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AIR QUALITY INDEX LEVELS OF PARTICULATE MATTER ($PM_{2.5}$) IN YENOGUA, NIGERIA

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ABSTRACT

Air pollution is an issue that has received worldwide awareness. The rationale for this research is concern for human health. $PM_{2.5}$ has been attributed to human mortality, morbidity, asthma, chronic obstructive pulmonary disease (COPD), pulmonary fibrosis, cancer, type 2 diabetes, neurodegenerative diseases, obesity, and a variety of other ailments, according to research. Due to the accessibility of indoor and outdoor environmental quality documents in developed countries, the problems are being mitigated, whereas little has been achieved in developing countries due to an insufficiency of records. The findings of this study can be used to close this gap as well as assist policymakers in Nigeria. while also assisting policymakers in Nigeria. In this work, the 11-day Air Quality Index (AQI) of Yenagoa, Bayelsa State was obtained using satellite-based data provided by IQAir. The results are shown as: AQI (46-80), $PM_{2.5}$ (11.1-26.2 $\mu g/m^3$), temperature (24-31 ^oC), speed (3.3-12.5 m/s), and relative humidity (RH) (60-91 %). The data clearly showed that the majority of the $PM_{2.5}$ concentrations were below the World Health Organization (WHO) guideline of 25 $\mu g/m^3$ daily. The levels of concern for AQI affirmed that air quality ranged between good and moderate, suggesting that the area's air quality is satisfactory with little or no risk.

Keywords: *AQI, satellite, WHO limit, Bayelsa State, levels of concern*

INTRODUCTION

Clean air is a vital need for our health, community well-being and the environment. Air pollution has been a global problem for more than fifty years and has persisted into modern times. This problem poses serious economic risks and environmental damage. Recent advances in global markets, modernization, urban growth, overpopulation, energy use, mass transit, and reciprocating machinery are all increasing air pollution globally. As indicated in the World Health Organization (WHO) position paper on air pollution levels and health, approximately

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seven million premature deaths occur annually as a direct result of air pollution-related diseases such as heart disease, lung cancer and chronic obstructive pulmonary disease, strokes, among others (Wambebe and Duan, 2020; WHO 2018; Chen and Khan, 2008). According to another WHO report, air pollution is among the most significant environmental health consequences of this period. It is on a note that over 90% of individuals worldwide inhale polluted air. Approximately 91 percent of the population lives in urban areas where air quality exceeds WHO standards for particulate matter ($PM_{2.5}$ and PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) as the main pollutant with the greatest public health concern.

Public air quality in urban countries has improved compared to urban centers in developing countries, one of which is Federal Capital City, Abuja, Nigeria (WHO, 2016a). Nigeria's poor air quality has made it the country with the highest mortality rate in Africa and even the fourth in the world (Health Effects Institute, 2018), and 150 out of 180 in the world for poor environmental performance in terms of air quality (Yale Center for Environmental Law and Policy, 2018). Poor air quality has been reported in several Nigerian cities (WHO, 2016b; Yakubu, 2017; Ede and Edokpa, 2017; Akinfolarin et al., 2017; Edokpa and Ede, 2019). This situation is further exacerbated by overpopulation, urbanization, anthropogenic activity, and climate change which continues to increase, resulting in concerns about the state of air quality in Abuja and other cities around the world (Kanee et al., 2020).

Due to the rapid advancement, urbanization, and industry in Africa, there has been an increase in air pollution; however, there have been some recent efforts, awakening, awareness campaigns, and perception programs to bring to the attention of the public the environmental and health problems of air pollution and climate change. The following are some of the more visible initiatives: Some of the programs assisted by WHO to improve the air quality and its health consequences include the Global Alliance for Clean Cookstoves and the Climate Clean Air Coalition. In African countries, especially Nigeria air pollution has become a big issue in the twenty-first century, due to high industrial activity, construction, and a rise in the number of emission sources such as vehicle emissions and gas flaring, among others. According to the Health Effects Institute's most recent annual state of the global air report, Nigeria ranks fourth in the world, with a fatality rate of 150 deaths per 100,000 Nigerians, and first in Africa (Health Effects Institute, 2019). The majority of Yenagoa pollution in Bayelsa State, Nigeria is caused by vehicle emissions, engine fumes, and work sites, among other things (Wambebe and Duan, 2020). Air quality data are essential in assisting decision - making process and establishing necessary solutions for the issues induced by the poor air quality in Yenagoa. Notwithstanding, even with all of the laws and regulations in place, the question of effectiveness remains.

The AQI is a color scheme indicator that is used worldwide to report and predict daily air quality. It is used to reveal the most common environmental pollutants regulated by the Clean Air Act, including ground-level ozone, particle pollution (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). The AQI informs the public about how healthy or contaminated the air is and how to prevent the health consequences of poor air quality (USEPA, 2021). The AQI is classified into various categories (six), each of which corresponds to a various level of public health concern. The baselines between all of these categories are determined by an examination of the evidence on health effects. The evidence for particle pollution is primarily comprised of epidemiology studies that assess the morbidity and mortality effects of acute and chronic particle pollution exposure. As records of AQI in Yenagoa are scarce, it is important to measure it as it will assist individuals in predicting the status (quality) of air before venturing outside their homes. People will also be aware of the health implications for their lives.

This study aims to present monitoring data of particulate matter ($PM_{2.5}$), AQI, temperature, wind speed, and humidity using satellite-based model data. The levels of health concern of the individuals of Yenagoa, Bayelsa State, were obtained using the AQI table.

RESEARCH METHOD

Yenagoa is LGA and the capital of Bayelsa State in southern Nigeria. It is located in the southern part of the country at 4°55′29″N 6°15′51″E. According to the 2006 census, LGA has an area of 706 km2 and a population of 352,285. In Southern Nigeria, Yenagoa is located in the transition zone of the Coastal sedimentary lowland hydrogeological province. Wetlands are heavily forested tidal plains formed by the reticulate pattern of the meandering Niger creeks and tributaries (Akpokodje, 1979; Oborie and Nwankwoala, 2017). A thick succession of sedimentary rocks sustains the area. As a result, the area is considered an available and reliable source of groundwater.

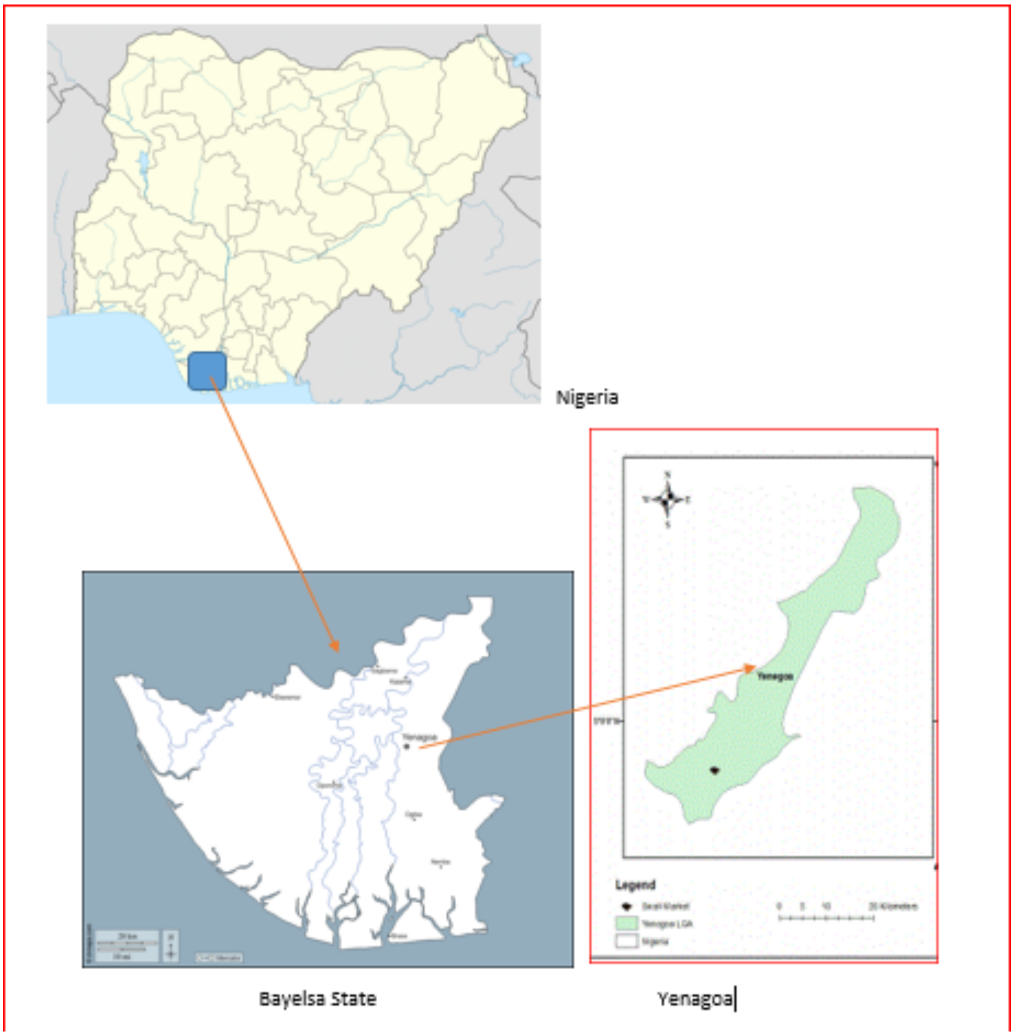
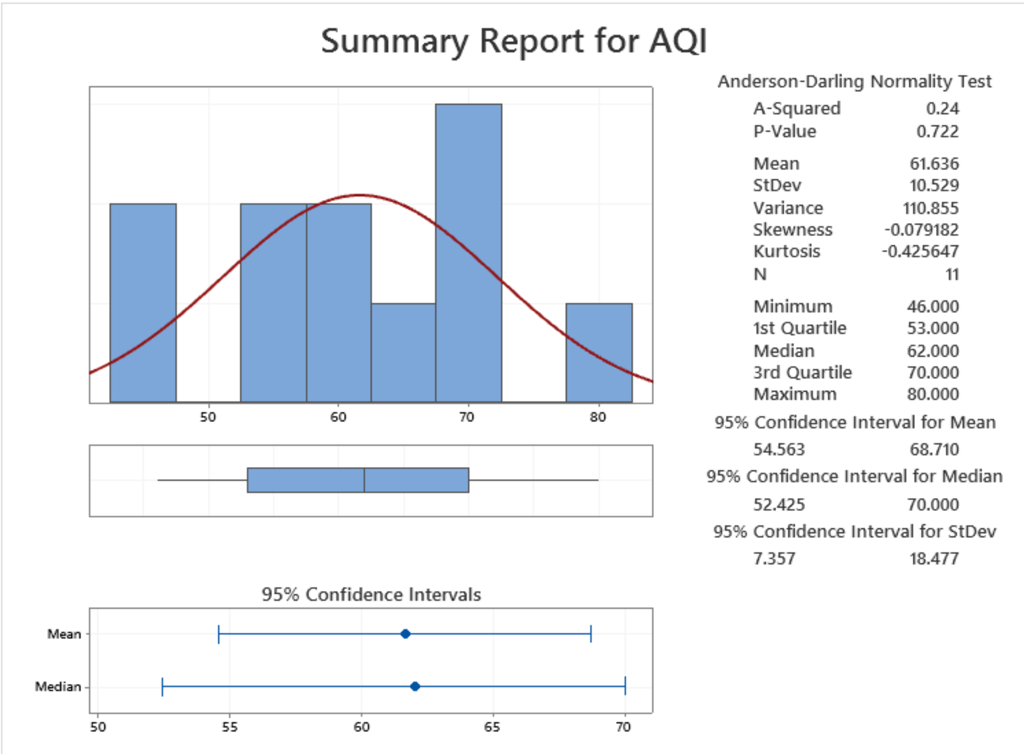


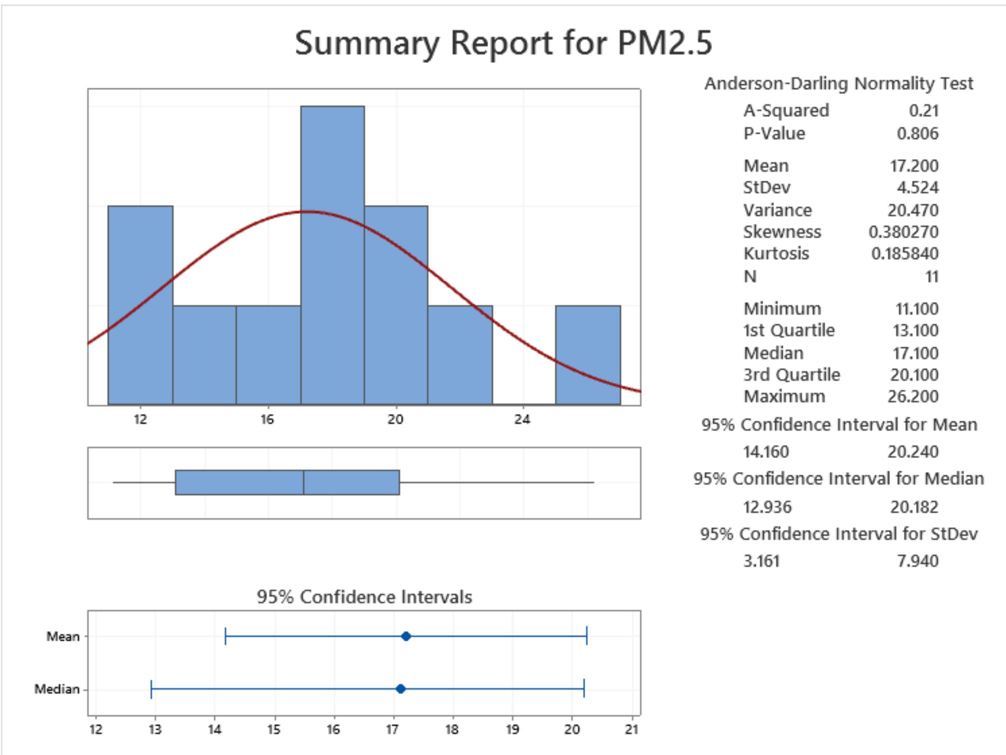
Figure 1. The map of the location Yenagoa, Bayelsa State

Due to the scarcity of wireless sensors, air quality in this model is determined using regular AQI satellite information originating from AirVisual (powered by IQAir, Switzerland, with primary activity in Germany, United States and China), low cost, i. e. citizenbased PM wireless sensor technology which has been launched worldwide (https://www.iqair.com/). IQAir collects data on AQI, PM2.5, temperature, wind speed and direction, and humidity using satellite imagery. The study uses eleven days of data from their website which provides current as well as forecast air quality data. Data is presented by guidelines from the Environmental Protection Agency (EPA). AQI data obtained in the city of Yenagoa were evaluated and statistically analyzed using Minitab software version 16. (Graphic descriptive statistics, Pearson correlations, Matrix plots, Dendrograms, and bar charts drawn with Excel version 2013)

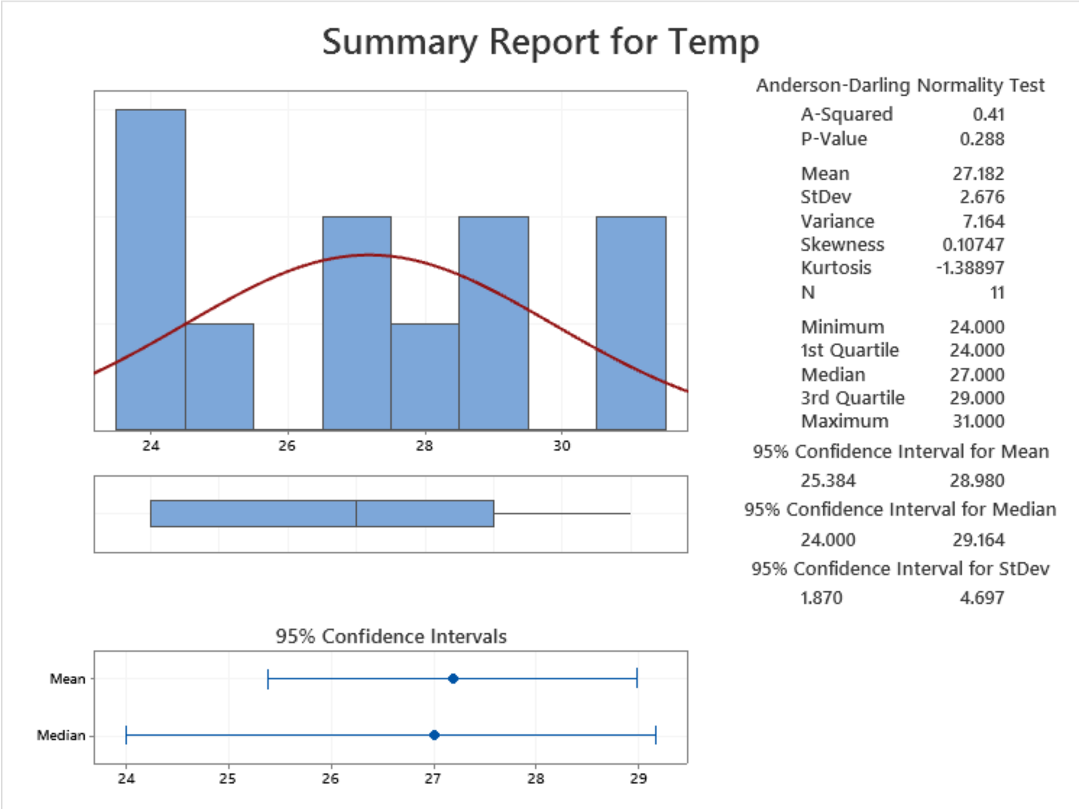
RESULTS AND DISCUSSION



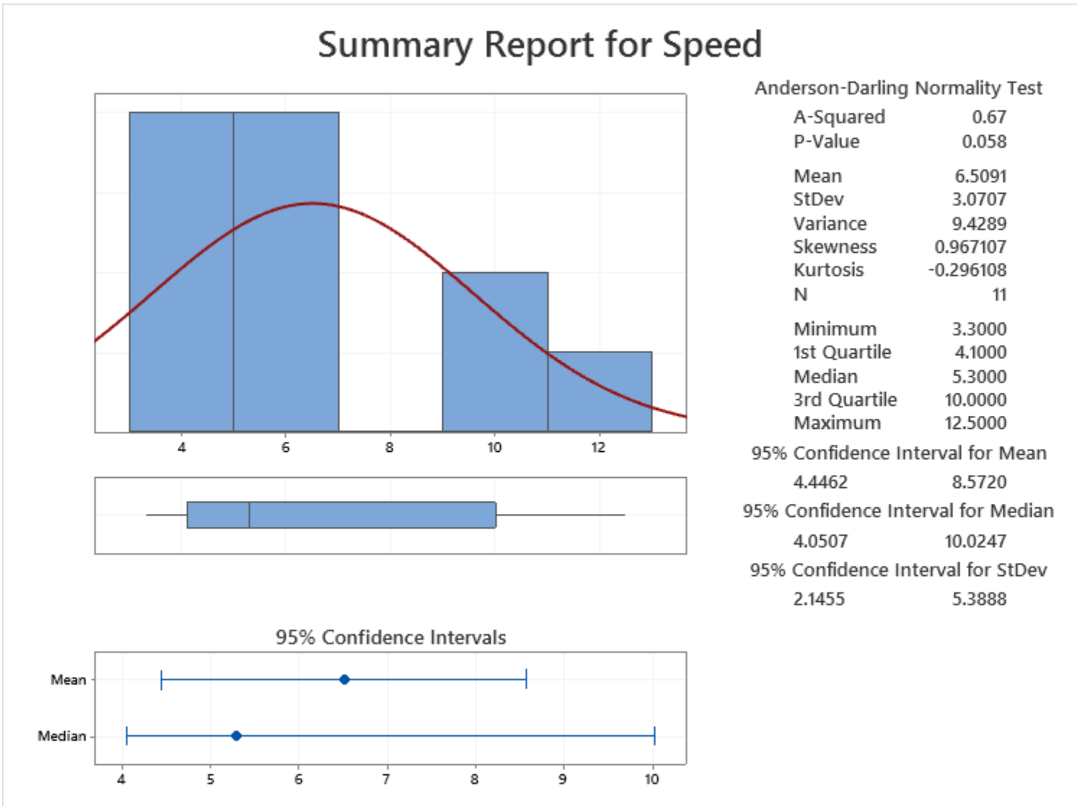
(a)



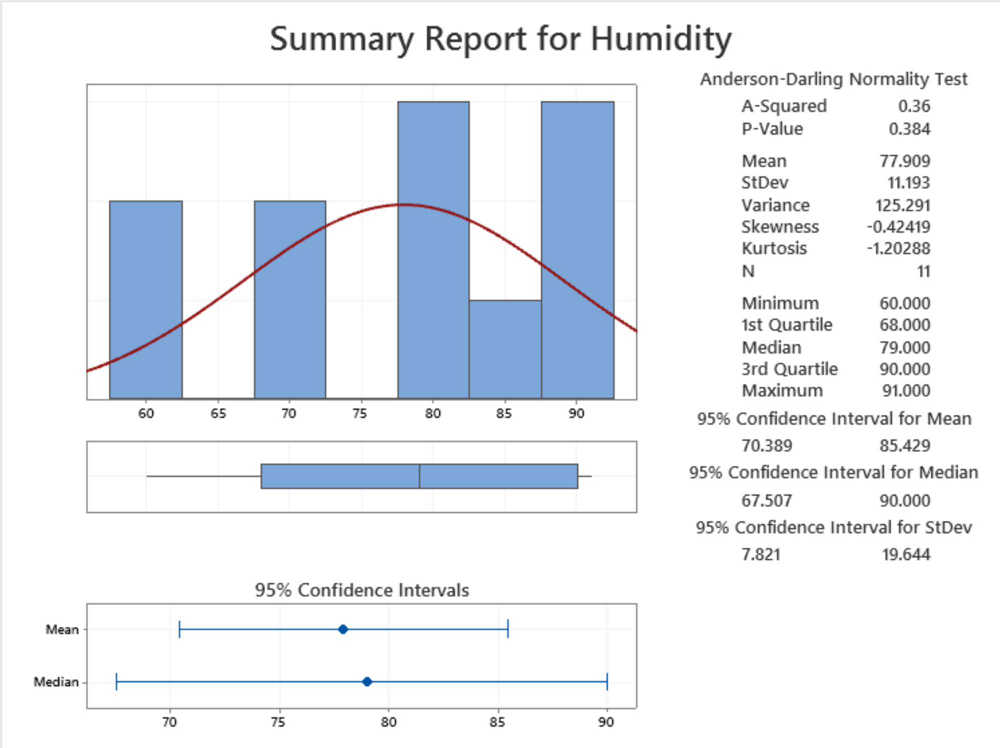
(b)


Summary Report for Temp
Anderson-Darling Normality Test
A-Squared 0.41
P-Value 0.288
Mean 27.182
StDev 2.676
Variance 7.164
Skewness 0.10747
Kurtosis -1.38897
N 11
Minimum 24.000
1st Quartile 24.000
Median 27.000
3rd Quartile 29.000
Maximum 31.000
95% Confidence Interval for Mean
25.384 28.980
95% Confidence Interval for Median
24.000 29.164
95% Confidence Interval for StDev
1.870 4.697
95% Confidence Intervals
Mean
Median

(c)


Summary Report for Speed
Anderson-Darling Normality Test
A-Squared 0.67
P-Value 0.058
Mean 6.5091
StDev 3.0707
Variance 9.4289
Skewness 0.967107
Kurtosis -0.296108
N 11
Minimum 3.3000
1st Quartile 4.1000
Median 5.3000
3rd Quartile 10.0000
Maximum 12.5000
95% Confidence Interval for Mean
4.4462 8.5720
95% Confidence Interval for Median
4.0507 10.0247
95% Confidence Interval for StDev
2.1455 5.3888
95% Confidence Intervals
Mean
Median

(d)



(e)

Figure 2. (a-e) The Basic Description of AQI, PM2.5, Temperature, Wind Speed, and Humidity

Figure 2a depicts the AQI results, which ranged from 46 to 80. At the 95 percent confidence level, the boxplot revealed a mean of 77.9 and a median of 79. Concerning Table 2 of AQI, Levels of Concern and Description, it can be stated that the levels of concern are between good (0-50) and moderate (51-100), indicating that Yenagoa town is satisfactory and acceptable during the periods of air quality monitoring, particularly for those who are unusually sensitive to air pollution. The AQI in this study differs from the mean values reported for Ojodu (61) and Opebi (80). (Abulude et al., 2021a).

Figure 2b depicts PM2.5 concentrations of 11.1 and 22.6 μg/m^3. For example, traffic activity in Yenagoa is thought to be at its peak during the early morning hours, which are the busiest times of the day compared to other times of the day, because this is when civil servants, commercial traders, students, and others rush to their various destinations. The results (mean) of the eleven-day monitoring are consistent with those reported elsewhere, particularly in Algeria, India, Kenya, and China (Table 2). However, when compared to some of the results obtained in Nigeria, the current results (Ikeja, Abuja, Port-Harcourt, and Ile-Ife). Furthermore, except for the first day, where a higher value was reported, the results reported here are lower than the WHO daily limit. In the case of the WHO annual limit, our results are significantly lower.

Meteorological parameters are critical in determining pollutant levels at a given rate of pollutant emission (Singal and Prasad, 2005). The research looked into the relationships between PM and meteorological factors. Wind speed, humidity, and temperature are examples of these (Figure 2c-e). Temperatures, wind speed, and relative humidity averaged 24-31oC, 2.3-21.5 m/s, and 60-91 percent, respectively. According to the results, the recorded humidity was relatively high (mean, 77.9 percent, Skewness – 0.42, Kurtosis -1.20). According to our observations, the concentration of PM2.5 increases as relative humidity decreases; similar effects were observed by Tai et al (2010). PM2.5 in the environment may be washed away by rain or blown away by the wind (Habitable Planet, accessed 2017). Pollutants can be trapped in high RH environments, resulting in high PM2.5 concentrations. Low RH levels can significantly reduce PM concentrations through precipitation and help to clear the atmosphere. Many particles in the air could be dissolved or removed by the kinetic energy exhibited by rainfall or wind. Meteorological factors have a significant impact on air pollution; for example, wind transports some pollutants from their sources across national boundaries and even across oceans. Air tranquility is important in determining the distance that the wind can travel as well as its concentration in the surrounding air (El-Helou et al., 2012). Smog is caused by temperature inversions, which occur when the air near the Earth's surface is colder than the air above. Temperature inversions also reduce vertical mixing and trap pollutants close to the Earth's surface. Low wind stagnation events are common during the dry season and can lead to the accumulation of pollutants over several day.

***Table 1.** AQI, Levels of Concern, and Description*

Daily AQI Colour	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution possesses little or no risk
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of the sensitive groups may experience more serious health effects
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected

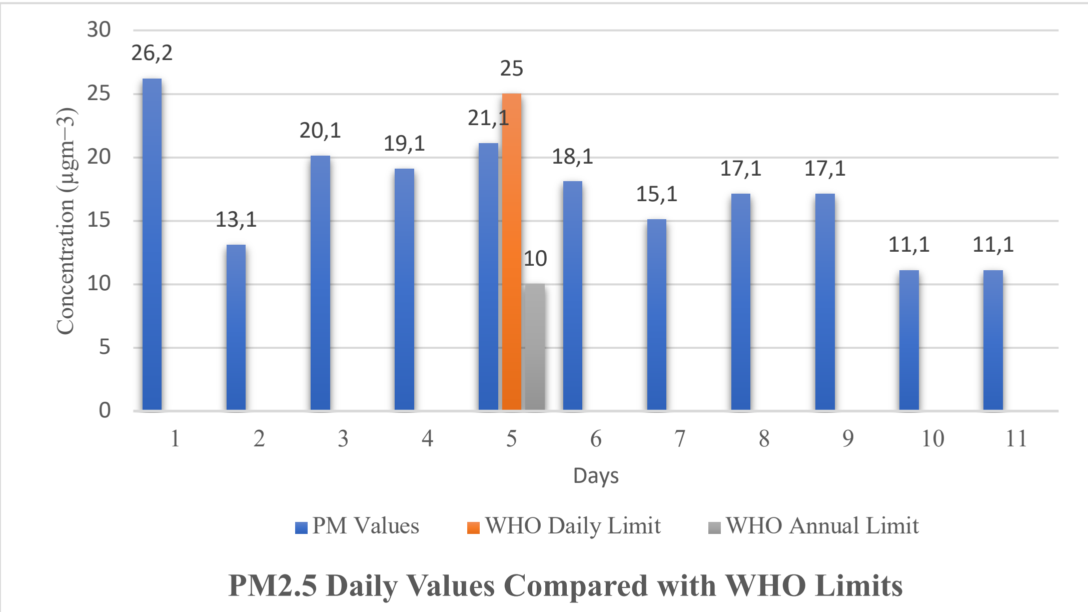


Figure 3. The Comparison of the PM2.5 with WHO Limits

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Table 2 The Comparison of the Results with Previous Studies

City, Country	AQI	$PM_{2.5}$ (μg/m³)	Temp (°C)	Speed (m/s)	Humidity (%)	References
airobi, Kenya	-	13.0 - 36.6	-	-	-	Pope et al., 2018
Ikeja, Nigeria	70 - 188	20 - 123	23 - 30	4-24	66 - 100	Abulude et al., 2021a
Ile-Ife, Nigeria	128	9.1 - 236.6	-	-	4.9 - 72.64	Abulude et al., 2021b
Algiers, Algeria	-	18.53–47.58	-	-	-	Talbi et al. 2018
Delhi, India	-	350	-	-	-	Tiwari et al. 2012
Patiala, India	-	148–256.9	-	-	-	Agrawal et al., 2021
Beijing, China	-	37.65	-	-	-	Liang et al., 2019
Port-Harcourt, Nigeria	> 200	-	-	-	-	Akinfolarin et al., 2017
Abuja, Nigeria	-	15.30 - 70.20	24 - 28	-	36 - 97	Wambebe and Duan, 2020
Abuja, Nigeria	4-42	18 – 95	28 - 30	-	-	Kanee et al., 2020
Yenagoa, Nigeria	46 - 80	11 - 26.2	24 - 31	3.3 - 12	60 - 91	This study

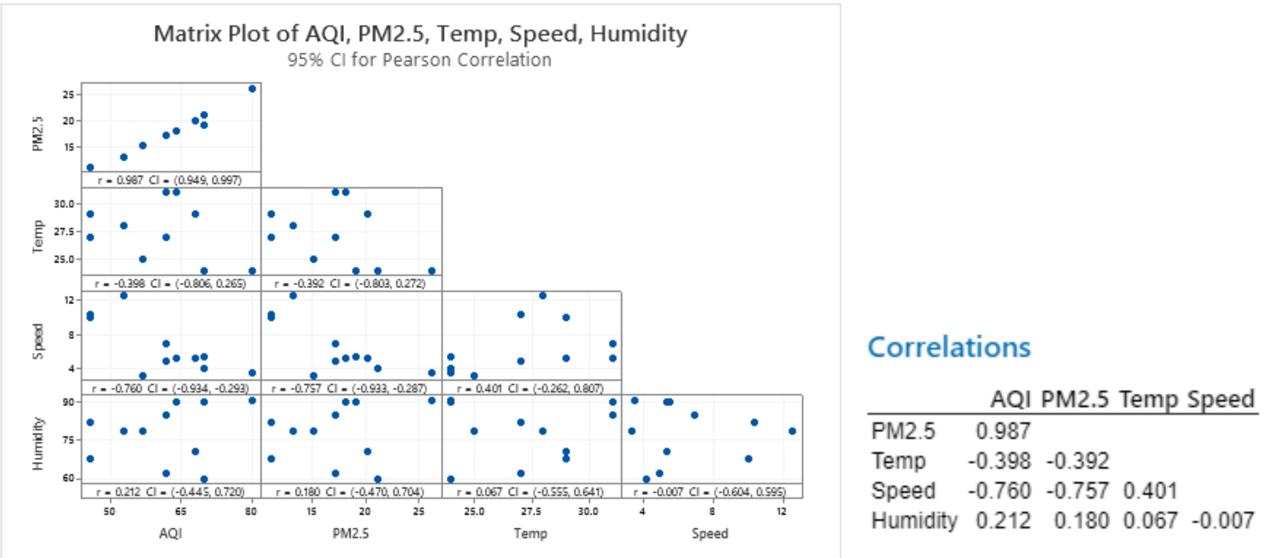

Figure 4. The Matrix and Correlation of the Parameters Monitore

Figure 4 depicts Pearson's correlation (r). The PM2.5 r value had a high positive correlation with AQI (r=0.987) and a high negative correlation (-0.757). Other correlations in the parameters are low at p 0.05. This indicated that PM sources are not the same, with a non-uniform dispersal pattern in the atmosphere, and that the AQI was determined by PM values during the monitoring period. Zhang et al. (2015) found that relative humidity, temperature, wind speed, and wind direction were the main meteorological factors that correlated with the concentration of airborne pollutants in Beijing, Shanghai, and Guangzhou

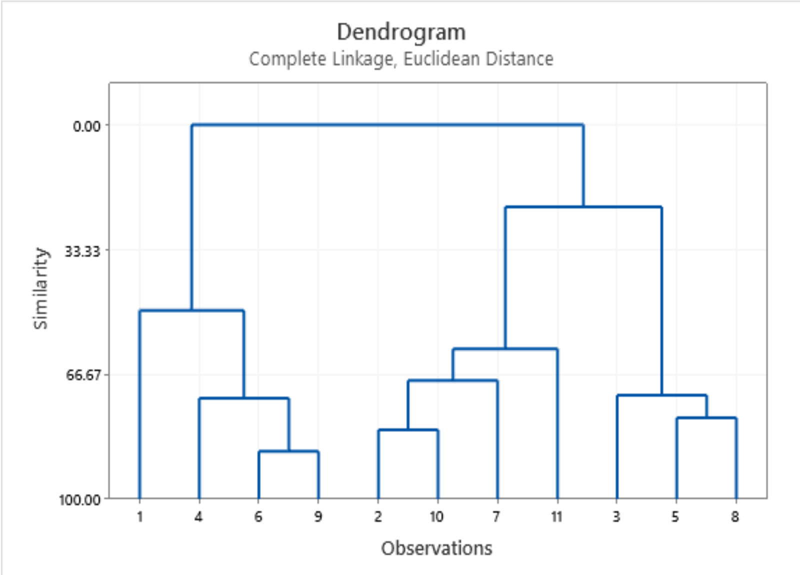

Figure 5. Dendrogram of the monitoring location using complete linkage and Euclidean distance.

The Hierarchical Clustering analysis (CA) is a multivariate method for identifying trends and clusters in a set of data, one of which represents particulate matter concentrations (Nez -Alonso et al. 2019). Grouping is the process of dividing a given set of data into many group observations with distinct features in terms of the group's fundamental values or characteristics. As a result, hierarchical cluster analysis seeks to maximize within-group variance while minimizing variance within the same group. One significant advantage is that any set of variables can be used to classify representatives of the given sample (Saksena et al. 2003).

In this study, Euclidean distances and complete linkage were used to calculate the distances between parameters using the average values of the monitored variables in the location. The CA results are displayed in the dendrogram chart (Figure 3). It reveals that the location has eleven observations with an average distance (from the centroid) of 12.1 and a cluster sum of squares of 1695.47. The figure shows clusters between 6 and 9, 5 and 10, and 5 and 8, with similar levels of 87, 81, and 78, respectively. This dendrogram was also created with a final partition of three clusters, which occurs at a similarity level of approximately 40. The first cluster (on the far left) is made up of four observations (the observations in rows 1, 4, 6, and 9 of the worksheet). The second cluster, to the right, is made up of four observations (the observations in rows 2, 10, 7, and 11 in the worksheet). The third cluster is made up of three observations (the observations in rows 3, 5, and 8). The clusters imply that there are correlations between the parameters monitored, particularly AQI and PM2.5. The abundance profiles of parameters from the same cluster show this correlation.

CONCLUSIONS

The main objective of this paper is to detect the air quality in Yenagoa for eleven days. AQI, PM2.5 and meteorological parameters (temperature, wind speed, and humidity) of the surrounding environment are also evaluated in this paper. The results showed that AQI was classified as good and safe for outdoor activities. Monitoring results show good results with PM2.5 levels lower than the WHO daily guidelines, but further monitoring is

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needed. A correlation was found between PM2.5 and meteorological parameters. The PM area is higher during the day than in any other session as these are times of high activity. Other factors that can contribute to the presence of PM include geographic location, meteorological conditions, and human activities (coal burning, transportation, dust, and population growth).

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