DOI: 10.24996/ijs.2024.65.6.42

Iraqi Journal of Science

ISSN: 0067-2904

Spatial Distributions of AQI, $PM_{2.5}$, Relative Humidity, Speed, and Temperature in Twenty-Two Towns in Nigeria

Francis Olawale Abulude[1*], Baig Abdullah Al Shoumik[2], Matthew Ojo Oluwafemi[3], Kikelomo Mabinuola Arifalo[4], Jamok Jacob Elisha[5], Abigail Oluwakemi Feyisetan[6]

[1]Environmental and Sustainable Research Group, Science and Education Development Institute, Akure, Ondo State, Nigeria

[2]Soil, Water and Environment Discipline, Khulna University, Khulna, Bangladesh

[3]Department of Horticulture and Landscape Technology; Federal College of Agriculture, Akure, Ondo State, Nigeria

[4]Department of Chemistry, Bamidele Olomilua University of Education, Ikere-Ekiti, Ekiti State, Nigeria

[5]Centre for Biotechnology Research and Training, Ahmadu Bello University, Zaria, Nigeria

[6]Department of Chemistry, Federal University of Technology, Minna, Niger State, Nigeria

Received: 27/2/2023 Accepted: 24/5/2023 Published: 30/6/2024

Abstract

The significant air pollution issue in Nigeria has sparked severe widespread fear. This research is a part of the effort to eliminate or reduce this threat. The research aimed to examine the distributions of Air quality index (AQI), Particulate matter with less than 2.5 µm diameter ($PM_{2.5}$), Relative humidity (RH), Wind speed, and Temperature (temp) in nineteen (19) Nigerian states, including the Federal Capital Territory (FCT). To accomplish this, satellite data obtained from IQAir's air quality monitoring platform for nineteen states and the Federal Capital Territory of Abuja between the 7th and 17th of October 2021 were used and statistically analyzed. The inverse distance weighting (IDW) interpolation method was applied to observe the spatial distribution of the data. The average AQI was 72.11, with minimum and maximum values of 26 and 17, respectively. The mean of $PM_{2.5}$ was 28.71±13.7 µg/m^3. The following meteorological average values were recorded: RH (62.43%), wind speed (6.96 m/s), and temperature (28.71^{o}C). The AQI was between good and unhealthy, the $PM_{2.5}$ was more than 17% (annual) and 52% (24 h), which is higher than World Health Organisation (WHO) limits, and the correlations between AQI, $PM_{2.5}$ and meteorological parameters were weak. According to the data, $PM_{2.5}$ was not distributed uniformly across the regions but varied spatially and temporally. It is advised that people check their local daily air pollution forecasts, avoid exercising outside, avoid working out in crowded areas, and use less energy at home to prevent an increase in AQI. It is recommended to monitor and maintain the air quality and minimize harmful anthropogenic activities to mitigate the threat.

Keywords: $PM_{2.5}$, Air Quality Index, Pollution issue, World Health Organisation, Nigeria

1. Introduction

The WHO brief on atmospheric healthy air states that diseases linked to air pollution, like heart disease, lung cancer, chronic obstructive pulmonary disease, and stroke, to name a few, are responsible for approximately seven million unexpected deaths each year [1, 2]. Ninety percent of individuals globally breathe dirty air, making air pollution one of our most significant public health threats [3].

* Email: walefut@gmail.com

According to the WHO brief, pollutants in the air contributed to around one million more fatalities in one year than AIDS, malaria, and tuberculosis combined. The WHO guidelines for particulate matter $PM_{2.5}$ and other pollutants exceed almost 91% of the globe's population's residences [1]. According to the research conducted by Cohen et al. [4], ambient $PM_{2.5}$ (particulate matter less than 2.5 micrometers in diameter) is to blame for up to 16.5% of the 4.2 million indicated premature deaths triggered each year, with an estimated 1.7 million lung cancer mortality globally [2].

Only 3% of cities and no countries fulfilled the most recent World Health Organization (WHO) $PM_{2.5}$ annual air quality guideline, according to Allegretti's 2021 World Air Quality Report [5]. It was also mentioned that the 2021 World Air Quality Report from IQAir is the world's first significant report on air quality to use the most recent version of the WHO $PM_{2.5}$ air quality guidelines. The old guideline reduced the yearly $PM_{2.5}$ guideline value from 10 $\mu g/m^3$ to 5 $\mu g/m^3$ when it was first announced in September 2021.

Asthma, stroke, heart disease, and lung ailments have all been linked to fine particulates, or $PM_{2.5}$, which is widely acknowledged to be the most dangerous and studied air pollutant. Every year, $PM_{2.5}$ causes millions of untimely deaths.

Recent public education efforts (campaigns, enlightenment, and sensitization) have drawn individuals' consciousness of the detrimental effects of air pollution and climate change, with Nigeria included [6]. Air pollution in Africa has risen due to swift growth, growing urbanization, and the manufacturing sector. According to the Health Effects Institute's latest annual State of the global air document, Nigeria ranked first in Africa and fourth globally, with 150 deaths per 100,000 citizens [7]. Nigeria's quality of life looks to be a matter of worry, according to Abulude et al. [8], given that it is ranked 152nd on the World Risk Index for Air Quality. In Nigeria, the yearly mean amount of particulates such as $PM_{2.5}$ is significantly surpassed [9]. The yearly variation of pollutants in Nigeria revealed high levels in harmattan and low levels in the rainy season; consequently, it is imperative to research the correlation between AQI traits and weather phenomena.

Air quality reporting has become a critical resource of health-based news for people across the globe. There are several sources for the information, for example, the U.S. Air Quality Index, indices of individual countries, NowCast, and others. The AQI is calculated by amassing data on several different pollutants in the air. This information is gathered using an innovative new air quality research network consisting of many ground-level sensors. Many of these are installed at government buildings and industrial sites, while others are attached to moving vehicles and carried around manually by teams of volunteers [10]. Finally, satellite images supplement the data, giving a broader overview of the pollution picture. The U.S. Air Quality Index (U.S. AQI) was developed by the United States Environmental Protection Agency (U.S. EPA) for reporting and forecasting daily air quality. The website AirNow is one of the places the information can be found. It uses color-coded categories for current reports and forecasts for five of the six major pollutants regulated by the Clean Air Act: ozone, particle matter, carbon monoxide, nitrogen dioxide, and sulfur dioxide. Each index is a function of the pollutant concentration in the air over a certain period. AirNow offers NowCast, which it terms as "current air quality.

The Air Quality Index (AQI), which divides the level of air pollution into a numerical rating system with the more significant the value, the greater the air pollution, according to Plaia and Ruggieri [11], presents insight into real-time ambient air quality about the measures of $PM_{2.5}$ associated health issues. To raise the general public's consciousness and encourage people to take action to preserve their physical health, the AQI relies on the health risks that people may experience due to exposure to $PM_{2.5}$ [12]. In this sense, IQAir operates the most extensive free real-time air quality monitoring platform in the world - AQI modeled utilizing satellite data to help numerous individuals globally access timely air quality information at all times. The AQI, city rankings, pollution alerts, and air pollution forecast are all available on the IQAir website (https://www.iqair.com), which makes it easier to organize one's days and remain safeguarded from air pollution.

The IQAir devices track the city's hourly average concentrations of specific pollutants. Additionally, it provides the public with a daily air quality index (AQI) number. The AQI, $PM_{2.5}$, and meteorological characteristics have not yet been analyzed using modeled satellite data from IQAir. These kinds of studies on the connections between climatic variables and air quality indicators are uncommon in Nigeria. By estimating the distributions of AQI, $PM_{2.5}$, temperature, humidity, and wind speed across nineteen (19) states, including the Federal Capital Territory (FCT), we want to fill this knowledge gap.

2. Materials and Methods

Nigeria, a populous African country, has 36 states and a Federal Capital Territory. It is a fast-growing country in population, urban development, industrial growth, vehicular traffic, and several others. This rapid urbanization and development has increased anthropogenic activities, causing several environmental problems in the northern and southern parts of the nation. In this research, 22 towns were studied to monitor air quality, Figure 1.

IQAir's air quality monitoring system (https://www.iqair.com) provided satellite data for this study. Data on the AQI, $PM_{2.5}$, temperature, wind speed, and relative humidity were collected. The information was gathered for 19 states and the Federal Capital Territory of Abuja between October 7-17, 2021. Governmental stations and low-cost sensors that detect pollutants ($PM_{2.5}$, CO, NO_2, SO_2, and O_3), the air quality index (AQI), global climate data, world weather, astronomy, and meteorological parameters (humidity, wind speed, and temperature) provided the data for AirVisual. Over 80,000 locations owned by citizen scientists over the globe provided sensors used to calculate AirVisual's AQI. Government stations provided O_3-level information. A 24-hour air quality history, an air quality forecast, and health advice were some of the many pieces of information offered by AirVisual.

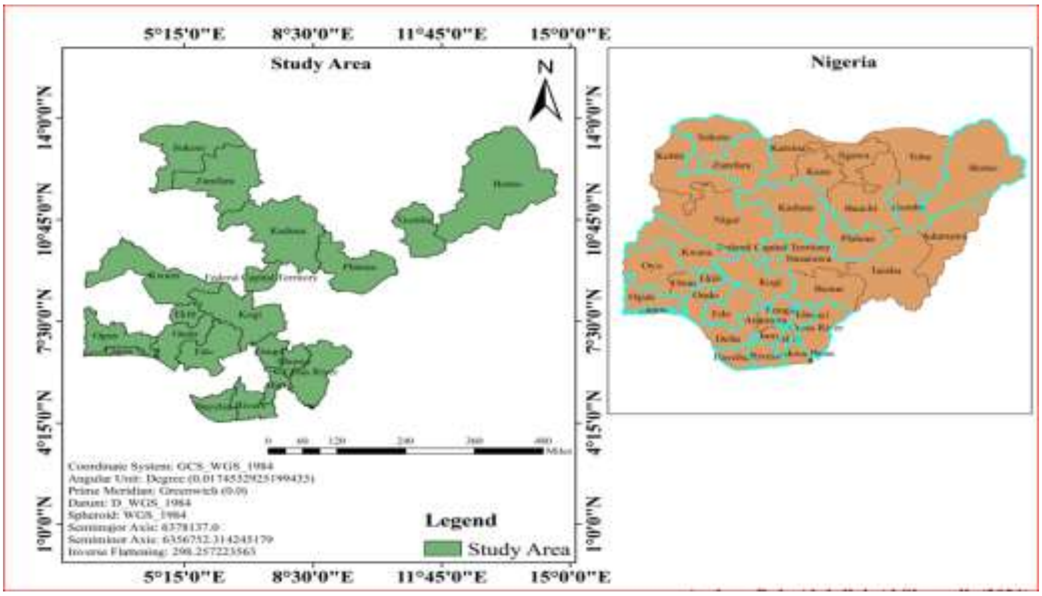


Figure 1: The chosen locations as study areas

2.1 Spatial distribution

Spatial distribution is a method that uses values from sampled areas to estimate the values from specific spots. Usually, two categories of interpolation methods were used in this procedure: deterministic and geostatistical. The values at the sampled spots were used to estimate the output at the unsampled locations using deterministic methodologies such as Inverse distance weighting (IDW) or Global polynomial interpolation. In contrast, geostatistical techniques, such as Kriging or Aerial interpolation, undertake a statistical analysis using the values at sampled locations to forecast the results of unsampled sites. To generate spatial patterns maps, ArcGIS 10.4.1 was used utilizing the IDW interpolation method with the following equation [13]:

$$Z(w_o) = \frac{\sum_{i=1}^{n} \frac{w_i}{d_{ij}^{\beta}}}{\sum_{i=1}^{n} \frac{1}{d_{ij}^{\beta}}} \quad \text{(Eq. 1)}$$

Here, $Z(w_o)$= interpolated value of an unknown point, n= the values of total sampling data, w_i= data value at an ith point, the d_{ij}= separation distance between sampled data and interpolated value, and β= weighting power.
The data obtained were statistically analyzed using Minitab and Excel 2013.

3 Results and Discussion

Table 2 represents the descriptive statistics of the study sites' AQI, PM2.5, and meteorological (RH, speed, and temperature) values. The average AQI was 72.11, with minimum and maximum values of 26 and 178, respectively. The mean, median, and standard deviation had 95% confidence intervals of 75.14, 7, and 25.70, respectively. The average AQI value across the studied area was 72.11 indicating a moderate level of concern (Index value 51-100) [5].

However, a lower value was observed southwestern part, which explains satisfactory air quality with little or no pollution risk. In comparison, a higher value in the southernmost region indicates unhealthy air, and a group of general people may experience health effects, while sensitive people may face severe health effects. The high values could be attributed to prevailing meteorological parameters indicating that weather impacted air quality in these locations. Similar findings have been reported in Nigeria - 68-94 AQI [8]; Nigeria - <25 AQI [13], and China - 80-142 AQI [14], but these were lower than the ranges reported for India between 90 and 380 AQI [15], China - 9 to 451 AQI [16]. Any increase in natural and human activities within an environment increases the probability of high AQI and vice versa. Cases of low AQI during COVID-19, when there was little activity, are typical examples [17-20].

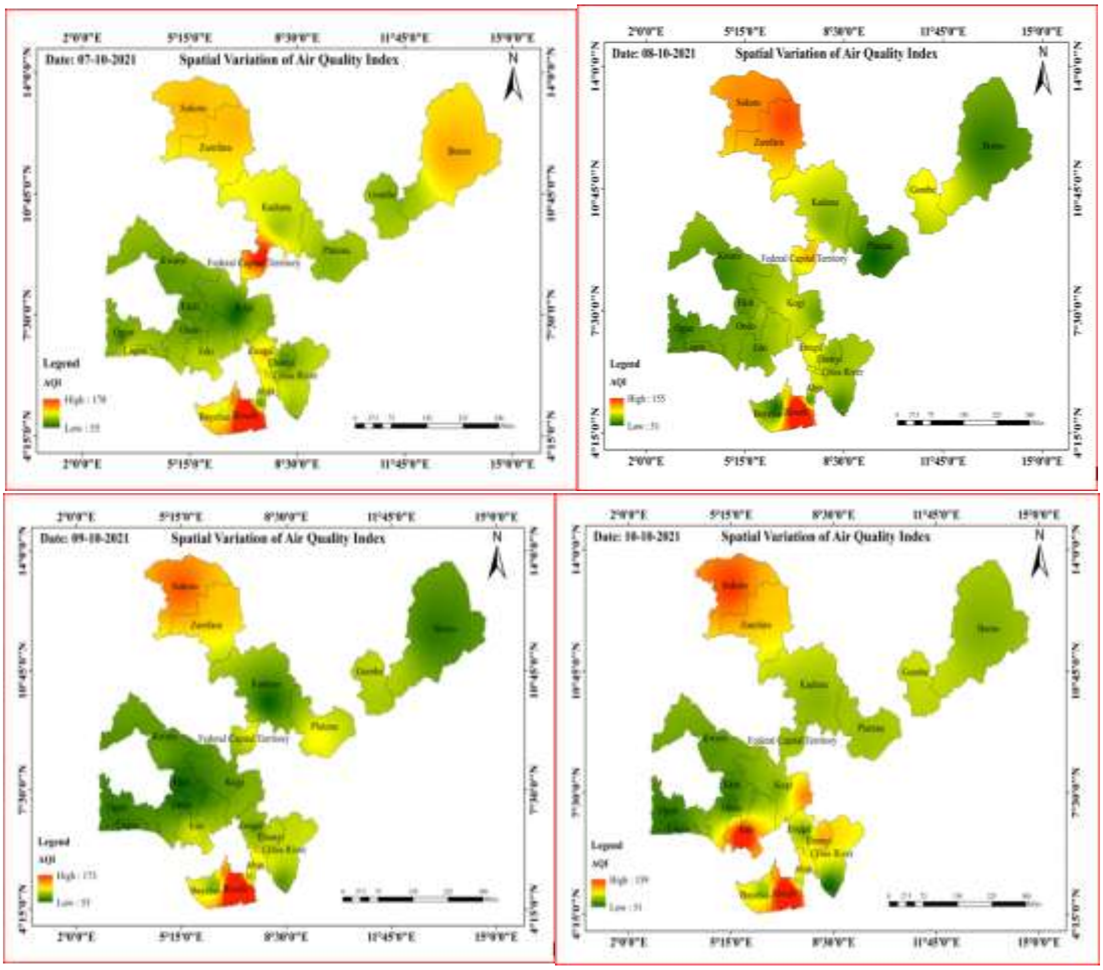
Table 1: The Summary of AQI, $PM_{2.5}$, RH, Wind speed, and Temp Values Obtained in the Study Locations

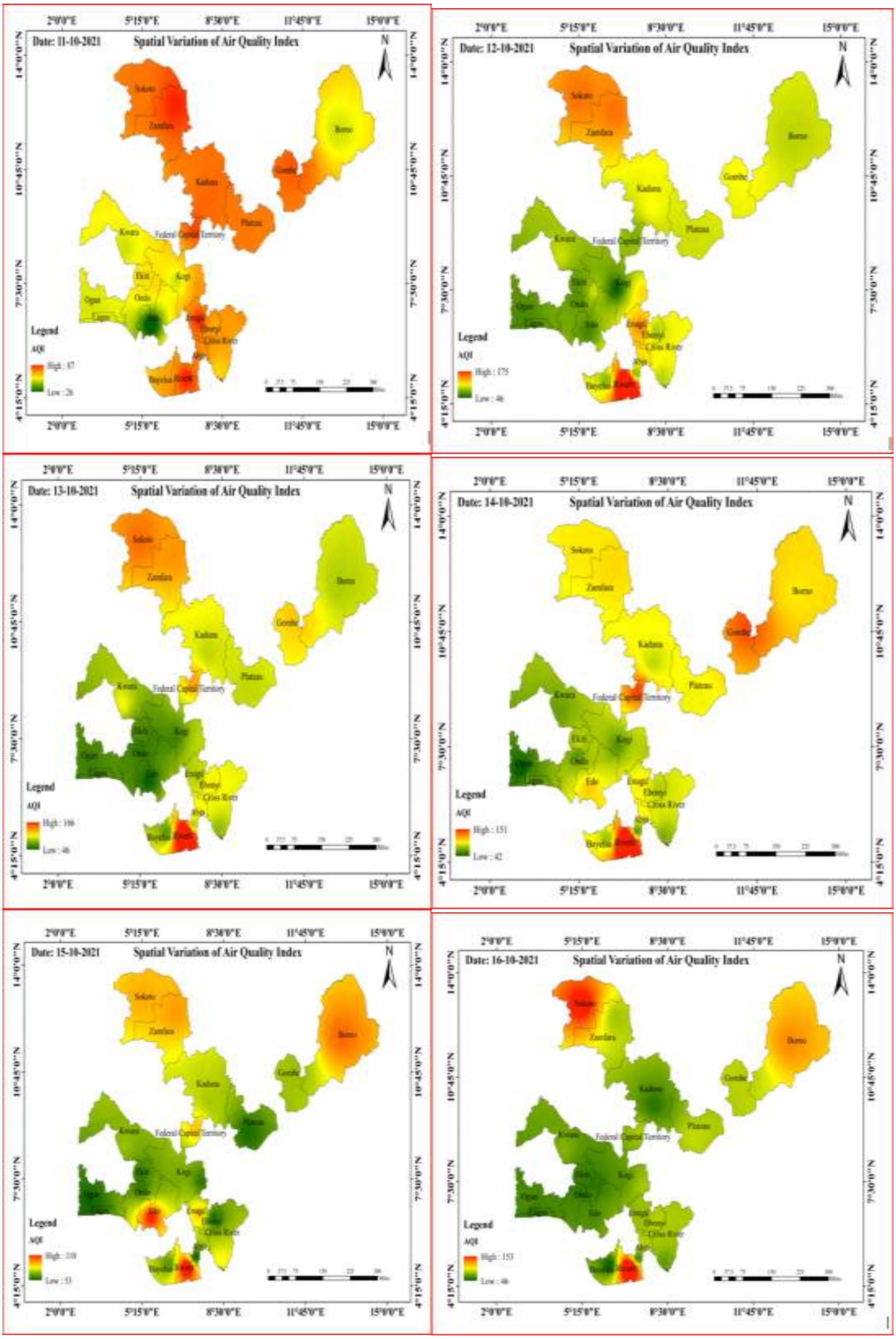
	AQI	$PM_{2.5}$	Temperature	Speed	Humidity
Mean	72.11	22.86	28.71	6.96	62.43
Standard Deviation	23.35	13.70	3.17	3.49	20.58
Coefficient of Variation (%)	32.38	59.93	11.03	50.22	32.97
Minimum	26.00	6.30	22.00	0.70	6.00
Q1	57.00	15.10	27.00	4.60	53.00
Q3	78.00	25.23	31.00	8.80	8.00
Maximum	178.00	102.00	37.00	21.30	100.00
Skewness	2.29	3.34	0.29	0.99	-0.84
Kurtosis	6.81	14.11	-0.07	1.68	0.05

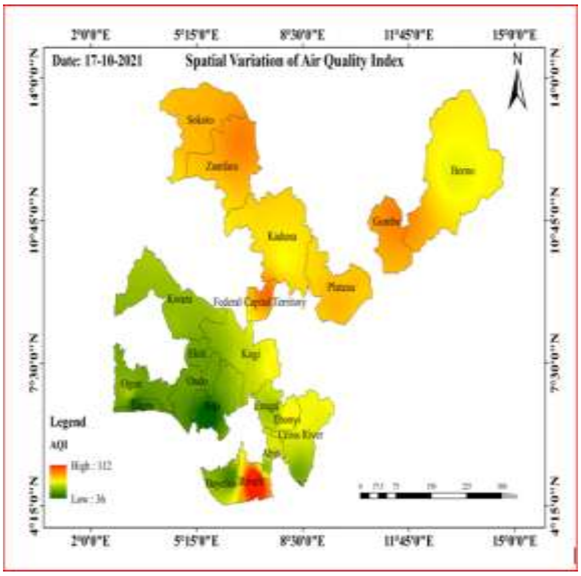
A-Squared	12.56	18.69	1.38	2.53	5.44
P-Value	<0.005	<0.005	<0.005	<0.005	<0.005
N	230	230	230	230	230

The descriptive statistics of $PM_{2.5}$ obtained in the study locations are shown in Table 1. The mean, standard deviation, variance, skewness, and kurtosis of the Anderson-Darling Normality Test were 28.71, 3.67, 10.03, 0.30, and -0.67, respectively. According to this test, if the data points deviate from the line in an apparent non-linear fashion, the data are not normally distributed. The test violates the normalcy hypothesis when the p-value is 0.05 or lower. It is 95% definite that the data do not follow the normal distribution if the normality test is negative. One may only claim no significant departure from normalcy after passing the normality test. The output of a normal Q-Q was used to determine normality graphically. When the data is plotted normally distributed, the data points deviate from the line in an apparent non-linear fashion. When comparing our mean results to the WHO air quality guidelines (2021) of 5 $\mu g/m^3$ (annual) and 15 $\mu g/m^3$ (24 h), it was found that our results are 17% (annual) and 52% (24 h) higher. In addition, when compared to previous research findings, it was discovered that our results were within the values (20-28 $\mu g/m^3$) obtained by Abulude et al. [21] but higher than the ones obtained (7.000-11.000 $\mu g/m^3$) in a tertiary institution in Akure, Nigeria, and lower than (15-95 $\mu g/m^3$) the findings of Kanee et al. [13].

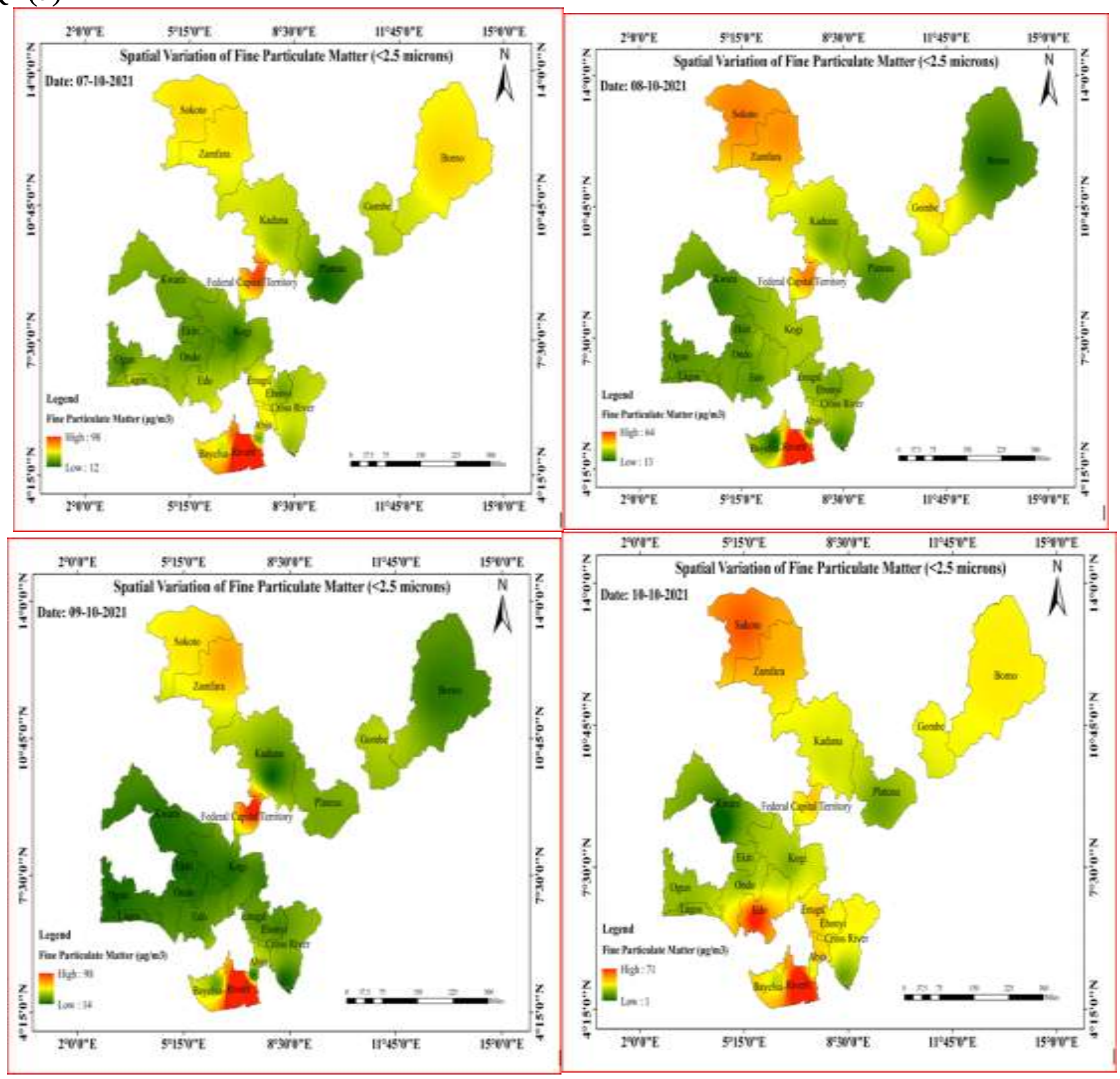
The RH of the study areas is illustrated in Table 1. The mean value was 62.43%, with a minimum of 6% and a maximum of 100%. The median, first, and third quartiles were 67, 53, and 78, respectively. The findings demonstrated that the $PM_{2.5}$ levels in the study areas increase

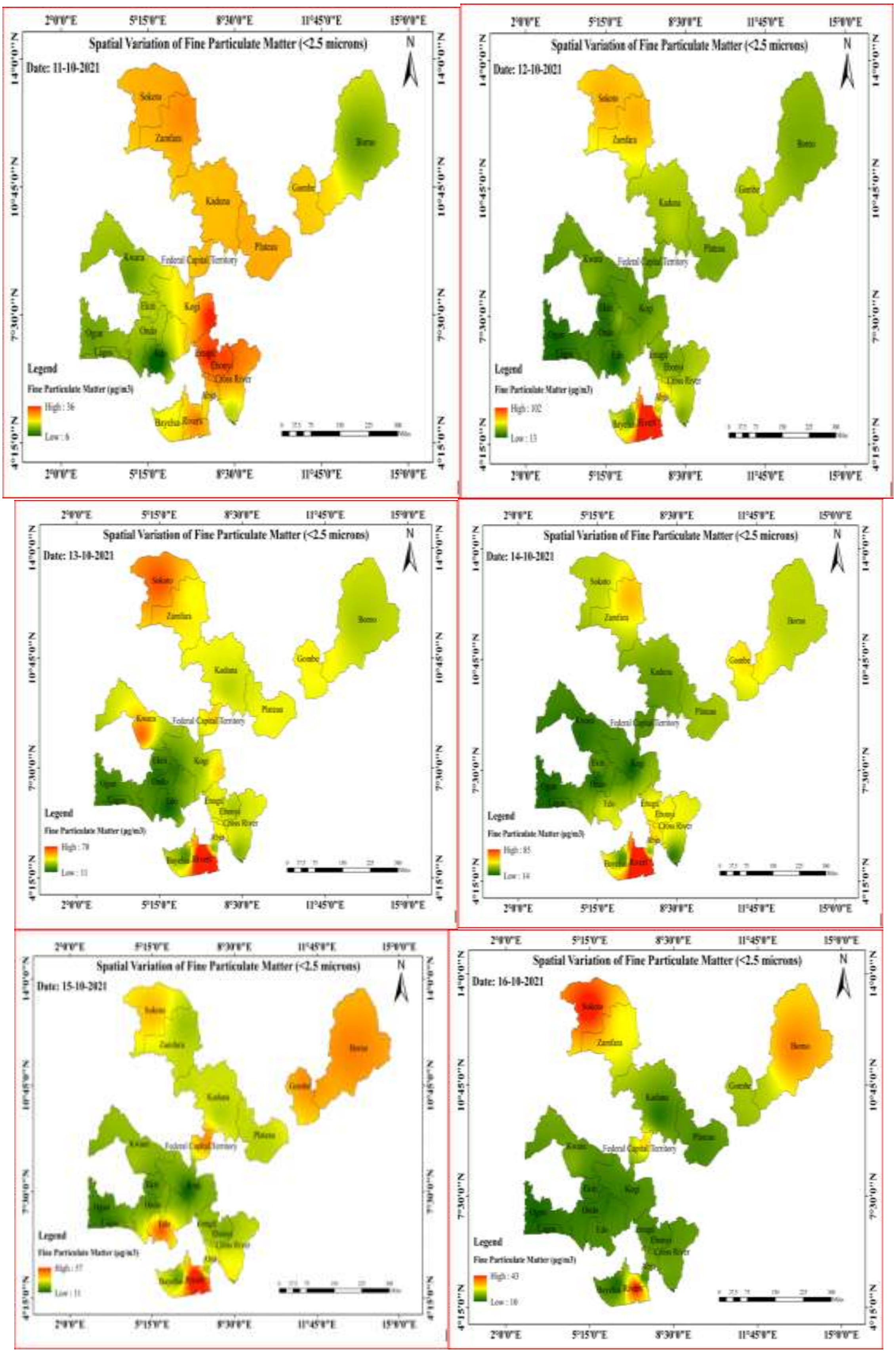


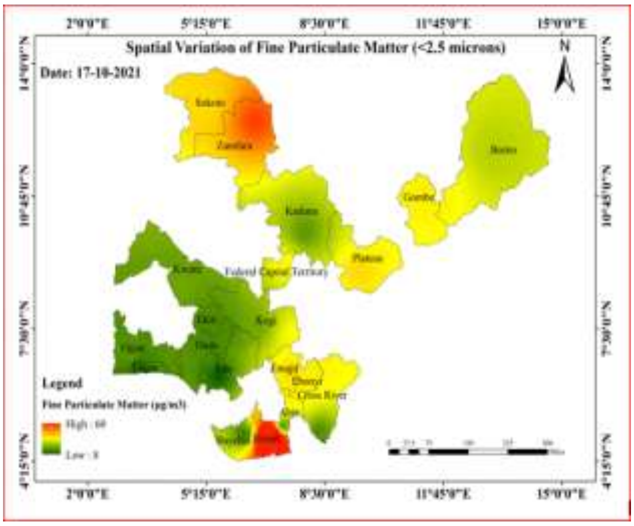

Date: 11-10-2021
Spatial Variation of Air Quality Index
Date: 12-10-2021
Spatial Variation of Air Quality Index
Date: 13-10-2021
Spatial Variation of Air Quality Index
Date: 14-10-2021
Spatial Variation of Air Quality Index
Date: 15-10-2021
Spatial Variation of Air Quality Index
Date: 16-10-2021
Spatial Variation of Air Quality Index
N
Legend
AQI
Sokoto
Zamfara
Kaduna
Borno
Gombe
Plateau
Kwara
Federal Capital Territory
Ekiti
Kogi
Ondo
Ogun
Lagos
Edo
Enugu
Ebonyi
Cross River
Abia
Bayelsa
Rivers
2°0'0"E
5°15'0"E
8°30'0"E
11°45'0"E
15°0'0"E
14°0'0"N
10°45'0"N
7°30'0"N
4°15'0"N


Date: 17-10-2021
Spatial Variation of Air Quality Index
N
Sokoto
Zamfara
Borno
Gombe
Kaduna
Plateau
Kwara
Federal Capital Territory
Ekiti
Kogi
Ogun
Ondo
Edo
Enugu
Ebonyi
Cross River
Abia
Bayelsa
Rivers
Legend
AQI
High : 112
Low : 36

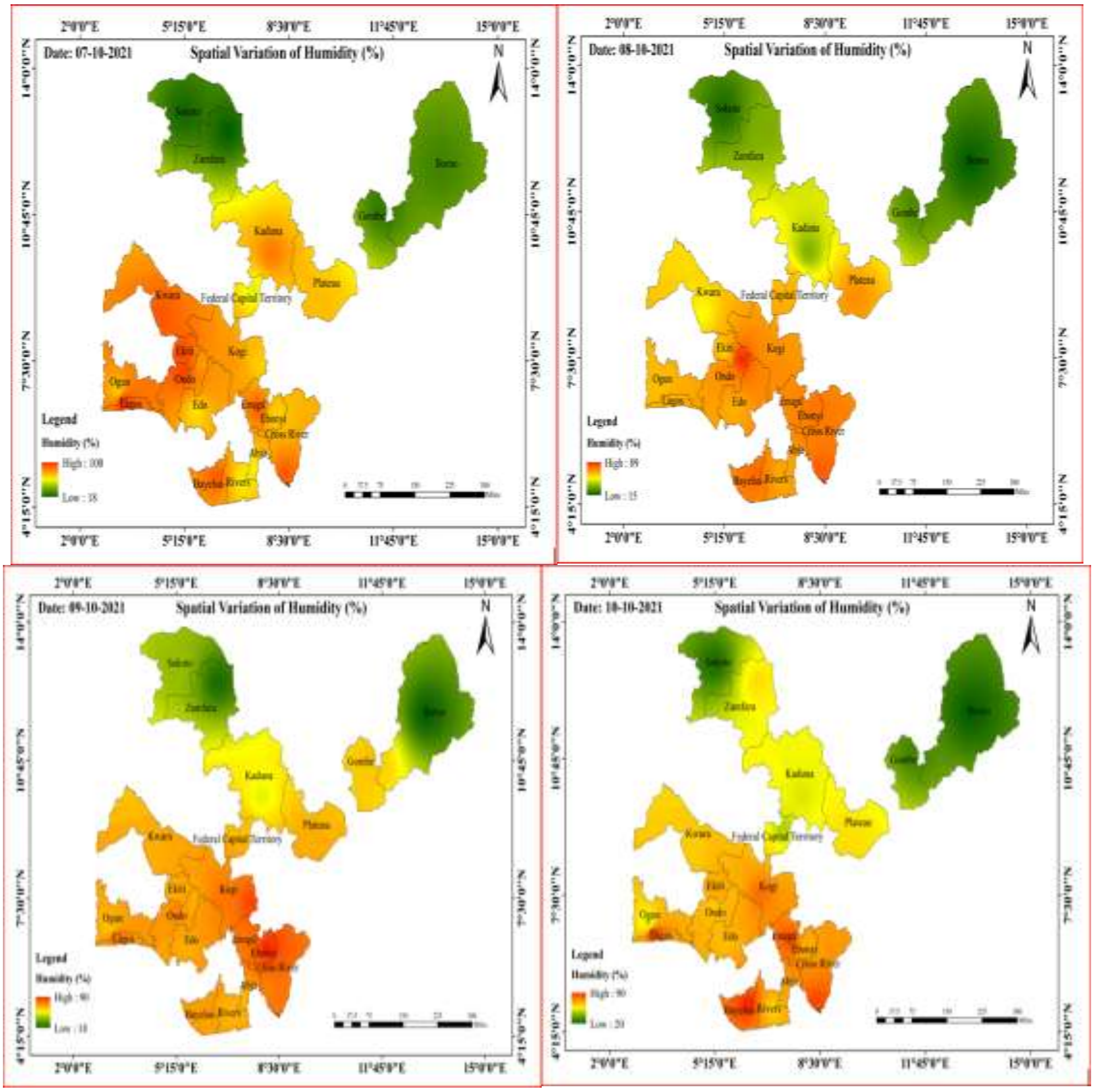
AQI (a)

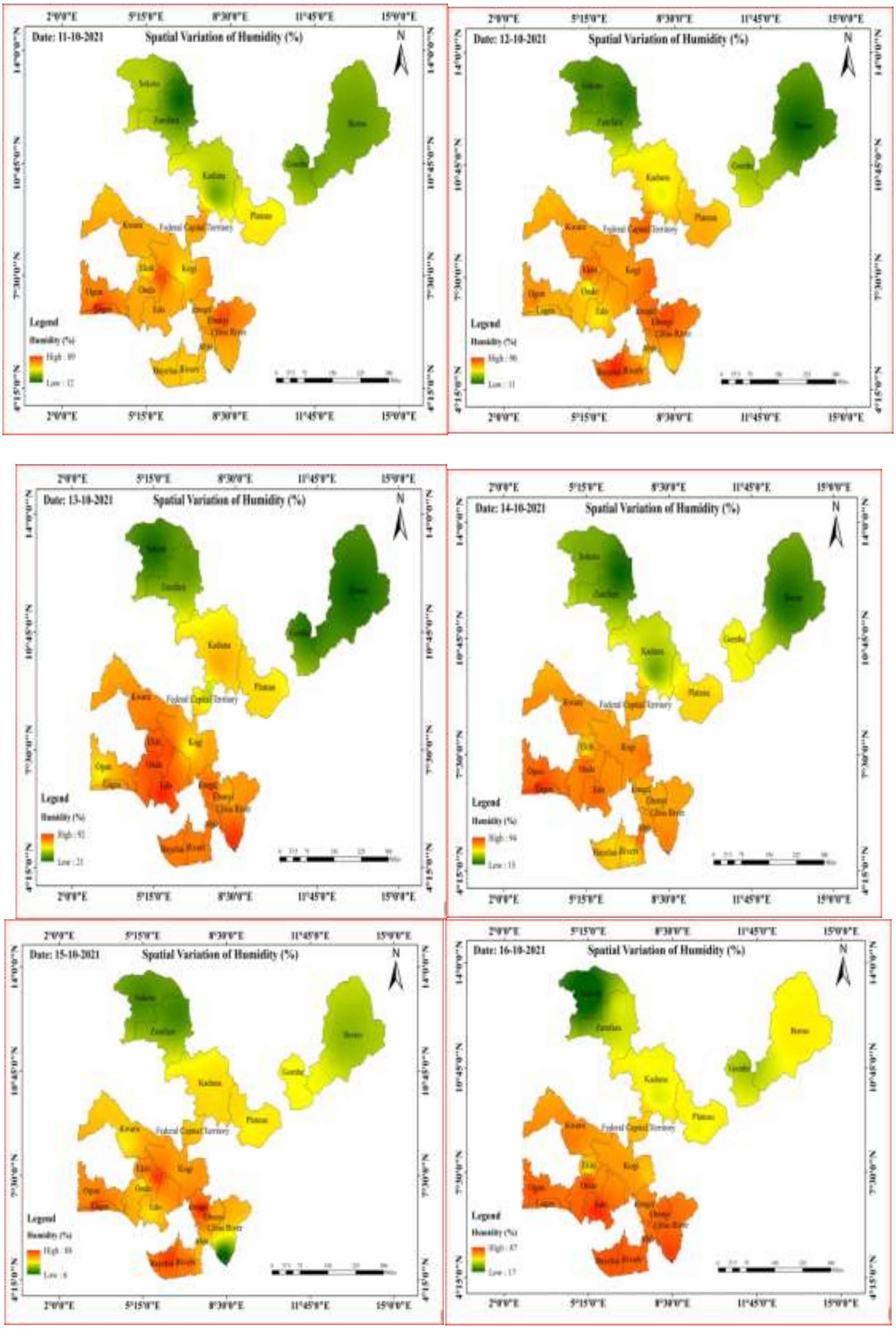

Spatial Variation of Fine Particulate Matter (<2.5 microns)
Date: 07-10-2021
Legend
Fine Particulate Matter (µg/m3)
Spatial Variation of Fine Particulate Matter (<2.5 microns)
Date: 08-10-2021
Legend
Fine Particulate Matter (µg/m3)
Spatial Variation of Fine Particulate Matter (<2.5 microns)
Date: 09-10-2021
Legend
Fine Particulate Matter (µg/m3)
Spatial Variation of Fine Particulate Matter (<2.5 microns)
Date: 10-10-2021
Legend
Fine Particulate Matter (µg/m3)

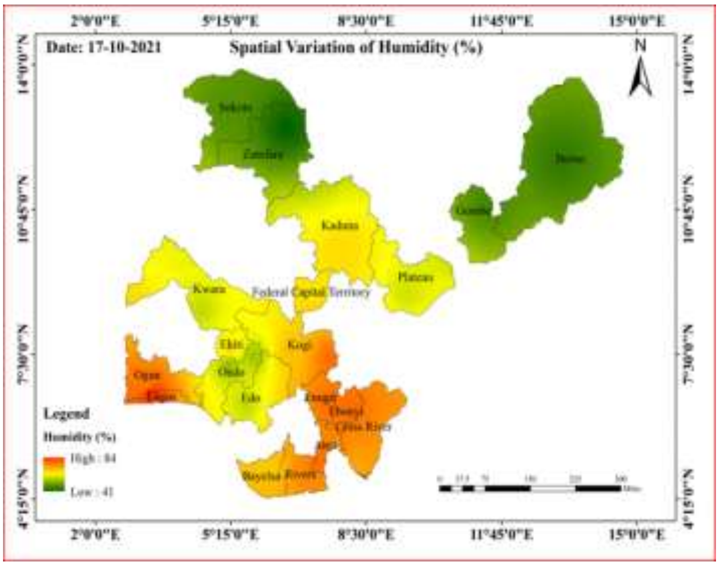

Spatial Variation of Fine Particulate Matter (<2.5 microns)
Date: 11-10-2021
Date: 12-10-2021
Date: 13-10-2021
Date: 14-10-2021
Date: 15-10-2021
Date: 16-10-2021
Legend
Fine Particulate Matter (μg/m3)
2°0'0"E
5°15'0"E
8°30'0"E
11°45'0"E
15°0'0"E
14°0'0"N
10°45'0"N
7°30'0"N
4°15'0"N
N


Spatial Variation of Fine Particulate Matter (<2.5 microns)
Date: 17-10-2021
Legend
Fine Particulate Matter (µg/m3)
High : 60
Low : 8
2°0'0"E
5°15'0"E
8°30'0"E
11°45'0"E
15°0'0"E
14°0'0"N
10°45'0"N
7°30'0"N
4°15'0"N
Sokoto
Zamfara
Kaduna
Borno
Gombe
Plateau
Kwara
Federal Capital Territory
Kogi
Ekiti
Ondo
Ogun
Edo
Enugu
Ebonyi
Cross River
Abia

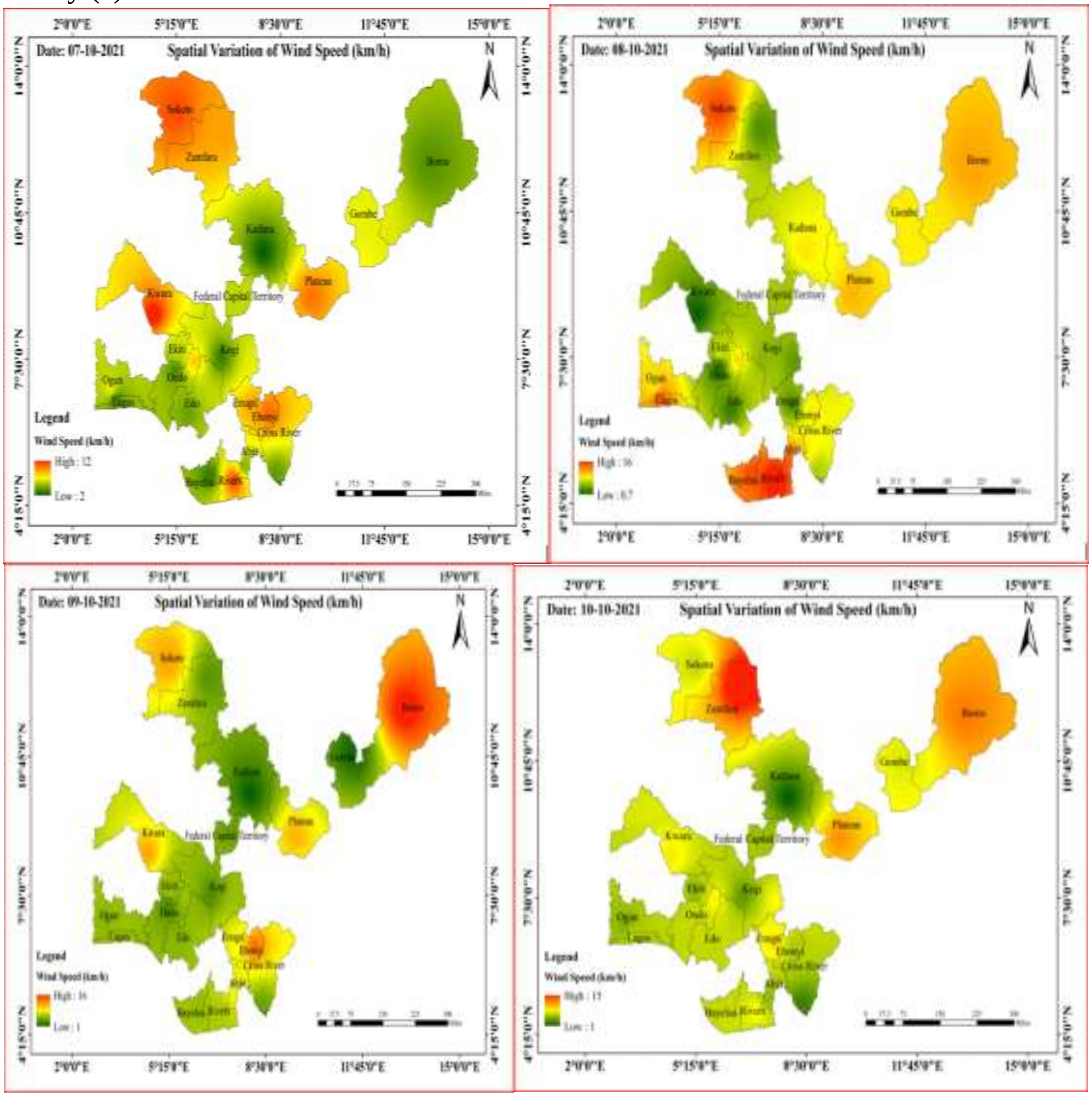
$PM_{2.5}$ (b)

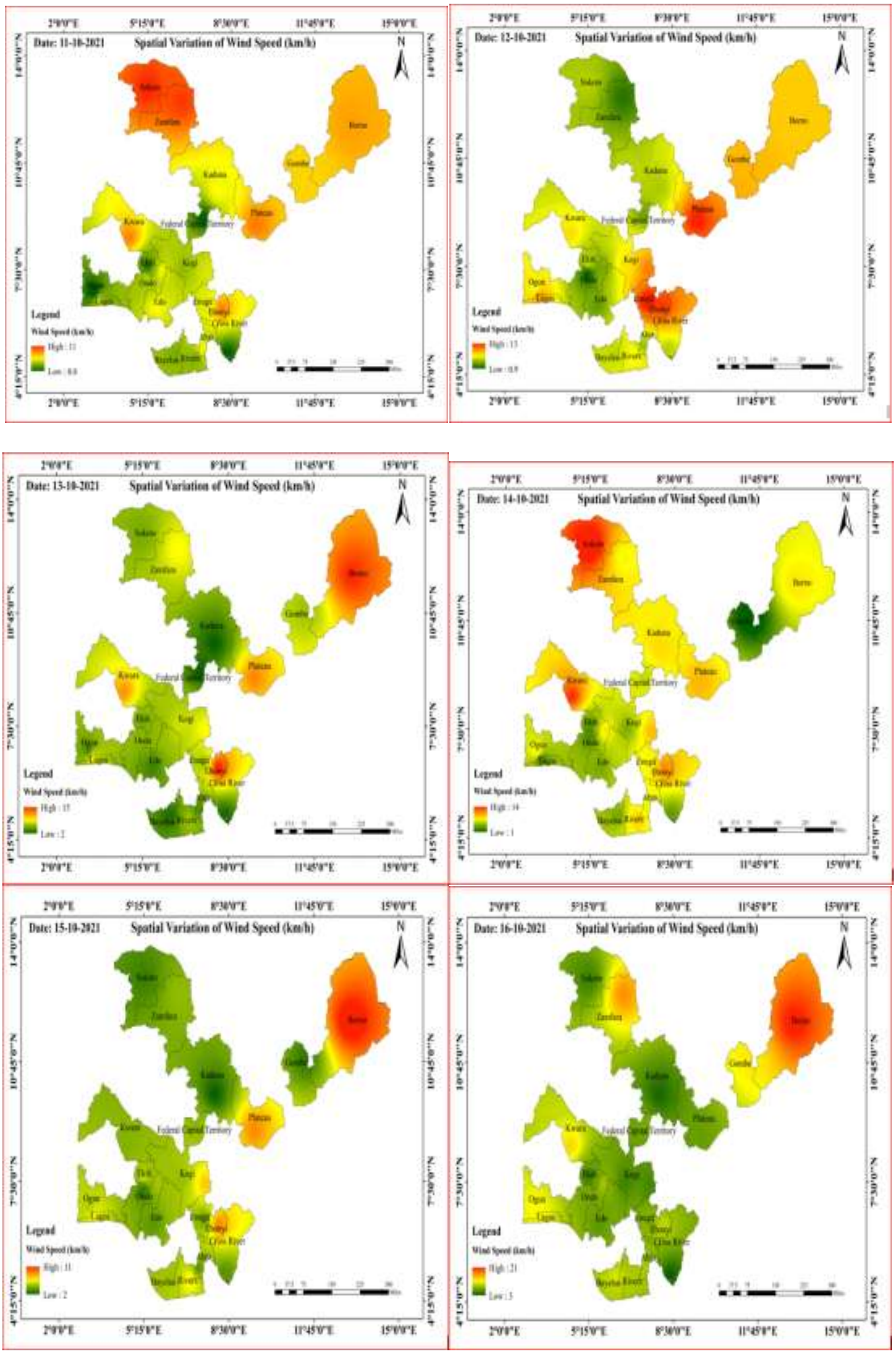

Date: 07-10-2021
Spatial Variation of Humidity (%)
Legend
Humidity (%)
High : 100
Low : 18
Date: 08-10-2021
Spatial Variation of Humidity (%)
High : 89
Low : 15
Date: 09-10-2021
Spatial Variation of Humidity (%)
High : 90
Low : 18
Date: 10-10-2021
Spatial Variation of Humidity (%)
High : 90
Low : 20
2°0'0"E
5°15'0"E
8°30'0"E
11°45'0"E
15°0'0"E
14°0'0"N
10°45'0"N
7°30'0"N
4°15'0"N
Sokoto
Zamfara
Kaduna
Borno
Gombe
Plateau
Kwara
Federal Capital Territory
Kogi
Ekiti
Ondo
Ogun
Lagos
Edo
Enugu
Ebonyi
Cross River
Abia
Bayelsa Rivers

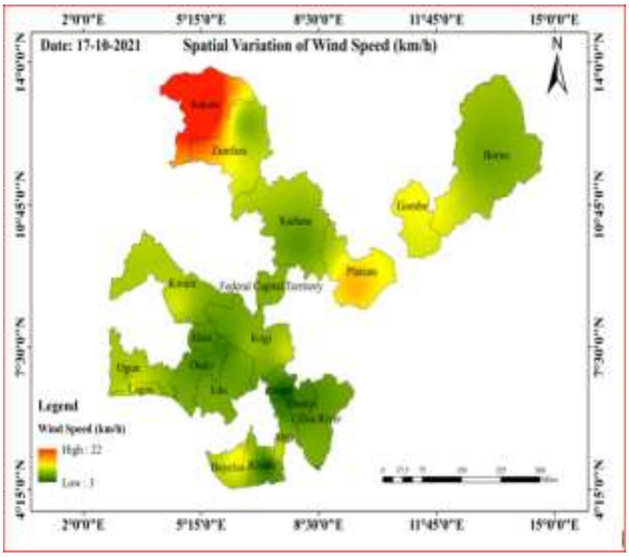

Date: 11-10-2021
Spatial Variation of Humidity (%)
Date: 12-10-2021
Spatial Variation of Humidity (%)
Date: 13-10-2021
Spatial Variation of Humidity (%)
Date: 14-10-2021
Spatial Variation of Humidity (%)
Date: 15-10-2021
Spatial Variation of Humidity (%)
Date: 16-10-2021
Spatial Variation of Humidity (%)
Legend
Humidity (%)
N
2°0'0"E
5°15'0"E
8°30'0"E
11°45'0"E
15°0'0"E


Date: 17-10-2021
Spatial Variation of Humidity (%)
N
Sokoto
Zamfara
Borno
Gombe
Kaduna
Plateau
Kwara
Federal Capital Territory
Ekiti
Kogi
Ondo
Ogun
Lagos
Edo
Enugu
Ebonyi
Cross River
Abia
Bayelsa Rivers
Legend
Humidity (%)
High : 84
Low : 41
2°0'0"E
5°15'0"E
8°30'0"E
11°45'0"E
15°0'0"E
14°0'0"N
10°45'0"N
7°30'0"N
4°15'0"N

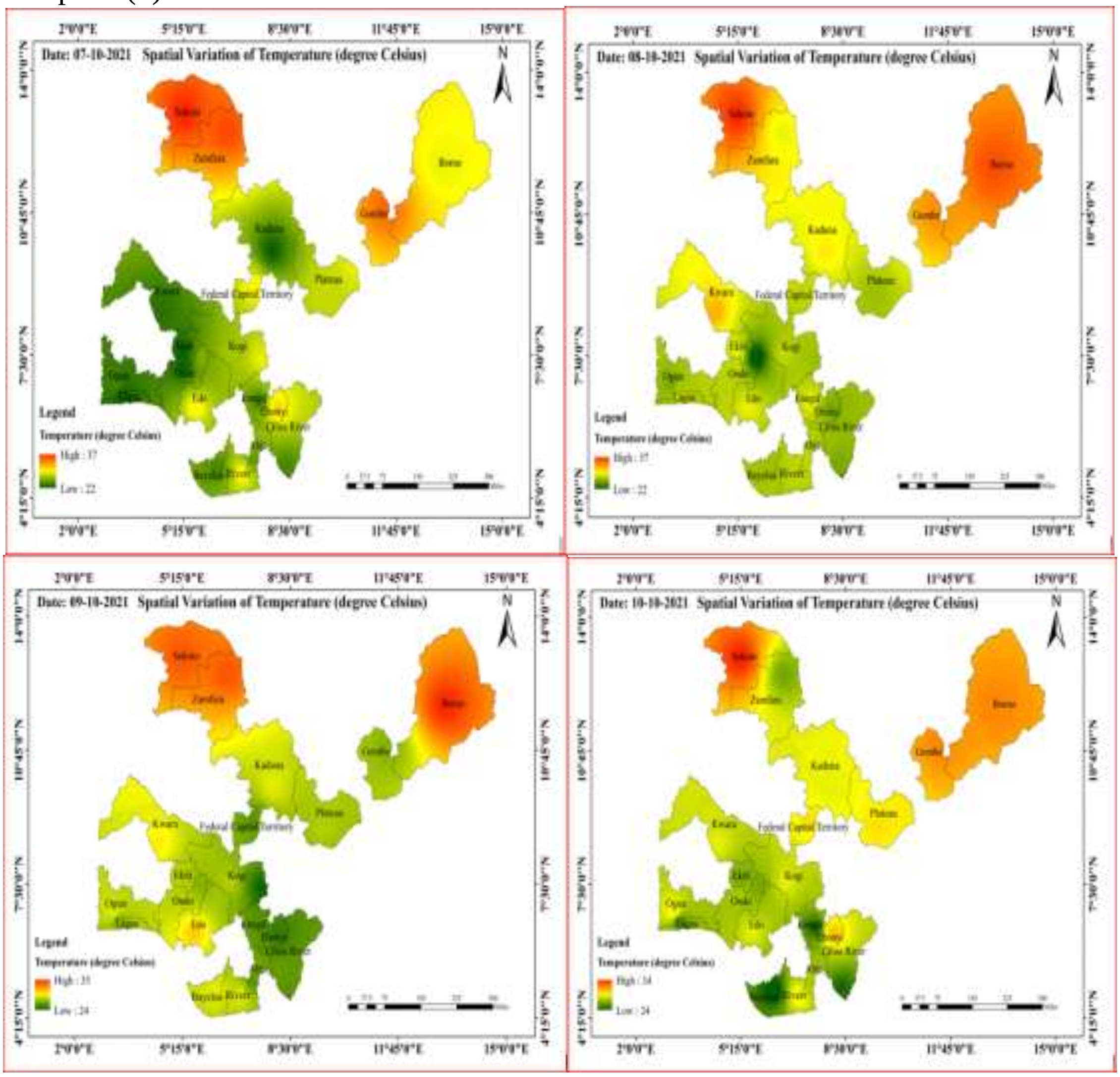
Humidity (c)

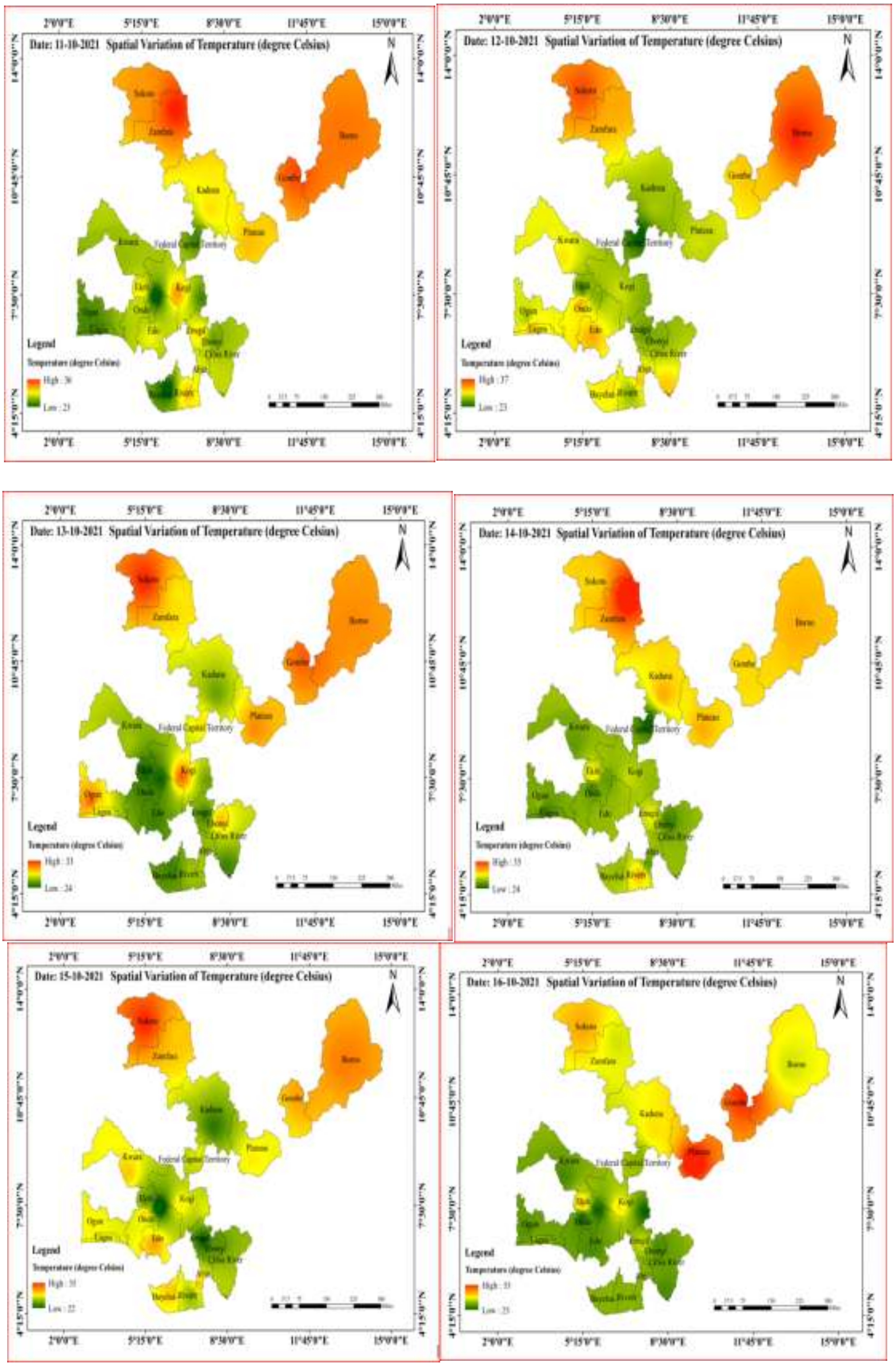

Date: 07-10-2021
Spatial Variation of Wind Speed (km/h)
Legend
Wind Speed (km/h)
High : 12
Low : 2
Date: 08-10-2021
Spatial Variation of Wind Speed (km/h)
Legend
Wind Speed (km/h)
High : 16
Date: 09-10-2021
Spatial Variation of Wind Speed (km/h)
Legend
Wind Speed (km/h)
High : 16
Low : 1
Date: 10-10-2021
Spatial Variation of Wind Speed (km/h)
Legend
Wind Speed (km/h)
High : 15
Low : 1

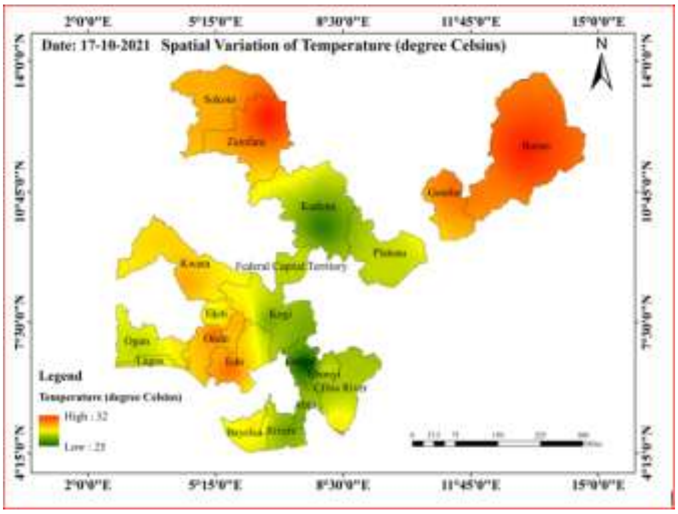

Date: 11-10-2021
Spatial Variation of Wind Speed (km/h)
Date: 12-10-2021
Spatial Variation of Wind Speed (km/h)
Date: 13-10-2021
Spatial Variation of Wind Speed (km/h)
Date: 14-10-2021
Spatial Variation of Wind Speed (km/h)
Date: 15-10-2021
Spatial Variation of Wind Speed (km/h)
Date: 16-10-2021
Spatial Variation of Wind Speed (km/h)
Legend
Wind Speed (km/h)
N


Date: 17-10-2021
Spatial Variation of Wind Speed (km/h)
Legend
Wind Speed (km/h)

Wind Speed (d)


Date: 07-10-2021 Spatial Variation of Temperature (degree Celsius)
Date: 08-10-2021 Spatial Variation of Temperature (degree Celsius)
Date: 09-10-2021 Spatial Variation of Temperature (degree Celsius)
Date: 10-10-2021 Spatial Variation of Temperature (degree Celsius)
Legend


Date: 11-10-2021 Spatial Variation of Temperature (degree Celsius)
Date: 12-10-2021 Spatial Variation of Temperature (degree Celsius)
Date: 13-10-2021 Spatial Variation of Temperature (degree Celsius)
Date: 14-10-2021 Spatial Variation of Temperature (degree Celsius)
Date: 15-10-2021 Spatial Variation of Temperature (degree Celsius)
Date: 16-10-2021 Spatial Variation of Temperature (degree Celsius)



Temperature (e)

Figure 3: (a-e): The Distributions of AQI, $PM_{2.5}$, RH, Speed, and Temp Values Obtained in the Study Locations

This outcome agrees with Zhang et al. [23] when the RH increases in China. In conclusion, neither excessively low nor excessively high relative humidity levels would support a sharp increase in $PM_{2.5}$ concentration. RH is a significant external meteorological element that affects the mass concentrations of aerosols. RH does not directly contribute to the rise in PM. In any case, fluctuations in $PM_{2.5}$ levels were influenced by various climatic factors, including wind speed, precipitation, air and soil temperatures, soil humidity, and relative air humidity [23]. Table 1 reveals the wind speed variable result. They differed as follows: mean (6.96 m/s), standard deviation (3.50), variance (12.20), and median (6.50).

The maximum wind speed was 21.30 m/s (peak speed), and the minimum speed was 0.7 m/s. Wind speed describes how quickly air moves past a given point; it could be seen that the areas with the highest wind speeds were in the country's northern region. These could result from high temperatures and a savannah area with fewer trees that could have served as windbreakers. When the wind speed is low, the polluted weather is mainly found in the northern part of the country. Moderate to severe pollution is uncommon when the wind speed exceeds 5 m/s. $PM_{2.5}$ concentrations are higher in polluted weather during the dry season. This study's findings compare with Liu et al.'s [24]. The temperature in degrees Celsius is shown in Table 1. Various climatic conditions, including wind speed, rainfall, air and soil temperatures, soil humidity, and relative air humidity, influence changes in PM2.5 concentration. The temperature ranged from 22 to 37^{o}C, and the results showed that low temperatures were observed in the southern part of the country, while high temperatures were observed in the north. The high temperature was linked to the photochemical reaction between the precursor chemicals. High temperatures influence particle creation and exacerbate air quality issues. Because air is often pretty static throughout a heat wave, polluted air is not distributed. Sunlight and high temperatures also promote chemical changes in pollutants, increasing smog [25].

Figure 3a shows the regional differences in the AQI for both north and south. The concentration levels in most parts of the north and south-south were above 65, with maximum values exceeding 178. On the contrary, concentration levels were lower in the southwest and southeast than in other regions. $PM_{2.5}$ concentrations were significantly higher in the north and south (River State-Port Harcourt) than in the southwest and southeast. In areas with high mass concentrations, it also has an aggregation effect. $PM_{2.5}$ concentrations had decreased significantly in the eighth, ninth, twelfth, and fourteenth dates (four times in Oct. 2021). Overall, the distribution of $PM_{2.5}$ concentrations in Nigeria's towns indicated a steady change from "high in the north and low in the south" to homogeneity across all towns over time. The interpolation of each location using the IDW method to obtain the spatial distribution of RH in locations during the study period was done (Figure 3c). RH concentration levels were lower in the north, whereas other parts of the country had high concentrations. The differences were substantial. Only on the 16th of October was when the north have a high RH concentration. Vertical mixing also provides the dynamic circumstances for the acumination and diffusion of air contaminants, and weak wind and humidity in the lower troposphere are necessary to create particulate matter [26].

Figure 3d depicts the wind speed distributions. The prevailing wind was strong throughout the northern part of the country, as was every other parameter measured in this study. The wind speed was mostly low in the south-south, south-west, and south-east directions. This fact is supported by the wind speed values obtained. Although regional transportation significantly impacted pollutant distribution, wind speed variation was the primary cause. Because of regional transport, topography, and wind direction, particulate matter spreads from the northwestern to the southwestern [27]. The temperature distribution is depicted in Figure 3e. Throughout the monitoring period, the north had high-temperature values. The reason is that the area is a temperate region where many natural and anthropogenic activities raise the temperature. Less rainfall is recorded in these areas yearly, contributing to the region's high temperatures. On the 15^{th} and 17^{th}, a high-temperature element existed in the southwest and southeast.

The r-coefficient comparison between the parameters and Pearson analysis is shown in Table 4. The analysis showed that r ranged from -0.1 to 0.9, consistent with Zhao et al. [28] and Wang and Ogawa [25]. Table 4 demonstrates the relationship between $PM_{2.5}$ and temperature. $PM_{2.5}$ has a weak positive correlation with temperature for most months (r=0.145; 95% Cl=0.016, 0.269). Other weak relationships include temperature, AQI (r=0.16), and RH (r= -0.82). The temperature is essential in this study because it can affect particle formation; thus, a high temperature can promote the photochemical reaction between precursors. Table 4 also shows a positive relationship between $PM_{2.5}$ and wind speed (r=0.1, 5% Cl= -0.032, 0.224). When the wind speed is low, it can move pollutants ahead within several geographical distributions, but when the wind speed is high enough, it can distribute large amounts of pollutants from a long distance away. The Pearson analysis showed a weaker correlation between wind speed and $PM_{2.5}$.

Table 4: Pairwise Pearson Correlations

Parameter		N	Correlation (r)	95% CI for ρ	P-Value
$PM_{2.5}$	AQI	230	0.911	(0.886, 0.931)	0.000
Temp	AQI	230	0.158	(0.029, 0.281)	0.017
Speed	AQI	230	0.121	(-0.008, 0.247)	0.067
Humidity	AQI	230	-0.198	(-0.320, -0.071)	0.002
Temp	$PM_{2.5}$	230	0.145	(0.016, 0.269)	0.028
Speed	$PM_{2.5}$	230	0.098	(-0.032, 0.224)	0.139
Humidity	$PM_{2.5}$	230	-0.163	(-0.286, -0.034)	0.013
Speed	Temp	230	0.098	(-0.032, 0.224)	0.139
Humidity	Temp	230	-0.820	(-0.858, -0.772)	0.000
Humidity	Speed	230	-0.103	(-0.229, 0.027)	0.119

AQI – Air Quality Index, Temp - Temperature

There were correlations between the mass of $PM_{2.5}$ and humidity. At a P value of 0.013, $PM_{2.5}$ had a very weak negative correlation (r= -0.163) with humidity in most months (Table 4). Positive correlations existed in some months, but the correlation coefficient was very low. According to Wang et al. [29], when RH exceeds 70% in the warmer months, $PM_{2.5}$ concentration has a strong negative correlation with humidity.

Conclusion

The findings of this study give the public significant details about the overall air quality in their region and explain how it may affect their health. The AQI has an average value within the levels of concern of goods. The minimum AQI values confirm satisfactory air condition with little or almost no risk of pollutants. However, the average AQI indicates acceptable air quality, which can be risky for some people, especially those unusually sensitive to air pollution, and the maximum AQI can pose a severe threat to the sensitive groups. In the case of $PM_{2.5}$, we found that when we compared our mean results to the WHO air quality guidelines (2021) of 5 $\mu g/m^3$ (annual) and 15 $\mu g/m^3$ (24 h), our results were 17% (annual) and 52% higher (24 h). The correlation between AQI-$PM_{2.5}$ and Temperature-RH was strong, but correlations between $PM_{2.5}$ and meteorological parameters were weak. According to the data, $PM_{2.5}$ was not distributed uniformly across the regions but varied spatially and temporally. There may be higher $PM_{2.5}$ levels in the north than in the southwest due to the combined effects of burning wood and biomass, cigarette smoke, automobile emissions, sources of soil dust, and poor weather on air pollution. Hot, dry season increases the likelihood of fires, which adds even more pollutants to the atmosphere. The high $PM_{2.5}$ value in Port Harcourt is attributed to gas flaring. To mitigate the threat, it is recommended to stop anthropogenic activities, monitor, and maintain air quality continuously to control air pollution.

Acknowledgments

The authors gratefully acknowledge the assistance of colleagues, the constructive contributions of anonymous reviewers, and the statistical analysis by Emmanuel Awogbindin of the Department of Computer Science, Bamidele Olumilua University of Education, Science, and Technology, Ikere, State, Nigeria.

Declarations

Funding: No funding for this work

Conflicts of interests: No conflicts of Interest

References

[1] WHO. “Air Pollution: Ambient Air Pollution: Health Impacts”; WHO: Geneva, Switzerland. Available online: https://www.who.int/airpollution/ambient/health-impacts/en/. 2018. (Assessed on 4 October 2018)

[2] WHO. “WHO global air quality guidelines: particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide”. World Health Organization. https://apps.who.int/iris/handle/10665/345329. 2021.

[3] WHO. “Factsheet on Ambient Air Quality and Health”; WHO: Geneva, Switzerland, 2018. Available online: http://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health. a2018. (Assessed on 4 May 2022).

[4] A.J. Cohen, M., Brauer, R., Burnett, H.R., Anderson, J., Frostad, K., Estep, K., Balakrishnan, B., Brunekreef, L., Dandona, et al. “Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: An analysis of data from the Global Burden of Diseases Study 2015”. *Lancet*, 389, 1907–1918. 2017.

[5] T., Allegretti. “2021 IQAir World Air Quality Report”. Updated 3/24/2022. https://www.iqair.com/blog/press-releases/WAQR_2021_PR. Accessed 5/6/2022. 2022.

[6] N.M., Wambebe and X., Duan. "Air Quality Levels and Health Risk Assessment of Particulate Matters in Abuja Municipal Area, Nigeria." *Atmosphere*, 11, 817; doi: 10.3390/atmos11080817. 2020.

[7] Health Effects Institute. "State of Global Air. Special Report"; Health Effects Institute: Boston, MA, USA. 2019

[8] F.O., Abulude, M.O., Oluwafemi, K.M., Arifalo, J.J., Elisha and A., Yusuf. "Real-Time Air Quality Index App: The Use of eWeather HDF App for Education in Monitoring of Pollutants and Meteorological Parameters in Nigeria." *ASEAN Journal of Science and Engineering Education* 2(2): 157-162. 2022.

[9] X.H., Li, W.W., and D.Q., Xu. "Typical Correlation Analysis of Air Quality and Meteorological Factors in Xi'an City," *Journal of Environmental Hygiene*, (3): 203-208. 2017.

[10] Envirotech Online, (2022). Air monitoring: What Is Classed as Unhealthy Air Quality? Digital Edition. https://www.envirotech-online.com/news/air-monitoring/6/breaking-news/what-is-classed-as-unhealthy-air-quality/57932?utm_source=iet&utm_medium=ebulletin&utm_term=air-monitoring&utm_content=June&utm_campaign=breaking-news&email=waleabul@outlook.com. Accessed 8th June, 2022.

[11] A., Plaia and M. Ruggieri. "Air quality indices: a review." *Rev Environ Sci Bio/Technol*, 10(2): 165-179. 2011.

[12] R., Zhao, Y., Zhang, and S. Guo. "Construction of an Improved Air Quality Index: A Case Report." *Iran Journal of Public Health*, Vol. 48, No.8, Aug 2019, pp.1523-1527. 2019.

[13] R.B., Kanee, A., Adeyemi, D.O., Edokpa, and P.N., Ede. "Particulate Matter-Based Air Quality Index Estimate for Abuja, Nigeria: Implications for Health." *Journal of Geoscience and Environment Protection*, 8, 313-321. 2020. https://doi.org/10.4236/gep.2020.85019

[14] J. Guo and Z. Feng. "Study on Spatial Temporal Distribution Characteristics of Air Quality Index in Beijing and Its Correlation with Local Meteorological Conditions Discrete" Dynamics in Nature and Society, Volume 2019, Article ID 1462034. https://doi.org/10.1155/2019/1462034

[15] M., Chakraborty, S. Debnath, and S. Ghosh. "A Study during Lockdown Period Based on AQI over Indian Mega cities during COVID-19". *Journal of Physics: Conference Series* 1797, 012056. 2020. doi:10.1088/1742-6596/1797/1/012056

[16] R. Cao, Y. Wang, X. Pan, X. Jin, J. Huang, and G. Li. "Estimating Short- and Long-Term Associations between Air Quality Index and COVID-19 Transmission: Evidence From 257 Chinese Cities". *Int J Public Health*, 21 July 2021. https://doi.org/10.3389/ijph.2021.1604215

[17] S. Sharma, M. Zhang, M. Anshika, J. Gao, H. Zhang, and S.H. Kota. "Effect of restricted emissions during COVID-19 on air quality in India". *Science of The Total Environment* Volume 728, 1 August 2020, 138878. https://doi.org/10.1016/j.scitotenv.2020.138878

[18] R. Zalakeviciute, R. Vasquez, D. Bayas, A. Buenano, D. Mejia, R. Zegarra, A. Diaz, and B. Lamb. Drastic Improvements in Air Quality in Ecuador during the COVID-19 Outbreak. *Aerosol Air Quality Research.* 20: 1783–1792. 2020. https://doi.org/10.4209/aaqr.2020.05.0254

[19] K. Xu, K. Cui, L.H. Young, L.H., Hsieh, Y.K., Wang, Y.F., Zhang, J. and Wan, S. "Impact of the COVID-19 Event on Air Quality in Central China". *Aerosol Air Quality Research*, vol. 20, pp. 915–929. 2020. https://doi.org/10.4209/aaqr.2020.04.0150

[20] S. Gope, S. Dawn, and S.S. Das. "Effect of COVID-19 pandemic on air quality: a study based on Air Quality Index". *Environmental Science Pollution Research* 28, 35564–35583. 2021. https://doi.org/10.1007/s11356-021-14462-9

[21] F.O. Abulude, I.A. Abulude, S.D. Oluwagbayide, S.D. Afolayan, and D. Ishaku. "Air Quality Index: a Case of 1-Day Monitoring in 253 Nigerian Urban and Suburban Towns". *Journal of Geovisualization and Spatial Analysis* 6(5):1-13. 2022. DOI: 10.1007/s41651-022-00100-6

[23] L. Zhang, Y. Cheng, Y. Zhang, Y. He, Z. Gu, and C. Yu. "Impact of Air Humidity Fluctuation on the Rise of PM Mass Concentration Based on the High-Resolution Monitoring Data." *Aerosol and Air Quality Research*, 17: 543–552. 2017. doi: 10.4209/aaqr.2016.07.0296

[24] Z. Liu, L. Shen, C. Yan, J. Du, Y. Li, and H. Zhao. "Analysis of the Influence of Precipitation and Wind on PM2.5 and PM10 in the Atmosphere". *Advances in Meteorology*. Volume 2020, https://doi.org/10.1155/2020/5039613

[25] J. Wang and S. Ogawa. “Effects of Meteorological Conditions on $PM_{2.5}$ Concentrations in Nagasaki, Japan”. *International Journal of Environmental Research and Public Health* 2015, 12, 9089-9101; doi:10.3390/ijerph120809089

[26] W.B. Xue, X.R. Shi, G. Yan, J.N. Wang, Y.L. Xu, Q. Tang, Y.L. Wang, Y.X. Zheng, Y. Lei. “Impacts of meteorology and emission variations on the heavy air pollution episode in North China around the 2020 Spring Festival. *Science. China Earth Science*. 64, 329–339. 2021.

[27] Q. Xing and M. Sun. “Characteristics of PM2.5 and PM10 spatial-temporal distribution and influencing meteorological conditions in Beijing”. *Atmosphere*, 13, 1120. 2022. https://doi.org/. 10.3390/atmos13071120

[28] C.X. Zhao, Y.Q. Wang, Y.J. Wang, H.L. Zhang, B.Q. Zhao. “Temporal and spatial distribution of $PM_{2.5}$ and PM_{10} pollution status and the correlation of particulate matters and meteorological factors during winter and spring in Beijing”. *Environmental Science*, 35, 418–427. 2014.

[29] Z.B. Wang, L.W. Liang, and X.J. Wang. “Spatio-temporal evolution patterns and influencing factors of PM2.5 in Chinese urban agglomerations”. *Acta Geographica Sinica.* 70, 1720–1734. 2015.