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Assessment of AQI, PM10, PM2.5, NO2, O3: The Case of Owo, Nigeria

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ABSTRACT

When evaluating the quality of the air, the most important pollutants to keep an eye on are particulate matter (PM), NO_2, CO, O_3, and SO_2 gases. Their impact on people and the environment is a simple fact. Before taking any action, it is necessary to determine how much of them are present in the air. Therefore, the purpose of this article is to evaluate the AQI, PM, and other pollutants present in the Nigerian town of Owo in Ondo State. This was accomplished with the help of the recently introduced AirVisual PM wireless sensor technology. It collects data on AQI, PM_{10}, $PM_{2.5}$, NO_2, and O3 using satellite imagery. The AQI was interpreted using the Aculeated Air Quality Scale. The findings revealed that the AQI was in the average range. The NO_2 values were lower than the advised limits when these findings were compared to WHO standards. While the O_3 values were significantly below the 8-hour daily maximum and peak session, the PM values significantly exceeded the annual and 24-hour mean limits. Nigeria should start making efforts right away to stop activities that could increase pollution both inside and outside of the town of Owo, which is a rapidly expanding town in the Ondo State.

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1. INTRODUCTION

Exposure to air pollution is estimated to result in millions of deaths and lost years of healthy life each year, imposing a significant burden of disease on human health globally. Air pollution is now acknowledged as the single biggest environmental threat to human health, with the burden of disease attributable to it estimated to be on par with other major global health risks like unhealthy diet and tobacco use. Despite some noticeable air quality improvements, since the 1990s, the number of deaths and years of healthy life lost around the world has hardly changed. Air quality in high-income places has significantly improved within the same period, it has gotten worse in most low- and middle-income countries, in line with rapid urbanization and economic growth. In addition, due to population aging and lifestyle changes, noncommunicable diseases (NCDs) are now the main causes of death and disability in the world. NCD prevalence has increased rapidly. A wide variety of illnesses affecting the cardiovascular, nervous, respiratory, and other organ systems make up NCDs. As evidence of its effects on other organ systems grows, air pollution is linked to an increase in morbidity and mortality from lung cancer, cardiovascular, respiratory, and other diseases. The cost of diseases brought on by air pollution is also very high economically. Governments all over the world are therefore working to enhance air quality, lessen the burden of air pollution on the public's health, and cut costs.

Particulate matter (PM), NO_2, CO, O_3, and SO_2 gases are the most crucial pollutants to watch when assessing the quality of the air. Fine particles in PM that are 10 microns or smaller (PM_{10}) can enter the respiratory system through breathing and can, among other things, cause severe respiratory diseases. PM10 is believed to be brought on by five different factors, according to Xu *et al.* (2020) fire, crustal mud, automotive waste, secondary inorganic aerosols, and biomass combustion. Particulate matters have also been linked to the resuspension of dust (Aquilina *et al.,* 2021). Although the O_3 stratosphere shields the surface of the Earth from ultraviolet radiation, some O_3 concentrations there are toxic to the respiratory and cardiovascular systems because of their strong oxidative reaction (Sicard et al. 2020). Humans are toxic to air pollutants like NO_2, SO_2, and CO, and both short- and long-term exposure is linked to lung infection (Pandey *et al.,* 2021).

The most recent studies on AQI, $PM_{2.5}$, $PM1_0$, NO_2, and O_3 in some cities are summarized in **Table 1**. Scientists from Nigeria and their international collaborators have conducted a variety of air quality measurements in Nigeria (Akinfolarin *et al.,* 2017; Abulude *et al.*, 2018a; Angaye *et al.,* 2019; Osimobi *et al.,* 2019; Croitoru *et al.,* 2020; Darful *et al.,* 2020; Abulude *et al.,* 2021). However, these measurements only cover a small area of the city (background, commercial, roads, and informal settlement homes), and only a small number of contaminants, mostly $PM_{2.5}$ and PM_{10}. PM concentrations sometimes seem to be significantly higher than the World Health Organization's (WHO) 24-hour average guideline. Surprisingly, no one has attempted to document the air quality in Owo, Ondo State, one of Nigeria's fastest-growing towns. In this study, we tracked air quality using standardized AQI-modelled satellite data from Owo. The study is anticipated to last 24 months. As a result, the study's goal was to conduct a six-month preliminary air quality assessment.

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Table 1. Summary of relevant research studies on AQI, PM_{10}, $PM_{2.5}$, NO_2, and O_3 assessment environments in different countries.

S/N	References	Key Findings	City (Country)	Study Focus
1	Angaye *et al.* (2019)	$PM_{1.0}$ is between 13.73 and 20.18 μg/m^3, $PM_{2.5}$ is between 19.11 and 28.83 μg/m^3, $PM_{4.0}$ is between 24.73 and 44.63 μg/m^3, $PM_{7.0}$ is between 41.07 and 67.04 μg/m^3, and PM_{10} is between 65.48 and 90.82 μg/m^3. Most of the players on the Air Quality Index football field received unhealthy or very unhealthy ratings. Several instances of threat to a weak group.	Yenogua (Nigeria)	In Yenagoa Metropolis, Nigeria, particulate matter from a football field was evaluated and its health risks were determined.
2.	Akinfolarin *et al.* (2017)	The findings revealed that industrial sites had higher $PM_{2.5}$ and PM_{10} concentrations than the control. $PM_{2.5}$ and PM_{10} concentrations varied seasonally, with the dry season indicating concentrations above the respective local acceptable limits of 150 μg/m^3 and 230 μg/m^3, respectively. In the wet season, the three new industrial sites' air quality indexes ranged from "good" to "moderate," while in the dry season, they ranged from "very unhealthy" to "hazardous."	Port-Harcourt, (Nigeria)	Assessment of Nigeria's Port Harcourt's Particulate Matter-Based Air Quality Index
3.	Zaib *et al.* (2022)	$PM_{2.5}$, PM_{10}, SO_2, NO_2, and CO decreased by 28.2%, 32.7%, 41.9%, 6.2%, and 27.3%, respectively, while O_3 increased by 3.96% in in NWC. $PM_{2.5}$ and PM_{10} levels exceeded the WHO and Chinese Ambient Air Quality Standards. SO_2 and NO_2 complied with the CAAQS. AQI and $PM_{2.5}/PM_{10}$ ratios showed the highest pollution levels in winter and the lowest in summer.	Shaanxi, Xinjiang, Gansu, Ningxia, and Qinghai (China)	Their study examines the spatial-temporal characteristics of ambient air quality in five provinces (Shaanxi (SN), Xinjiang (XJ), Gansu (GS), Ningxia (NX), and Qinghai (QH)) of northwest China (NWC)
4	Li *et al.* (2018)	The results showed that there were 19 d (5.2%) in API, 28 d (7.7%) in AQI, and 183 d (50 .1%) in NAQI when the indices were more than 100. In API, PM_{10} and SO_2 were regarded as the primary pollutants, whereas all five air pollutants in AQI were regarded as primary. Furthermore, four air pollutants (other than CO) in NAQI were regarded as primary pollutants. PM_{10}, as the primary pollutant, contributed greatly to these air quality indices and accounted for 51.2% (API), 37.0% (AQI), and 52.6% (NAQI).	Mainland China	Assessment and comparison of three different air quality indices in China

Table 1 (continue). Summary of relevant research studies on AQI, PM_{10}, $PM_{2.5}$, NO_2, and O_3 assessment environments in different countries.

S/N	References	Key Findings	City (Country)	Study Focus
5.	Jassim & Coskuner (2017)	The results of this study demonstrated that PM_{10} and $PM_{2.5}$ are the most critical air pollutants in Bahrain with $PM_{2.5}$ prevailing during January 2012 and PM_{10} prevailing during August 2012.	Kingdom of Bahrain	Assessment of spatial variations of particulate matter (pm_{10} and $pm_{2.5}$) in Bahrain identified by air quality index (AQI)
6.	Benchrif *et al.* (2021)	The results showed that the frequency distribution for NO_2 is more variable than that for $PM_{2.5}$, and the distribution is flatter from 2020 to the baseline 2018-2019 period. Besides, AQI, in most of the cities, has varied from high to mild pollution during the lockdown and was moderate before. Although during the lockdown, a reduction of 3 to 58% of daily NO_2 concentrations was observed across the cities, an increase was detected in three cities including Abidjan (1%), Conakry (3%), and Chengdu (10%).	Twenty-one cities around the world	Air quality during three covid-19 lockdown phases: AQI, $PM_{2.5}$, and NO_2 assessment in cities with more than 1 million inhabitants
7.	Keshtkar *et al.* (2022)	This study investigated the hourly concentrations of six particulate matter (PM), including $PM_{2.5}$, PM_{10}, and air contaminants such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO). Changes in pollution rate during the study period can be due to reduced urban traffic, small industrial activities, and dust mites of urban and industrial origins.	Iran	Analysis of changes in air pollution quality and the impact of COVID-19 on environmental health in Iran: application of interpolation models and spatial autocorrelation

2. METHODS

Owo, town, Ondo state, southwest Nigeria, at the intersection of roads from Siluko, Kabba, and Akure, and at the southern edge of the Yoruba Hills (elevation 1,130 feet [344 m]). It is a significant location for cocoa collection and a marketplace. In the vicinity, which was once covered in a thick tropical rainforest, cotton and teak are grown.

Due to the dearth of wireless sensors and the expensive equipment, the air quality in Owo is estimated using standard AQI satellite data from AirVisual, a low-cost, citizen-based PM wireless sensor technology that has been launched globally (https://www.iqair.com/ or https://www.iqair.com/nigeria/ondo/owo). AirVisual is powered by IQAir, Switzerland, with primary operations in Germany, the United States, and China. IQAir uses satellite imagery to gather information on AQI, PM_{10}, $PM_{2.5}$, NO_2, and O_3. The Aculeated website, https://www.accuweather.com, provided the air quality scale that was used to interpret the

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AQI results. Six months' worth of data from their website was used for this study. On their website, they offer both a forecast and data on the current state of the air. The information was presented following the Environmental Protection Agency's standards. **Figure 1** showed the study location. The obtainable AQI data on Owo town was evaluated and statistically analyzed using Minitab software version 16 and Excel 2013.

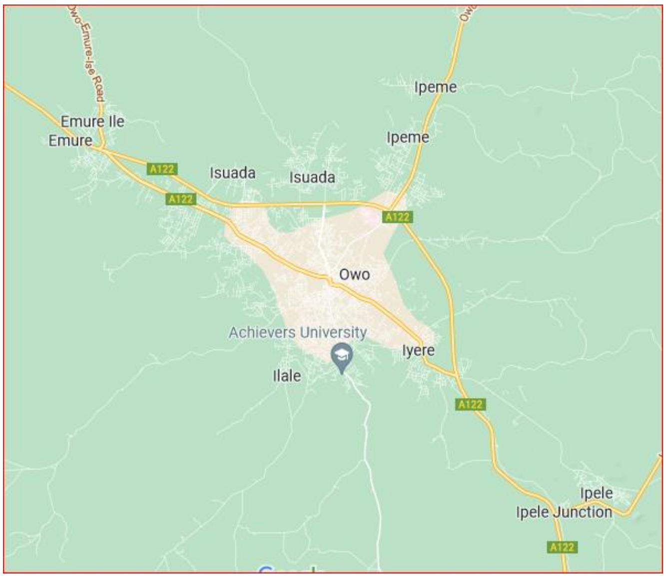

Figure 1. The study location.

3. RESULTS AND DISCUSSION

Following are the AQI results are shown in **Table 2**: First quartile (18), third quartile (18), minimum (18.0), maximum (76.0), and mean (18) from 0.00 to 2.00 µg/m^3, NO_2 was present. The mean of O3 was 19.33 µg/m^3, and the standard deviation was 6.31. The range of $PM_{2.5}$ was 13 to 76 µg/m^3, while the range of PM_{10} was 12 to 65 µg/m^3.

NO_2, $PM_{2.5}$, PM_{10}, O_3 (µg/m^3), *Peak season is defined as an average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running average O_3 concentration.

The NO_2 values were lower than the advised limits when these findings were compared to WHO standards. While the O_3 values were much lower than the 8 h daily max and 8 h peak session, the PM values were higher than the annual and 24 h mean limits. The reason for the high $PM_{2.5}$ and PM_{10} levels may be related to the intensive farming practices that took place during the study's timeframe. This population growth will undoubtedly lead to an increase in anthropogenic activities both inside and outside the town. Local traffic influences may be the main cause of pollutant variation in areas with low O_3 and NO_2 levels. This does not imply that air travel is not important. Rural areas typically have higher ozone levels because there are fewer local nitrogen dioxide emissions to displace any ozone that has formed in the atmosphere. The results of this study's $PM_{2.5}$ analysis exceeded the 19.11–28.83 µg/m^3 range reported by Angaye et al., In this study, the PM_{10} concentrations were less than 72 µg/m^3 (Li *et al.,* 2018), 54.17–1139.63 µg/m^3 (Akinfolarin *et al.,* 2017), 101.8–336.6 µg/m^3 (Jassim & Coskuner, 2017), and 115.29–121.30 µg/m^3 (New Delhi, India) – (Kolata, India). These variations were brought about by various human-made and natural activities within the regions. Except for NO_2, which peaked only in June, **Figure 2** showed that March and June had the highest elevations of all the pollutants. The high values found during these times may be due to emissions from forest fires.

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Table 2. The AQI, NO_2, $PM_{2.5}$, PM_{10}, and O_3.

Month	AQI	NO_2	$PM_{2.5}$	PM_{10}	O_3
March	69.0	0.000	69.00	58.00	29.00
April	18.0	0.000	17.00	18.00	14.00
May	18.0	0.000	18.00	14.00	12.00
June	76.0	2.000	76.00	65.00	18.00
July	24.0	0.000	13.00	12.00	24.00
August	19.0	1.000	15.00	15.00	19.00
Mean	37.3	0.500	34.70	30.33	19.33
Std Dev	27.4	0.837	29.32	24.32	6.31
Minimum	18.0	0.000	13.00	12.00	12.00
Maximum	76.0	2.000	76.00	65.00	29.00
1st Quartile	18.0	0.000	14.50	13.50	13.50
3rd Quartile	70.8	1.250	70.80	59.75	25.25
WHO (Annual mean)	-	10	5	15	-
2021 (24 h mean)	-	25	15	45	-
(8 h daily max)					100
(8 h mean, peak season*)	-	-	-	-	60

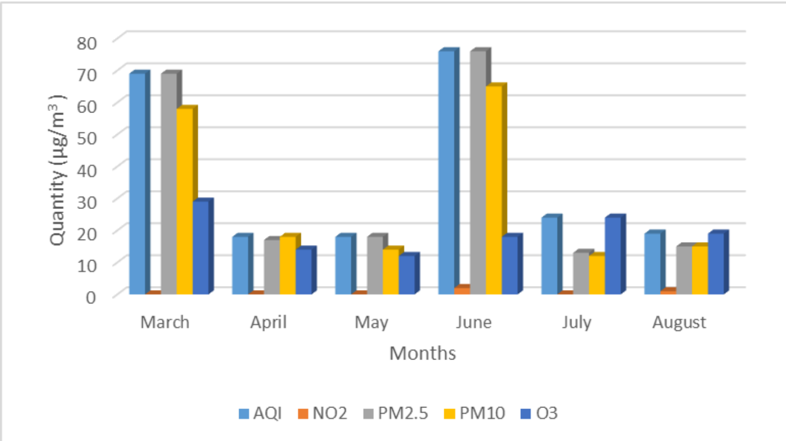

Figure 2. The variations of the pollutants within the months.

The Aculeated Air Quality Scale for the Interpretation of AQI rates the AQI between 18 and 76 in this study as excellent and poor, respectively, which can be seen in **Table 3**. While the 76 indicated that the air has reached a high level of pollution and is unhealthy for sensitive groups, the interpretation for the 18 showed that the air quality is ideal for the majority of people and one will enjoy typical outdoor activities. Anyone experiencing symptoms like throat irritation or breathing difficulties should limit their time outside. The AQI in the study is significantly lower than what Akinfolarin *et al.* (2017) found in Port Harcourt, where they found levels ranging from "Very unhealthy" to "dangerous." The factors that contribute to airborne contaminants in various cities around the world include the burning of fossil fuels, vehicle movement, high population growth, rapid economic development, and resuspended soil dust. The meteorological factors were related to one another. Since rain indicates a wet deposition effect on particulates, the coefficients of correlation obtained may be the result of the washout phase. The photochemical reaction between precursors can be aided by temperature because it can affect how particles and gases form.

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Table 3. Aculeated Air Quality Scale for the Interpretation of AQI.

Category	Levels	Interpretation
Excellent	0-19	The air quality is ideal for most individuals; enjoy your normal outdoor activities.
Fair	20-49	The air quality is generally acceptable for most individuals. However, sensitive groups may experience minor to moderate symptoms from long-term exposure.
Poor	50-99	The air has reached a high level of pollution and is unhealthy for sensitive groups. Reduce time spent outside if you are feeling symptoms such as difficulty breathing or throat irritation.
Unhealthy	100-149	Health effects can be immediately felt by sensitive groups. Healthy individuals may experience difficulty breathing and throat irritation with prolonged exposure. Limit outdoor activity.
Very Unhealthy	150-249	Health effects will be immediately felt by sensitive groups who should avoid outdoor activity. Healthy individuals are likely to experience difficulty breathing and throat irritation; consider staying indoors and rescheduling outdoor activities.
Dangerous	250+	Any exposure to the air, even for a few minutes, can lead to serious health effects on everybody. Avoid outdoor activities.

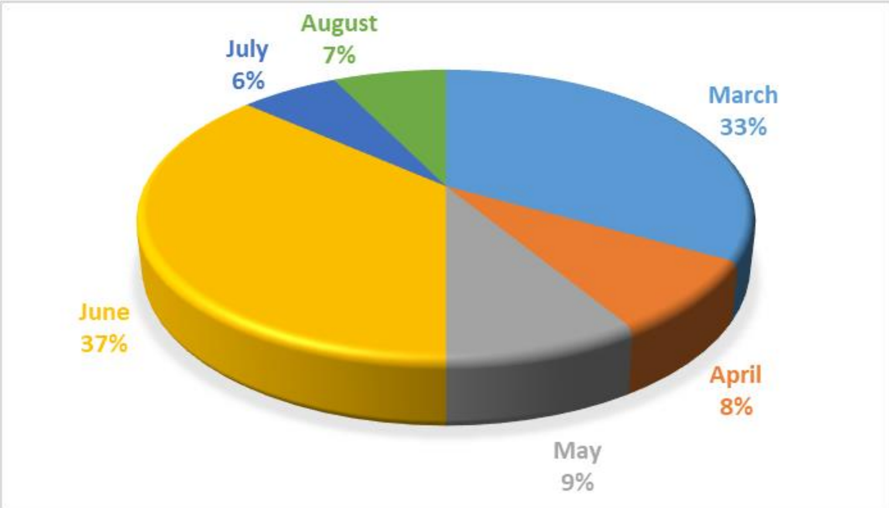

Figure 4. $PM_{2.5}$ The contributions of each pollutant in each month.

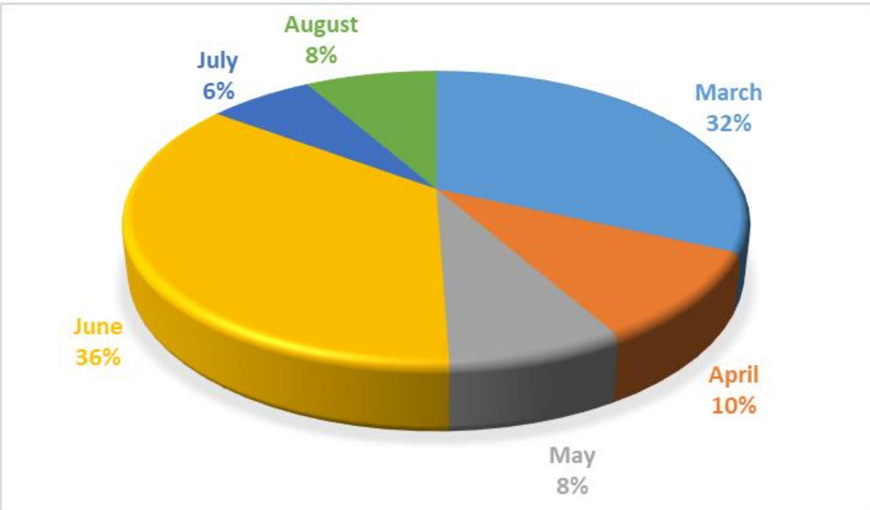

Figure 5. PM_{10} The contributions of each pollutant in each month.

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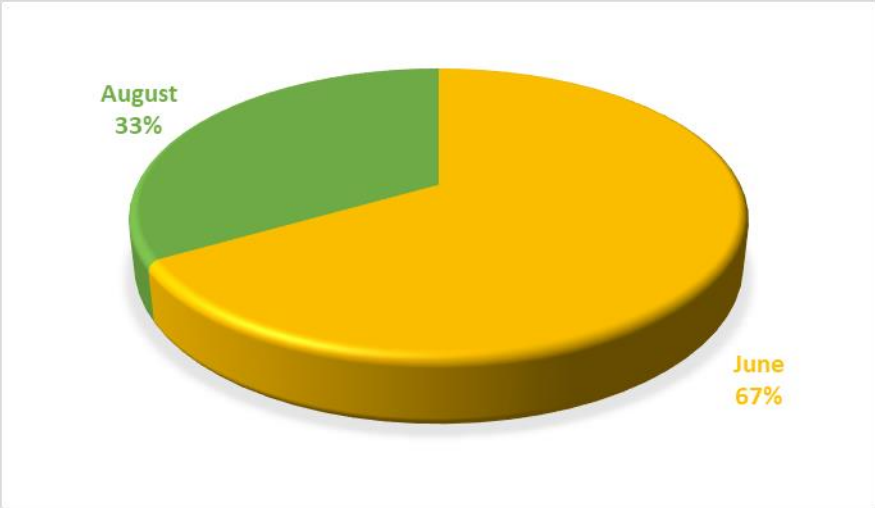

Figure 6. NO_2 The contributions of each pollutant in each month.

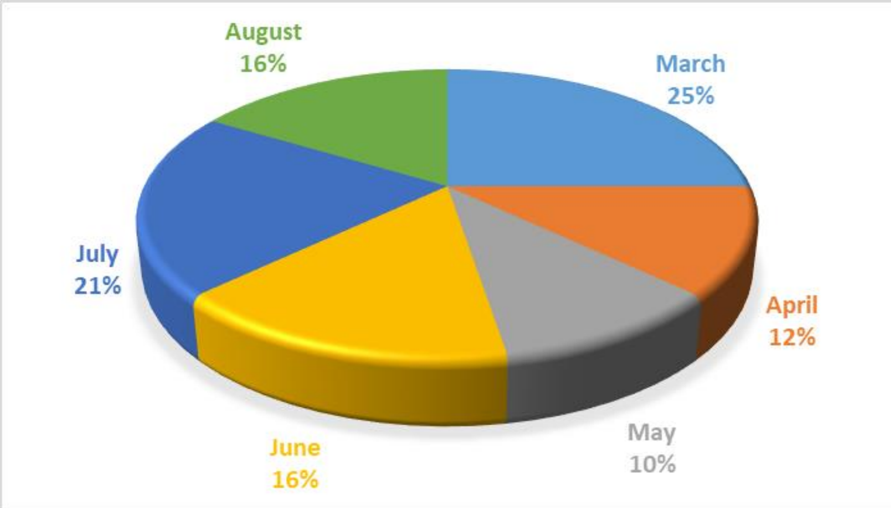

Figure 7. O_3 The contributions of each pollutant in each month.

The months with the most acceptable levels of air pollution were March (31%) and June (34%) according to the AQI. This implies that some vulnerable members of society might not find outdoor activities to be the best option. The level of air pollution and the resulting health risk increase with increasing AQI values. Similar to the previous two months, the pollutants that were released into the environment were $PM_{2.5}$ (31%) and PM_{10} (34%). While PM_{10} is more likely to accumulate on the surfaces of the larger airways in the upper region of the lung, $PM_{2.5}$ is more likely to enter and accumulate on the surfaces of the deeper regions of the lung. Particles that land on the surface of the lungs can cause lung inflammation and tissue damage. Unless they are in specially filtered environments, everyone is constantly exposed to some degree. Visibility and air quality are both impacted by airborne particles. High NO_2 contributions were observed in June and August, while none were observed in the other months. The NO_2 AQI typically falls in the "Good" category. However, NO_2 in the atmosphere continues to have a negative impact on people's health and the environment because it is converted to other pollutants that have their adverse effects. Airways in the human respiratory system can become irritated when breathing air with a high NO_2 concentration. Short-term exposures like these can exacerbate respiratory conditions, especially asthma, causing respiratory symptoms like coughing, wheezing, or difficulty breathing, hospital

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admissions, and ER visits. The months with the highest O_3 concentrations were March (25%) and July (21%). The background weather may be the primary factor in the higher Ozone (O_3) concentrations in March compared to those in July.

4. CONCLUSION

Using a low-cost, citizen-based PM wireless sensor technology introduced globally by AirVisual powered by IQAir, Switzerland, this study evaluated AQI, PM_{10}, $PM_{2.5}$, NO_2, and O_3 in Owo, Nigeria. Accuweather Air Quality Scale interpreted the AQI data. According to the findings, the AQI fell between excellent and poor, suggesting that some at-risk members of society might not find outdoor activities to be the best choice. With rising AQI values, air pollution levels and the ensuing health risk rise. When these results were compared to WHO standards, the NO_2 values were lower than the recommended limits. The PM values exceeded the annual and 24-hour mean limits, while the O_3 values were significantly below the 8-hour daily maximum and peak session. The results of the studies varied widely, and these differences were caused by a variety of man-made and natural activities in the regions. Even though Owo is a town in Ondo State that is rapidly growing, Nigeria should start making efforts now to stop activities that could increase pollution both inside and outside the town.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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