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Multiple linear regression analysis for air pollutant concentrations in Coimbatore city

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ABSTRACT

Air pollution has been aggravated by increasing traffic, rapid economic development and industrialisation, and higher levels of energy consumption. The increase in population, unplanned urban and industrial development has led to the problem of air pollution. The measurements of wind speed and direction, temperature, humidity, rainfall and solar radiation are important parameters used in the study of air quality monitoring results and to further understand the chemical reactions that occur in the atmosphere. Meteorological monitoring is used to predict air pollution events such as inversions, high pollutant concentration days and to simulate and predict air quality using computer models. The objective of this paper is to design an air quality management system.Air quality data was collected from 25 stations in and around Coimbatore city.Regression analysis has been done to establish the effect of the meteorological parameters with the concentration of air pollutants.

KEYWORDS

Particulate matter;
Nitrogen oxide;
Sulphur dioxide;
Meteorological parameters;
Statistical analysis.

INTRODUCTION

Vehicular emissions are of particular concern since these are ground level sources and thus have the maximum impact on the general population. Also, vehicles contribute significantly to the total air pollution load in many urban areas, increase in consumption patterns and higher demands for transport, energy, other infrastructure, thereby leading to pollution problems. The air pollutants can be divided into two groups .The traditional Major Air Pollutants (MAP, comprising sulphur dioxide, nitrogen dioxide, carbon monoxide, particles, lead and the secondary pollutant ozone) and the Hazardous Air Pollutants (HAP, comprising chemical, physical and biological agents of different types). Sulphur dioxide (SO_2) is the classical air pollutant associated with sulphur in fossil fuels. The emission can be successfully reduced using fuels with low sulphur content e.g. natural gas or oil instead of coal[1].Nitrogen oxides (NOx) are formed by oxidation of atmospheric nitrogen during combustion. The main part, especially from cars, is emitted in the form of the nontoxic nitric oxide (NO), which is subsequently oxidised in the atmosphere to the secondary 'real pollutant NO_2. The emissions can be reduced by optimisation of the combustion process (low NOx burners in power plants and lean burn motors in motor vehicles) or by means of catalytic converters in the exhaust[2].

STUDY AREA CHARACTERISTICS

Coimbatore is the second largest city in Tamilnadu. The city has six major arterial roads and three National Highways. Most of the textile industries are situated in Coimbatore. The population of the city is around 1.25 million.There are about 50,000 small, medium and large scale industries in the city. Due to industrialisation and urbanisation Coimbatore's air quality is worsening. The ambient air quality of Coimbatore has deteriorated with an increase in the number of vehicles and industrial pollution.It has been found that in some areas the levels of suspended particulate matter is higher than the WHO prescribed limit of 200 mg/m^3 and respirable particlate matter of 35 mg/m^3.

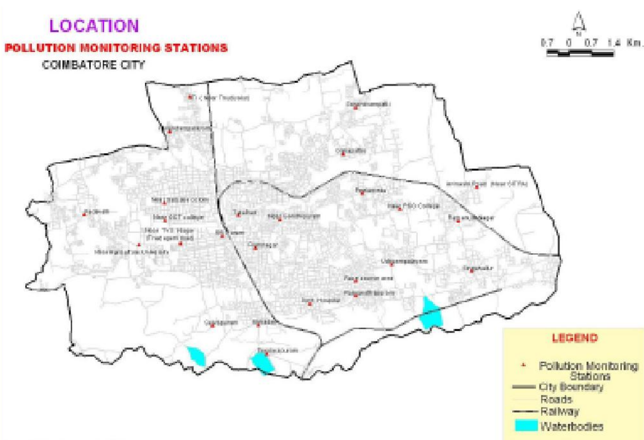

Figure 1 : Locations of monitoring stations

METHODOLOGY

Analysis of particulate matter

The high-volume sampler is used for sampling and monitoring. The high volume air sampler was placed on buildings at a height of 4m, near to the intersection of roads and an average of 8 hours reading were recorded. The sampler uses a continuous duty and TSPM (Total suspended particulate matter) is measured by passing air at flow rate of about 1.1 m^3/min through high efficiency cyclone which retains the dust particles greater then 10 micron size and allows only fines (less than 10 micron particles) to reach the glass micro fiber filter where these particles are retained. When fitted with a particle size classifier, it separates particles greater than 10µm size from the air stream. The air stream is then passed through a filter paper to collect particles lesser than 10µm size (PM_{10}). Gravimetric measurements yield values of suspended particulate matter, as the sum of the two fractions, and PM_{10} is the material retained on the filter paper.

TSPM = Filter paper average + Pouch average

Analysis of NO_X

Air was collected over NaOH solution and analysed by Jacobs and Hochhesier method in the laboratory .The NO_2 produced is allowed to react with H_3PO_4, sulphanilamide and N(1-naphthyl) ethylenediamine dichloride. Air is bubbled through 50 ml of absorbing reagent of NaOH at 200 ml/min for 24 hours.10 ml of the sample is taken and added to 1 ml diluted H_2O_2, 10 ml of diluted sulphanilamide and 1.4 ml of N(1-naphthyl) ethylenediamine dihydrochloride and mixed thoroughly. After 1 hour a purple azo dye is formed and absorbance at 543 nm is measured.

Analysis of SO_2

SO_2 was collected over a scrubbing solution using a sampling train containing $HgCl_4^{2-}$ ($HgCl_2$ +KCl), fitted to the high volume sampler. Sulphur dioxide was analysed using modified West-Gaeke method in the laboratory. The solution is allowed to react with HCHO and then with para-rosaniline hydrochloride. The absorbance of the product red-violet is measured at 548mm.30 to 60 L of air is pumped through 10mL of the scrubbing solution in a small impinger, at 1 to 2l/min. Then 1 ml of dilute pararosaniline reagent solution and 1 ml of 0.2% HCHO solution is added. After 20 to 30 minutes, the absorbance at 560 nm is measured[3].

Meteorological data

Any study of air pollution should include a study of the weather patterns (meteorology) of the local area because the air pollutants are influenced by the movements and characteristics of the air mass into which they are emitted. If the air is calm and pollutants cannot disperse then the concentration of these pollutants will build up. Conversely, if a strong, turbulent wind is blowing any pollution generated will be rapidly dispersed into the atmosphere and will result in lower concentrations near the pollution source. The measurements of wind speed, temperature, humidity, rainfall and solar radiation are important parameters used in the study of air quality monitoring results and to further understand the chemical reactions that occur in the atmosphere. Meteorological monitoring is used to predict air pollution events such as inversions, high pollutant concentration days and to simulate and predict air quality using computer models[4]. The meteorological data was collected from the Surface and Ground water Department at Taramani.

TABLE 1 : Meteorological data

	Average Max. Temp in °C	Average Min. Temp in °C	Average Mean. Temp in °C	Ave. Relative Humidity in %	Ave. Wind Velocity in KMPH	Rainfall in mm
Jan	31.71	17.90	24.81	77.79	4.77	4.60
Feb	34.38	20.23	27.34	77.84	4.89	-
Mar	37.68	23.03	30.37	76.07	3.84	-
Apr	38.47	24.27	31.37	79.30	2.72	37.40
May	38.58	25.07	31.82	77.60	3.38	9.20
Jun	35.12	24.42	29.77	81.74	3.81	24.20
Jul	31.74	23.42	27.57	84.47	2.26	41.20
Aug	32.63	23.07	27.84	83.60	1.73	44.00
Sep	32.55	23.20	27.90	83.18	2.03	20.00
Oct	32.44	22.81	27.63	82.82	1.49	60.20
Nov	31.77	20.70	26.23	82.28	2.45	20.20
Dec	30.26	19.42	24.84	81.24	4.76	70.60

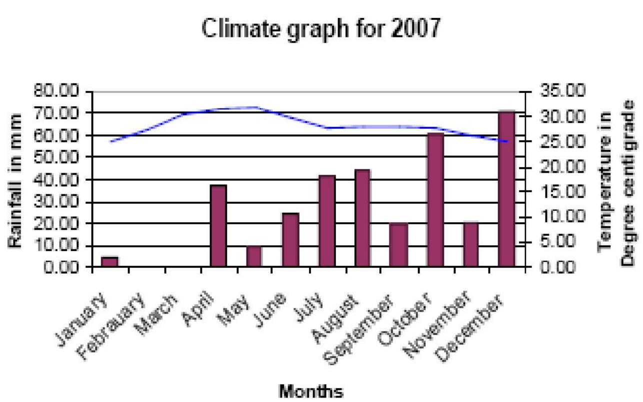

Figure 2 : Climate graph for 2007

RESULTS AND DISCUSSIONS

A box plot is a way of summarizing a set of data measured on an interval scale. It is often used in exploratory data analysis. It is a type of graph which is used to show the shape of the distribution, its central value, and spread. The picture produced consists of the most extreme values in the data set (maximum and minimum values), the lower and upper quartiles, and the median. Box plots are also very useful when large numbers of observations are involved and when two or more data sets are being compared. They are helpful for indicating whether a distribution is skewed and whether there are any unusual observations (outliers) in the data set. Box plots are plotted to find the concentration variations through-

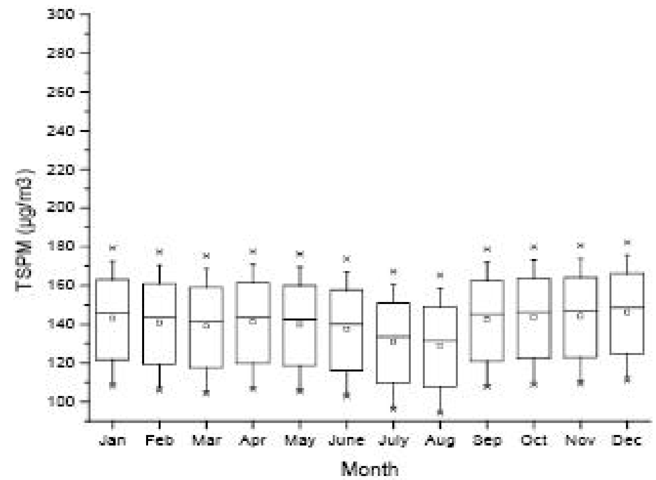

Figure 3 : Monthly concentration of TSPM

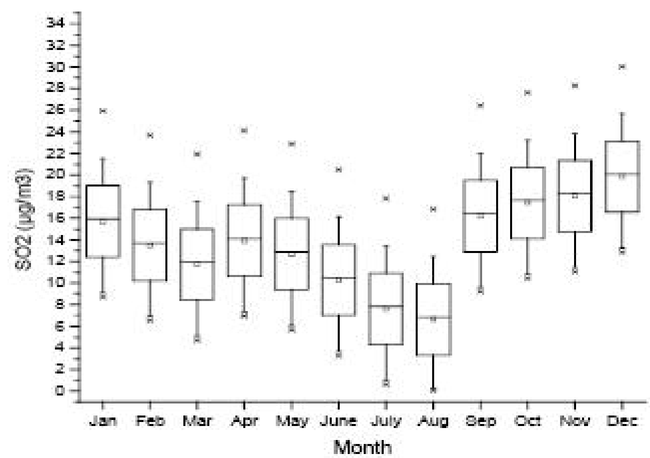

Figure 4 : Monthly concentration of SO_2

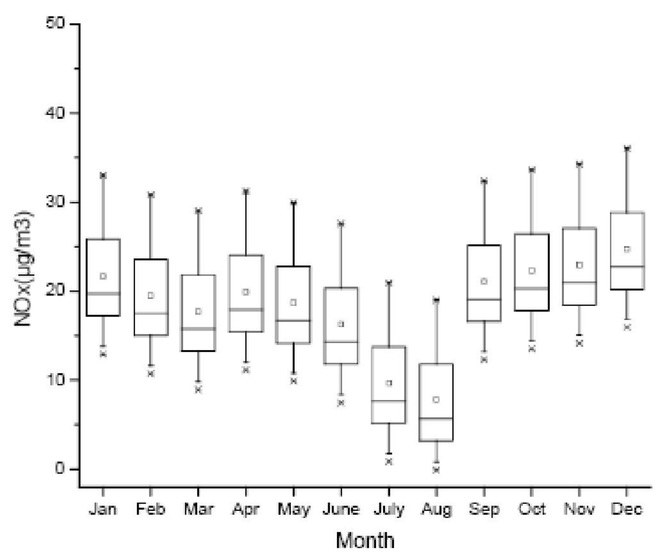

Figure 5 : Monthly concentration of NOx

out the year. It is found that the pollutant concentrations are high during the rainy season.

Linear least squares regression is by far the most widely used modeling method. However, the regression model can be estimated by calculating the parameters of the model for an observed data set[5]. The general purpose of multiple regressions is to learn more about the relationship between several independent or predictor variables and a dependent or criterion variable[6]. Regression analysis was carried out for the data taken during Feb-March 2007 and the results are tabulated as follows:

TABLE 2 : Results of statistical analysis

	TSPM	SO_2	NOx
Multiple R	0.730001	0.662118	0.90563
R Square	0.532902	0.4384	0.820165
Adjusted R Square	0.439482	0.32608	0.784198
Standard Error	16.97328	3.636688	2.271736

The monitored data at the selected 25 stations in Coimbatore City are analyzed by multi regression and the evolved models for prediction of each of the pollutants as a function of the chosen meteorological parameter are given below.

$$SPM = 5.07+3.087*T+1.187*RH-0.118*WD-1.118*WV$$

$$SO_2 = -2.89+0.536*T+0.157*RH-0.033*WD-0.485*WV$$

$$NOx = 5.05+0.879*T+0.181*RH-0.045*WD-0.822*WV$$

T-Temperature; RH- Relative Humidity; WD-Wind Direction; WV-Wind Velocity

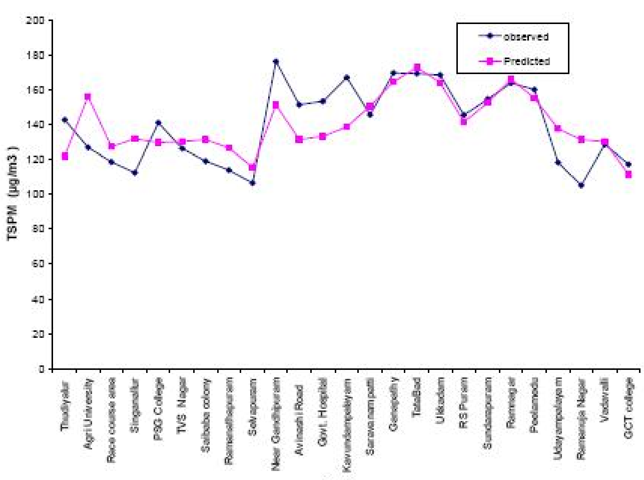

Figure 6 : Observed and predicted values of TSPM

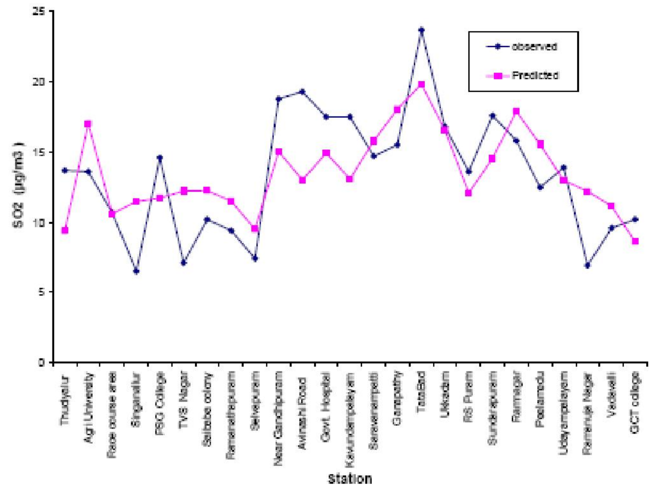

Figure 7 : Observed and predicted values of SO_2

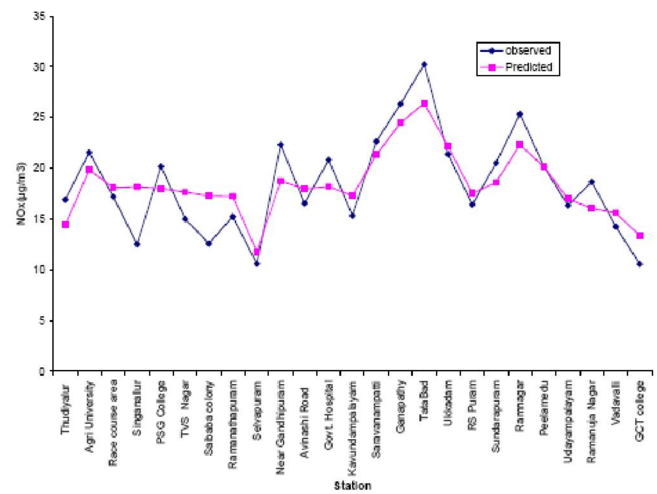

Figure 8 : Observed and predicted values of NOx

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