Journal of Scientific Research & Reports

17(3): 1-17, 2017; Article no.JSRR.36613
ISSN: 2320-0227

The Role of Meteorology for Seasonal Variation in Air Pollution Level in Eleme, Rivers State, Nigeria

B. Yorkor[1*], T. G. Leton[1] and J. N. Ugbebor[1]

[1]Department of Civil and Environmental Engineering, Faculty of Engineering, University of Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author BY designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TGL and JNU managed the analyses of the study. Author JNU managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2017/36613
Editor(s):
(1) Masum A. Patwary, Geography and Environmental Science, Begum Rokeya University, Rangpur, Bangladesh.
Reviewers:
(1) Zwozdziak Anna, Wroclaw University of Science and Technology, Poland.
(2) Eric S. Hall, USA.
(3) Durdana Rais Hashmi, Pakistan.
(4) Hideharu Shintani, Chuo University, Japan.
(5) Chadetrik Rout, Maharishi Markandeshwar University, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/22383

Original Research Article

Received 2nd September 2017
Accepted 5th December 2017
Published 20th December 2017

ABSTRACT

Meteorological variables play important roles in the dispersion and dilution of air pollutants in an area. This study investigates the influence of meteorological parameters on seasonal variations of air pollutants in a semi industrial area. A ten year set of air quality and meteorological data were collected and used in the study. Data analysis was done using MatLab and SPSS software. The study showed that the degree of air pollution in the area varies according to two prevailing wind directions that dominated the area. The study indicated that NO_2 decreases with wind speed and relative humidity, and slightly increases with wind direction and temperature. CH_4 increases with wind speed and temperature and decreases with wind direction and relative humidity. CO slightly increases with wind direction and relative humidity, and decreases with wind speed and temperature. While SO_2 increases with wind speed and wind direction, and slightly decreases with temperature and relative humidity. Results indicated that the coefficient of determination (R^2) for both dry and rainy seasons are very low, indicating that there is a weak linear relationship between pollutant concentrations and meteorological parameters in both dry and rainy seasons. The study

*Corresponding author: E-mail: yorkor.banaadornwi@uniport.edu.ng;

revealed that there is no significant relationship between pollutant concentrations and meteorological parameters. The study showed that the relationships between pollutant concentrations and meteorological parameters in the area are highly nonlinear. The yearly mean concentration of methane hydrocarbon was 146.2 μg/m^3 in the dry season and 167.8 μg/m^3 in the rainy season. The yearly mean concentration of carbon monoxide was 59.0 μg/m^3 in the dry season and 60.4 μg/m^3 in the rainy season. The yearly mean concentration of nitrogen dioxide in the dry season was 67.2 μg/m^3 and 49.1 μg/m^3 in the rainy season, while the yearly mean concentration of sulphur dioxide in the dry season was 47.7 μg/m^3 and 48.8 μg/m^3 in the rainy season. Seasonal variation showed no significant change in pollutant concentrations in both dry and rainy seasons (P>0.05).

Keywords: Air pollutants; meteorological parameters; dry season; and rainy reason.

1. INTRODUCTION

The degree of air pollution in a locality tends to vary widely with meteorological variations in the area [1]. As a result certain weather conditions can trigger an air pollution episode. Therefore, the understanding of the seasonal variations of meteorological conditions in an area is necessary for proper design of point sources (such as flue gas stacks), as well as implementing appropriate control measures. Various meteorological factors affect the dispersion of pollutant's emissions into the atmosphere [2]. The meteorological conditions of an area are among the factors that affect the transport, dilution and dispersion of air pollutants. Meteorological parameters vary widely as a function of seasons, latitude, and topography, and influence to a large extent the concentration of air pollutants in a particular environment [1]. Wind direction determines the movement of air pollutants in a particular direction across an area. Increase in wind speed will increase the rate of dispersion and dilution of pollutants, thereby reducing ground level concentrations of pollutants. This paper investigates the influence of meteorological parameters on seasonal variations of air pollutants in a semi industrial area. Concentrations of atmospheric pollutants are influenced by the variations in source strengths and meteorological conditions such as wind speed and direction, temperature, relative humidity and mixing height [3]. A study on the effect of meteorology on atmospheric pollutant concentrations using a statistical regression model has been previously attempted [4]. Concentration levels of carbon monoxide and oxides of nitrogen were found to increase with lower levels of temperature and wind speeds, while, concentration of ozone in an area was found to increase with elevated levels of temperature, wind speeds and relative humidity [4].

2. METHODOLOGY

2.1 Study Area

The Eleme region (Fig. 1) is located within the coastal area of the Rivers State in the Niger Delta region of Nigeria. Its Longitude is 7.1028°E and Latitude is 4.7992°N. The complex coastline and low-lying flat topology of the area result in complex surface wind speed patterns, especially during low wind activity when land and sea breezes dominate the surface wind of the area. Eleme region hosts several major national and international industrial facilities, including two refineries, a petrochemical plant and two fertilizer plants. The East-West highway traverses the length and breadth of Eleme, and as a result often experiences heavy vehicular movement. Moderate temperatures and high humidity are common characteristics of the study area. The area experiences a tropical climate that consists of a rainy season (April to October) and a dry season (November to March) [5,6].

2.2 Data Collection

A ten year (2006 to 2015) air quality and meteorological data set were used in the study. The ten year data were obtained from the International Institute of Tropical Agriculture (IITA), Onne weather station [7]. The Meteorological Services Department (MSD) of IITA in collaboration with the Nigerian Meteorological Agency (NIMET) obtained meteorological and air quality data using satellite remote sensing. In this study, the months of November to March represent the dry season period, while the months of April to October represent the rainy season period [5,6].

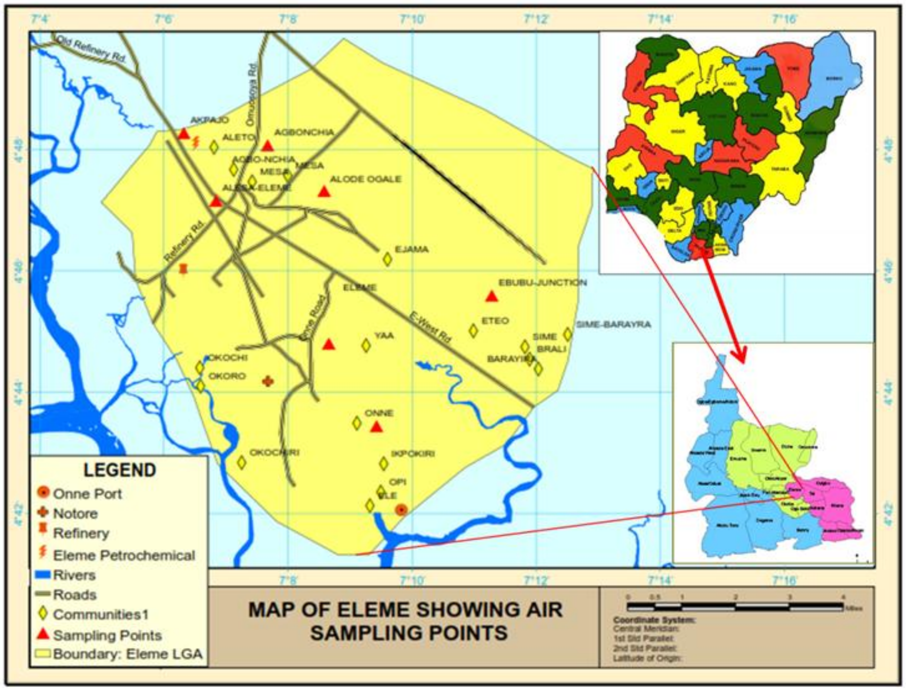


Fig. 1. Map of Eleme region

2.3 Multiple Linear Regression (MLR) Models

Multiple linear regression models were applied to predict SO_2, NO_2, CO and CH_4 concentrations with meteorological parameters. The multiple linear regressions were performed using Statistical Package for the Social Science (SPSS) software, originally developed by International Business Machines (IBM). The regression equations used are:

$$Y_i = b_0 + \sum_{j=1}^{p} b_j X_{ij} + \varepsilon_i \quad (1)$$

$$Y_i = \begin{pmatrix} b_0 + b_1 X_{i1} + b_2 X_{i2} + \ldots\ldots\ldots\ldots \\ + b_n X_n \end{pmatrix} + \varepsilon_i , \quad (2)$$

where Y represents the predicted values, b_0 represents the constant of regression, b_1, …., b_n are the coefficients of regression, X_1,.., X_n are observed values, ε_i is the difference between the predicted, the observed values for the i^{th} sample, and n is the number of data points. Predicted concentration of air pollutants can be represented as a function of meteorological parameters as follows:

$$\begin{aligned} Y_{pred} &= f(X_i) \\ Y_{pred} &= f(Wsp_i, \mathrm{Wd_i}, \mathrm{Temp_i}, \mathrm{Rh_i}) \end{aligned} \quad (3)$$

$$\begin{aligned} Y_{pred} &= b_0 + b_1 * Wsp_i + b_2 * Wd_i + b_3 * Temp_i \\ &+ b_4 * Rh_i + \varepsilon_i \end{aligned} , \quad (4)$$

where Wsp is the wind speed, Wd is the wind direction, Temp is the temperature, and Rh is the relative humidity. The mean value of data was computed using Equation (5).

$$\overline{X} = \frac{1}{n} \sum_{i=1}^{n} X_i \quad (5)$$

The mean square error of the MLR was given as:

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (Y_{Pred} - X_i)^2 \quad (6)$$

The sum of squares of the regression was computed using:

$$SS_{reg} = \sum_i \left(Y_{pred} - \overline{X}\right)^2 \quad (7)$$

The residual sum of squares was computed using:

$$SS_{res} = \sum_i \left(X_i - Y_{pred}\right)^2 = \sum_i \varepsilon^2 \quad (8)$$

The total sum of squares was given as:

$$SS_{tot} = SS_{reg} + SS_{res} = \sum_i \left(X_i - \overline{X}\right)^2 \quad (9)$$

The coefficient of determination (R^2) was computed as:

$$R^2 = \frac{\text{Explained variation}}{\text{Total variation}} = \frac{SS_{reg}}{SS_{tot}} = \frac{\sum_i \left(Y_{pred} - \overline{X}\right)^2}{\sum_i \left(X_i - \overline{X}\right)^2} \quad (10)$$

3. RESULTS AND DISCUSSION

3.1 Ambient Temperature

The yearly dry season ambient temperature observed in the study area ranged from 28.5°C (low) in 2009 to 34.8°C (high) in 2008 (Fig. 2), with a cumulative mean value of 31.7°C. Observed ambient temperatures in the rainy season ranged from 26.17°C (low) in 2009 to 33.84°C (high) in 2008, with mean a cumulative value of 29.9°C. The temperature values are common characteristics in the tropical region where this study was conducted [6]. The reason for the temperature disparity between the two seasons is due to the tropical nature of the study area and the transition phase between dry season and rainy season [5]. Yearly mean temperature varies from season to season as shown in Fig. 2, and was highest in 2008 due to a long period of sunshine and less rainfall. According to Chidolu and Nsofor [8], temperature increased by 31.5% in the dry season, especially during December-February Harmattan period, and by 13.4% in July-September, when rainfall is at its peak. Observed yearly mean temperature variations in dry and rainy seasons in the study area indicated that diurnal temperature variation is maximum 1-3 hours after noon and minimum in the early hours of dawn.

3.2 Relative Humidity

Observed yearly mean relative humidity in the dry season ranged from 59.1% (low) in 20013 to 68.32% (high) in 2011 (Fig. 3) with a cumulative mean of 63.7%. The yearly mean relative humidity observed in the rainy season ranged from 69.8% (low) in 2013 to 81.71% (high) in 2006 (Fig. 3), with a cumulative mean of 76.5%. Relative humidity oscillates in tandem with air temperature, but in opposite directions. High relative humidity of this nature (Fig. 3) is normal in the rainy season [5] because of the continuous complete cloud cover observable in this period. Mean yearly values went up to 80% in 2006, 2007 and 2011. Yearly mean relative humidity for the dry and rainy seasons is shown in Fig. 3.

3.3 Wind Speed, Direction and Air Mass

Yearly mean wind speed in the dry season ranged from 1.56 ms^{-1} (low) in 2013 to 2.48 ms^{-1} (high) in 2010 (Fig. 4), with a cumulative mean of 2.0 ms^{-1}. Mean wind speed observed in the rainy season ranged from 1.57 ms^{-1} (low) in 2007 to 3.07 ms^{-1} (high) in 2008 (Fig. 4), with a mean of 2.2 ms^{-1}. Wind direction in the dry season was predominantly South-West, while wind direction

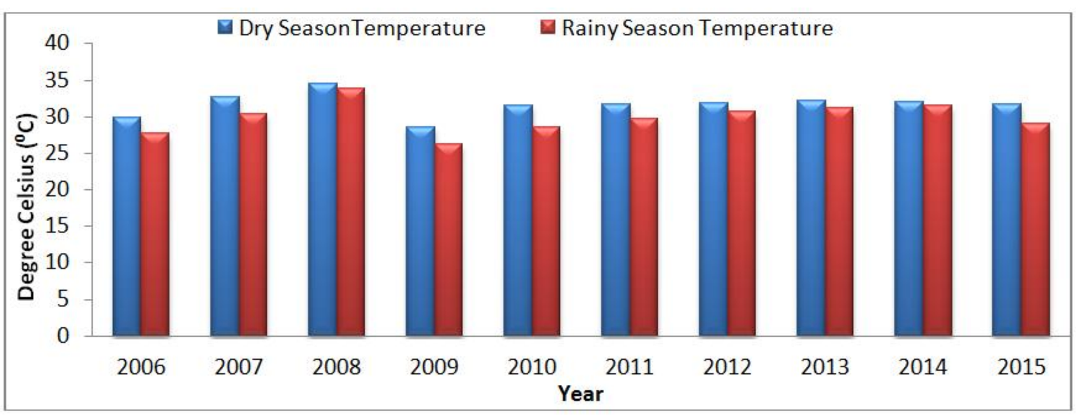


Fig. 2. Yearly mean temperature

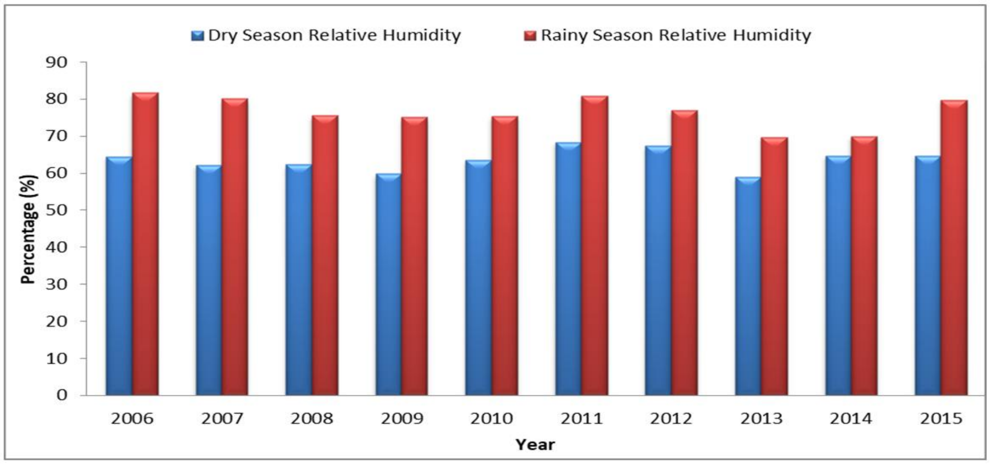


Fig. 3. Yearly mean relative humidity

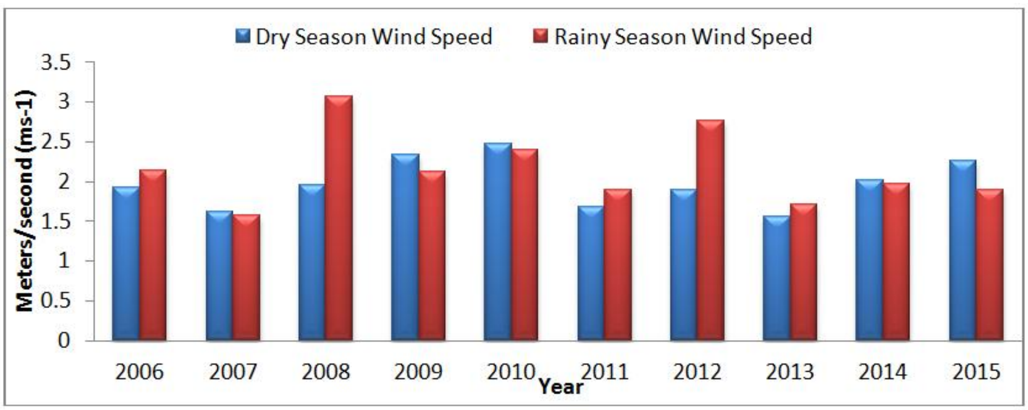


Fig. 4. Yearly mean wind speed

in the rainy season was predominantly North-East as shown in Fig. 5 (a) and (b). Pollution wind roses of Fig. 5 indicate the two prevalent wind directions that influence the dispersion of air pollutants in the area. The Fig. 5 (a) indicates that higher pollutant concentrations are associated with South-West in the dry season influenced by North-East wind. While Fig. 5(b) indicates the higher pollutant concentrations are associated with North-East in the rainy season influenced by South-West wind. This implies that any pollutants discharged from point source facilities in the area will always be dispersed along the Northern direction in the rainy season and in a Southern direction in the dry season. The pollution roses also indicate that concentrations pollutants increase with increased wind speed.

During the dry season period, the North-East Trade Wind blows South through the area. This hot-by-day and cold-by-night wind brings in dust. Clouds during this period are absent, so temperature is relatively high during the day but low at night. Visibility is restricted in the months of December to February by the Harmattan dust carried from the Sahara desert [5]. As the sun moves into the northern hemisphere in March, the influence of the Harmattan dust reduces, and the maritime wind begins to dominate the area for the rest of the year. Heavy thunderstorms occur from the months of March to May, indicating the transition from the dry season to the rainy season [9]. The coastal zone where this study was carried out is dominated by the tropical maritime air-mass most of the year. The influence of this moisture-laden wind depends on the position of the counter-tropical continental air mass, separated by the inter-tropical discontinuity (ITD), which forms the zone of relatively low pressure system [5,8]. Also, the months of September and October had another round of heavy thunderstorms indicating a transition from the rainy season to the dry season. The two transition phases in the area complete the yearly seasonal cycle. Meteorological parameters are highly variable due to seasonal variations and the coastal nature of the study area. During the rainy season periods, atmospheric 'wash-out' conditions occurred, which is responsible for the level of pollutant concentrations observed. The north-east trade wind [5] that blows in the dry season is responsible for prolong suspension of pollutants in the ambient air of the study. The south-west wind blowing towards the area in the wet season transports air pollutants from source facilities (waste treatment facilities in the oil and gas free zone, fertilizer plants etc.) situated along the coastline in the area. While in the dry season, the north-east trade wind transports air pollutants from source facilities (petrochemical, fertilizer plants etc.) located upland of the area.

Figs. 6 to 9 show the relationships between pollutant concentrations and meteorological parameters. The figures indicate that NO_2 concentrations are negatively correlated with the wind speed, and relative humidity and marginally correlated with wind direction and temperature. CH_4 concentrations are positively correlated with wind speed and temperature and negatively correlated with wind direction and relative humidity. CO concentrations are slightly negatively correlated with wind speed and temperature and marginally correlated with wind direction and relative humidity. SO_2 concentrations are positively correlated with wind speed and wind direction and negatively correlated with temperature and relative humidity. These results are consistent with similar results obtained by Akpinar et al. [10].

Relationships between predicted and observed pollutant concentrations are shown in Figs. 10 and 11. While the statistical results of the multi linear regression are shown in Table 1. The derived regression equations between pollutant concentrations and meteorological parameters in the dry season are given in Equations (11) to (14), while the derived equations for the rainy season are given in Equations (15) to (18). The results showed that the computed values of the coefficient of determination (R^2) for both the dry and rainy seasons are very low, indicating that there is a weak linear relationship between pollutant concentrations and meteorological parameters. The F-values for both the dry and rainy seasons also showed that there is no significant relationship between pollutant concentrations and meteorological parameters.

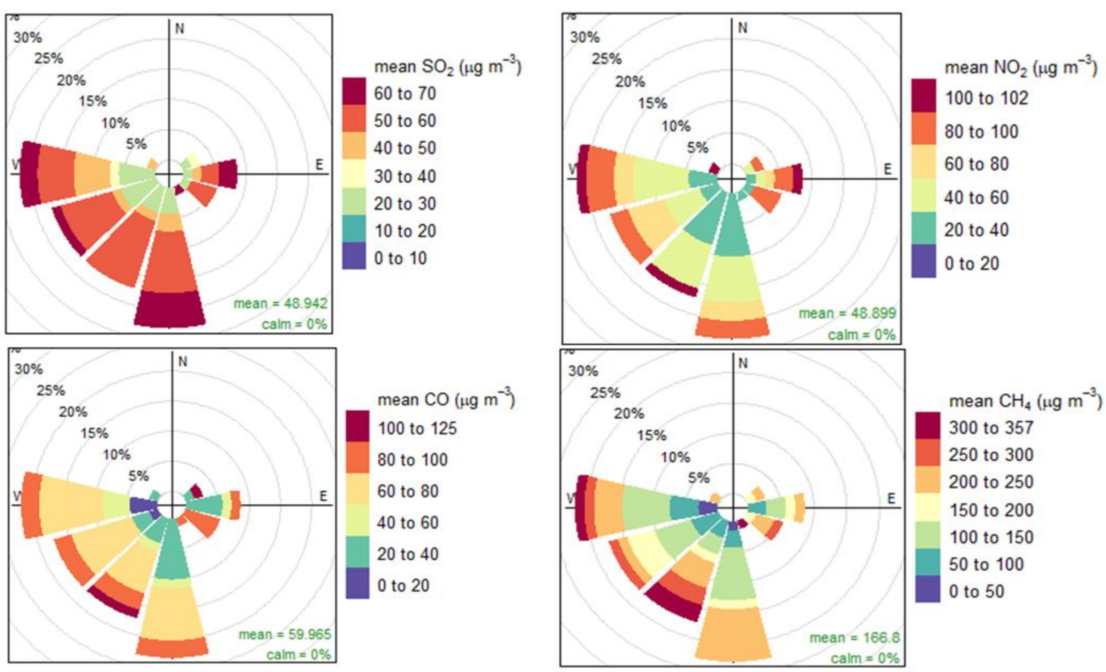


Fig. 5. (a) Dry season pollution wind rose

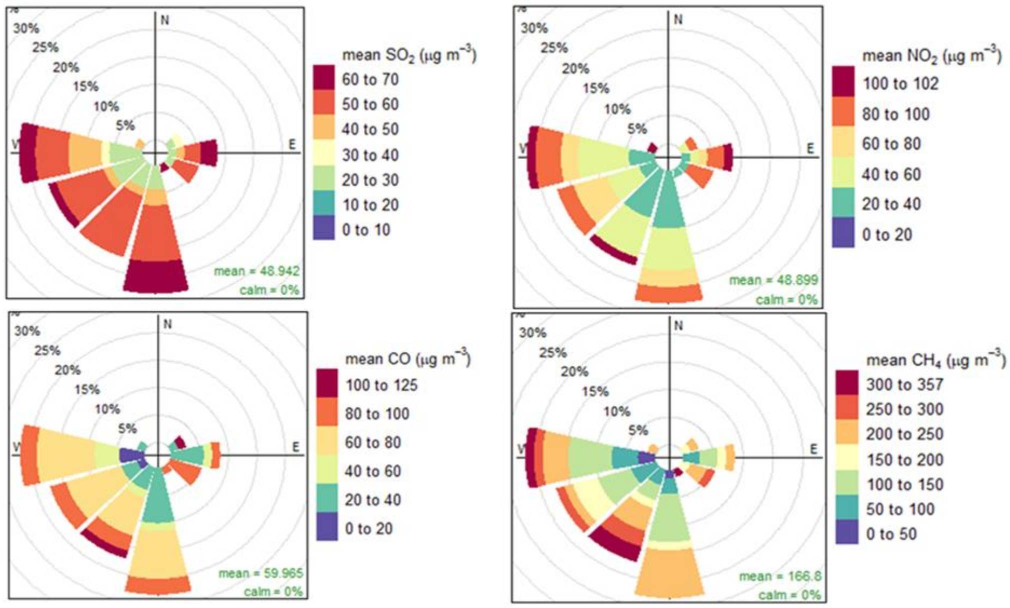


Fig. 5. (b) Rainy season pollution wind rose

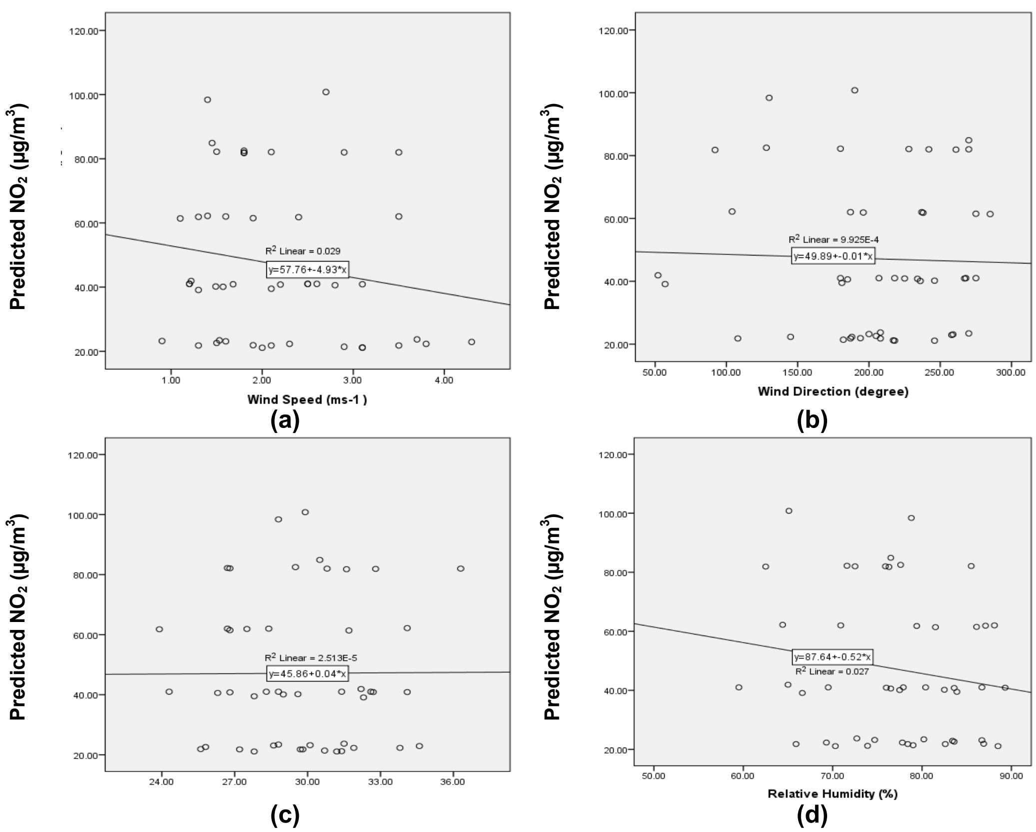
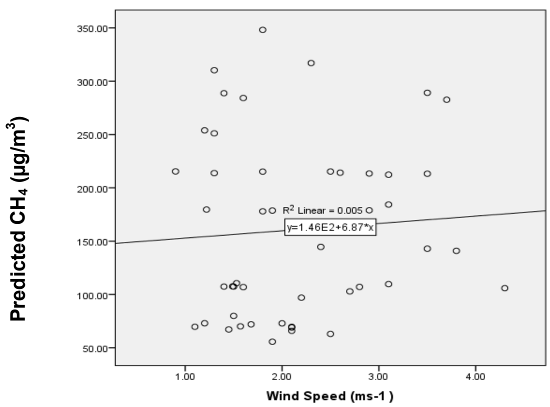


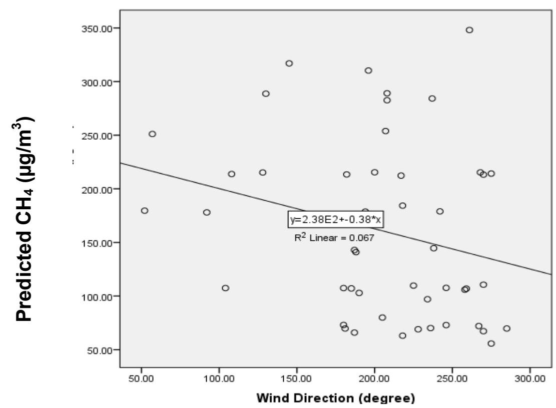
Fig. 6. NO_2 concentrations versus meteorological parameters

The relationships between pollutant concentrations and meteorological parameters are possibly highly nonlinear. This agrees with studies by Akpinar et al. [10], Cai et al. [11] and

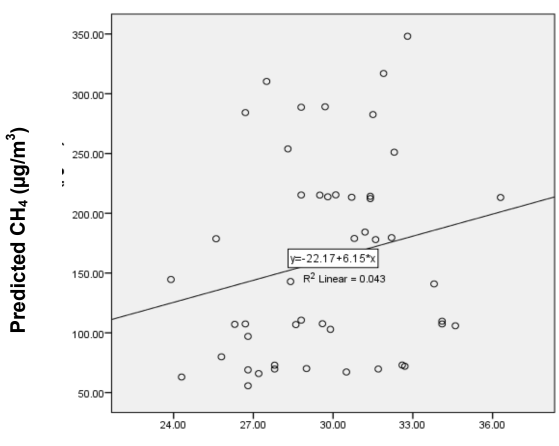
Elangasinghe et al. [12]. The derived (MLR) equations can be used to predict air pollutant concentrations in the area, and can serve as useful tools in an environmental impact assessment (EIA) and audit studies for future prediction of air quality impacts of developments in the area.



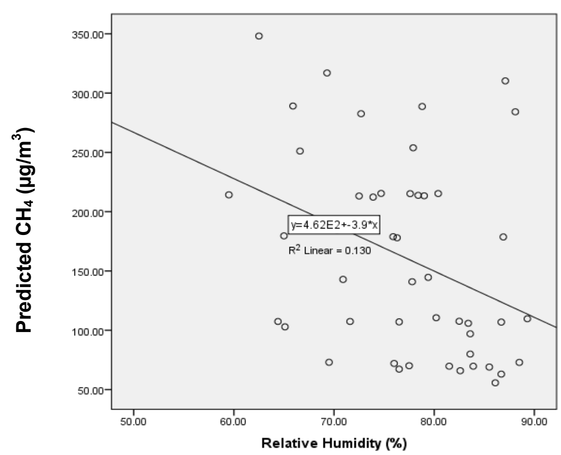
(a)



(b)



(c)



(d)

Fig. 7. CH_4 concentrations versus meteorological parameters

Table 1. Statistical results of multi linear regression models

	SS_{reg} (µg/m^3)	SS_{res} (µg/m^3)	R^2	MSE (µg/m^3)	F-value	Sig.
			Dry season			
SO_2	95.605	8718.874	0.11	23.901	0.118	0.975
NO_2	3852.38	18511.620	0.172	963.095	2.237	0.081
CO	5219.737	26581.133	0.164	1304.934	2.111	0.096
CH_4	11490.851	252393.299	0.044	2872.713	0.489	0.743
			Rainy season			
SO_2	1437.781	10939.987	0.116	359.445	2.103	0.091
NO_2	1185.52	43574.770	0.026	296.38	0.435	0.783
CO	2007.387	47861.790	0.04	501.847	0.671	0.614
CH_4	42759.515	423240.675	0.092	10689.879	1.616	0.181

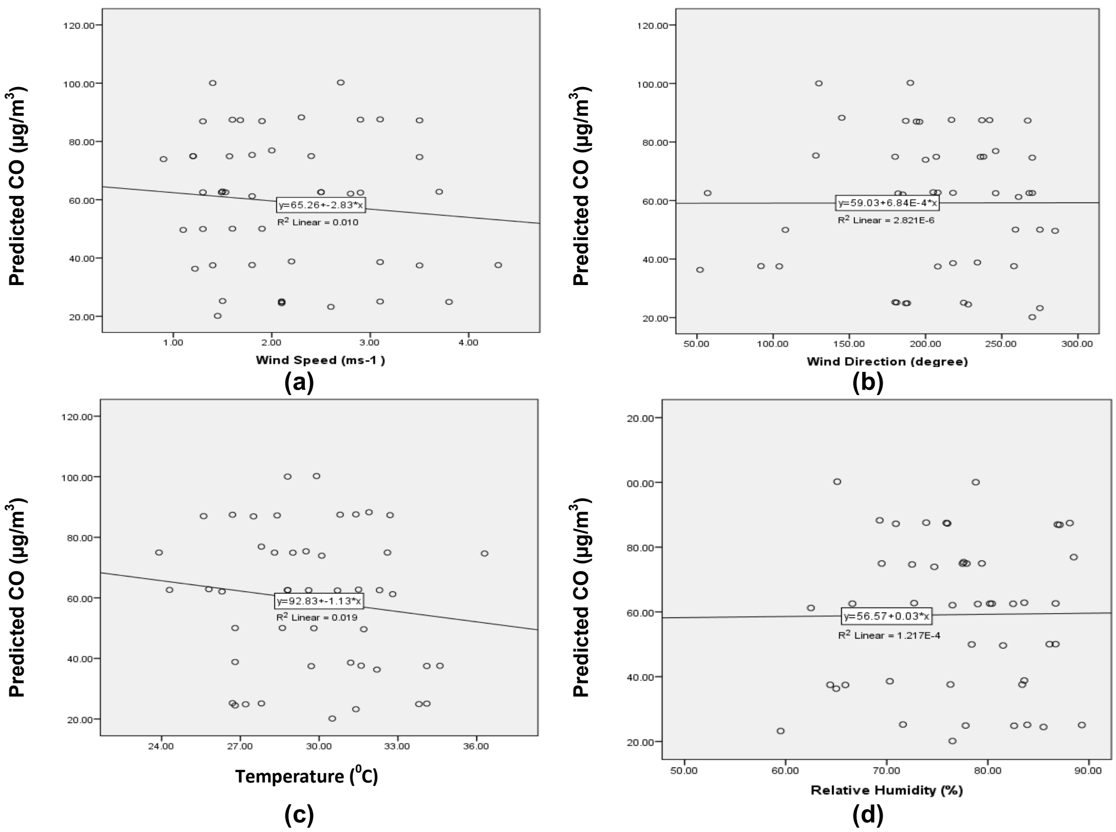


Fig. 8. CO concentrations versus meteorological parameters

Multiple linear regression (MLR) models for the Dry season:

SO_2 = 38.046 + 0.290*Wsp - 0.001*Wd + 0.454*Temp - 0.081Rh
NO_2 = 106.337 + 1.710*Wsp + 0.002*Wd + 0.850Temp - 1.081Rh
CO = 127.890 - 11.142*Wsp + 0.073*Wd - 1.136*Temp - 0.292*Rh
CH_4 = 298.362 - 19.971*Wsp + 0.021*Wd - 3.339*Temp -0.197*Rh

Multiple linear regression (MLR) models for the Rainy season:

SO_2 = 51.261 + 5.336*Wsp - 0.017*Wd - 0.377*Temp + 0.011Rh
NO_2 = 93.684 + 1.693*Wsp - 0.011*Wd - 0.297Temp - 0.487Rh
CO = 13.941 + 2.974*Wsp - 0.070*Wd + 0.183*Temp + 0.630*Rh
CH_4 = 398.078 - 5.972*Wsp - 0.026*Wd + 0.661*Temp -3.042*Rh

The yearly mean concentrations of sulphur dioxide in the dry season ranged from 44.0 μg/m^3 (low)in 2014 to 53.4 μg/m^3 (high) in 2013 (Fig. 12), with a cumulative mean of 47.7 μg/m^3. The rainy season yearly mean ranged from 36.9 μg/m^3 (low) in 2007 to 54.3 μg/m^3 (high) in 2006 (Fig. 12) with a cumulative mean of 48.8 μg/m^3. The dry season concentrations of nitrogen dioxide in study area ranged from 48.0 μg/m^3 (low) in 2015 to 82.0 μg/m^3 (high) in 2010 (Fig. 13), with a cumulative mean value of 67.2 μg/m^3. The concentrations of nitrogen dioxide in the rainy season ranged from 41.1 μg/m^3 (low) in 2007 to 71.8 μg/m^3 (high) in 2015 (Fig. 13), with a cumulative mean value of 49.1 μg/m^3. Concentrations of carbon monoxide in the dry season ranged from 35.0 μg/m^3 (low) in 2014 to 95.0 μg/m^3 (high) in 2012 (Fig. 14), with a cumulative mean of 59.0 μg/m^3. The concentrations of carbon monoxide in the rainy season ranged from 32.1 μg/m^3 (low) to 91.7 μg/m^3 (high) in 2015 (Fig. 14), with a cumulative mean of 60.4 μg/m^3. Similarly, yearly mean concentrations of methane hydrocarbon in the dry season ranged from 76.8 μg/m^3 (low) in 2006 to 226.1 μg/m^3 (low) in 2015 (Fig. 15), with a cumulative mean of 146.2 μg/m^3. The yearly mean concentrations in the rainy season ranged from 69.4 μg/m^3 (low) in 2006 to 255.0 μg/m^3 (high) in 2013 (Fig. 15), with a cumulative mean of 167.8 μg/m^3. The NO_2 cumulative mean value of 67.2 μg/m^3 exceeded the United States National Ambient Air Quality Standards (NAAQS) limit of 60 μg/m^3 by 12%. This may negatively affect human health.

The average concentration of pollutants clearly displayed annual variations, with peak concentrations in the months of December, January, April, June and July as shown in Figs. 16 to 23. There was a slight increase in the concentrations of SO_2, NO_2 and CO in the dry season as compared to the rainy season, as average concentrations of these pollutants were marginally lower in the months of the Rainy season (Figs. 16 to 21). This could result from the fact that these pollutants undergo transformation in the atmosphere to form acidic compounds such as nitric and sulphuric acids, which are washed-out and fall-out as acid rain during heavy downpours. However, no significant variations were observed in both the dry and rainy seasons (P-value > 0.05) as shown in Table 2. Concentrations of CH_4 were slightly higher in the rainy season than in the dry season (Figs. 22 and 23). This is because CH_4 is not soluble in water and does not undergo 'wash-out'. The study further revealed that there was no significant variation (P-value = 0.062979) of CH_4 concentrations in both the dry and rainy seasons. Generally, analysis of the significant difference between seasonal concentrations of air pollutants (Table 2) revealed that there was no significant variation in pollutant concentrations in the dry season and rainy seasons. This implies that concentration levels of air pollutants in the study area are relatively constant, mostly due to cluster of industrial activities and heavy vehicular movement in the area. Weli and Ayoade [9] in their study obtained similar result, and attributed the reasons to the prevalence of hydrocarbon industrial facilities in the region.

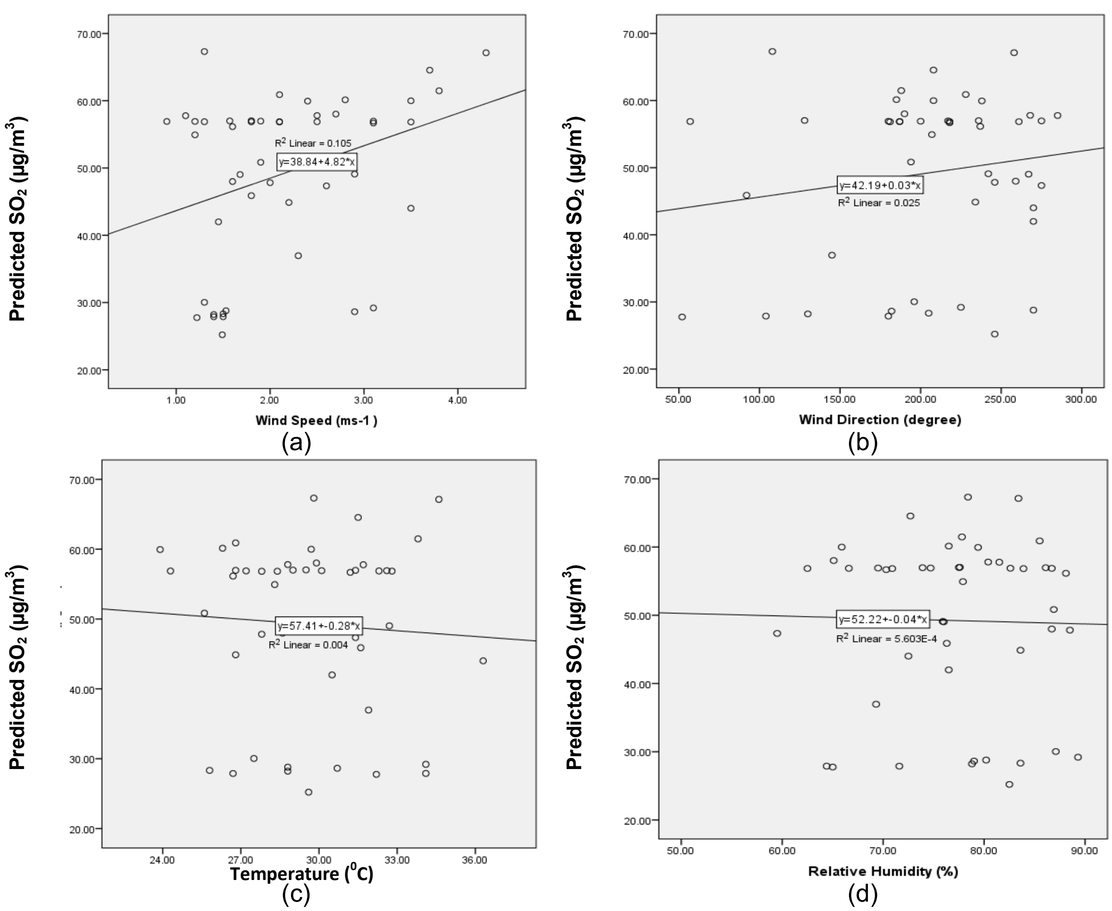


Fig. 9. SO_2 concentrations versus meteorological parameters

Monthly averages showed that pollutant concentrations are slightly high in the months of the dry season which could be attributed to the prevailing Harmattan dust. The average concentration of pollutants clearly showed annual variations, with peak concentrations in the months of December, January, April, June and July. There was no significant variation in pollutant concentrations in the both dry and rainy seasons which could be attributed to increased clustering of hydrocarbon related activities and heavy vehicular movement.

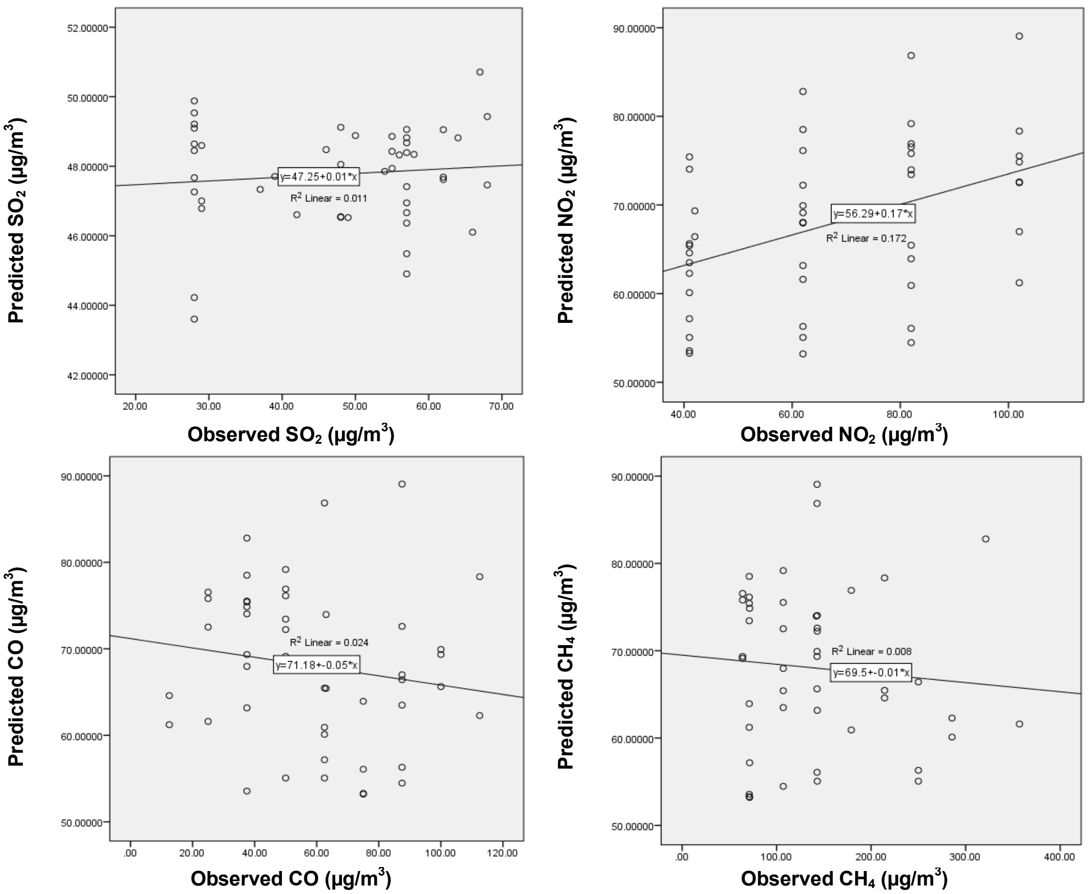
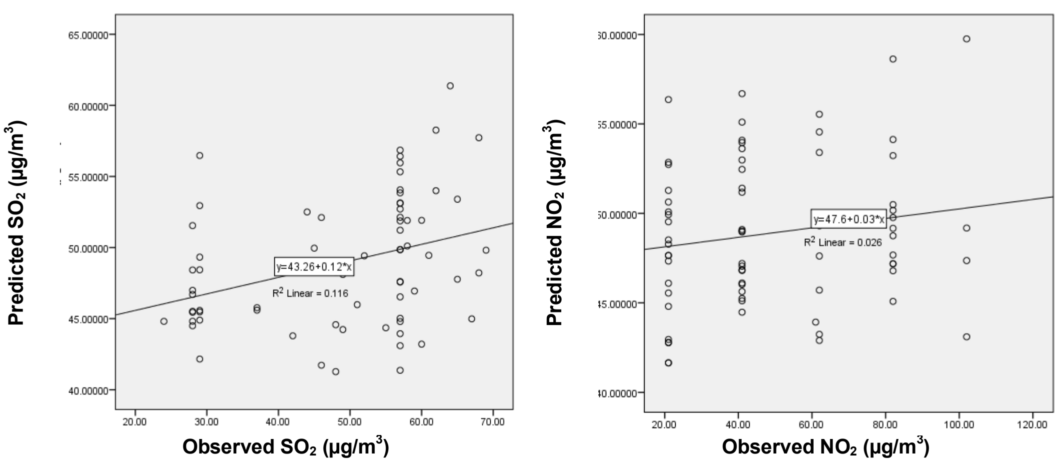


Fig. 10. Predicted versus observed concentrations in the dry season



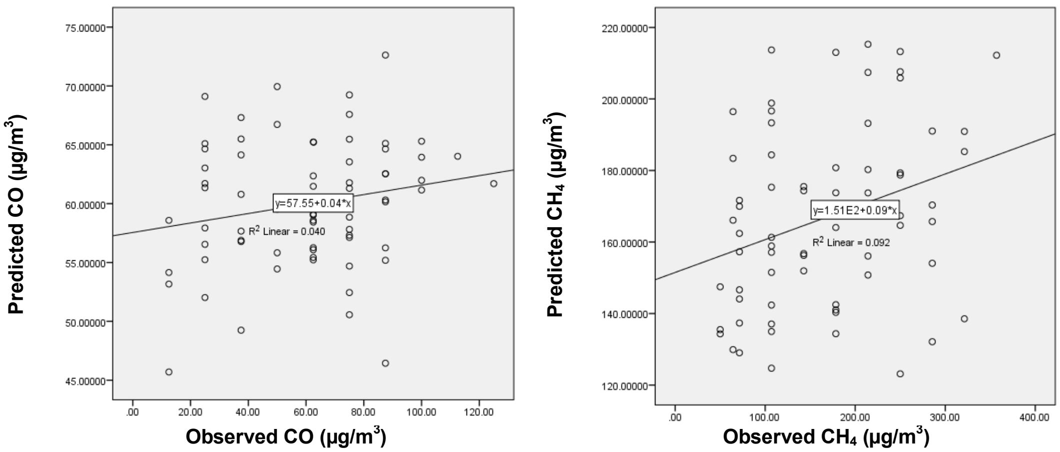


Fig. 11. Predicted versus observed concentrations in the rainy season

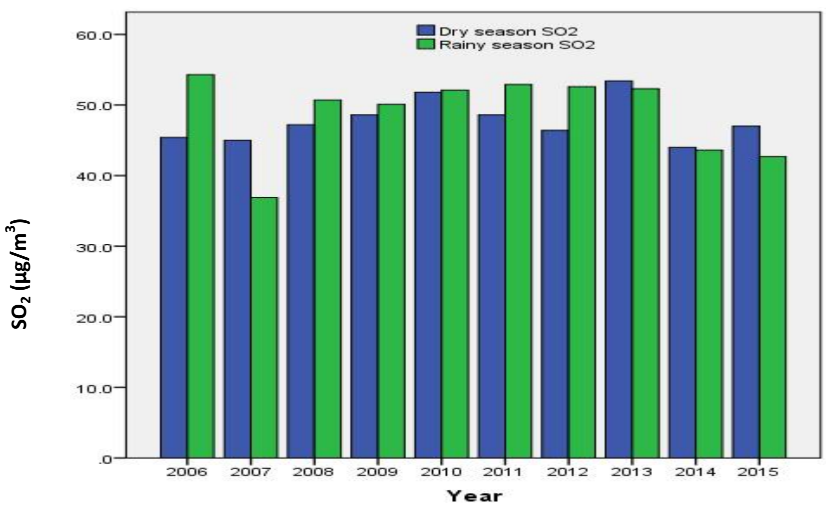


Fig. 12. Yearly mean concentrations of Sulphur Dioxide (SO_2)

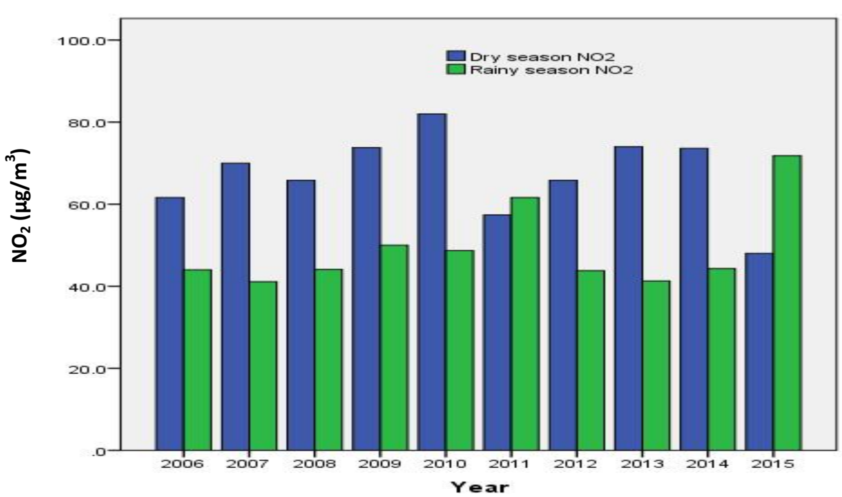


Fig. 13. Yearly mean concentrations of Nitrogen Dioxide (NO_2)

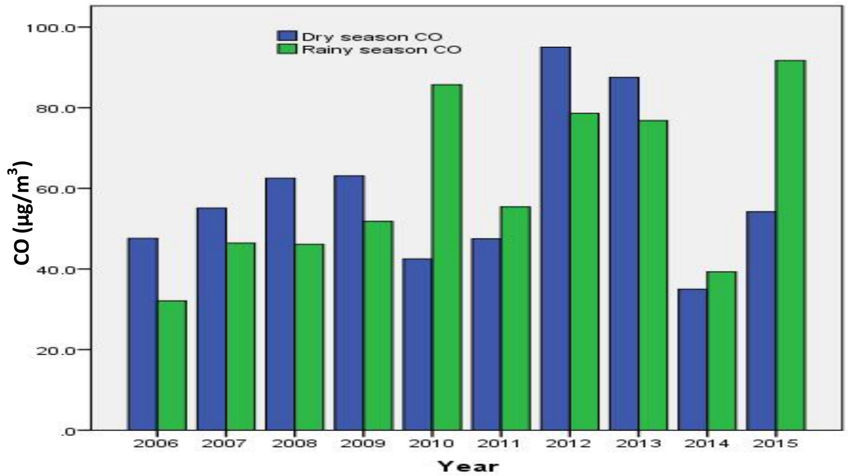


Fig. 14. Yearly mean concentrations of Carbon Monoxide (CO)

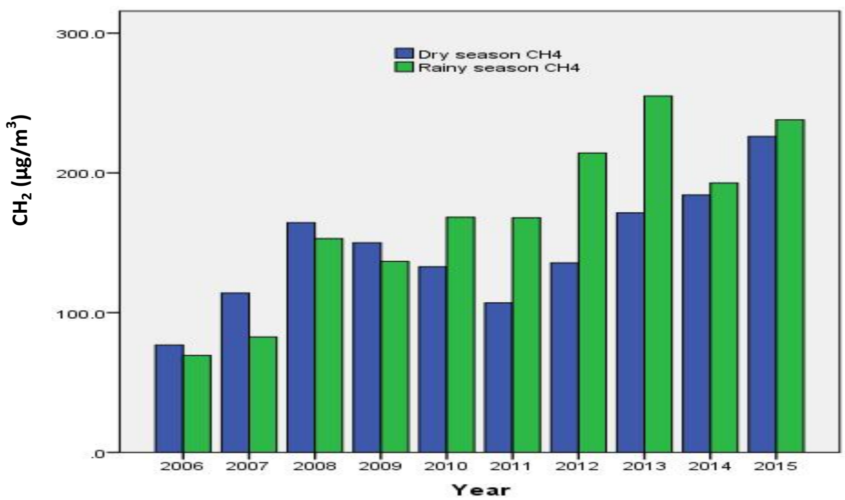


Fig. 15. Yearly mean concentrations of Methane Hydrocarbon (CH_4)

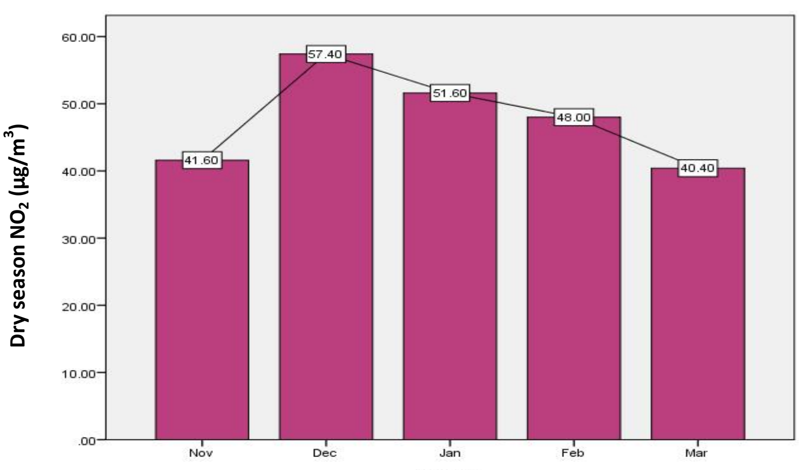


Fig. 16. Average monthly concentrations of Sulphur Dioxide (SO_2) in dry season

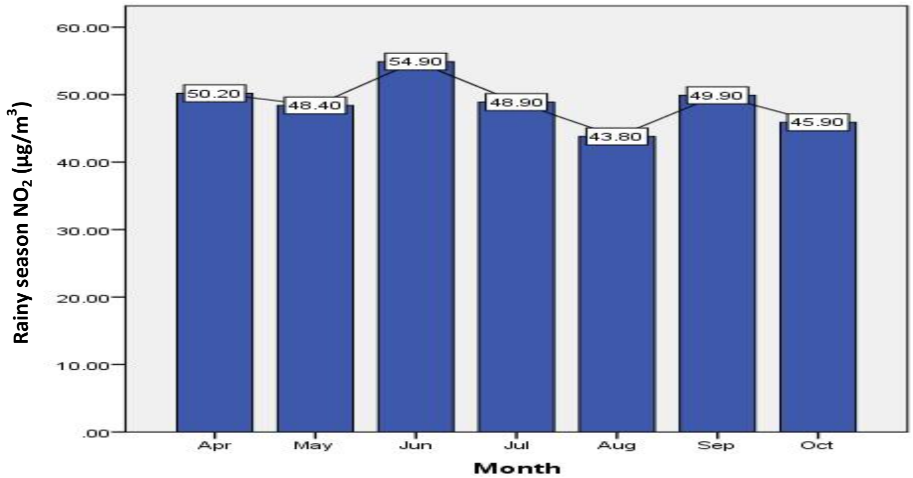


Fig. 17. Average monthly concentrations of Sulphur Dioxide (SO_2) in rainy season

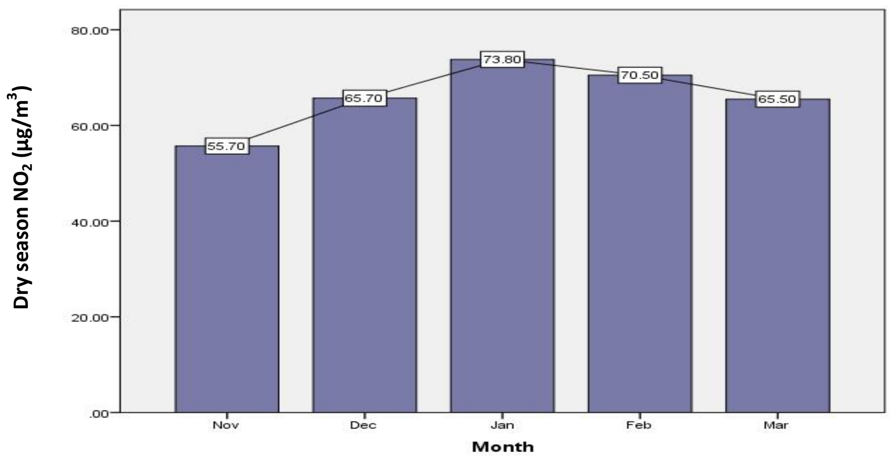


Fig. 18. Average monthly concentrations of Nitrogen Dioxide (NO_2) in dry season

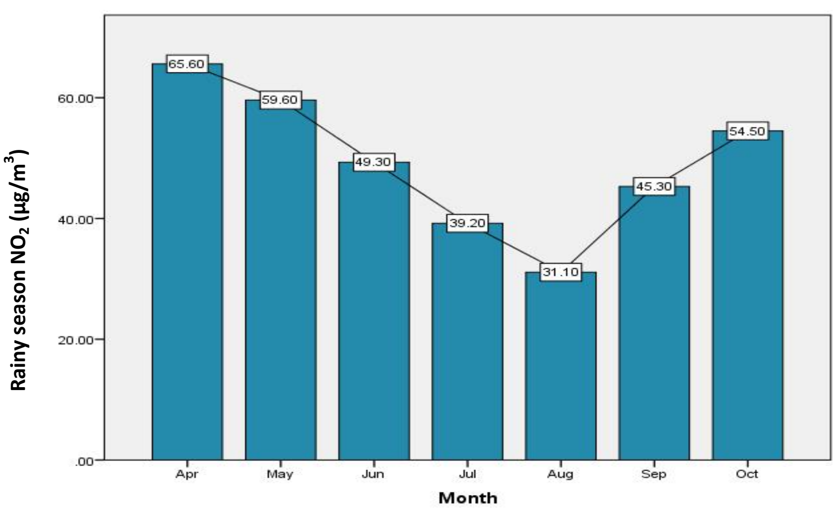


Fig. 19. Average monthly concentrations of Sulphur Dioxide (SO_2) in rainy season

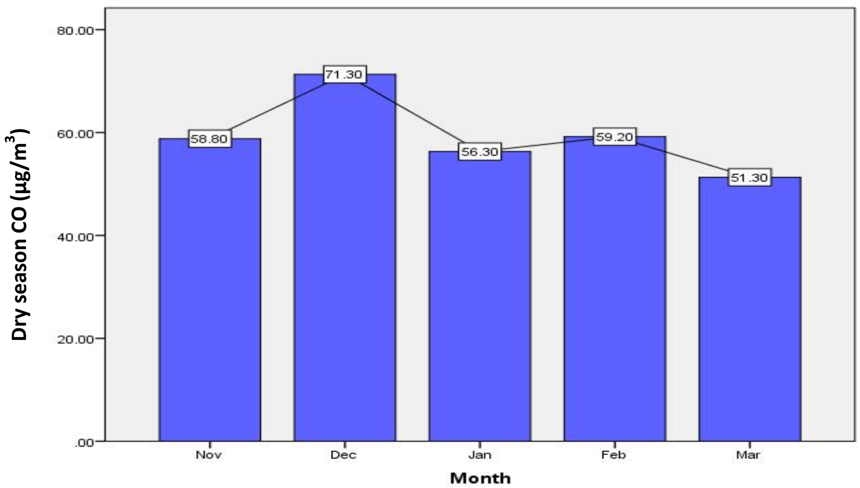


Fig. 20. Average monthly concentrations of Carbon Monoxide (CO) in dry season

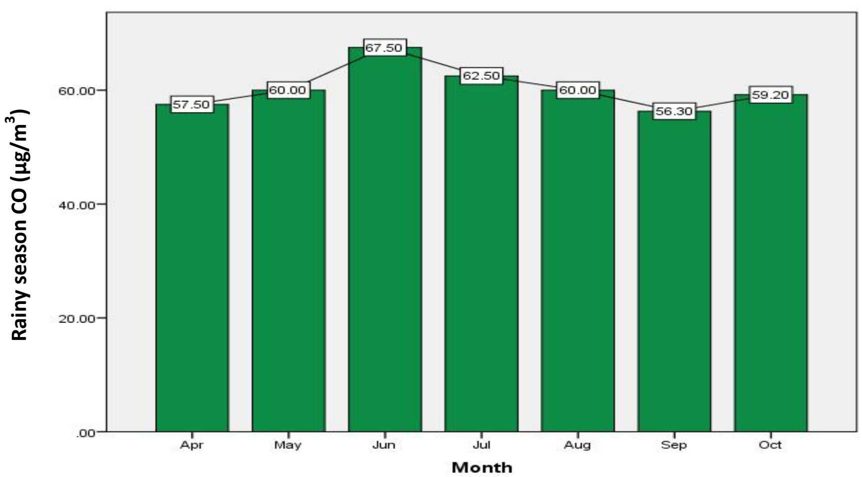


Fig. 21. Average monthly concentrations of Carbon Monoxide (CO) in rainy season

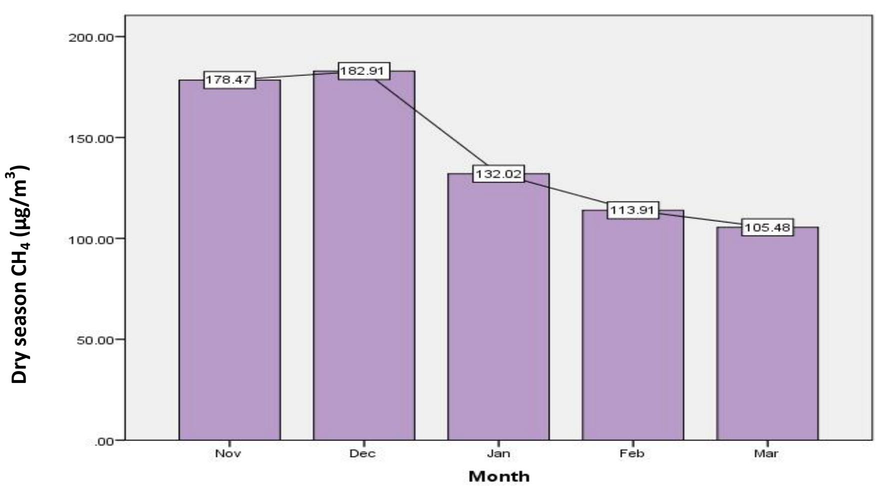


Fig. 22. Average monthly concentrations of Methane Hydrocarbon (CH_4) in dry season

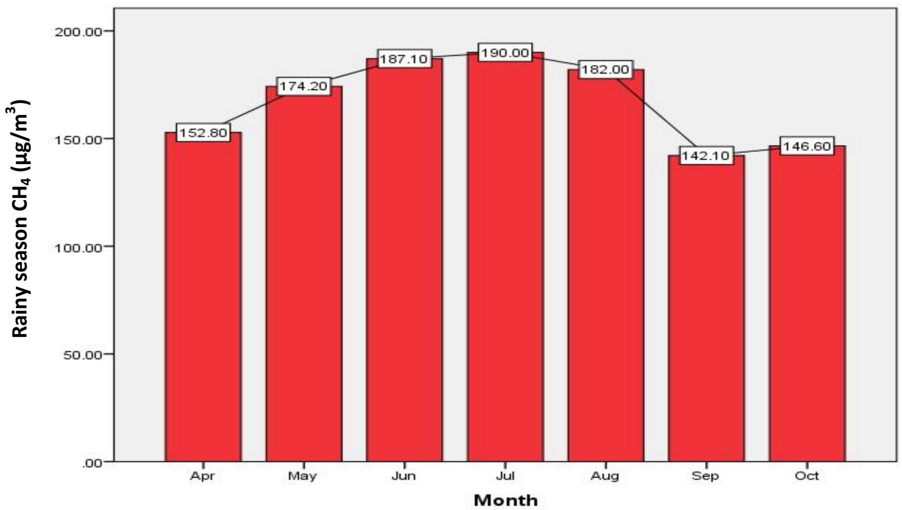


Fig. 23. Average monthly concentrations of Methane Hydrocarbon (CH_4) in rainy season

Table 2. Significant level between dry and rainy season pollutants concentration

Pollutant	P-value*	Level of significant
CH_4	0.062979	Not significant
CO	0.33493	Not significant
NO_2	0.057565	Not significant
SO_2	0.849429	Not significant

Significant at 95% significant level

4. CONCLUSION

The study revealed that the area is one where air pollutants are contained in an enclosed area affect by two major wind patterns, which influence the local meteorological conditions. The study further revealed that pollutants released from point source industrial facilities in the area will generally be dispersed along the northern direction in the rainy season and southern direction in the dry season. The degree of air pollution in the area varies according to two prevailing wind directions. The study showed a weak relationship between pollutant concentrations and meteorological parameters.

5. RECOMMENDATION

Based on the findings of this study, the following recommendations are suggested:

1. Industries operating in the area should pay particular attention to human settlements located in the two prevailing wind directions that dominate the area.
2. Industries operating within the study area should be closely monitored by both State and Federal regulatory agencies to ensure that air pollution control devices are installed on all point source facilities.
3. State and Federal governments should pay particular attention to air pollution problems in the study area by establishing air quality monitoring stations in Eleme region.
4. Organizations intending to carry new developments resulting in the discharge of gaseous emissions in the area should be aware of human settlements in the northern and southern directions.
5. Further investigation is recommended and a comprehensive air quality study of the area should be implemented to analyze particulate matter and ozone.

ACKNOWLEDGEMENT

The authors wish to acknowledge to the management of International Institute of Tropical Agriculture (IITA), Onne weather station, Rivers State, Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Rao MN, Rao HVN. Air pollution. Tata McGraw-Hill Publishing Company Limited, 22nd Reprint, New Delhi, India; 2005.

2. Davis ML, Cornwell DA. Introduction to environmental engineering. McGraw – Hill Companies, Inc; New York, 4ed; 2008.
3. Mkoma SL, Mjemah IC. Influence of meteorological ambient air quality in Morogoro, Tanzania. International Journal of Environmental Sciences. 2011;1(6).
4. Ocak S, Turalioglu FS. Effect of meteorology on the atmospheric concentrations of traffic related pollutants in Erzurum, Turkey. J. Int. Environmental Application & Science. 2008;3(5):325-335.
5. Adejuwon JO. Rainfall seasonality in the Niger Delta Belt, Nigeria. Journal of Geography and Regional Planning. 2012;5(2):51-60.
6. Igweze AH, Amagoh MN, Ashinze AN. Analysis of rainfall variations in the Niger Delta Region of Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT). 2014;8(1 Ver. V1):25-30.
7. IITA Meteorological Data: International Institute of Tropical Agriculture (IITA), Onne, Eleme, Rivers State, Nigeria; 1997.
8. Chidolu EO, Nsofor GN. Environmental impact assessment of the Eleme petrochemical complex. In Petroleum Industry and the Nigerian Environment. Proceedings of Seminar, NNPC, Lagos; 1987.
9. Weli VE, Ayoade JO. Seasonal analysis of atmospheric pollutants concentrations in urban and rural landuse areas of Rivers State, Nigeria. International Journal of Environment and Pollution Research. 2014;2(3):1-16.
10. Akpinar EK, Akpinar S, Öztop HF. Statistical analysis of meteorological factors and air pollution at winter months in Elaziğ, Turkey. Journal of Urban and Environmental Engineering. 2009;3(1):7-16.
11. Cai M, Yafeng Y, Min X. Prediction of hourly air pollutant concentrations near urban arterials using artificial neural network approach. Transportation Research Part D Elsevier. Transportation Research Part D. 2009;14:32–41.
Available:www.elsevier.com/locate/trd
12. Elangasinghe MA, Singhal N, Dirks KN, Salmond JA. Development of an ANN–based air pollution forecasting system with explicit knowledge through sensitivity analysis. Atmospheric Pollution Research. 2014;5:696-708.
Available:www.atmospolres.com

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/22383