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MEASUREMENT AND ANALYSIS OF AIR QUALITY PARAMETERS IN AMBIENT AIR FOR CALABAR NIGERIA, WEST AFRICA

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Abstract

The measurement and characterization of pollutants in ambient air for Calabar, Nigeria was carried out between a period of seven months. Ratio analysis was used to determine the source of SO_2, CO, and NO_2 gases in ambient air. For NO_2 the least value obtained was 0.086±0.109ppm. For SO_2, the largest value was 0.363±0.274ppm. For CO the largest value was 24.581±46.780ppm. For O_3 the largest value was 0.89±2.294ppm. CO_2, the largest value was 510.8±37.35ppm. For $PM_{2.5}$, the largest value was 0.046±0.029ppm. This value is lower than the annual mean and 24hour mean. For PM_{10}, the largest value was 0.916±2.470ppm. This value is lower than he annual mean and 24hour mean. Ratio analysis of the data tells us that mobile sources were the dominant contributor to the pollutants in ambient air. Anthropogenic and biological factors were the dominant factors contributing to the pollutants in ambient air.

Keywords: Carbon monoxide, Carbon dioxide, Annual mean, Sulphur dioxide, Methane, Ozone.

1. Introduction

Urban air pollution is fast becoming an issue of regional as well as global concern. The threat posed to human life and property by air pollution makes it mandatory to device control measures to combat it. This would be facilitated by establishing reliable information about the source-receptor relationship of the pollutants (Oluyemi and Asubiojo, 2001). Different scientists have worked on this problem to measure the concentration of pollutants in ambient air so they could devise ways to combat it. Nwachukwu et al. (2012) conducted a survey on the effects of air pollution on disease of the people of Rivers State. They discovered that the ambient air quality observed in the state were lead = 0.1115ppm/yr, particulates = 10ppm/yr, N-oxides = 2.55ppm/yr, SO_2 = 1ppm/yr, VOC = 82.78ppm/yr. This was far worse than the World Health Organisation Standard which is Particulates = 10^5ppm/yr. They found that air pollution has a direct impact on health. Oluyemi and Asubiojo (2001) carried out a comprehensive air pollution study in Lagos State in view of the level of industrialization of the city and its nearness to the ocean. Air particulates were analysed by the combination of wavelength – dispersive X-ray fluorescence and atomic absorption spectroscopy methods. Elemental concentration was subjected to factor analysis. Prominent among sources identified with the ranges of contribution include soil 35 – 54%, marine 26 – 34%, Automobile exhaust 0.3 – 3.5%, refuse incineration 2 – 3% and regional sulphate 2 – 12%. Makra *et al.* (2001) carried out analysis of air quality parameters in Conrad County, Hungary. From their analysis, they found that SO_2/CO ratio is far less than 1, which shows that there are no factories near the station discharging SO_2. Also, since NO/NO_2 ratio is not greater than 1, it means that the station is without being influenced by pollution from traffic. PM/CO ratio is far less than 1 indicates that PM sources are highly related to vehicles' activities. Zagha and Nwaogazie (2015) carried out a road side air pollution assessment in Port-Harcourt, Nigeria. In their study, the level of air pollution along road sides at selected locations in Port Harcourt metropolis was assessed. The ambient air quality was done with respect to CO, SO_2, NO_x and PM_{10} at four locations. The measured parameters were found to be in the range SO_x (0-0.75ppm) and PM_{10} (26 - 199μg/m^3). Air quality index values in the study varied between a maximum of 267.17 and a minimum of 14.71 showing that the health of people who spend long hours along road sides are at risk. Tawari and Abowei (2012) carried out an air pollution assessment in the Niger Delta area of Nigeria. They found out that the overall average values of each pollutant for the 72hour experimental duration in Calabar was found to be in the following range, CO: 5.0 – 6.1ppm, NO_2: 0-0.05ppm, PM_{10}: 202 - 230μg/m_3 and noise level was 60.5 – 63db. Adoki 2012 conducted an air quality survey in Oyigbo and environs in the Niger Delta area of Nigeria. It revealed that air quality in the area is affected to varying degrees by industrial, human and natural activities. Results show that SO_x values were below acceptable values for ambient conditions at most of the locations. The annual average SO_x levels ranged between 920μg/m^3 and 430μg/m^3 against the DPR limits of 150μg/m^3. NOx emissions whose annual averages ranged between 81.0μg/m^3 and 150μg/m^3.

The main objective of this study is to characterize the air pollutants in ambient air of Calabar, Nigeria, perform a ratio analysis of the measured pollutants ([CO] to [NO_2], and [SO_2] to [NO_2]) in Calabar to gain insight in emission sources; and compare these results with available emission inventories for these pollutants. Also, to perform factor analysis to gain insight on the factors influencing these pollutants in ambient air of Calabar. This study would be significant for regulatory agencies to conduct monitoring and plan mitigation measures in order to improve the air quality of the city. Moreover, this data set would be of immense value to the urban, regional, and global air quality modeling community.

1.1 Study area

Calabar is the capital of Cross River state, South-South Nigeria. The city is watered by the Calabar River and Great Qua Rivers Creeks of the Cross River. Its Coordinates are lat. 5^o 16'07.6"N, Long. 8^o23' 34. 56E. Calabar has an estimated population of 1.2million residents. Calabar covers an area of 604km^2(Umoh, et al., 2013).

1.2 Meteorology of Calabar

Calabar is located in southern Nigeria. March and April are the months preceding the heavy rains in Calabar. The maximum value of sunshine hours usually occurs in February (5.30hr) and minimum occurs in August (1.46hrs) (Umoh, et. al., 2013). The Relative Humidity is usually maximum in August (82.09%) and minimum in February (55.27%). Maximum annual Rainfall (mm) occurs in July (451mm) and minimum in December (31mm). Wind speed gets to its highest value in April (4.89m/s) and May and minimum in November (3.95m/s) (Umoh, *et al.*, 2013).

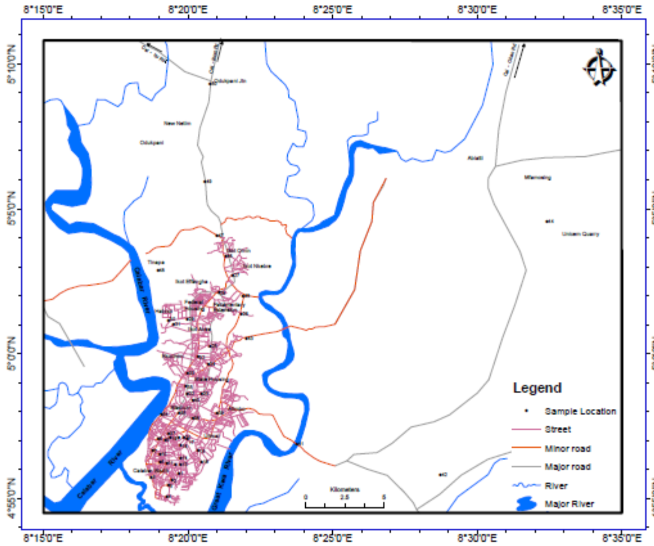

Fig1: map of the study area

2.0 Materials and Methods

The data used in this research was obtained within the period May 2016 to December 2016, Eight (8) months. For the stationary equipment, data covered the period January 2015 to December 2017. The pollutants measured were ozone (O_3), Sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter ($PM_{2.5}$ and PM_{10}). Ratio analysis was used to determine the source of SO_2, CO, and NO_2 gases in ambient air.

The equipment used for the measurement include:

GAS analyser- Aeroqual series 500- ENV.

Gas sensor heads

Aeroqual NH_3 0-100ppm model 0506155-002

Aeroqual H_2S 0-10ppm model 2306153 -004

Aeroqual VOC 0- 25ppm model 2305143 -079

Aeroqual CH_4 0- 100ppm model 0307150- 002

Aeroqual SO_2 0-10ppm model 1905152- 006

Aeroqual O_3 0-10ppm model 1407150 -003

Aeroqual CO 0- 100ppm model 0807155 -004

Aeroqual NO_2 0-1ppm model 2906150-003

Aeroqual CO_2 0-2000ppm model 0807150-001

Particle Sampler – Aerocet 5315 particle mass/ particle count for measuring particulate matter ($P.M_{2.5}$, $P.M._{10}$)

2.1 Methodology

The gases were measured using the Gas analysers – aeroqual series 500 which came with the different gas heads. Each gas head is inserted on the top of the main gas analyser which then takes three minutes to warm up. The value of the particular gas measured at a particular location of study is then displayed on the gas analyser following the three minutes warm up time. The values are displayed in part per billion (ppb), part per million (ppm) or $\mu g/m^3$ depending on the settings. For this project, the values of the gases are presented in ppm.

The meteorological parameters present at the different locations of interest were measured using the Micro climate – Extech 4-in 1 environmental meter model 45170. It takes the measurements of the different parameters such as wind Speed, Relative humidity, Air Temperature. The coordinates and elevation of the different stations were obtained using Garmin etrex 20 GPS, a GPS equipment. Another set of data for this research was obtained by an AQM65 equipment. A compass was used in determining the direction of the wind at all the locations of the project. The methods used in analysing the data were ratio analysis and factor analysis. The statistical package for the social sciences (SPSS) software together with the open-air package in R were used to carry out this analysis.

Table 1: Study locations

STATION CODE	LOCATIONS	LATITUDE	LONGITUDE	ELEVATION(m)
AQ1	CRUTECH GATE ROUND ABOUT	4º55’53.1’’	8º19’42.0’’	26
AQ2	UNICAL MAIN STATION POINT	4º57’07.78’’		
AQ3	IKA IKA OKUWA MARKET	4º58’35.46’’	8º20’26.28’’	83
AQ4	DESTINATION CROSS RIVER ROUND ABOUT BY BASIN AUTHORITY	5º02’43.35’’	8º21’26.58’’	93
AQ5	ARMY JUNCTION BY WELCOME TO CALABAR	5º 02’04.36’’	8º28’01.06’’	102
AQ6	EPZ TANK FARM	5º 01’08.1’’	8º19’20’’	53
AQ7	MARINA RESORT	4º57’55.4’’	8º19’05.5’’	20
AQ8	UNICEM FACTORY SITE	5º04’05.9’’	8º30’44.9’’	28
AQ9	LEMNA DUMP SITE	5º01’59.7’’	8º21’54.8’’	27
AQ10	TINAPA BUSSINESS RESORT	5º02’54.3’’	8º18’58.8’’	31
AQ11	ODUKPANI JUNCTION	5º09’19.00’’	8º20’45.7’’	31

3.0 Results and Discussion

3.1 Results

3.1.1 Concentration of pollutants

The research carried out at the eleven stations shows that for NO_2 the least value obtained was 0.086±0.109ppm. The value was obtained at Cross River University of Technology gate. This value is higher than the annual mean and 24 hours mean which are 0.08ppm and 0.12ppm respectively recommended by the nation standard for air pollution in Nigeria. The least value was 0.062±0.025ppm. This value is lower than he annual mean and 24hour mean. This value was obtained at UNICEM factory.

For SO_2 the least value obtained was 0.135±0.148ppm. The value was obtained at Odukpani junction. This value is greater than the annual mean and 24 hours mean which are 0.08ppm and 0.12ppm respectively recommended by the nation standard for air pollution in Nigeria. The largest value was 0.363±0.274ppm. This value is larger than he annual mean and 24hour mean. This value was obtained at Cross River University of technology gate.

For CO the least value obtained was 0.0ppm. The value was obtained at Cross River University of technology gate. This value is lower than the annual mean and 24 hours mean which are 4.05ppm and 8.11ppm respectively recommended by the nation standard for air pollution in Nigeria. The largest value was 24.581±46.780ppm. This value is larger than he annual mean and 24hour mean. This value was obtained at Odukpani junction.

For O_3 the least value obtained was 0.322±0.085ppm. The value was obtained at Unical main station. This value is higher than the 24 hours mean which is 0.1ppm recommended by the World Health Organisation standard for air pollution. The largest value was 0.89±2.294ppm. This value is larger than he annual mean and 24hour mean. This value was obtained at UNICEM factory.

For $PM_{2.5}$, the least value obtained was 0.023±0.014ppm. The value was obtained at EPZ tank farm. This value is lower than the annual mean and 24 hours mean which are 0.3ppm and 0.5ppm respectively recommended by the nation standard for air pollution in Nigeria. The largest value was 0.046±0.029ppm. This value is lower than the annual mean and 24hour mean. This value was obtained at Odukpani Junction.

For PM_{10}, the least value obtained was 0.064±0.048ppm. The value was obtained at Marina Resort. This value is lower than the annual mean and 24 hours mean which are 0.12ppm and 0.15ppm respectively recommended by the nation standard for air pollution in Nigeria. The largest value was *0.916±2.47ppm. This value is lower than he annual mean and 24hour mean. This value was obtained at Odukpani Junction.

3.1.2 RATIO ANALYSIS

Table 2: ratio analysis of pollutants from research Source: (Rasheed, et.al., 2014).

Region	CO/NOx	SO_2/NOx
Eastern United States	4.3	0.94
	8.4	0.05
Mobiles	0.95	1.8
Point sources		
Pennsylvania are	2.6	1.7
	7.8	0.05
Mobiles	0.8	2.3
Point sources		
Western United States	6.7	0.41
	10.2	0.05
Mobiles	1.2	1.1
Point sources		

Denver metropolitan area	7.3	0.19
	10.5	0.05
Mobiles	0.18	0.44
	16.3	0.73
Point sources	50	0.58
Raleigh, NC		
New Delhi, India		

Table 2 shows that Mobile sources often have the characteristic of high CO/NO_x ratios and low SO_2/NO_x ratios, whereas higher SO_2/NO_x ratios and lower CO/NO_x ratios are associated with point sources.

Table 3 Regression equations for the stations under study

	SO_2/NO_2			CO/NO_2		
	R	R^2	Regression equation	R	R^2	Regression Equation
AQ1	0.39	0.15	[SO2] = -0.910[NO2] + 0.47	-	-	-
AQ21	0.22	0.05	$SO_2 = -2.67[NO_2] + 0.471$	0.37	0.13	$CO= -82.8[NO_2] + 7.84$
AQ23	0.42	0.18	$SO_2 = -3.53[NO_2] + 0.578$	0.29	0.08	$CO= -197.79[NO_2] + 26.74$
AQ27	0.13	0.02	$SO_2 = -1.047[NO_2] + 0.326$	0.03	0.001	$CO= -8.659[NO_2] + 3.164$
AQ28	0.34	0.11	$SO_2 = -2.29[NO_2] + 0.441$	0.17	0.28	$CO= -20.77[NO_2] + 3.239$
AQ30	0.37	0.14	$SO_2 = -2.34[NO_2] + 0.375$	0.17	0.03	$CO= -25.76[NO_2] + 4.16$
AQ34	0.06	0.004	$SO_2 = -4.24[NO_2] + 0.181$	0.10	0.10	$CO= 11.165[NO_2] + 0.598$
AQ44	0.47	0.22	$SO_2 = -4.22[NO_2] + 0.476$	0.13	0.16	$CO= 25.213[NO_2] + 0.738$
AQ45	0.05	0.002	$SO_2 = -0.226[NO_2] + 0.205$	0.05	0.002	$CO= -5.599[NO_2] + 2.43$
AQ48	0.04	0.002	$SO_2 = 0.269[NO_2] + 0.179$	0.16	0.03	$CO= 14.96[NO_2] + 0.127$
AQ50	0.41	0.164	$SO_2 = -1.49[NO_2] + 0.255$	0.37	0.134	$CO= 200.48[NO_2] – 0.782$

$$[SO_2] = -0.91[NO_2] + 0.47 \quad (1)$$

This equation can be compared to the equation of a straight-line y = mx + c.

Where y is the dependent variable, x is the independent variable, m is the slope and c is the intercept.

From equation (1), 0.910 is the slope of the regression line and tells us about the source of the pollutants (ie either from point sources or from mobile sources). While the intercept in this case 0.47, tells us about the background concentration of the gas in this case SO_2 in the study location. Background concentration is defined here as the annual mean surface-mixing ratio advected into an airshed at a particular location (Aneja et. al. 2001).

The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases.

The value of 0.91 tells us that SO_2 is mostly produces by point sources at the Cross River University of Technology gate.

For the University of Calabar main station point, the ratio analysis gives

$[SO_2] = -2.67[NO_2] + 0.471$ (2)

From equation (2), 2.67 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 2.67 tells us that SO2 is mostly produces by point sources at the University of Calabar main station.

$[CO] = -82.8[NO_2] + 7.84$ (3)

From equation (3), 82.8 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 82.8 tells us that CO is mostly produces by mobile sources at the University of Calabar main station.

For IkaIkaUkwa market, the result of the ratio analysis gives

$[SO_2] = - 3.53[NO_2] + 0.578$ (4)

From equation (4), 3.53 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 3.53 tells us that SO2 is mostly produces by point sources at IkaIkaUkwa Market.

$[CO] = -197.79[NO_2] + 26.74$ (5)

From equation (5), 197.79 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 197.79 tells us that CO is mostly produces by mobile sources at IkaIkaUkwa market.

For Destination Cross River Junction

$[SO_2] = -1.047[NO_2] + 0.326$ (6)

From equation (6), 1.047 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 1.047 tells us that SO2 is mostly produces by point sources at Destination Cross River Junction

$[CO] = -8.659[NO_2] + 3.164$ (7)

$R = 0.034, \quad R^2 = 0.001$

From equation (7), 8.659 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 8.659 tells us that CO is mostly produces by mobile sources at the Destination Cross River Junction.

For Army Junction by welcome to Calabar

$[SO_2] = - 2.29[NO_2] + 0.441$ (8)

$R = 0.338, \quad R^2 = 0.114$

From equation (8), 2.29 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 2.29 tells us that SO2 is mostly produces by point sources at Army Junction by welcome to Calabar.

$[CO] = -20.77[NO_2] + 3.239$ (9)

From equation (9), 20.77 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 20.77 tells us that CO is mostly produces by mobile sources at the Army junction by welcome to Calabar.

For EPZ tank farm

$[SO_2] = -2.34[NO_2] + 0.375$ (10)

From equation (10), 2.34 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 2.34 tells us that SO2 is mostly produces by point sources at EPZ tank farm.

$[CO] = -25.76[NO_2] + 4.16$ (11)

$R = 0.165$, $R^2 = 0.027$

From equation (11), 25.76 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 25.76 tells us that CO is mostly produces by mobile sources at EPZ tank farm.

For Marina Resort

$[SO_2] = -4.24[NO_2] + 0.181$ (12)

From equation (12), 4.24 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 4.24 tells us that SO_2 is mostly produces by point sources at Marina Resort.

$[CO] = -11.165[NO2] + 0.598$ (13)

$[CO] = -11.165[NO_2] + 0.598$ (13)

$R = 0.099$, $R^2 = 0.099$

From equation (13), 11.165 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 11.165 tells us that CO is mostly produces by mobile sources at Marina Resort.

For UNICEM factory

$[SO_2] = -4.22[NO_2] + 0.476$ (14)

$R = 0.468$, $R^2 = 0.219$

From equation (14), 4.22 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 4.22 tells us that SO2 is mostly produces by point sources at UNICEM factory.

$[CO] = 25.213[NO_2] + 0.738$ (15)

From equation (15), 25.213 is the slope of the graph. The graph also has a positive slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 25.213 tells us that CO is mostly produces by mobile sources at UNICEM factory.

For Calabar refuse dump site

$[SO_2] = -0.226[NO_2] + 0.205$ (16)

$R = 0.047$, $R^2 = 0.002$

From equation (16), 0.226 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 0.226 tells us that SO2 is mostly produces by point sources at Calabar refuse dump site.

$[CO] = -5.599[NO_2] + 2.43$ (17)

$R = 0.047$, $R^2 = 0.002$

From equation (17), 5.559 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 5.559 tells us that CO is mostly produces by mobile sources at the Calabar refuse dump site.

For Tinapa Business Resort

$[SO_2] = -0.269[NO_2] + 0.179$ (18)

$R = 0.042$, $R^2 = 0.002$

From equation (18), 0.269 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 0.269 tells us that SO_2 is mostly produces by point sources at Tinapa business resort.

$[CO] = -14.96[NO_2] + 0.127$ (19)

$R = 0.161$, $R^2 = 0.026$

From equation (19), 14.96 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 14.96 tells us that CO is mostly produced by mobile sources at the Tinapa business resort.

For Odukpani Junction

$$[SO_2] = -1.49[NO_2] + 0.255 \quad (20)$$

$R = 0.406$, $R^2 = 0.164$

From equation (20), 1.49 is the slope of the graph. The graph also has a negative slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 1.49 tells us that SO_2 is mostly produced by point sources at Odukpani Junction.

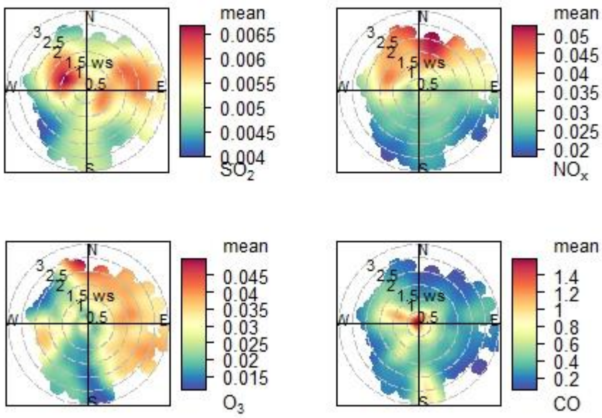

Fig 2. Polar plots for pollutants for December 2015

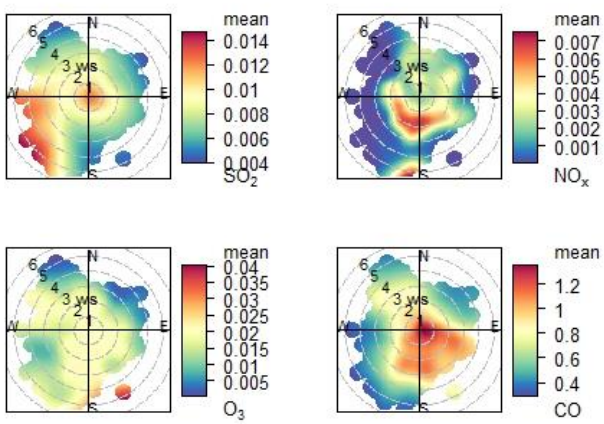

Fig 3. Polar plots for pollutants for year 2016

$$[CO] = 200.48[NO_2] - 0.782 \quad (21)$$

$R = 0.365$, $R^2 = 0.134$

From equation (21), 200.48 is the slope of the graph. The graph also has a positive slope. This shows that as the values of one variable is increasing, the other is decreasing. Positive slope tells us that as the value of one variable increases, the other also increases. The value of 200.48 tells us that CO is mostly produces by mobile sources at Odukpani Junction.

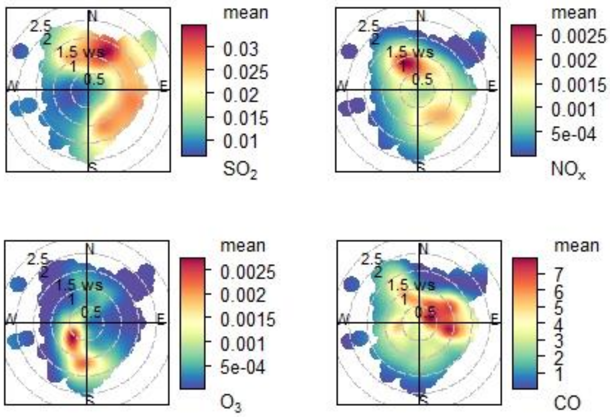

Fig 4. Polar plots for pollutants for year 2017

Bipolar plots

Fig 2 shows polar plots for SO_2, O_3, NO_x and CO in December 2015. The figure shows that there was indication of increasing SO_2 concentrations when wind speed increased from the East and also North-West at wind speed 0.5 to 2ms. For a variety of wind speeds, there is also evidence of a source to the East and North-West. There was indication of increasing NO_x concentration when wind speed increased from the North. For a variety of wind speeds, there is also evidence of a source to the North. There was indication of increasing O_3concentration when wind speed increased from the North East. For a variety of wind speeds, there is also evidence of a source to the North-East. There was indication of increasing CO concentration when wind speed increased from the West. For a variety of wind speeds, there is also evidence of a source to the West. Fig 3 shows polar plots for SO_2, O_3, NO_x and CO for the year 2016. The figure shows that there was indication of increasing SO_2 concentrations when wind speed increased from the South-West. For a variety of wind speeds, there is also evidence of a source to the South-West. There was indication of increasing NO_x concentration when wind speed increased from the West. For a variety of wind speeds, there is also evidence of a source to the West. There was indication of increasing O_3concentration when wind speed increased from the South-East. For a variety of wind speeds, there is also evidence of a source to the South-East. There was indication of increasing CO concentration when wind speed increased from the South-East. For a variety of wind speeds, there is also evidence of a source to the South-East. Fig 4 shows polar plots for SO_2, O_3, NO_x and CO for the year 2017. The figure shows that there was indication of increasing SO_2 concentrations when wind speed increased from the North-East. For a variety of wind speeds, there is also evidence of a source to the North-East. There was indication of increasing NO_x concentration when wind speed increased from the North-East. For a variety of wind speeds, there is also evidence of a source to the North-East. There was indication of increasing O_3concentration when wind speed increased from the South West. For a variety of wind speeds, there is also evidence of a source to the South-West. There was indication of increasing CO concentration when wind speed increased from the North-East. For a variety of wind speeds, there is also evidence of a source to the North-East.

4.0 Summary and Conclusion

Air quality studies has been carried out for Calabar, Nigeria. It was discovered that the research carried out at the eleven stations shows that for NO_2 the least value obtained was 0.086±0.1095ppm. The value was obtained at Cross River University of Technology gate. For SO_2, the largest value was 0.363±0.274ppm. This value is larger than he annual mean and 24hour mean. This value was obtained at Cross River University of technology gate. For CO the largest value was 24.581±46.78ppm. This value is larger than the annual mean and 24hour mean. This value was obtained at Odukpani junction. For $O_{3,}$ the largest value was 0.89±2.294ppm. This value is larger than he annual mean and 24hour mean. This value was obtained at UNICEM factory. For $PM_{2.5,}$ the largest value was 0.046±0.029ppm. This value is lower than the annual mean and 24hour mean. This value was obtained at Odukpani Junction.

For PM_{10}, the largest value was 0.916±2.47ppm. This value is lower than he annual mean and 24hour mean. This value was obtained at Odukpani Junction. Air pollutant concentration is high in Calabar. Ratio analysis of the data tells us that mobile sources were the dominant contributor to the pollutants in ambient air. Anthropogenic were the dominant factors contributing to the pollutants in ambient air. The stakeholders in the environmental sector together with the government should come out with ways to cut down on the amounts of pollutants in the atmosphere. Since mobile factors are dominant, cars should be reduced on the roads. Alternatively, catalytic converters should be attached to the exhaust pipe of motor vehicles to reduce pollutants.

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