ASEAN Journal of Science and Engineering

Journal homepage: http://ejournal.upi.edu/index.php/AJSE/

Monitoring of air quality with satellite-based sensor: The case of four towns in Southeast, Nigeria

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ABSTRACT

Air pollution is an important issue globally because it is linked to health risks or death as the case may be. No nation has placed a carefree attitude on the menace. Constant monitoring to reduce or bring it to an end is on the increase. Internet of Things (IoT) is one of the tools used in monitoring air quality. The main functionality of IoT includes sensing out the surrounding environment collecting the data from the surrounding and transmitting those data to the remote data centers or the cloud. In this study, Satellite model information provided by Plume Labs, Paris, France was used for the determination of the air quality in four towns (Owerri, Awka, Aba, and Nsukka) in the Southeastern part of Nigeria. The data were obtained from the Plume Labs website between the hours of 6-9 am and 7-9 pm every day for a period of sixty (60 days). The air qualities of the towns were obtained by comparing the satellite results with Plume Air Quality Index Indicator (PAQI). PAQI has seven levels (Low, Moderate, High, Very High, Excessive, Extreme, and Airpocalypse) of pollution which are linked to the World Health Organization (WHO) limits. The results depicted that the air quality of the cities has reached elevated levels of pollution above the 24-hour daily limit set by the WHO, which is an indication that everyone may start to experience serious health effects. A long-term exposure constitutes a real health risk.

ARTICLE INFO

Article History:
Submitted/Received 17 Dec 2021
First revised 19 Jan 2022
Accepted 21 Mar 2022
First available online 23 Mar 2022
Publication date 01 Mar 2023

Keyword:
Air Quality Index (AQI),
Data,
IoT,
Nigeria,
Satellite,
WHO limits.

1. INTRODUCTION

Cosmopolitan air quality is typically caused by many different emission sources, such as agricultural/commercial/residential fuel traffic, industrial, and combustion, and composed of a unique combination of gaseous and particulate airborne pollutants, including nitrogen dioxide (NO_2), sulfur dioxide (SO_2), fine particulate matter (PM2.5), and ground-level ozone (PM2.5) (described as aerodynamic diameter particulate matter) (PM2.5). In many nations, air quality has been a major source of concern. According to the World Health Organization (WHO), well over seven million people worldwide die each year as a result of these pollutants, and more than 80% of the urban population lives in areas where air quality exceeds WHO guideline limits.

Low-cost sensors, satellite modeling, citizen scientists, and non-scientists involved in specific issues who gather or analyze data to make a significant contribution to scientific research or advocate for environmental or public improvements in health, are becoming increasingly popular. Numerous nonprofits, including the New York City Community Air Survey (NYCCAS), AirVisual, and Air Matters, to name a few, have advanced into this field of community involvement and community-based exploratory research by creating air quality toolkits for 'citizen-science' and AQI modeled using satellite to obtain pollution source data and using fresh, low-cost air pollution survey data to create community air pollution surveys.

A smart city is one with six major components: smart economy, smart transportation, smart environment, smart citizens, smart life, and smart management. The application of smart computing technologies to provide critical infrastructure components and services to cities, such as city governance, education, and smart management. The availability of data generated by sensors is an important feature of smart cities. In other words, as a result of the preceding explanation, there is a desire for Lagos to become a smart city in Nigeria.

Nigerian scientists and international collaborators have taken a variety of air performance measures in Nigeria. However, these are limited-point measurements taken throughout the city (background, commercial, roadways, and informal settlement households) and for a small number of contaminants, primarily PM2.5 and PM10. In some cases, PM levels exceed the World Health Organization's (WHO) 24-hour average guideline. In this study, we used the standard Plume Air Quality Index Indicator (PAQI) concerning four towns (Awka, Nsukka, Owerri, and Aba), Southeast of Nigeria. Air Quality Index (AQI) is a measure that allows a single value to determine the air quality as a whole. This displays the levels of emissions in a way that helps us to easily grasp the effect of exposure on our well-being. To reduce the cost of evaluating the air quality, Plume Air Quality Index (PAQI) was developed.

The objectives of this study were to monitor and quantify the air quality (AQI, PM2.5, PM10, NO2, and O3) of the present locations. To achieve this aim, satellite data were obtained from the Plumb Labs website and results obtained were compared with PAQI with the view of determining the health implications.

2. EXPERIMENTAL

Nigeria's South East is one of the country's six geopolitical zones. Abia, Anambra, Ebonyi, Enugu, and Imo are the states that make up the region. The southeast Geopolitical Zone contains 99.9% of the Igbo population. Southeast Nigerians are primarily farmers who live on a subsistence level through rain-fed agriculture. The rainy season lasts from May to October, and the dry season lasts from November to April. However, due to climate change, there appears to be no clear demarcation between the rainy and dry seasons, making farmers

DOI: http://dx.doi.org/10. 17509/xxxx.xxxx
p- ISSN 2776-6098 e- ISSN 2776-5938

unpredictable of the seasons. However, the rainy seasons are frequently longer than the dry seasons, with annual rainfall ranging between 2000 and 3000 mm and a mean temperature of 280°C.

Over 70% of the Southeast's inhabitants is a farmer who grows primarily staple food crops such as cassava, yam, maize, cocoyam, vegetables, rice, bananas, and many others. There are also a lot of fruit trees (oranges, mangoes, cashews, pears, and so on) and oil palms that grow wild in the grooves. Some farmers are involved in livestock management, specifically the production of poultry, pigs, sheep, and goats (Chendo et al., 2019).

This study used regular PAQI Satellite model information provided by Plume Labs, Paris, France (https://plumelabs.com/en/) to assess air quality. Four cities in Southeast Nigeria were chosen (elevation: 38 meters, latitude: 9o 4' 55.19N, longitude: 8 o 40' 30.99E). Enugu, Anambra, Imo, and Abia were the states measured in this work, and their locations are Nsukka (6.8429, 7.3733), Awka (6.2220, 7.0821), Owerri (5.4891, 7.0176), and Aba (5.1216, 7.3733), respectively (**Figure 1**). The information was gathered from the Plume Labs website every day between the hours of 6-9 am and 7-9 pm for a period of sixty days (60 days). The air quality of the towns was determined by comparing satellite data with the Plume Air Quality Index Indicator (PAQI) (**Table 1)**. The values obtained were computed and statistically analyzed using Minitab software version 16.

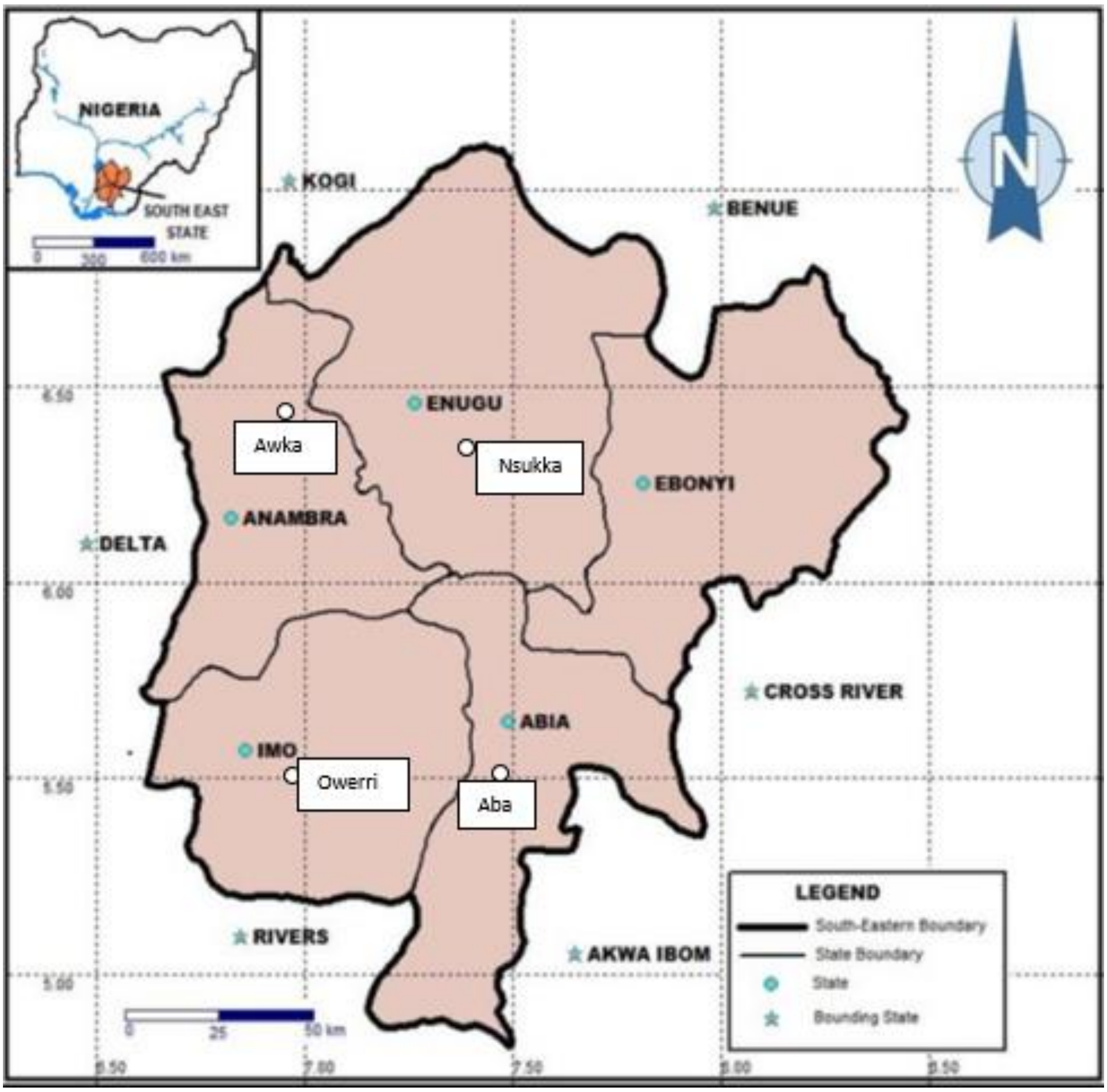


Figure 1. Map of Southeast Nigeria where satellite monitored.

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Table 1: The locations, coordinates, and plume website where PAQI was obtained.

State	Town	Coordinate	Plumb Website
Enugu	Nsukka	6.8429, 7.3733	https://air.plumelabs.com/air-quality-in-Nsukka-9LNq
Anambra	Awka	6.2220, 7.0821	https://air.plumelabs.com/air-quality-in-Awka-9R1r
Imo	Owerri	5.4891, 7.0176	https://air.plumelabs.com/air-quality-in-Owerri-9KVk
Abia	Aba	5.1216, 7.3733	https://air.plumelabs.com/air-quality-in-Aba-9Sa3

3. RESULTS AND DISCUSSION

The mean air quality index values obtained in the study are shown in **Table 2**. It differed as follows: 6-9 am Akwa (AQI – 82); Owerri (46); Nsukka (26); and Abia (31) for 7-9 pm, it was 53, 39, 48, and 57. High values were found to be reported during the day in Akwa and Owerri, but not in Nsukka or Abia. In Akwa and Owerri, the level of work varies throughout the day. For example, traffic activities at various locations are thought to be at their peak during the early morning hours, which are the busiest times of the day when compared to other times of the day, because this is when all work and schooling begin.

The different concentrations of PM were determined based on the data obtained from the sampling locations and the sizes and diameters of the particulate matter. **Figures 2a** and **Figure 2b** show that PM2.5 and PM10 concentrations were high in Akwa, Owerri, Aba, and Nsukka during the morning and evening hours. The highest concentrations were at Akwa (morning only) with PM2.5 (110 $\mu g/m^3$) and PM10 (78 $\mu g/m^3$), while the lowest was at Nsukka (morning) with 20 and 18 $\mu g/m^3$ respectively. The levels of particulate matter in this study were far lower than the PM 2.5 concentrations reported by Opara et al., 2021, which ranged from 122.30-501.76 $\mu g/m^3$.

The allowable limit for PM2.5 is 35 $\mu g/m^3$, and only Aba, Akwa Ibom, and Owerri exceeded this exposure limit. The Nigerian (NAAQS) allowable limit for PM10 is 150 $\mu g/m^3$, and when compared to the data from this study, both morning and evening results obtained from the towns did not exceed the Nigerian allowable limit. The WHO standard limits (g/m3) for NO_2 and O_3 in 2021 are 10 (annual), 25 (24 h), 100 (8 h), and 60 (peak season), respectively. The levels of gas pollutants reported in this study are well below the allowable limits. The World Health Organization's air quality guidelines (AQG) function as a global target for national, regional, and city governments to plan toward boosting citizens' quality of life and reducing air pollution.

According to the findings (**Table 2**), Akwa had moderate air-quality days due to increased pollution activities during this time period compared to other towns. The air-quality indicator shows that as natural and human activities increase in the areas, air quality degrades. The results of this study were lower than those reported for Port Harcourt, where a study discovered extremely unhealthy (AQI = > 200) and dangerous (AQI = > 300) conditions (Kabamba *et al*., 2016). The high AQI values were recorded as a result of heavy traffic, industrial gases, and dust. People who worked long hours, as well as asthmatics, children, the elderly, and people with heart or lung diseases, were at the greatest risk of severe health complications (Nwaogazie and Zagha, 2015; Abulude & Abulude., 2021).

DOI: http://dx.doi.org/10. 17509/xxxx.xxxx
p- ISSN 2776-6098 e- ISSN 2776-5938

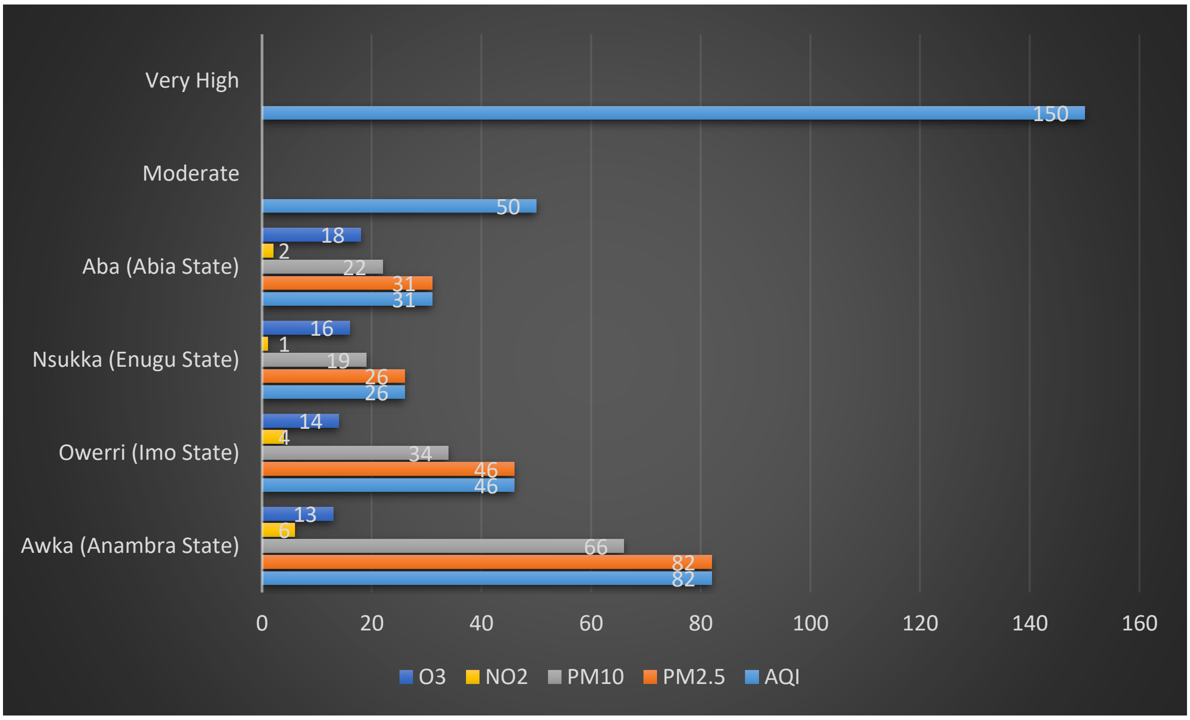


Figure 2a. Air Quality Index and the Concentrations of Pollutants of the Locations (6 – 9 am).

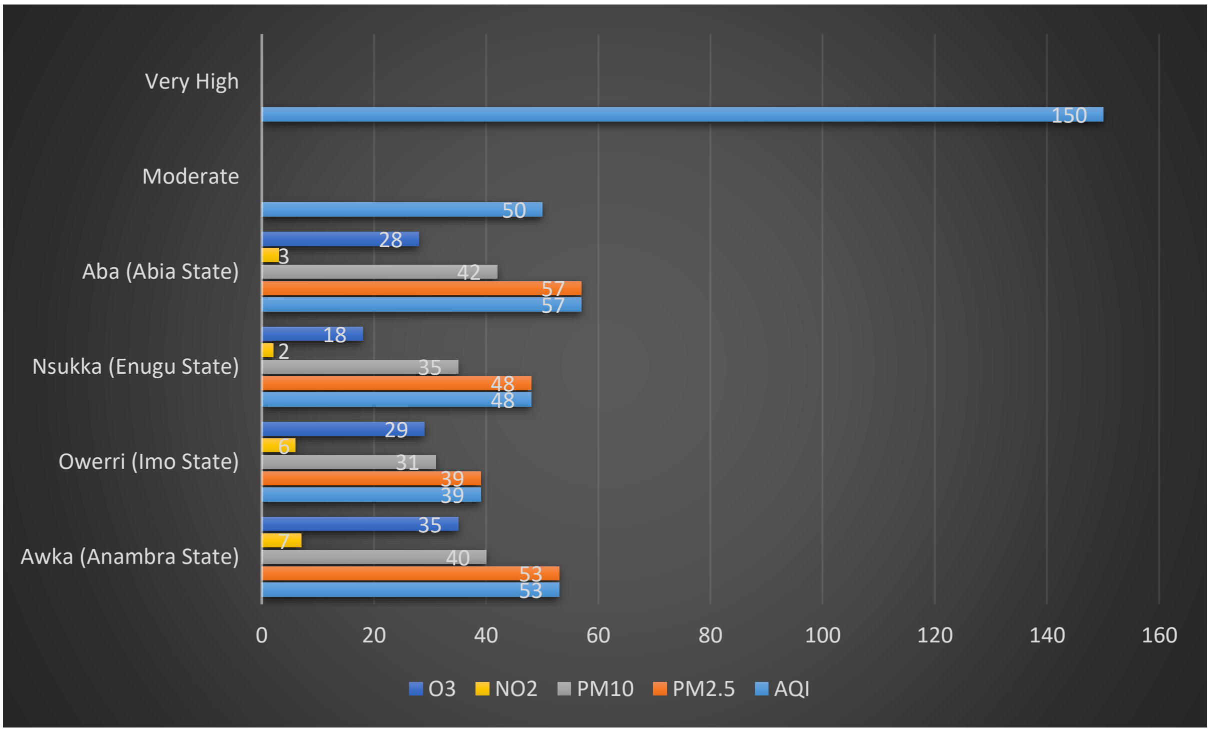


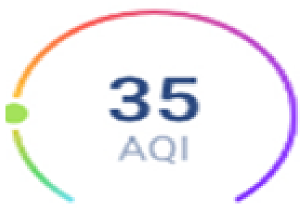
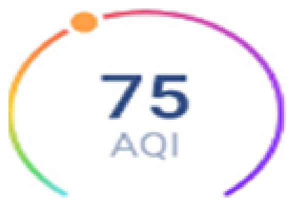
Figure 2b. Air Quality Index and the Concentrations of Pollutants of the Locations (7 – 9 pm).

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Table 2. The Data obtained from the Satellite monitored.

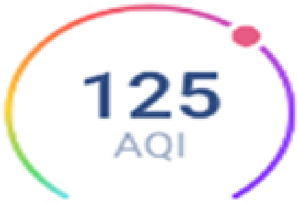
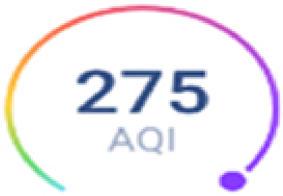
Town/State		**6.00 - 9:00 AM**					**7.00 - 9:00 PM**				
		AQI	**$PM_{2.5}$**	**PM_{10}**	**NO_2**	**O_3**	**AQI**	**$PM_{2.5}$**	**PM_{10}**	**NO_2**	**O_3**
Awka (Anambra State)											
	Mean	82	82	66	6	13	53	53	40	7	35
	Minimum	72	72	54	4	11	50	50	34	5	29
	Maximum	110	110	78	8	16	61	61	55	9	40
Owerri (Imo State)											
	Mean	46	46	34	4	14	39	39	31	6	29
	Minimum	41	41	28	2	10	29	29	26	3	23
	Maximum	56	56	48	7	26	55	55	44	10	38
Nsukka (Enugu State)											
	Mean	26	26	19	1	16	48	48	35	2	18
	Minimum	20	20	15	1	11	41	41	29	1	10
	Maximum	34	34	28	1	24	65	65	55	4	31
Aba (Abia State)											
	Mean	31	31	22	2	18	57	57	42	3	28
	Minimum	28	28	18	1	15	46	46	34	2	20
	Maximum	45	45	35	5	27	66	66	56	6	35

Table 3. The PAQI.

Gauge	**PAQI Value**	**Meaning**
	Low, 0 - 20	The air is clear - perfect for outdoor activities.
	Moderate, 21 - 50	Air quality is considered acceptable however, there may be certain health concern for people with specific sensitivities.
	High, 51 - 100	Above 50, pollution is high, everyone may start to experience more serious health effects. Long term exposure constitutes a real health risk.

DOI: http://dx.doi.org/10. 17509/xxxx.xxxx
p- ISSN 2776-6098 e- ISSN 2776-5938

Table 3 (continue). The PAQI.

Gauge	PAQI Value	Meaning
	Very High, 101 - 150	The air has reached a very high level of pollution. Effects can be immediately felt by individuals at risk. Everybody feels the effects of prolong exposure.
	Excessive, 151 - 200	The pollution levels have reached a critical level. Individuals at risk feel immediate effects. Even healthy people may show symptoms for short exposures.
	Extreme, 201 - 250	The pollution has reached extreme levels. Immediate effects on health.
	Airpocalypse, 252+	Airpocalypse! Immediate and heavy effects on everybody.

4. CONCLUSION

In this study, satellite model information provided by Plume Labs, Paris, France was used for the determination of the air quality in four towns (Owerri, Awka, Aba, and Nsukka) of the Southeastern part of Nigeria. The data were obtained from the Plume Labs website between the hours of 6-9 am and 7-9 pm every day for a period of sixty (60 days). The highest concentrations were at Akwa (morning only) with PM2.5 (110 μg/m^3) and PM10 (78 μg/m^3), while the lowest was at Nsukka (morning) with 20 and 18 μg/m^3 respectively. The levels of particulate matter in this study were far lower than the PM 2.5 concentrations reported by Opara et al., 2021, which ranged from 122.30-501.76 μg/m^3. The air qualities of the towns were obtained by comparing the satellite results with Plume Air Quality Index Indicator (PAQI). PAQI has seven levels (Low, Moderate, High, Very High, Excessive, Extreme, and Airpocalypse) of pollution which are linked to the World Health Organization (WHO) limits.

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

5. ACKNOWLEDGMENT

The authors would like to thank the reviewers as well as everyone who helped with the execution of this study.

6. AUTHORS' NOTE

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

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DOI: http://dx.doi.org/10. 17509/xxxx.xxxx
p- ISSN 2776-6098 e- ISSN 2776-5938