



STATISTICAL ANALYSIS OF NO_x LEVEL OF AMBIENT AIR WITH METEOROLOGICAL CONDITIONS AT FEW SELECTED ZONE OF KOTA CITY, RAJASTHAN, INDIA.

Chemistry

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ABSTRACT

The present study, reports the relationship between NO_x concentration of three sampling zone and meteorological parameters such as wind speed, temperature and relative humidity that was monitored during the year January 2016- December 2016. The result are analyzed using the multiple linear regression model, pearson correlation and using few general statistical parameters like root mean square deviation, mean deviation, standard deviation and coefficient of determinant. Result show that positive significant correlation between concentration of NO_x and temperature in zone A and zone B while negative correlation has been found to be in zone C. Regression analysis shows that NO_x concentration increases with wind speed and temperature. The regression equations show that there is a good agreement between predicted and measured value. The good correlation coefficients reflect the effectiveness of this equation as well.

KEYWORDS

Meteorological parameters, Regression analysis, Statistical, Pearson coefficients, NO_x air pollution.

INTRODUCTION

The air pollution in urban areas has different characteristics on account of the changing meteorological factors due to rapid Industrial growth an traffic pollution. The level of the air pollution concentrations is correlated with the combination of the various meteorological factors. For that reason, the air pollution concentrations and meteorological data should be evaluated statistically (Demirci & Cuhadaroglu, et al 2000)^[1]. In order to correlate a given set of observations from air monitoring and meteorological stations, calculating statistical relationships among the variables is possible by using some statistical techniques such as regression analysis. Some statistical models establish how close relationships are between concentration estimates and values actually measured under similar circumstances. Effects of all factors that determine atmospheric pollutant concentrations are implicitly accounted for in the air quality data used to develop and optimize the models. These models also have low development cost and resource requirements (Turalioglu et al. 2005)^[2].

There is numerous research presented statistical relationship between meteorological parameters to air pollutants (Witz and Moore et al 1981)^[3] showed the relationship between air pollutants (CO, NO, NO_x, hydrocarbons) and meteorological parameters (wind direction, wind speed, early morning temperature, and frequency of inversions) using a stepwise multilinear regression analysis in Los Angeles in 1979. There is a close relationship between air pollutants and meteorological parameters. (Katsoulis et al 1996)^[4] Presented that air pollutants such as CO, O₃, NO_x concentrations were strongly affected by traffic, wind speed, height of inversion during 1984-1993 in Athens, Greece (Ocak and Demircioglu et al 2002)^[5] used multiple liner regression analysis to estimate SO₂ and PM concentrations using meteorological parameters (relative humidity, temperature, wind speed) and previous day's pollutants concentration in Erzurum for 1995-1996 winter seasons (Dominick et al 2012)^[6] studied the influence of meteorological parameters such as temperature, relative humidity, and wind speed on a daily average computation of PM₁₀ and NO₂ at three selected stations in Malaysia and found that the temperature has a positive correlation to the concentration of PM₁₀ but a negative correlation to relative humidity for all three stations. (Zaharim et al 2009)^[7] studied the interaction between the particulate and temperature and found positive correlation in Malaysia. The associations between meteorological parameters and particulates were studied and found that the increase of rain fall and humidity establishes negative correlation with PM₁₀, and the wind speed inducing the increment of average PM₁₀ concentration in (Giri et al 2008)^[8].

Multivariate statistical approaches such as Multiple Linear Regressions (MLR) are used to predict the relationship between input variables (predictors) and output variables (predicts) without detailing the causes of these relationships (Yang et al 2002, Banergee et al 2011)^[9, 10]. The application of the MLR technique allows the formulation of explicit equations that are simple and can be used to improve understanding (Paschalidou et al 2009)^[11]. The MLR

technique has been used in previous studies (Barrero et al 2006, Banerjee et al 2011, Ghazali et al 2010, Vlachogianni et al 2011, Tai et al 2010, Lykoudis et al 2008)^[12, 13, 14, 15, 16, 17] to investigate the relationship between the concentration of air pollutants and meteorological parameters.

Air pollution problems in an around Kota city is a major concern of the study because more than 20 small and large scale industries as situated in and around Kota city of Rajasthan first major coal fired thermal power plant 1240MW is also located in heart of Kota city. 180 meters high stack continuously release flue gas in to the atmosphere at an approx. velocity of 25m/sec. So as to disperse the emitted gases over a wide spread area.

Kota is located along eastern bank of the Chambal River in the southern part of Rajasthan. The cartographic coordinates are 25.18°N 75.83°E. It covers an area of 318km² (363% of the Rajasthan state.) It has an average elevation of 271 meters (889 ft.) Kota has semi arid climate summer are long, hot and dry starting in late march and lasting till the end June. The average annual rainfall in the Kota districts is 660.6mm.

Air pollution occurs within the atmospheric planetary boundary layer under the combined effects of meteorological factors, earth surface topographic features and releases air pollutants from various sources. Meteorological factors such as wind velocity, wind direction, temperature, and relative humidity together with earth surface roughness are effective agents for mixture of air pollutants. The most important role of meteorology is in the dispersion, transformation and removal of air pollutants from atmosphere. The wind speeds determine the amount of dispersion of pollutants in the atmosphere. By keeping this view in mind my research study has been focus on Statistical analysis of NO_x Level of ambient air with meteorological factors at three selected zone of Kota city, Rajasthan India.

The monitoring and analysis have been carried out through out the year twice in a weak, during the year t January 2016- December 2016.

MATERIAL AND METHODS

1. Study Area

Air monitoring stations was installed at locations such as kerbside, residential, Industrial, outskirts, commercial and sensitive areas of city. The study has been carried out by monitoring ambient air quality for thirty days continuously in each season (winter, pre-monsoon, monsoon and post-monsoon) at each identified location. Analyses of the above monitored parameters were done by the recommended methods. The actual meteorological data obtained from weather monitoring station are used for air quality modeling.

Study area is divided into 3 parts.

Zone: A. Kota super thermal power plant, Kota.

Zone: B. Aerodrome circle, Kota

Zone: C. DCM factory. Kota

More than 5laks populations have been residing within a radius 10kms distance from KSTPS, and other industries in Kota, the normal wind direction is towards south-southwest. Plume from the stacks of KSTPS is in the direction of populated location of the city. For determining the effects of plumes from the stacks of KSTPS and other Industries machine are installed at 3 different location of Kota city as show in Table 1.

Table 1. Air quality monitoring stations at the study areas

Station ID	Station location	Latitude	Longitude
S1	K.S.T.P.S.	25°11'N75°50'E	25.18°N75.83°E
S2	Aerodrome circle	25°11'N75°50'E	25.18°N75.83°E
S3	D.C.M.	25°11'N75°50'E	25.18°N75.83°E

The 3 station are expected to be highly polluted due to industrialization, rapid development and rapid economic growth accompanied by population growth. The locations and coordinates of the selected air quality sampling zone are show in Table 1.

2. Sampling and analysis

High Volume Samplers HVS was the basic instruments used to monitor Ambient Air Quality. Envirotech APM 460 is the “DXNL” version of APM 460NL. It is lighter, more compact, can be carried in a car dickey and is ideal for field use. It can be used either by mounting it on roof tops of van building or separately outside as the requirement of monitoring necessary. Nitrogen Oxides are collected by bubbling air through a sodium hydroxide solution to from a stable solution of sodium nitrite. The nitrite ion produces during sampling is determined calorimetrically by reacting the exposed absorbing reagent with phosphoric acid, sulphanilamide and N (1- naphthyl) ethylendiamine dihydrochloride.

DATA ANALYSIS

1. MLR (Multiple Linear Regression)

Regression analysis can be used to summarize data as well as to study relations between the variables. If the number of independent variables more than one, multiple linear regression analysis is used and general regression equation which four independent variables can be expressed as:

$$Y = A + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + E \tag{1}$$

Where A is constant of regression and B is coefficient of regression. The values of the constant and coefficients are determined using the least-squares method which minimizes the error, seen as E in the above regression equation (Akkaya, et al 1995)^[18]. A commonly used measure of goodness of fit of a linear model is R², sometimes called the coefficient of determination. It is defined as the proportion of the variation in the dependent variable and expressed as:

$$R^2 = 1 - \frac{\sum (\hat{Y}_i - \bar{Y})^2}{\sum (Y_i - \bar{Y})^2} \tag{2}$$

Where \hat{Y}_i is the value of Y predicted by the regression line, \bar{Y} is the value of Y observed, and Y_i is the mean value of the Y_i s. If all the observations fall on the regression line, R² is 1. If there is no linear relationship between the dependent and independent variables, R² is 0. The significance level of the constant and coefficients are statistically tested using the T distribution (Koutsoyiannis, et al 1989; Çuhadaroğlu and Demirci, et al 1997)^[19,20].

In the statistical analysis, the correlations between the air pollutant concentrations and meteorological factors have been analyzed. In spite of establishing the correlations between the air pollutant concentrations and meteorological factors by Eq.(1), the equations expressed as $Y = f(X_1), Y = f(X_2), \dots, Y = f(X_2, X_3), \dots, Y = f(X_1, X_2, X_3, X_4)$ have also been analyzed separately and the independent variables which have small values of R² have been eliminated. Using the remaining variables, equations having one, two, three or four variables are developed (Bowerman and O'Connell, et al 1987, Çuhadaroğlu and Demirci, et al 1997)^[21,20].

1. Pearson correlation analysis

In the present study, the Pearson Correlation (r) is used to find a correlation between at least two continuous variables. The Pearson

value or Pearson correlations is denoted as r. The general formula of the r is shown in Eq.3 (Dowdy et al 1983)^[22]

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{N}}{\sqrt{(\sum X^2 - \frac{(\sum X)^2}{N})(\sum Y^2 - \frac{(\sum Y)^2}{N})}} \tag{3}$$

Where N is the sample size, X the value of the independent variable, and Y the value of the dependent variable. The r value can fall between -1 and +1. A value of r = -1 demonstrates that there is a perfect negative relationship between the two variables. If r = 0, it shows a lack of correlation and a value of r = +1 equates to a perfect positive correlation (Dowdy et al 1983)^[22].

RESULT AND DISCUSSION

1. Monthly average distribution of NOx with meteorological parameters:

NOx monitoring with meteorological parameters of different sampling zone were carried out twice in a weak, an assessment of meteorological influence on NOx concentration were completed using Excel spreadsheets and subsequently data analysis completed using SPSS statistical software tool. Results of NOx monitoring along with temperature, wind speed, wind direction and humidity at all the three selected zone are listed in Table 2,3,and 4.

Analysis was carried out twice in a week at particular monitoring zone, although table contains descriptions of average value of these parameters month wise. During the study period in january2016 – December 2016, highest NOx mean concentration was recorded 41.10 ug/m³ at the Zone A. (KSTPS colony). Next lower concentration is of Zone B. Aerodrome (Motor vehicular traffic – oriented commercial site) has NOx mean concentration less than KSTPS. Zone C. Lowest mean concentration represent near the DCM factory (Planting Areas)

Table 2. Monthly average variation of NOx concentration with Temperature, Humidity, Wind speed and wind direction (January 2016-December 2016).(Zone A)

Sampling Month	Nitrogen Dioxide (NO2) µg/m3	Temperature °C	Wind speed km/hr	Wind direction	Humidity %
Jan-16	36.3	25.77	1.77	11.25	34.22
Feb-16	42.02	27.57	4.71	101.25	30.28
Mar-16	37.00	34.44	3	11.25	19.66
Apr-16	39.29	40	4.33	281.25	16
May-16	39.48	41.87	5	281.25	22.5
Jun-16	33.43	39.11	4.33	281.25	42.66
Jul-16	32.01	29.55	2.66	281.25	79.33
Aug-16	24.34	28	3.88	303.75	83.22
Sep-16	20.38	32.75	3.5	281.25	58.25
Oct-16	25.71	33.5	4.62	303.25	37
Nov-16	32.02	30.88	2.11	101.25	25.55
Dec-16	33.53	26.33	3.11	281.25	37.77

Table 3: Monthly average variation of NOx concentration with Temperature, Humidity, Wind speed and wind direction (January 2016- December 2016)..(Zone B)

c	Nitrogen Dioxide (NO2) µg/m3	Temperature °C	Wind speed km/hr	Wind direction	Humidity %
Jan-16	47.56	25.62	1.50	11.25	35.22
Feb-16	39.37	27.55	2.88	11.25	31.33
Mar-16	40.91	35.22	2.88	101.25	21.66
Apr-16	43.91	39.12	4.50	281.25	19.75
May-16	36.38	41.55	4.88	11.25	25.88
Jun-16	33.51	38.44	4.66	326.25	46.11
Jul-16	34.24	30.25	3.37	11.25	75.37
Aug-16	23.86	28.37	3.00	281.25	79.87
Sep-16	25.78	31.77	3.00	11.25	60.33
Oct-16	29.19	31.11	3.66	11.25	40.00
Nov-16	31.68	30.62	1.50	11.25	25.87
Dec-16	41.54	27.44	3.44	281.25	29.00

Table 4: Monthly average variation of NOx concentration with Temperature, Humidity, Wind speed and wind direction (January 2016 - December 2016).(Zone A)

Sampling Month	Nitrogen Dioxide (NO ₂) µg/m ³	Temperature °C	Wind speed km/hr	Wind direction	Humidity %
Jan-16	45.97	25.50	1.5	11.25	39.25
Feb-16	39.93	28.00	3.75	11.25	28.25
Mar-16	33.34	34.37	3.00	281.25	23.87
Apr-16	44.84	38.55	2.55	281.25	19.44
May-16	42.67	41.44	4.33	281.25	26.56
Jun-16	32.29	40.12	3.25	326.25	38.75
Jul-16	30.76	30.00	3.66	281.25	78.00
Aug-16	21.81	28.66	3.40	11.25	80.88
Sep-16	20.33	32.77	3.33	11.25	58.22
Oct-16	24.64	32.62	3.00	11.25	41.37
Nov-16	30.81	30.55	1.33	11.25	26.00
Dec-16	38.62	27.55	2.88	326.25	29.22

2. Statistical analysis of NOx concentration with meteorological parameters

Descriptive statistical parameters like correlation, mean, root mean square, mean deviation, standard deviation and coefficient determinant were constructed in order to show differences between categories. Statistical parameters of all the three monitoring zone are listed in table 5, 6 and 7.

Table 5: Statistical analysis of Zone A

Statistical Parameters	Concentration of NOx v/s Temperature °C	Concentration of NOx v/s Wind speed km/hr	Concentration of NOx v/s Humidity%
Correlation (R)	0.204482828	0.117517369	-0.65863406
Mean	32.72	18.27208333	36.74791667
Root mean Square	5.0764	1.7320	6.1457
Mean deviation	4.78	14.68708333	10.71173611
Standard Deviation	5.94457151	15.69973968	16.44785356
coefficient of determinant (R ²)	6.778951725	6.877295409	5.21102118

Table 6: Statistical analysis of Zone B

Statistical Parameters	Concentration of NOx v/s Temperature °C	Concentration of NOx v/s Wind speed km/hr	Concentration of NOx v/s Humidity%
Correlation (R)	0.019928572	-0.057424526	-0.669325515
Mean	33.95791667	19.46666667	38.26333333
Root mean Deviation	5.0616	1.6970	5.3851
Mean deviation	5.391909722	16.19416667	11.02805556
Standard Deviation	6.427294366	17.31329614	15.31779887
coefficient of determinant (R ²)	7.661940042	7.650816099	5.693716831

Table 7: Statistical analysis of Zone C

Statistical Parameters	Concentration of NOx v/s Temperature °C	Concentration of NOx v/s Wind speed km/hr	Concentration of NOx v/s Humidity%
Correlation (R)	0.103844954	-0.167650254	-0.64669073
Mean	33.1725	18.41625	37.32583333
Root mean Deviation	5.2488	1.9364	4.4090
Mean deviation	5.677083333	15.41791667	11.49298611
Standard Deviation	7.060218774	16.87896628	16.00103853
coefficient of determinant (R ²)	9.111489932	9.03135885	6.987588487

Table:5, zone (A). Show the highest +ve significant correlation between concentration of NOx v/s temperature and concentration of NOx v/s wind speed r=0.204, wind speed r=0.117 and negative significant correlation was between relative humidity and concentration of NOx (-0.658).

Table:6, zone(B) Show that +ve significant correlation between NOx level and temperature near as -ve correlation is found between wind speed and humidity

Table:7, zone(C) Show that there is significant Correlation between ambient temperature and NOx concentration there as -ve significant correlation is found bet between wind speed and relative humidity.

3. Regression analysis

Nox data together with meteorological parameters such as wind speed, temperature, relative humidity, were analyzed by multiple linear regressions using the EXCELL Software programmer. NOx was considered as dependent variables and meteorological parameters such as temperature, wind velocity and relative humidity were considered as independent variables. The regression equation between meteorological parameters and NOx concentration for different zone are represented as:

Zone A: $NOx = 41.32065 - 0.13497 * [Temperature] + 1.064064 * [Wind\ speed] - 0.1992 * [Humidity] \dots (4)$

Zone B: $NOx = 49.76878 - 0.45796 * [Temperature] + 2.991182 * [Wind\ speed] - 0.25164 * [Humidity] \dots (5)$

Zone C: $NOx = 35.06896 - 0.04712 * [Temperature] + 3.861192 * [Wind\ speed] - 0.31443 * [Humidity] \dots (6)$

This equation reveals that NOx concentration increases with increasing wind speed, temperature, and relative e humidity with the help of equation 4, 5, 6 measured data were compared with calculated ones.

The data set (all values) of January 2016-December 2016 winter season was used for testing regression model. As seen Fig.1, 2, 3 there is a good agreement between predicted and measured values. The good correlation coefficients reflect the effectiveness of this equation as well.

The prediction of NOx is given by the equation $y = -0.006x^5 + 0.197x^4 - 1.970x^3 + 7.558x^2 - 9.432x + 36.80$ for zone A in Fig.1 and for zone B., the equation is $y = -0.011x^4 + 0.406x^3 - 4.476x^2 + 16.82x + 19.87$ in Fig.2 and for zone C the equation is $y = -0.022x^4 + 0.716x^3 - 7.611x^2 + 28.94x + 5.108$, in Fig 3.

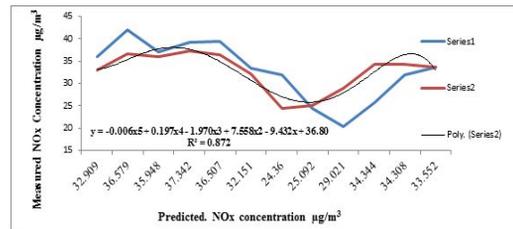


Fig 1 Predicted and Measured value NOx concentration of zone A

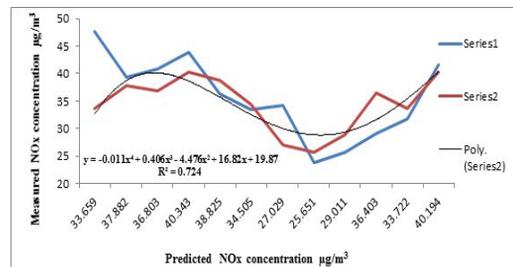


Fig 2. Predicted and Measured value NOx concentration of zone B

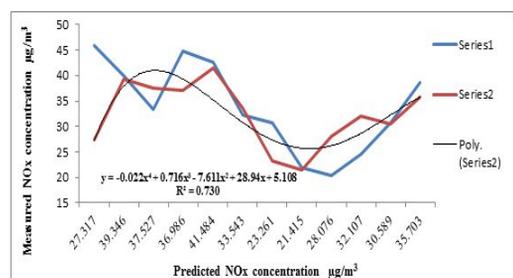


Fig 3 Predicted and Measured value NOx concentration of zone C

DISCUSSION

When we analyze monthly data, we notice that very high level concentration of NOx observed during the winter season. The NOx level lower in post monsoon period or during the monsoon and levels were consistently lower in September to October almost for every sampling zone. The concentration found to different significantly in Pre-Monsoon, Monsoon, Post-Monsoon, and winter.

Many weather parameters temperature and wind direction are to mean factors influences the pollutant load. The influences of wind speed and direction is reported from a study at Kota (Orlic, et al; 1999)^[23].

Temperature affect ambient chemical reactions, radiation sets up photochemical reactions with other pollutants; precipitation and relative humidity largely removes pollutants from the atmosphere (Seinfeld and spynos, et al 1998)^[24] from the result obtain as indicated table 1, 2, 3 and wind rose pictures. It can be seen that at maximum temperature and at maximum winds speed and NOx concentration is higher.

Effect's of humidity on NOx concentration is not very much prominent generally it is seen that high value of relative humidity remove pollutant from the atmosphere. (Seinfeld and spynos, et al 1998)^[24].

CONCLUSION

The present study shows that monthly average concentration of NOx recorded at zone-A, zone B, zone C although analyses has been carried out twice in week at every monitoring station, continuously up to 8hr. but It is difficult to report all data's there for we have taken monthly average concentration of all monitoring zones. from experimental data and graphical data it has been concluded that high concentration of NOx has been observed during the summer season air quality comparatively good then post Monsoon, when wind speed is high the dispersions of air pollutant is all monitoring station has been found to be within permissible limit.

The Pearson correlation analyses indicate significant correlation between air pollutants (NOx) and meteorological factor's (Ambient temperature, relative humidity and wind speed) at the studied location. The analyses show that wind speed has a -ve correlation to the concentration of NOx. The result also show that temperature has a +ve correlation to the concentration of NOx but a -ve correlation to relative humidity for all three station.

These suggest that the wind direction and speed is good indicator for the distributions of both air pollutants. The temperature usually increase evaporation processes and the high relative humidity will lead to the amount of water vapor and rain that will down wash the amount of pollutants.

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