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Research Article

SEASONAL VARIATION OF MONTHLY AIR QUALITY INDICES FOR CALABAR, NIGERIA

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ABSTRACT

Air Quality Index (AQI) for the city of Calabar has been computed for the different seasons of the year covering December 2015 to November 2016. The values obtained from the calculation of the combined AQI shows that the AQI for the different months of the year were categorized as "good". The highest value of 15.87 was obtained in December 2015 and the least value of 5.06 was obtained in April 2016. The coefficient of determination obtained for the period of study shows that total suspended particulate (TSP) had the highest effect on the variation of AQI with the value of 87.3%, while temperature with value 1.8% had the least effect on the variation of AQI within the study period. The AQI calculated from the individual pollutants showed that Ozone had the highest value of 18.75 in December 2015 and its least value of 7.81 in March 2016. Carbon monoxide (CO) had the highest value of 29.7 in September 2016 and its least value of 6.06 in April 2016. Sulphur dioxide (SO_2) had the highest value of 22.06 in July 2016 and August its least value of 8.8 in December and January 2016. NOx had the highest value of 93.75 in December 2015 and its least value of 0 in April, July, October and November 2016. All the calculated AQI for the individual pollutants were categorized as "Good" except NOx which was categorized as moderate.

INTRODUCTION

An Air Quality Index (AQI) may be defined as a numerical rating that reflects the composite Influences on overall quality of a number of air quality parameters (Vennapu, 2014). AQI is typically a numerical scale, usually colour coded, intended to convey the likely severity of the adverse health effects at the monitored concentration levels (Cairncross, *et al.*, 2007). Nigeria as a developing country is facing serious air pollution crisis as some major cities have very poor air quality. In Nigeria, Lagos is of particular interest for air pollution studies because of its high population density coupled with intense industrial and commercial activity (Oluyemi and Asubiojo, 2001). Calabar is also gaining attention because of its tourism potentials. The determination of the quality of air is a very important factor in assessing the suitability of the air we breathe. Evaluating Air Quality Index (AQI) is one such method of determining the quality of air in an area (Kumar, *et al.*, 2015).

Several Authors have worked on the estimation of AQI such as (Reddy, *et al.*, 2003; Srivastava and Rajasree 2006; Tiwari, 1987; Vennapu, 2014; Kumar, *et al.*, 2015; Murad, *et al.*, 2014; Shivangi, *et al.*, 2015;

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Chuanglin, *et al*., 2015; Akuagwu, *et al*., 2016; Shukla, *et al*., 2010). This paper looks at the estimation of seasonal air quality index for the urban city of Calabar.

GEOGRAPHY OF CALABAR

Calabar, the location of the study, is a city in the Niger Delta Area of Nigeria. It is the capital of Cross River state, Southern Nigeria. The city is watered by the Calabar River and Great Qua Rivers Creeks of the Cross River. Its Coordinates are lat. 5˚16’07.6”N, Long. 8˚23’34. 56E. Calabar has an estimated population of 1.2 million residents. Calabar covers an area of 604 km^2 (Umoh, *et al*., 2013). March and April are the months preceding the heavy rains in Calabar. The project site which is at the University of Calabar is at an elevation of 62 m with lat. 4°57’07’’ and long. 8˚20’51’’. Calabar is almost surrounded by sea water at distances between three to five kilometres to the south, east and west to the station. Two major winds which affect the climate of West African coast blow across this region bringing about two major seasons in the area, namely: wet and dry seasons, probably named after the pattern at which the rain falls. While the wet season last between April and October, the dry season is normally from November to March of the following year (Ewona and Udo, 2008) (Fig. 1).

RESEARCH METHODOLOGY

Materials and Methods

The data for this research has been obtained from the stationary Aeroqual AQM65 equipment procured by funds from Tertiary Education Fund (TETFUND). This equipment is stationed at the University of Calabar main monitoring station. It measures continuously the following gases: SO_2, NOx, O_3, H_2S, CO, TSP and meteorological parameters such as wind speed, wind direction, Temperature and relative humidity. The AQM 65 is a fully integrated air quality monitoring station that delivers ‘near reference’ levels of performance. The AQM 65 measures the criteria pollutants to WHO air quality limits. The data covers a period of one year from December 2015 to November 2016.

Methodology

R-programming language was used in performing the correlation analysis in this study. The statistical package for the social sciences (SPSS) was used in obtaining the coefficient of determination.

Calculating the combined AQI

Let there be n air quality parameter P_i (i=1, 2, 3…n),

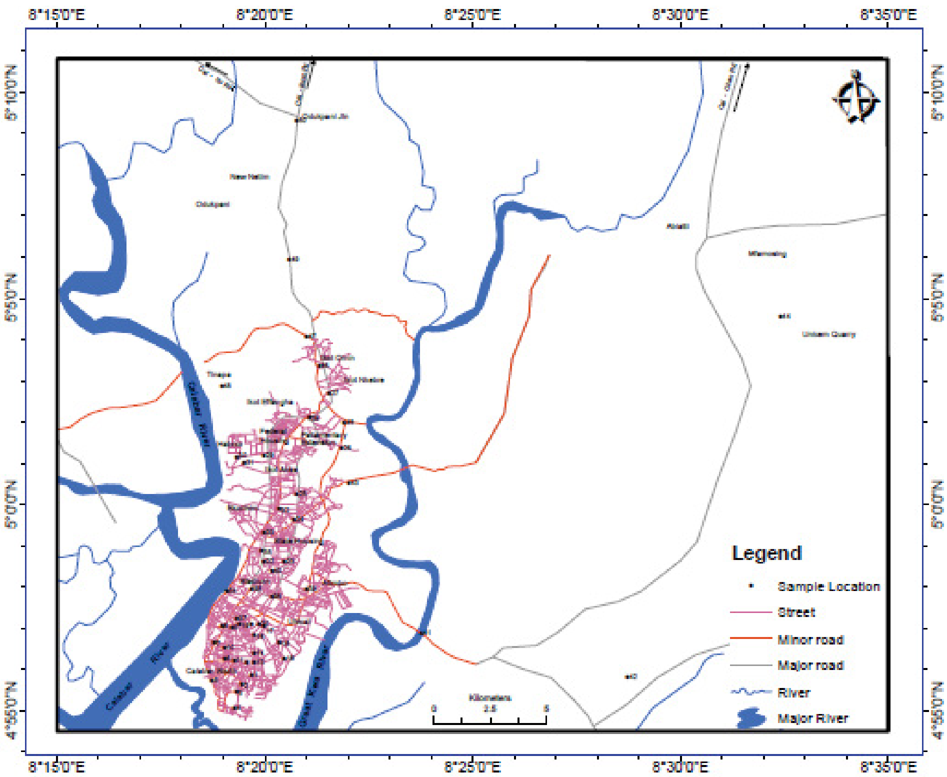

Fig. 1 Map of the study area.

which are to be taken into account for calculating the AQI. Let V_i be the observed values of the ith parameter in the ambient air and let V_{si} be the standard value recommended for this parameter. Then the quality rating Q_i for this parameter is given by:

$$Q_1 = 100(V_i / V_{si}) \quad (1)$$

If Q_i<100, it is to be noted that the given parameter is within the prescribed limit. On the other hand, If Q_i>100, it implies that the ith parameter exceeds the prescribed standard and the ambient air is harmful for breathing by human beings. It is assumed here that all the parameters have equal importance and so only the unweighted air quality indices are calculated. The geometric unweighted AQI may be calculated from the Quality rating Q_i by taking their geometric mean.

This relation is simplified and hence

AQI=Antilog (∑Log Qi)/n (2)

The Ambient AQI can be calculated using (1) and (2) (Kumar, *et al.*, 2015) (Table 1).

Air quality index based on the individual pollutants

AQI for the four pollutants were calculated by using equation 3 below. The equation is used to calculate the AQI of a location based on the measured concentration of a particular pollutant. Ip is the AQI that is to be calculated based on the pollutant. Cp is the concentration of the pollutant rounded to a reasonable decimal. BPHi is the breakpoint that is greater than or equal to the rounded concentration of the pollutants. BPLo is the breakpoint that is less than or equal to the rounded concentration of the pollutant Cp. IHi is the AQI value that corresponds to BPHi. While ILo is the AQI value that corresponds to BPLo. The measured concentration of the four pollutants were used in the computation of the AQI. The AQI was based on the breakpoints published by the (United State Environmental Protection Agency (USEPA), 2006). These breakpoints are presented in Table 2. The average of the AQI for each point was calculated to represent the AQI for the point.

Table 1. AQI categorization table.

Category	AQI	Description of Ambient Air
I	0-50	Good
II	51-100	Moderate
III	101- 150	Unhealthy for sensitive groups
IV	151-200	Unhealthy
V	201 - 300	Very Unhealthy
VI	301 - 400	Hazardous
VII	401 - 500	Hazardous

AQI Equation

$$IP = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}}(Cp - BP_{LO}) + I_{LO} \quad (3)$$

Where: I_P=The index for pollutant P

C_P=The rounded concentration of pollutant P

BP_{Hi}=The breakpoint that is greater than or equal to C_P

BP_{Lo}=The breakpoint that is less than or equal to C_P

I_{Hi}=The AQI value corresponding to BP_{Hi}

I_{Lo}=The AQI value corresponding to BP_{Lo}

RESULTS AND DISCUSSION

Concentration of pollutants

The concentration of pollutants measured within the study period shows that, hydrogen sulphide has the highest value of 0.096 ppm in May 2016 and its lowest value of 0 ppm in October and November 2016. Ozone has the highest value of 0.024 ppm in

Table 2. Break points for the different pollutants.

O_3 (ppm) 8-hour	O_3 (ppm) 1-hour	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)	AQI	Category
0.000–0.064	-	0.0 – 15.4	0 – 54	0.0 – 4.4	0.00 – 0.034	(2)	0 -50	Good
0.065 –0.084	-	15.5 – 40.4	55 – 154	4.5 – 9.4	0.035 – 0.144	(2)	51 – 100	Moderate
0.085 –0.104	0.125 – 0.164	40.5 – 65.4	155 – 254	9.5 -12.4	0.145 – 0.224	(2)	101 – 150	Unhealthy For sensitive groups
0.105 –0.124	0.165 – 0.204	65.5 – 150.4	255 – 354	12.5 – 15.4	0.225 – 0.304	(2)	151 – 200	Unhealthy
0.125 –0.374	0.205 – 0.404	150.5 – 250.4	355 – 424	15.5 – 30.4	0.305 – 0.604	0.65 – 1.24	201 – 300	Very unhealthy
(3)	0.405 – 0.504	250.5 – 350.4	425 – 504	30.5 – 40.4	0.605 – 0.804	1.25 – 1.64	301 – 400	Hazardous
(3)	0.505 – 0.604	350.5 – 500.4	505 - 604	40.5 – 50.4	0.805 – 1.004	1.65 – 2.04	401 - 500	Hazardous

Note: NO_2 has no short-term NAAQS and can generate an AQI only above a value of 200 (United State Environmental Protection Agency (USEPA), 2006).

December 2015 and its lowest value of 0.010 ppm in March and December 2016. CO has the highest value of 2.620 ppm in September 2016 and its lowest value of 0.533 ppm in April 2016. SO_2 has the highest value of 0.02 ppm in December 2016 and its lowest value of 0.005 ppm in February 2016. NOx has the highest value of 0.03 ppm in December 2015 and its lowest value of 0.0 ppm in April, July, October and December 2016. The calculated AQI values had the highest value of 15.87 in December 2015 and its lowest value of 5.060 in April 2016. Table 1 shows the AQI categorization table. This table shows the different categories of AQI and its description. The AQI categorization falls between 0 – 500, with 0 -50 being categorized as "Good" and 401 – 500 being categorized as "Hazardous". Table 2 shows the breakpoints for the different pollutants as published by the United States Environment protection agency USEPA. The break points were used to calculate the AQI for the individual pollutants.

(Fig. 2) shows plot for the calculated values of AQI. The (Fig. 2) shows that the calculated AQI values was high in December 2015 but dropped in March and April 2016. The value went up slightly and stabilized throughout the year.

Table 3 shows the individual AQI values calculated based on the concentration of the pollutants; ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2) and nitrogen oxides (NOx). Ozone had the highest value of 18.75 in December 2015 and its least value of 7.81 in March 2016. CO had the highest value of 29.7 in September 2016 and its least value of 6.06 in April 2016. SO_2 had the highest value of 22.06 in July 2016 and August its least value of 8.8 in December and January 2016. NOx had the highest value of 93.75 in December 2015 and its least value of 0 in April, July, October and November 2016. (Fig. 3) shows that the AQI calculated from ozone dropped in March and April and increased from May towards the end of the year. (Fig. 4) shows AQI calculated from CO. The AQI increased from April to November 2016. (Fig. 5) shows AQI calculated from SO_2. The AQI increased in July and dropped towards December 2016. (Fig. 6) shows AQI for NOx. The AQI values dropped in March 2016 and did not increase much throughout the year.

Correlation coefficient

There is need to carry out correlation between pollutants though Table 4 shows that the AQI for the study location all fall in the "good" category. This is to help the authors to see the effect these pollutants have on each other and also on the AQI of the study location. The correlation coefficients are shown in Table 5. A quick inspection of the table shows that AQI correlates strongly with NOx with R=0.93. this

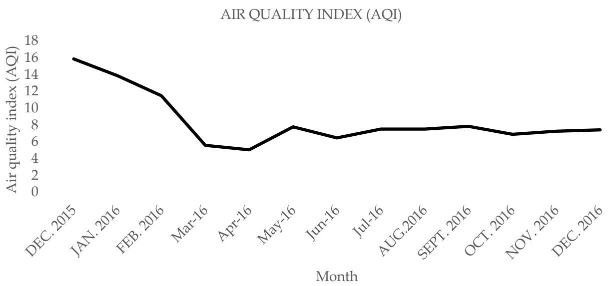

Fig. 2 Graph showing monthly variation of combined AQI.

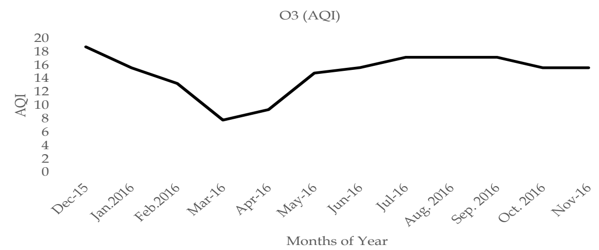

Fig. 3 Graph showing monthly variation of AQI calculated from ozone.

Table 3. Values of AQI for the different pollutants.

Z	O_3	AQI Category	CO	AQI Category	SO_2	AQI Category	NOx	AQI Category
Dec 2015	18.75	Good	9.0	Good	8.8	Good	93.75	Moderate
Jan.2016	15.62	Good	6.67	Good	8.8	Good	71.88	Moderate
Feb.2016	13.28	Good	16.83	Good	7.35	Good	15.63	Good
March 2016	7.81	Good	7.20	Good	8.82	Good	3.13	Good
April 2016	9.38	Good	6.06	Good	8.82	Good	0	Good
May 2016	14.84	Good	10.38	Good	11.76	Good	15.63	Good
June 2016	15.65	Good	9.24	Good	10.29	Good	3.13	Good
July 2016	17.19	Good	17.33	Good	22.06	Good	0	Good
Aug. 2016	17.19	Good	16.13	Good	22.06	Good	3.13	Good
Sep. 2016	17.19	Good	29.7	Good	20.59	Good	3.13	Good
Oct. 2016	15.63	Good	18.52	Good	19.11	Good	0	Good
Nov 2016	15.63	Good	16.25	Good	14.71	Good	0	Good

value shows that NOx has the greatest effect on the AQI at the location. Relative humidity also has a strong correlation with AQI, though negatively, with R=-0.86. This negative value shows that the increase in relative humidity at the location led to the decrease in AQI. CO had the least correlation with AQI with R=-0.12. Ozone had R=0.46, while SO_2 had R=-0.33. Wind speed had a fairly weak correlation of R=0.48. It shows that wind speed affected the AQI positively in some way. Table 6 shows Coefficient of determination between AQI and pollutants. The coefficient of determination R^2 between AQI and H_2S is R^2=0.094. This tells us that 9.4% of the variation in the Air Quality index within the period of study is related to the effect of H_2S. The coefficient of determination R^2 between AQI and O_3 is R^2=0.211. This tells us that 21% of the variation in the Air Quality index within the period of study is related to the effect of O_3. The coefficient of determination R^2 between AQI and CO is R^2=0.014. This tells us that 1.4% of the variation in the Air Quality index within the period of study is related to the effect of CO. The coefficient of determination R^2 between AQI and SO_2 is R^2=0.108. This tells us that 10.8% of the variation in the Air Quality index within the period of study is related to the effect of SO_2. The coefficient of determination R^2 between AQI and NOx is R^2=0.858. This tells us that 85.8% of the variation in the Air Quality index within the period of study is related to the effect of NOx. The coefficient of determination R^2

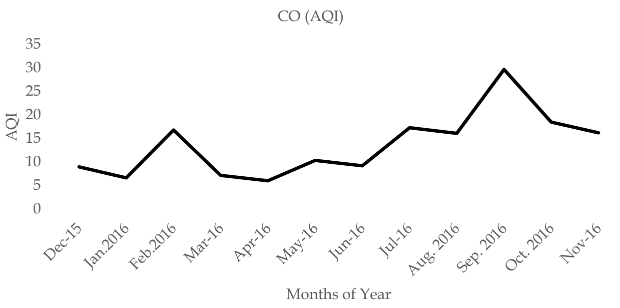

Fig. 4 Graph showing monthly variation of AQI calculated from carbon dioxide.

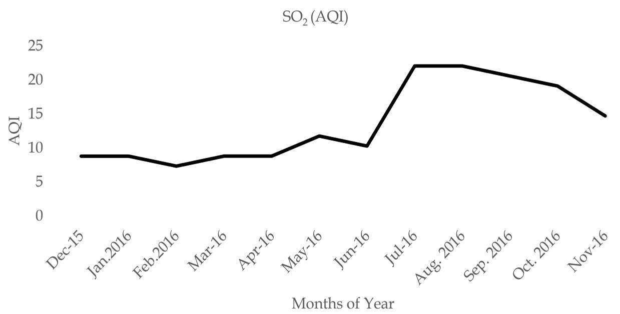

Fig. 5 Graph showing monthly variation of AQI calculated from sulphur dioxide.

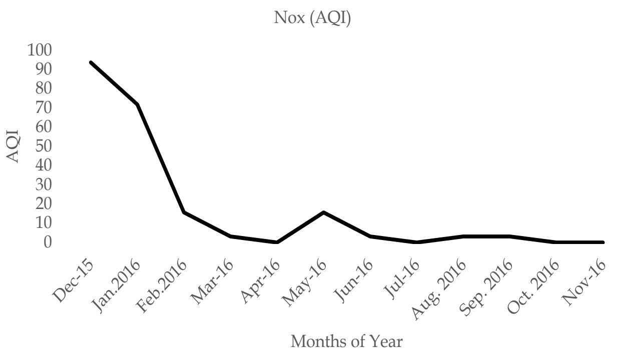

Fig. 6 Graph showing monthly variation of AQI calculated from nitrogen dioxides.

Table 4. The combined AQI for the study location.

Month	Air Quality Index (AQI)	Category
Dec. 2015	15.87	Good
Jan. 2016	13.88	Good
Feb. 2016	11.49	Good
March 2016	05.59	Good
April 2016	05.06	Good
May 2016	7.79	Good
June 2016	6.47	Good
July 2016	7.52	Good
Aug.2016	7.52	Good
Sept. 2016	7.85	Good
Oct. 2016	6.90	Good
Nov. 2016	7.27	Good
Dec. 2016	7.43	Good

Table 5. Correlation coefficient for the pollutants and combined AQI values.

Variables	O_3	SO_2	CO	NOx	AQI	WS	TEMP	RH
O_3	1							
SO_2	0.01	1						
CO	0.45	0.50	1					
NOx	0.38	-0.45	-0.36	1				
AQI	0.46	-0.33	-0.12	0.93	1			
WS	-0.28	-0.72	-0.42	0.50	0.48	1		
TEMP	-0.68	-0.06	-0.31	0.06	0.14	0.47	1	
RH	-0.08	0.34	0.35	-0.86	-0.87	-0.64	-0.52	1

Table 6. Coefficient of determination between AQI and pollutants.

Correlation	R^2
AQI with H_2S	0.094
AQI with O_3	0.211
AQI with CO	0.014
AQI with SO_2	0.108
AQI with NOx	0.858
AQI with TSP	0.873
AQI with wind speed	0.235
AQI with Temperature	0.018
AQI with Relative humidity	0.766

between AQI and TSP is R^2=0.873. This tells us that 87.3% of the variation in the Air Quality index within the period of study is related to the effect of TSP. The coefficient of determination R^2 between AQI and wind speed is R^2=0.235. This tells us that 23.5% of the variation in the Air Quality index within the period of study is related to the effect of wind speed. The coefficient of determination R^2 between AQI and Temperature is R^2=0.018. This tells us that 1.8% of the variation in the Air Quality index within the period of study is related to the effect of Temperature. The coefficient of determination R^2 between AQI and Relative humidity is R^2=0.766. This tells us that 76.6% of the variation in the Air Quality index within the period of study is related to the effect of Relative humidity.

SUMMARY AND CONCLUSION

The Air Quality Index (AQI) for the city of Calabar has been computed for the different seasons of the year covering December 2015 to December 2016. The values obtained from the calculation of the combined AQI shows that the AQI for the different months of the year were categorized as "good". The highest value of 15.87 was obtained in December 2015 and the least value of 5.06 was obtained in April 2016. The coefficient of determination obtained for the period of study shows that total suspended particulate (TSP) had the highest effect on the variation of AQI with the value of 87.3%, while temperature with value 1.8% had the least effect on the variation of AQI within the study period. The AQI calculated from the individual pollutants showed that Ozone had the highest value of 18.75 in December 2015 and its least value of 7.81 in March 2016. CO had the highest value of 29.7 in September 2016 and its least value of 6.06 in April 2016. SO_2 had the highest value of 22.06 in July 2016 and August its least value of 8.8 in December and January 2016. NOx had the highest value of 93.75 in December 2015 and its least value of 0 in April, July, October and November 2016. All the calculated AQI for the individual pollutants were categorized as "Good" except NOx which was categorized as moderate.

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