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Particulate Matter-Based Air Quality Index Estimate for Abuja, Nigeria: Implications for Health

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Abstract

In recent years, urban air quality in developing countries such as Nigeria has continued to degenerate and this has constituted a major environmental risk to human health. It has been shown that an increase in ambient particulate matter (PM_{10}) load of 10 μg/m^3 reduces life expectancy by 0.64 years. Air Quality Index (AQI) as demonstrated in this study shows how relatively clean or polluted the boundary layer environment of any location can be. The study was designed to measure the level of suspended particulate matter ($PM_{2.5}$ and PM_{10}) for dry and wet seasons, compute the prevalent air quality index of selected locations in Abuja with possible health implications. Suspended particulate matter ($PM_{2.5}$ and PM_{10}) was assessed using handheld aerosol particulate sampler. The US Oak Ridge National AQI was adopted for the eleven (11) locations sampled and monitored. The study results showed that the air quality of the selected areas in Abuja were generally good and healthy. Dry season, assessments, showed 15 - 95 μg/m^3 and 12 - 80 μg/m^3 for $PM_{2.5}$ and PM_{10}, respectively. While in wet season, 09 - 75 μg/m^3 and 07 - 65 μg/m^3 were recorded for $PM_{2.5}$ and PM_{10}. However at Jebi Central Motor Park, there was light air contamination with AQI of 42 for dry season and 31 for wet season. Other locations had clean air with AQI ≤ 11. It is revealed that clean air exists generally during the wet season. Comparing study outcome to other cities in Nigeria, residents of Abuja are likely not to be affected with health hazards of particulate matter pollution. Nonetheless, the high range of $PM_{2.5}$ and PM_{10} (fine and coarse particles) ratio evaluated i.e., 1.06 - 1.79 was higher than the WHO recommended standard of 0.5 - 0.8. This ratio remains a health concerns for sensitive inhabitants like pregnant women and their foetus as well as infants below age five whose respiratory airways are noted to have high surface areas and absorption capacity for fine particulate matter. Vegetation known to absorb suspended particulate matter should be planted across Abuja metropolitan areas and air quality monitoring stations installed at strategic locations for continuous monitoring and evaluations.

Keywords

Air Pollution, Particulate Matter, Air Quality Index, Abuja, Health Effects

1. Introduction

Atmospheric air pollution is the 4th largest health threat worldwide and the top most environmental risk to human health (WHO, 2016a). Outdoor air pollution contributes about 4.2 million premature deaths annually, with particulate matter noted as the major contributor to air pollution and having the greatest health risk among the air pollutants (WHO, 2020). Globally, nine out of ten people breathe unsafe polluted air; resulting to approximately 7 million deaths annually, as more than 90% of people live in settlements with unhealthy air quality (WHO, 2016a; WHO, 2018a). An increase in ambient particulate matter (PM_{10}) load by 10 μg/m^3 have been reported to reduce life expectancy by 0.64 years (Ebenstein, Greenstone, & Zhou, 2017; Edokpa & Ede, 2019). It is specified that reducing PM_{10} pollution from 70 to 20 (μg/m^3) and annual $PM_{2.5}$ from levels 35 (μg/m^3) commonly noted in developing countries to 10 (μg/m^3) can reduce air pollution related death by 15% (WHO, 2018b).

Urban air quality is noted to be improving in cities of developed countries as against those of low- and middle-income countries such as Abuja in Nigeria (WHO, 2016b). Nigeria is said to have the highest burden of mortalities from poor air quality in Africa and 4th globally (Health Effects Institute, 2018). The country was ranked 150th out of 180 countries for poor environmental performance index on air quality (Yale Center for Environmental law and Policy, 2018). Some cities across Nigeria have been noted to have poor air quality (WHO, 2016c; Yakubu, 2017; Ede & Edokpa, 2017; Akinfolarin et al., 2017; Edokpa & Ede, 2019) and with continuous increase in population, urbanization, anthropogenic activities and climate change, concern on the state of air quality in Abuja and other cities across the world such remains important discuss (Petkova et al., 2013). The study assessed suspended particulate matter of size PM_{10} and $PM_{2.5}$ during dry and wet seasons, through which prevalent ambient air quality of the selected locations were evaluated and air quality index (AQI) computed.

2. Materials and Methods

2.1. Description and Meteorology of Study Areas

The surveyed locations are situated in Abuja, the Federal Capital Territory of Nigeria and about 500 meters or 1600 feet above sea level. Inhabitants engage mostly in administrative business, with less or insignificant industrial activities. Abuja lies between latitude 8˚25' and 9˚25' north of the equator and longitude 6˚45' and 7˚45' east of Greenwich. It has a land area of 8000 square Kilometers. In the north, it is bounded by Kaduna state, Niger state on the west, Nasarawa state on east and south-east by a south-west by Kogi state respectively (FCDA, 2019). It temperature ranges between 25˚C - 31˚C with an equitable climate that is neither too hot nor cold (Balogun, 2001). The study environment experiences two weather conditions annually. These are the rainy season (March through October) and the dry season (October through March). Within these periods, a brief *Harmattan* period, resulting to dusty haze and intense coldness and dryness due to north east trade wind (FCDA, 2019). **Figure 1** show the map of Abuja with surveyed locations.

2.2. Application of Air Quality Index (AQI)

Air borne particulate matter ($PM_{2.5}$ and PM_{10}) were assessed using hand held China Way CW-HAT200 Aerosol particulate sampler or counters. The particulate matter was measured by counting and sizing the number of particles in the air. The instrument was held 2 m above ground level and the air particulates concentration of the sample location determined. The observation was done such that a location was randomly monitored hourly between 6am to 12noon for dry (11^{th}-15^{th} February 2019) and wet (17^{th}-21^{st} June 2019) season respectively. After which daily mean level of the particulate matter was averaged and computed. **Table 2** and **Table 3** shows the mean concentrations values of particulates measured form the various sampled locations. Criteria pollutants were measured by using a BOSEAN portable gaseous emission analyser to determine

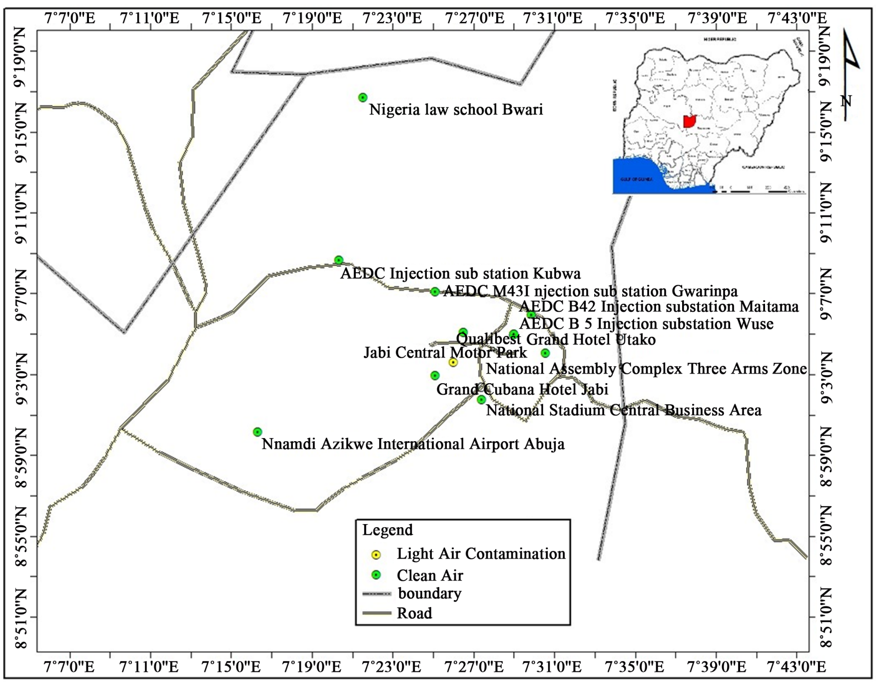

Figure 1. Map of Abuja showing sampled locations.

Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2) and Carbon monoxide (CO). In this method, air was drawn into the analyser gas sensors where it irradiated with pulses of ultra-violet light. Any specified gas of interest in the sample is excited to a higher energy level and upon returning to its original state, light or fluorescence is released. The amount of fluorescence measured was proportional to the gas concentration.

The coordinates of the location was obtained with a GARMIN OREGON 550t Serial number IMY059637 GPS Receiver instrument configured in the Nigerian Minna datum with the geodetic co-ordinates of the points already imputed into the system. In the navigation mode, this equipment provides a compass of the target position, elevation above sea level and the UTM Coordinates of this target position. The meteorological parameters was measured with a 5 in 1 (Ambient Temperature, wind speed, wind direction, relative humidity, atmospheric pressure) SPER Scientific 850,022 Serial number AE. 64,638. The monitor was held at arm's length above the head and approximately 2.5 m above the ground and no closer than 3 m to any reflecting surface.

The US Oak Ridge National Laboratory (ORNL) AQI was utilised for analysis of air quality index. The ORNL AQI has advantage for the relative ranking of overall air quality status at different locations of the study area with different air pollutants parameter. The AQI values were categorised as clean air, light air contamination, moderate air contamination, heavy air contamination, severe air contamination (Edokpa & Ede, 2019). The AQI for each period in the study area was estimated with the help of a mathematical equation developed by the Oak Ridge National Laboratory (ORNL) and given as:

$$\text{AQI} = \left[5.7\sum I_i\right]1.37$$

where, $I_i = X/X_s$ X = observed pollutants concentrations for PM_{10} and $PM_{2.5}$; X_s = pollutant standard at National hourly values of 70 μg/m^3 and 30 μg/m^3 for PM_{10} and $PM_{2.5}$, respectively; I = pollutant, while 5.7 and 1.37 are constants. The index scale is demarcated from 0 to 100 and further divided into 5 sub categories of air quality groups. This index rating is shown in **Table 1**.

3. Results and Discussion

3.1. Data Presentation

Table 2 and **Table 3** show the outcome of field measurements conducted during

Table 1. Air quality index.

Index Value	Description
00 - 25	Clean air
26 - 50	Light air contamination
51 - 75	Moderate air contamination
76 - 100	Heavy air contamination
AQI > 100	Severe air contamination

Table 2. Dry season sampling: 11th-15th February 2019.

Name of Location	Location of Coordinates		$PM_{2.5}$ (μg/m³)	PM_{10} (μg/m³)	Rel. Hum. (%)	Temp. (˚C)	SO_x (ppm)	NO_x (ppm)	CO (ppm)
AEDC M43 Injection Substation (Gwarinpa)	N09˚07'03.4"	E007˚25'08.6"	034	023	52	32	0.01	0.02	3
AEDC B42 Injection Substation (Maitama)	N09˚05'54.8"	E007˚29'53.1"	021	018	50	33	0.01	0.01	2
AEDC Injection Substation (Kubwa)	N09˚08'39.2"	E007˚20'22.2"	020	017	48	34	0.01	0.08	10
AEDC B5 Injection Substation (Wuse)	N09˚04'34.3"	E007˚29'04.6"	018	014	46	32	0.01	0.02	3
Qualibest Grand Hotel (Utako)	N09˚04'28.37"	E007˚27'04.33"	021	017	47	30	0.01	0.01	2
Jabi Central Motor Park	N09˚03'53.69"	E007˚26'02.20"	095	080	44	33	0.04	0.10	16
National Assembly Complex (Three Arms Zone)	N09˚03'58.36"	E007˚30'29.86"	015	012	50	30	<0.01	<0.01	1
Grand Cubana Hotel (Jabi)	N09˚03'45.23"	E007˚25'22.15"	029	024	45	34	0.10	0.20	7
Nnamdi Azikwe International Airport (Abuja)	N09˚00'12.96"	E007˚16'47.46"	031	025	40	30	0.02	0.03	2
National Stadium (Central Business Area)	N09˚02'17.57"	E007˚27'13.77"	039	032	46	33	0.01	0.04	3
Nigerian Law School (Bwari)	N09˚16'43.69"	E007˚21'33.15"	038	034	48	31	0.01	0.04	2
World Health Organization (WHO) Air Quality Standard (WHO, 2018b)			**25 μg/m³ (24 hours mean); 10 μg/m³ (annual mean)**	**50 μg/m³ (24 hours mean); 20 μg/m³ (annual mean**	-	-	**0.007 ppm (24 hours mean); 0.5 ppm (10 minute mean)**	**0.05 ppm (24 hours mean); 0.07 ppm (1 hour mean)**	**8.11 ppm (8 hours mean); 24.3 ppm (1 hour mean)**

Table 3. Wet season sampling: 17th-21st June 2019.

Name of Location	Location of Coordinates		$PM_{2.5}$ (μg/m³)	PM_{10} (μg/m³)	Rel. Hum. (%)	Temp. (˚C)	SO_x (ppm)	NO_x (ppm)	CO (ppm)
AEDC M43 Injection Substation (Gwarinpa)	N09˚07'03.4"	E007˚25'08.6"	025	014	69	28	0.01	0.02	2
AEDC B42 Injection Substation (Maitama)	N09˚05'54.8"	E007˚29'53.1"	012	009	68	29	<0.01	<0.01	2
AEDC Injection Substation (Kubwa)	N09˚08'39.2"	E007˚20'22.2"	015	012	70	30	0.01	0.08	8
AEDC B5 Injection Substation (Wuse)	N09˚04'34.3"	E007˚29'04.6"	012	009	70	29	<0.01	<0.01	3
Qualibest Grand Hotel (Utako)	N09˚04'28.37"	E007˚27'04.33"	013	009	73	28	<0.01	<0.01	0

Continued

Jabi Central Motor Park	N09˚03'53.69"	E007˚26'02.20"	075	065	72	31	0.02	0.09	14
National Assembly Complex (Three Arms Zone)	N09˚03'58.36"	E007˚30'29.86"	009	007	72	29	<0.01	<0.01	0
Grand Cubana Hotel (Jabi)	N09˚03'45.23"	E007˚25'22.15"	018	014	70	29	0.10	0.20	5
Nnamdi Azikwe International Airport (Abuja)	N09˚00'12.96"	E007˚16'47.46"	023	019	68	30	<0.01	<0.01	2
National Stadium (Central Business Area)	N09˚02'17.57"	E007˚27'13.77"	030	025	65	29	0.01	0.04	3
Nigerian Law School (Bwari)	N09˚16'43.69"	E007˚21'33.15"	035	033	68	31	<0.01	<0.01	1
World Health Organization (WHO) Air Quality Standards (WHO, 2018b) **WHO's Guidelines for NO_x, SO_x and CO is by standard conversion from μg/m^3 to ppm.			**25 μg/m^3 (24 hours mean); 10 μg/m^3 (annual mean)**	**50 g/m^3 (24 hours mean); 20 μg/m^3 (annual mean)**	-	-	**0.01 ppm (24 hours mean); 0.19 ppm (10 minute mean)**	**0.08 ppm (24 hours mean); 0.11 ppm (1 hour mean)**	**8.73 ppm (8 hours mean); 26.2 ppm (1 hour mean)**

the study survey at the various locations. The recorded air quality indicators are used to analyse the AQI for the locations and shown in **Table 4**.

3.2. Analysis of Results

Generally, the study result showed that the air quality of Abuja remains good and very different from what is obtained from other Nigerian cities such as Port Harcourt (Taiwo et al., 2015; Ede & Edokpa, 2015; WHO, 2016; Quartz Africa, 2017). The status of air quality in the area shows that the enforced urban plan setting is viable for air quality management. The National Assembly Complex-three Arms Zone had the best state of air, this might not be far from less population density, better state of vehicles with little or no emissions and presence of tree in the area. On the contrary, Jabi Central Motor Park location had the worst state of air (AQI of 42 for dry season and 31 for wet season) when compared to other locations in the study (shown in **Table 4**). This can be explained from the population density of the area, the industrial nature of the area, the volume of cars and it exhaust fumes and possibly wind direction. This supports the studies that found population density and industrial ecology as implicative factors of air population (Weli, 2014). In terms of seasonal variations, the result shows that Air quality of wet season was cleaner than that of dry season. In as much the study found Abuja to have clean air, the study results also negate reports of coarse particles (PM_{10} and above) in the air of Nigerian cities (Offor et al., 2016) as the computed $PM_{2.5}$ and PM_{10} ratios indicated higher values of fine particles (1.06 - 1.79) above WHO standard of 0.5 - 0.8. This is worrisome, as smaller particles are known to easily enter into the lower region of the lungs (Miller et al., 2018). The health implications of smaller particulate size such as $PM_{2.5}$ have been established (Mark et al., 2018).

Table 4. Air quality index.

NAME OF LOCATION	AQI (Dry season)	Implication (Dry season)	AQI (Wet Season)	Implication (Wet season)
AEDC M43 Injection Substation (Gwarinpa)	9	Clean air	6	Clean air
AEDC B42 Injection Substation (Maitama)	5	Clean air	3	Clean air
AEDC Injection Substation (Kubwa)	5	Clean air	4	Clean air
AEDC B5 Injection Substation (Wuse)	5	Clean air	3	Clean air
Qualibest Grand Hotel (Utako)	5	Clean air	3	Clean air
Jabi Central Motor Park	42	Light air contamination	31	Light air contamination
National Assembly Complex (Three Arms Zone)	4	Clean air	2	Clean air
Grand Cubana Hotel (Jabi)	8	Clean air	5	Clean air
Nnamdi Azikwe International Airport (Abuja)	9	Clean air	6	Clean air
National Stadium (Central Business Area)	12	Clean air	8	Clean air
Nigerian Law School (Bwari)	12	Clean air	11	Clean air

4. Conclusion

Although seasonal variation was noted, with wet season having the better AQI, the study found AQI of Abuja, the Federal Capital of Nigeria, to be generally clean. Of all the study sampled locations, Jabi Central Motor Park was the only location with light contaminated air (AQI of 31) while the rest locations recorded less than AQI of 25 (≤11 AQI). The population density, vehicular emissions rates and industrial nature of Jabi Central Motor Park were likely factors responsible for it moderate contamination. The study showed that residents of Abuja are likely to be at low risk of air pollution morbidities compared to other cities in Nigeria. But the $PM_{2.5}$ and PM_{10} ratio evaluation remain a concern, especially for pregnant women and their foetus, infants (0 - 5 years) and persons with existing respiratory dysfunctions. Air Quality Monitoring Stations should be installed at strategic locations for continuous air quality trend monitoring, especially as the city get more populated and urbanized. Systematic collaboration should be instituted between environmental and health agencies for data sharing and proactive public health interventions. Regular monitoring will ensure that vulnerable groups are protected and expose to ambient air with minimal air pollution risk. Also, special trees known to absorb fine particulates should be planted across the city.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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