out by governmental historical datasets of temperature, humidity, pressure, wind flow and $PM_{2.5}$ measurements. Also, weather live forecasts of climatic parameters and air quality at various locations were used by the source in the database for validity and reliability of data. The data extraction was on hourly basis of 7:00Am, 10:00Am, 1:00PM, 4:00PM, 1:00AM from Monday to Sunday in one Month. The Air Quality Index (AQI) of each city was corresponded and matched with Air Quality Index (AQI) Chart as in Table 2.1. The AQI was calculated using the formula:

Calculating the Air Quality Index (AQI) Equation

$$Ip = \frac{IHi - ILO}{BPHi - BPLo}(Cp - BPLo) + ILo$$

Where:

IP	=	Index for Pollutant P
CP	=	Rounded Concentration of Pollutant P
BPHi	=	Breakpoint Greater Than/Equal to CP
BPLo	=	Breakpoint Less Than/Equal to CP
IHi	=	AQI Value Corresponding to BPHi

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ILo = AQI Value Corresponding to BPLo

Table 2.1: Air Quality Index (AQI) Chart

AQI	Air Pollution Level	Health Impact	Cautionary Statement (for PM2.5)
0 - 50	Good	The air quality is considered satisfactory and air pollution poses little or no risk	Not applicable
51 -100	Moderate	The air quality is acceptable; but for some pollutants there may be moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Vulnerable groups are children and adults, and people with respiratory disease, such as asthma, should reduce prolonged outdoor activities.
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Vulnerable groups are children and adults, and people with respiratory disease, such as asthma, should reduce prolonged outdoor activities
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects	Vulnerable groups are children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor activities.
201-300	Very Unhealthy	Serious health warnings of emergency conditions. The entire population is more likely to be affected.	Vulnerable groups are children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.
300+	Hazardous	Health alert: everyone may experience more serious health effects	Everyone should avoid all outdoor activities

3. RESULTS AND DISCUSSIONS

In Port Harcourt city there was high interaction between humidity and Air Quality Index (AQI) in the area (Figure 3.1). During the period, maximum humidity was 100% and minimum humidity was 74%. This showed that the city of Port Harcourt is located at humid zone of Nigeria with high content of atmospheric water moisture. The AQI of Port Harcourt showed the city had maximum level of toxic pollutants, having recorded maximum AQI of 72 and minimum of 29 respectively. This corresponded with the findings of [11]. That the black soot of Port Harcourt had contaminated the air quality of Port Harcourt environment. It was noted that the low wind flow of Port Harcourt had promoted more concentration of effluents and harmful particulate matters in the air such as the devastating black soot that was enriched with carbon substance.

Temperature in Port Harcourt had maximum value of 29^0C and minimum of 22^0C indicating that Port Harcourt is a coastal city in Nigeria located approximately to the Ocean of the Atlantic thereby receiving sea to land breeze for cooling the ambient air. Port Harcourt had maximum wind condition of 16.6 Km/h and minimum of 3.1 Km/h within the urban canopy layer due to the obstruction and interference of tall trees and buildings that serve as wind breakers to the horizontal flow of air movement. The city had maximum pressure of 1014mb indicating that the city airmass is heavy and slow to wind flow system. The Particulate matter ($PM_{2.5}$) had maximum level of 19.1µg/m² and minimum of 7.1µg/m² showing that the city was intensely polluted with air contaminants. The high particulate matter content and high AQI shown in Table 2.1 indicated the Port Harcourt people were vulnerable to breathing related ailments such as that of asthma and they should avoid prolonged outdoor exertion.

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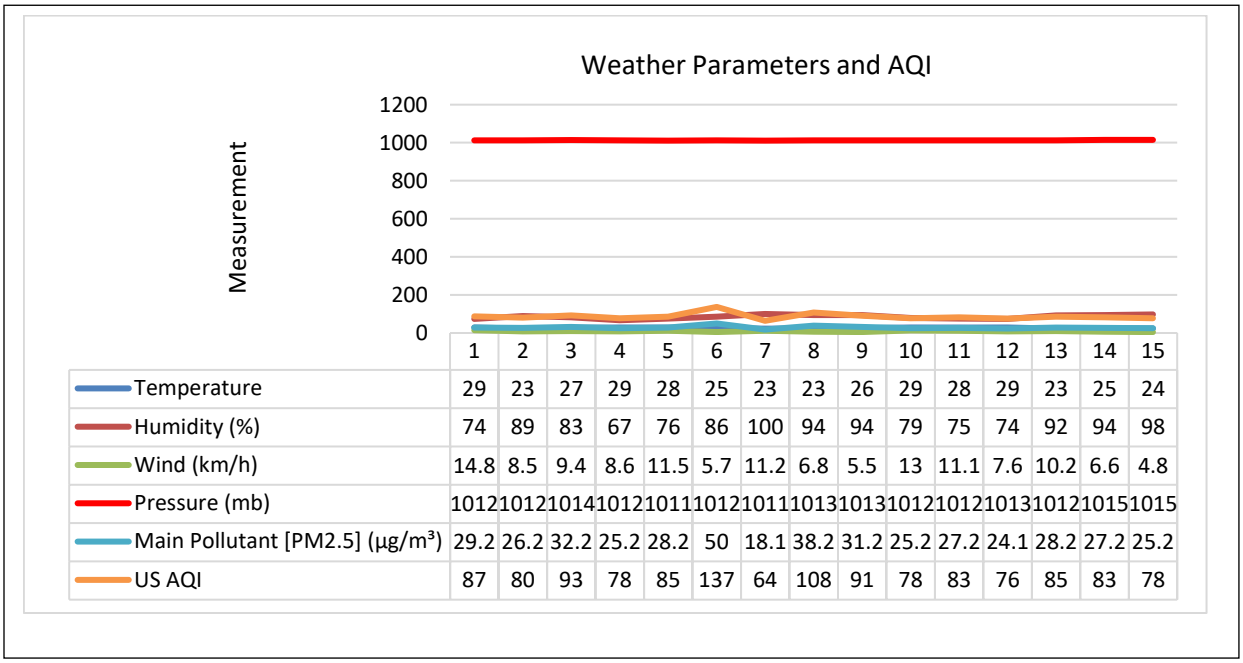
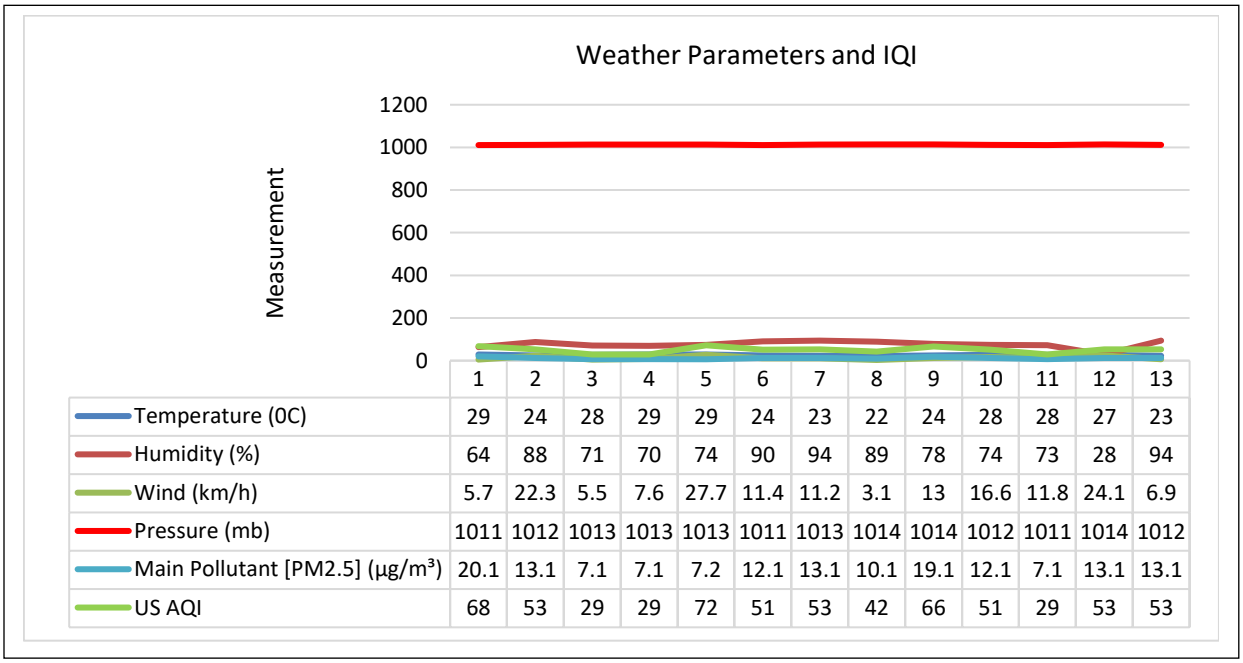


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Temperature	29	23	27	29	28	25	23	23	26	29	28	29	23	25	24
Humidity (%)	74	89	83	67	76	86	100	94	94	79	75	74	92	94	98
Wind (km/h)	14.8	8.5	9.4	8.6	11.5	5.7	11.2	6.8	5.5	13	11.1	7.6	10.2	6.6	4.8
Pressure (mb)	1012	1012	1014	1012	1011	1012	1011	1013	1013	1012	1012	1013	1012	1015	1015
Main Pollutant [PM2.5] (µg/m³)	29.2	26.2	32.2	25.2	28.2	50	18.1	38.2	31.2	25.2	27.2	24.1	28.2	27.2	25.2
US AQI	87	80	93	78	85	137	64	108	91	78	83	76	85	83	78

Figure 3.1: Climate Parameters and AQI of Port Harcourt

In Minna city, there was high interaction between humidity and wind (Figure 3.2). This showed that the city was located within the Sub-humid Zone of Nigeria. The maximum humidity was recorded at 94% and minimum of 28%. Due to the less vegetation of Minna and relatively low canopy layer, the maximum wind flow was 27.7 Km/h and minimum of 5.5Km/h. During the raining season, mean maximum temperature was recorded at 29^{0}C and minimum of 22^{0}C especially the hammattern period of the dry season. Pressure in Minna recorded 1014mb showing that Minna city had free wind flow system within the canopy layer. Thus, Particulate matter ($PM_{2.5}$) had maximum value of 20.1µg/m^2 and minimum of 7.1µg/m^2 indicating that the air quality was dusty by observation. The AQI of the city had maximum value of 72 and minimum of 29 showing that people with respiratory disease such as asthma should limit prolonged outdoor exertion.



	1	2	3	4	5	6	7	8	9	10	11	12	13
Temperature (0C)	29	24	28	29	29	24	23	22	24	28	28	27	23
Humidity (%)	64	88	71	70	74	90	94	89	78	74	73	28	94
Wind (km/h)	5.7	22.3	5.5	7.6	27.7	11.4	11.2	3.1	13	16.6	11.8	24.1	6.9
Pressure (mb)	1011	1012	1013	1013	1013	1011	1013	1014	1014	1012	1011	1014	1012
Main Pollutant [PM2.5] (µg/m³)	20.1	13.1	7.1	7.1	7.2	12.1	13.1	10.1	19.1	12.1	7.1	13.1	13.1
US AQI	68	53	29	29	72	51	53	42	66	51	29	53	53

Figure 3.2: Climate Parameters and AQI of Minna

In Maiduguri, there was high interaction between wind flow system and humidity (Figure 3.3). Maximum humidity was recorded at 76% and minimum of 25% indicating the level of dryness of the city as it is located in the Semi-Arid Zone of Nigeria

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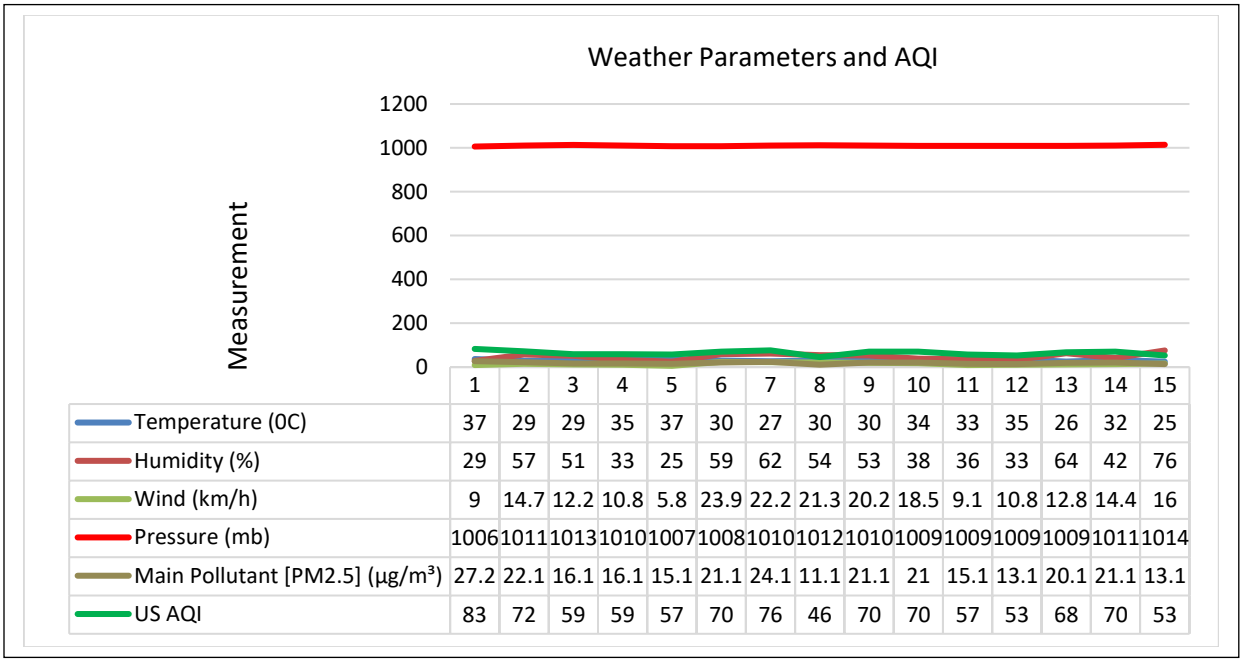
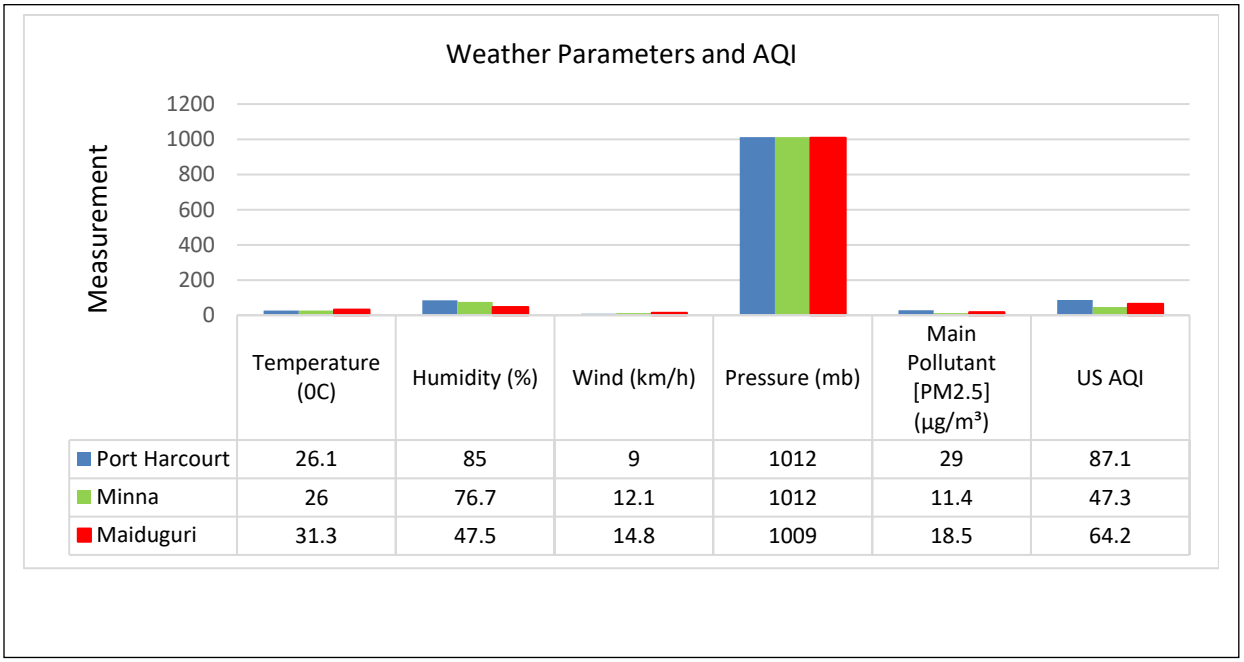
characterized with low atmospheric moisture content. The wind flow had maximum value of 29.9Km/h and minimum of 9Km/h during the study period. Maximum temperature was recorded at 37^{0}C and minimum of 25^{0}C indicating the severity of hotness of the ambient air of the city. Maximum pressure was recorded at 1014mb and minimum of 1006mb indicating the high intensity of wind flow system. Particulate matter ($PM_{2.5}$) was maximum at 72.27.1µg/m^2 and minimum of 11.1µg/m^2 showing that the ambient air of Maiduguri was dusty and contaminated. The AQI showed maximum record of 83 and minimum value of 46 indicating that people with respiratory diseases such as asthma should reduce outdoor activities.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Temperature (0C)	37	29	29	35	37	30	27	30	30	34	33	35	26	32	25
Humidity (%)	29	57	51	33	25	59	62	54	53	38	36	33	64	42	76
Wind (km/h)	9	14.7	12.2	10.8	5.8	23.9	22.2	21.3	20.2	18.5	9.1	10.8	12.8	14.4	16
Pressure (mb)	1006	1011	1013	1010	1007	1008	1010	1012	1010	1009	1009	1009	1009	1011	1014
Main Pollutant [PM2.5] (µg/m^3)	27.2	22.1	16.1	16.1	15.1	21.1	24.1	11.1	21.1	21	15.1	13.1	20.1	21.1	13.1
US AQI	83	72	59	59	57	70	76	46	70	70	57	53	68	70	53

Figure 3.3: Climate Parameters and AQI of Minna



	Temperature (0C)	Humidity (%)	Wind (km/h)	Pressure (mb)	Main Pollutant [PM2.5] (µg/m^3)	US AQI
Port Harcourt	26.1	85	9	1012	29	87.1
Minna	26	76.7	12.1	1012	11.4	47.3
Maiduguri	31.3	47.5	14.8	1009	18.5	64.2

Figure 3.4: Comparative View of Climate Parameters and AQI of Port Harcourt, Minna and Maiduguri

The comparative view of Port Harcourt, Minna and Maiduguri indicated that the mean temperature of Port Harcourt (26.1^{0}C) was relatively the same as that of Minna 26^{0}C. Thus, Maiduguri had the highest mean temperature of 31.3^{0}C. However, for humidity in Port Harcourt recorded (85%) as the highest among the three cities studied, thus, Minna recorded 76.7% and lastly the

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humidity of Maiduguri had 47.5% as the city with the highest dryness of the weather condition locate in the Sem-Arid zone. Port Harcourt had the least wind system of 9Km/h, Minna (12.1Km/h) and Maiduguri recorded the highest wind flow of 14.8Km/h indicating the intensity of the atmospheric turbulence in Maiduguri town., Port Harcourt had wind pressure of 1012mb and Minna (1012mb) which both had similar atmospheric wind pressure system characterized in their Humid and Sub-Humid zones respectively. Maiduguri had the lowest pressure value of 1009mb due to the low moisture in the air. Port Harcourt $PM_{2.5}$ recorded 29μg/m², Minna had 11.4μg/m² and Maiduguri recorded 18.5μg/m² indicating that Port Harcourt had the highest particulate matter contamination. The mean AQI index showed that Port Harcourt (87.1) had the highest particulate matter pollution, followed by Maiduguri (64) and the least was Minna (43) in the particulate matter air contamination. The high contamination of Port Harcourt ambient air was due to industrial wastes release to the atmospheric canopy layer such as the black soot (black carbon). The high level of AQI among the studied cities was due to the severity of particulate dust released by the surface area especially during the hammatern of the dry season in Nigeria. The cities of Port Harcourt, Minna and Maiduguri showed that the city dwellers were vulnerable to asthma and should reduce outdoor functions.

4. CONCLUSION

This study, climate parameters and Particulate Matter (PM2.5) and their implications to Air Quality Index (AQI) of Port Harcourt, Minna and Maiduguri of Nigeria has exposed the pattern of climatic parameters and the pollution characteristics of the three cities in Nigeria. This study has shown that the interaction between climate parameters can bring about some changes in the air pollution of a particular city. Thus, a city with turbulent and high wind flow systems will evacuate pollutants away from the city, but calm atmospheric city air will increase the concentration levels of pollutants. The city of Port Harcourt which is located in the Humid zone has greater air pollution with calm air condition that resulted to high concentration of pollutants such as the devasting black soot. Maiduguri which is located in the Semi-Arid zone has dusty air particulate matter but has turbulent wind system to evacuate pollutants in the city. Minna, situated in the Sub-Humid zone has the second air quality index and the highest wind flow system that can easily evacuate atmospheric air pollutants in the city. Therefore, it is very important for cities of the world to monitor the climatic ambient air characteristics in order to understand the quality of the air people inhale. Doing so, will involve cities to practice urban greening where greater parts of the air pollutants can sink to the ground as trees and forests act as receptors to air pollution. Hence, there is need for people to reduce the release of harmful chemicals into the atmosphere as many people are exposed to air pollution in this century of severe global warming.

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Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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