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STATISTICAL METHODS FOR THE ASSESSMENT OF AIR POLLUTION OF JHANSI CITY, UTTAR PRADESH, INDIA

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ABSTRACT

Studies on air pollution in large cities of India showed that ambient air pollution concentrations are at such levels where serious health effects are possible. This paper presents overview on the status of air quality index (AQI) of Jhansi city by using multivariate statistical techniques. This base line data can help governmental and non-governmental organizations for the management of air pollution.

Figures : 07 References : 18 Tables : 07
KEY WORDS : Air pollution, Air quality Index, Statistical tools, Jhansi

Introduction

In smart India, the increased levels of pollution is a major environmental problem. Pollution has become a great topic of debate at all levels in our country, especially the air pollution because of the enhanced anthropogenic activities. Among the harmful chemical compounds entering the atmosphere as a result of fossils fuels burning are carbon monoxide (CO), sulfur dioxide (SO_2) nitrogen oxide (NO_2), and tiny solid particles including lead from gasoline additive.

Rapid unplanned urbanization, high influx of population, ever increasing automobiles and industrialization amidst urban areas are among the chief sources to result increased air pollution. Smaller size particulate is most likely to cause adverse health effects. India has 23 major cities of over 1 million people and ambient air pollution levels exceed the WHO standards in many of them[4]. The single most important factor responsible for deterioration of air quality in the cities is the exponential increase in the number of vehicles[10]. Vehicular pollution contributes to 70% of total pollution in Delhi, 52% in Mumbai and 30% in Calcutta [3,12]. Pollution in the cities has associated serious to moderate health problems due to high levels of total suspended particulate matter (TSPM), sulfur dioxide (SO_2) and lead. At least 500,000 premature deaths and 4 to 5 million new cases of chronic bronchitis are reported each year. Further 4% to 8% of premature deaths on a global scale are due to exposure to high levels of particulate matter in ambient air[17]. Ambient air levels exceeding the WHO levels in 36 major Indian cities and towns result in 40 thousand premature deaths, around 19 million respiratory hospital admissions and sickness requiring medical treatment and 1.2 billion incidences of minor sickness annually.

To monitor the quality of air in different cities of India, a network of air quality monitoring stations has been established by National Environmental Engineering Research Institute (NEERI), Nagpur in cities where its zonal lab is situated. However, there is no air monitoring station of NEERI in Jhansi[2]. Therefore, in the present study, ambient air quality was monitored at residential and commercial area of Jhansi city to assess the prevailing concentration of the SPM, RSPM, SO_2 and NO_2.

Material and Methods

Jhansi is a city of Uttar Pradesh state of Sourthern India. The city is a major road and rail junction and is the administrative seat of Jhansi District and Jhansi Division. The original walled city grew up around its stone fort, which crowns a neighboaring rock. The National Highway Development Project, initiated by the government of India has sparked Jhansi development. The North-South Corridor connecting Kashmir to Kanya Kumari passes through Jhansi. The East-West corridor also goes through this city, so there has been a sudden rush to infrastructure and real estate development in the city.

Monitoring Site

Two locations selected for air quality monitoring in Jhansi city (Fig. 1) which cover to whole city. Location is divided into different categories as follows

1. Residential area (Shivaji Nagar near University).
2. Commercial area (Shahar, Manik chowk).

Methodology for Estimation of Air Pollutants:

Respirable Dust Sampler (RDS) APM 460 was

TABLE- 1: Methodology for Air Quality Monitoring by Respirable Dust Sampler (RDS) APM 460

Particulars	RSPM	SPM	SO_2	NO_2
Sampling equipment	Respirable Dust Sampler (RDS) APM 460	Respirable Dust Sampler (RDS) APM 460	RDS with gaseous sampling attachment	RDS with gaseous sampling attachment
Collection Media	Glass fibre filter paper	Dust cup	TCM (Tetrachloromercurate)	NaOH plus sodium arsenite
Flow Rate	1.0-1.3 m^3 / min	1.0-1.3 m^3/min	0.5 L/min	0.5 L/min
Analytical Method	Gravimetric method	Gravimetric method	Spectrophotometry method (West and Gaeke method)	Spectrophotometery method (Jacobs-Hochheiser)
Time Frequency	8 Hourly	8 Hourly	4 Hourly	4 Hourly
Sampling Duration	Continuously for 24 Hours	Continuously for 24 Hours	Continuously for 24 Hours	Continuously for 24 Hours

used for collecting air samples from different localities of city. The Respirable Dust Sampler is popular and frequently used equipment for the determination of Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM), SO_2 and NO_2 gaseous pollutants.

Air Quality Index (AQI):

AQI is developed to provide the information about air quality. From a series of observations, an index (a ratio or number) is derived which is an indicator or measure of condition or property the concentration of the major pollutants based on monitored and subsequent converted into the AQI (Table-2) using standard formula[15].The categorization of ambient air quality on the basis of AQI is presented in Table 2.

TABLE- 2 : Shows the Air Quality Categories Based on AQI

II	10-25	Clean
III	25-50	Fairly clean
IV	50-75	Moderately polluted
V	75-100	Polluted
VI	100-125	Heavily Polluted
VII	> 125	Severely Polluted

The air quality index (AQI) was calculated using the method[15]. First of all, the air quality rating of each pollutant was calculated by the following formula:

$$Q = \frac{V \times 100}{Vs}$$

Where Q= Quality rating,

V= the absorbed value of the pollutants,

Vs= Standard value recommended for that pollutants.

TABLE-3 : Shows the National Ambient Air Quality Standards (NAAQS) for 24 hours time average

Pollutants	**Concentration in Ambient air (ig/m^3)**	
	Residential area	**Industrial area**
SO_2	80	80
NO_2	80	80
SPM	200	500
RSPM	100	100

Source: Central Pollution Control Board (CPCB), 2009 New Delhi India.

TABLE-4 : Quantitative chemical analysis result of air quality of commercial area of Jhansi city during January 2011 to December 2015

S.No.	2011				2012				2013				2014				2015			
Month/ Parameter	SO_2	NO_2	RSPM	SPM	SO_2	NO_2	RSPM	SPM	SO_2	NO_2	RSPM	SPM	SO_2	NO_2	RSPM	SPM	SO_2	NO_2	RSPM	SPM
January	10.15	29.56	147.43	308.57	9.58	26.87	139.13	287.03	9.41	26.41	132.36	269.79	7.16	18.60	138.03	277.10	8.29	19.45	113.19	238.26
February	9.08	28.33	146.00	298.77	8.71	27.99	137.93	279.33	8.59	23.77	124.80	259.47	7.23	23.47	111.88	222.46	9.01	28.27	138.85	284.23
March	9.21	28.33	140.17	282.37	9.36	27.27	135.93	278.70	8.54	24.80	112.40	232.87	7.01	19.91	93.40	197.87	7.32	21.16	134.22	274.96
April	9.55	26.79	137.80	284.63	8.38	24.12	141.30	295.13	7.96	24.81	137.40	285.97	8.41	21.25	128.63	270.40	8.45	20.62	139.80	282.53
May	10.25	28.26	131.27	275.83	9.37	27.57	133.20	275.23	8.33	25.23	134.27	272.58	10.18	27.93	132.03	276.27	8.98	21.76	136.74	280.07
June	9.15	21.18	130.77	274.37	8.60	25.39	139.90	285.33	6.45	18.16	111.97	231.73	9.08	20.68	136.97	278.56	9.38	24.19	142.89	286.19
July	7.39	20.42	100.60	219.90	6.69	17.37	64.97	148.43	5.16	14.65	38.07	80.21	7.35	20.00	117.93	253.30	7.33	19.68	108.63	217.85
August	7.14	20.43	110.13	225.30	7.23	19.51	87.60	186.03	5.46	17.21	73.70	154.77	7.14	19.91	100.83	211.93	7.27	22.69	108.11	222.04
September	8.29	25.37	111.63	233.73	6.08	18.06	79.41	171.69	8.01	25.75	128.87	267.33	7.76	21.81	127.17	262.87	8.56	26.78	122.00	247.37
October	8.31	22.57	130.90	266.60	7.49	18.31	142.00	286.50	7.03	19.87	111.73	233.30	10.47	23.30	151.83	301.80	7.16	26.35	130.85	265.59
November	8.99	21.72	138.07	286.80	10.20	19.78	151.67	311.27	8.19	21.53	134.80	271.93	9.40	27.88	144.63	295.03	10.84	25.17	164.84	325.84
December	9.91	26.88	132.33	275.23	9.62	23.54	136.93	283.87	8.27	23.56	148.63	303.67	8.14	20.50	99.93	208.83	7.35	22.45	119.92	249.58
AQI	48.97				46.77				45.65				45.70				46.77			

TABLE-5 : Quantitative chemical analysis result of air quality of residential area of Jhansi city during January 2011 to December 2015

S.No.	2011				2012				2013				2014				2015			
Month/ Parameter	SO_2	NO_2	RSPM	SPM	SO_2	NO_2	RSPM	SPM	SO_2	NO_2	RSPM	SPM	SO_2	NO_2	RSPM	SPM	SO_2	NO_2	RSPM	SPM
January	9.42	27.00	118.23	247.40	7.22	19.92	109.67	235.17	6.72	18.69	109.00	216.90	5.98	16.71	106.17	224.87	8.25	25.58	108.68	220.60
February	8.00	26.33	118.43	249.77	8.03	20.18	101.43	211.20	7.21	16.34	90.92	180.54	6.52	15.72	67.63	131.63	7.88	26.25	113.69	234.19
March	8.24	24.71	112.07	228.33	8.35	21.82	97.10	203.93	5.95	17.92	93.20	199.67	5.75	17.70	87.57	174.80	6.25	20.30	100.00	212.00
April	8.12	24.38	108.77	235.63	6.36	20.39	108.67	230.23	7.05	21.78	108.73	226.53	7.02	18.67	94.24	202.47	7.01	19.68	113.17	235.47
May	8.28	26.00	114.73	243.17	8.37	22.99	117.57	245.80	6.36	18.06	100.71	209.81	8.19	25.41	114.67	242.93	7.26	20.32	123.09	256.96
June	6.98	18.32	105.27	222.67	7.81	19.92	117.47	245.23	5.34	16.85	80.23	167.53	7.10	19.39	93.67	197.77	7.21	21.10	117.37	242.67
July	6.70	18.41	75.50	160.97	5.69	13.30	55.87	121.45	4.50	13.48	50.38	114.69	6.33	17.25	84.33	179.20	5.38	16.55	79.52	156.78
August	6.49	18.53	85.07	175.07	5.81	16.50	59.31	126.62	4.72	14.69	49.67	104.73	5.63	18.41	78.43	170.13	6.09	20.73	90.85	178.28
September	7.22	19.95	83.27	178.43	6.16	14.04	56.76	118.79	6.84	23.97	109.33	222.30	6.44	21.43	100.07	210.20	7.39	21.31	94.22	188.89
October	6.98	19.50	120.30	238.53	6.97	14.08	93.33	199.73	5.97	17.66	94.40	196.90	8.02	20.38	128.80	260.30	5.72	19.04	100.81	212.70
November	7.58	19.63	114.33	240.23	7.55	19.23	120.33	247.57	7.29	19.41	118.27	234.20	8.32	22.87	106.53	224.43	9.41	22.34	135.15	263.74
December	9.04	22.68	113.47	237.37	6.31	22.02	115.30	237.73	6.91	20.49	135.70	280.33	5.88	18.36	80.67	169.77	6.52	20.36	104.42	219.08
AQI	41.68				37.15				34.67				37.15				39.81			

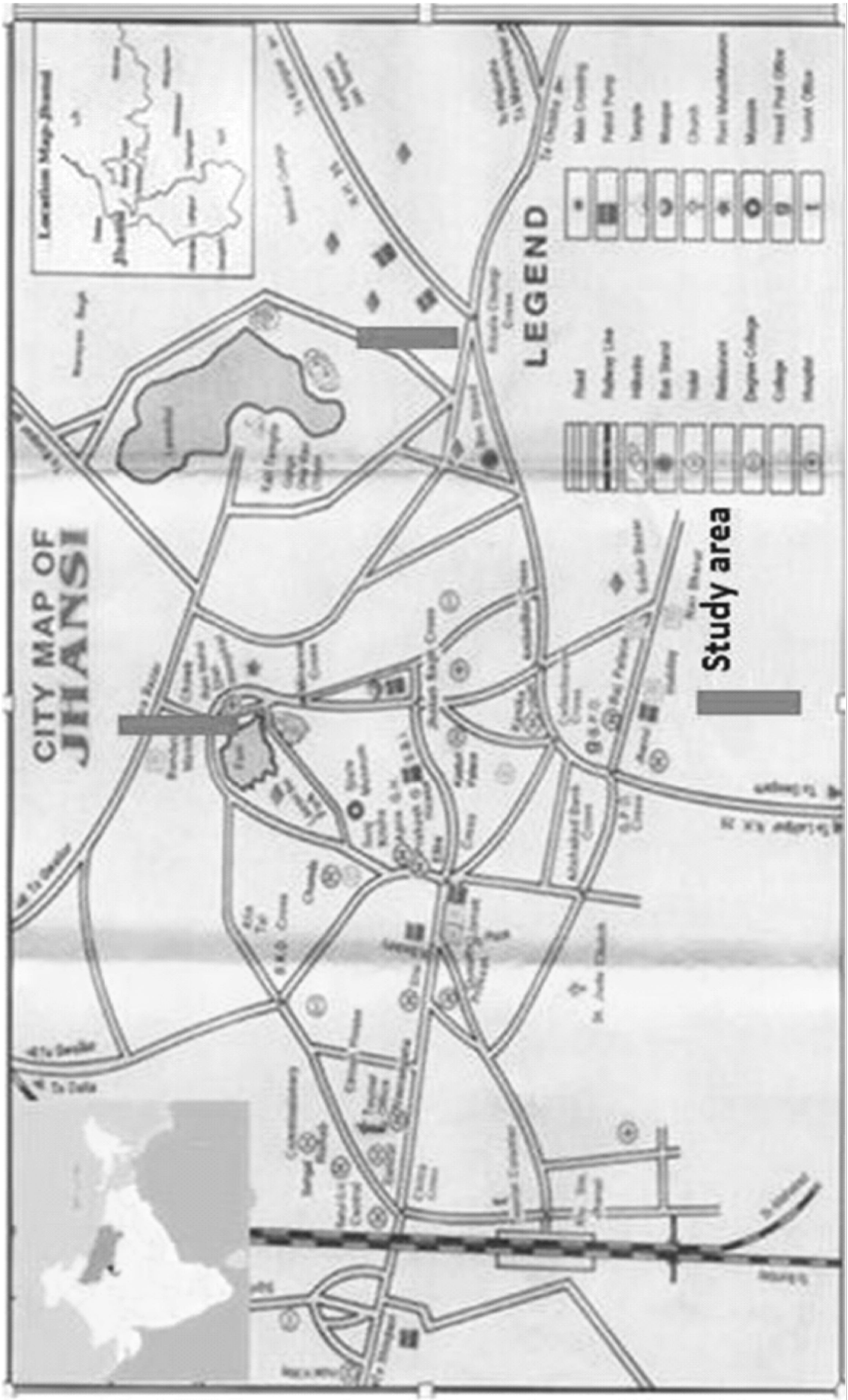

Fig. 1: Study Area

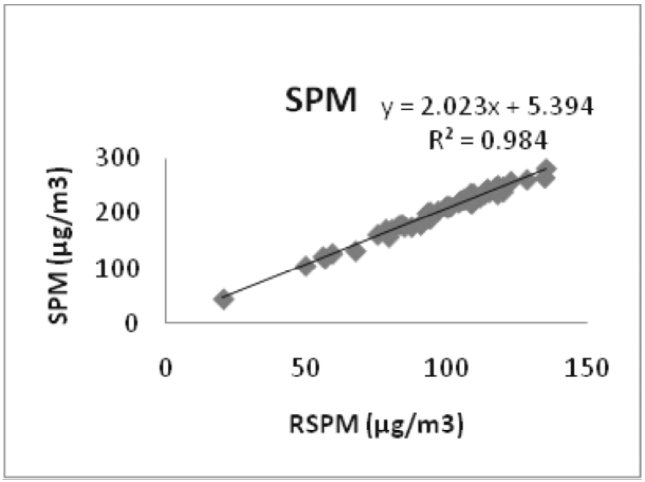

Fig. 2 : Scatterplot of RSPM versus

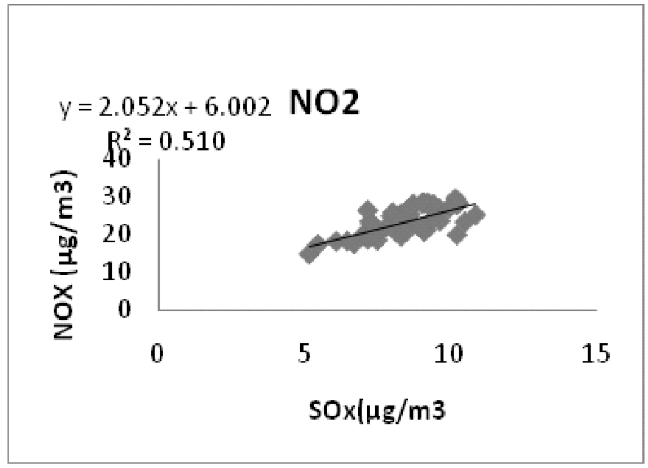

Fig. 4 : Scatterplot of SO_2 versus

The Vs value used as the recommended national ambient air quality standard (Table-1) for different areas.

Indicates the number of pollutants considered for air quality monitoring. Then, geometric mean of these n number shows the quality rating as calculated in the following way

$$G = \text{Anti log} \frac{(\log_a + \log_b + \log_c + \ldots\ldots\ldots\ldots \log_x)}{n}$$

Where G= geometric mean, while a, b, c and x represent different values of quality rating and "n" is the number of values quality rating.

Statistical Analysis

Pearson Correlation: Pearson correlation coefficient is commonly used to measure and establish the strength of a linear relationship between two variables or two sets of data. It is a simplified statistical tool to show the degree of dependency of one variable to the other[1]. The Pearson correlation coefficient (r*xy*) is computed by using the formula as given [6,7,11]. The correlation co-efficient „r was calculated using the equation-

$$r_{xy} = \frac{n \sum (x_i y_i) - (\sum x_i) - (\sum y_i)}{\sqrt{[n \sum x_i^2 - (\sum x_i)^2] \; [n \sum y_i^2 - (\sum y_i)^2]}}$$

Where Xi and Yi represents two different parameters

n = Number of total observations.

The correlation coefficient is always between -1 and +1. A correlation closer to +/- 1 implies that the association is closer to a perfect linear relation. Interpretation of the Pearson correlation coefficients, adopted in the present study are: r = -1 to -0.7 (strong negative association); r = +0.7 to +1.0 (strong positive association); r = -0.7 to -0.3 (weak negative association); r = +0.3 to +0.7 (weak positive association); r = -0.3 to +0.3 (negligible or no association). Thus, for the eleven water quality parameters, the possible correlations between every pair were computed using SPSS (Version 17.0) and are arranged into a correlation matrix. Precisely, a correlation matrix is a table of all possible correlation coefficients between a set of variables.

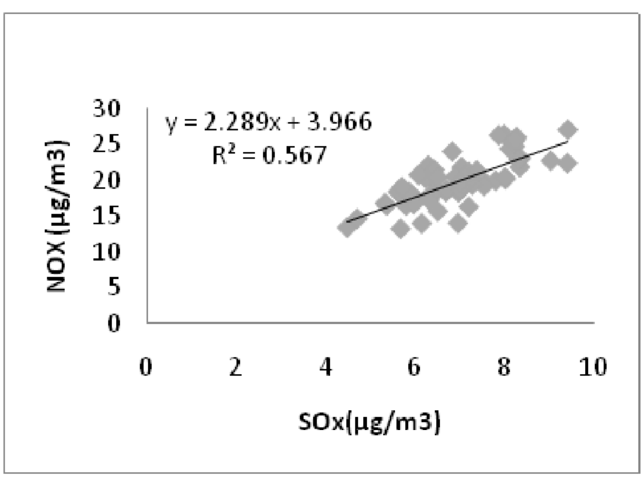

Fig. 3 : Scatterplot of SO_2 versus NO_2

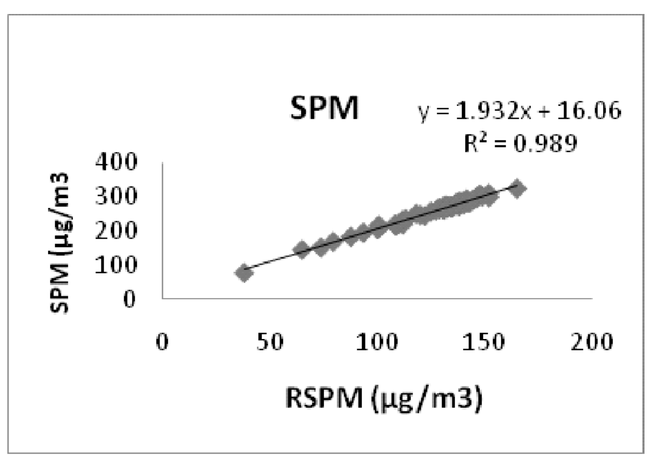

Fig. 5 : Scatterplot of RSPM versus

TABLE-6 : Correlations of commercial area (C)

Correlations of commercial area (C)				
	SO2	NO2	RSPM	SPM
SO_2	1	.753**	.707**	.705**
NO_2	.753**	1	.696**	.704**
RSPM	.707**	.696**	1	.992**
SPM	.705**	.704**	.992**	1
**. Correlation is significant at the 0.01 level (2-tailed).				

Linear Regressions: In this study, we have applied the linear regression approach to develop a relationship between several independent/predictor variables and a dependent/predict and variables. This method is successfully used by different authors to establish statistical model[14].

Cluster Analysis: Cluster analysis (CA) is one of a large family of statistical techniques whose main purpose is to categorize entities *e.g.* sampling sites into distinct groups or clusters according to some criteria, such that the within-group similarity is maximized and among-group similarity is minimized. Hierarchical agglomerative clustering is the most common approach, which provides intuitive similarity relationships between any one sample and the entire data set[8]. The Euclidean distance is a commonly used distance coefficient, which usually gives the similarity between two samples and a distance that can be represented by the difference between analytical values from both the samples[9]. The result of hierarchical clustering is typically illustrated by a dendrogram (a tree-like plot), which provides a visual summary of the agglomeration processes, depicting a picture of the clusters and their similarity, with a dramatic reduction in dimensionality of the original data set[13]. It is done by using SPSS software version 20.

Results and Discussion

Ambient air quality of residential and commercial area of Jhansi City has been monitored for five years since January 2011 to December 2015 tabulated in Table-4 and 5. The present study indicates the air pollutants concentrations and air quality index (AQI) at four monitoring sites of Jhansi city. Tables-3 and 4 represent the correlation between different parameters at selected monitoring sites. Figures 2 to 5 represent the regressions between different parameters. clustering of air pollution

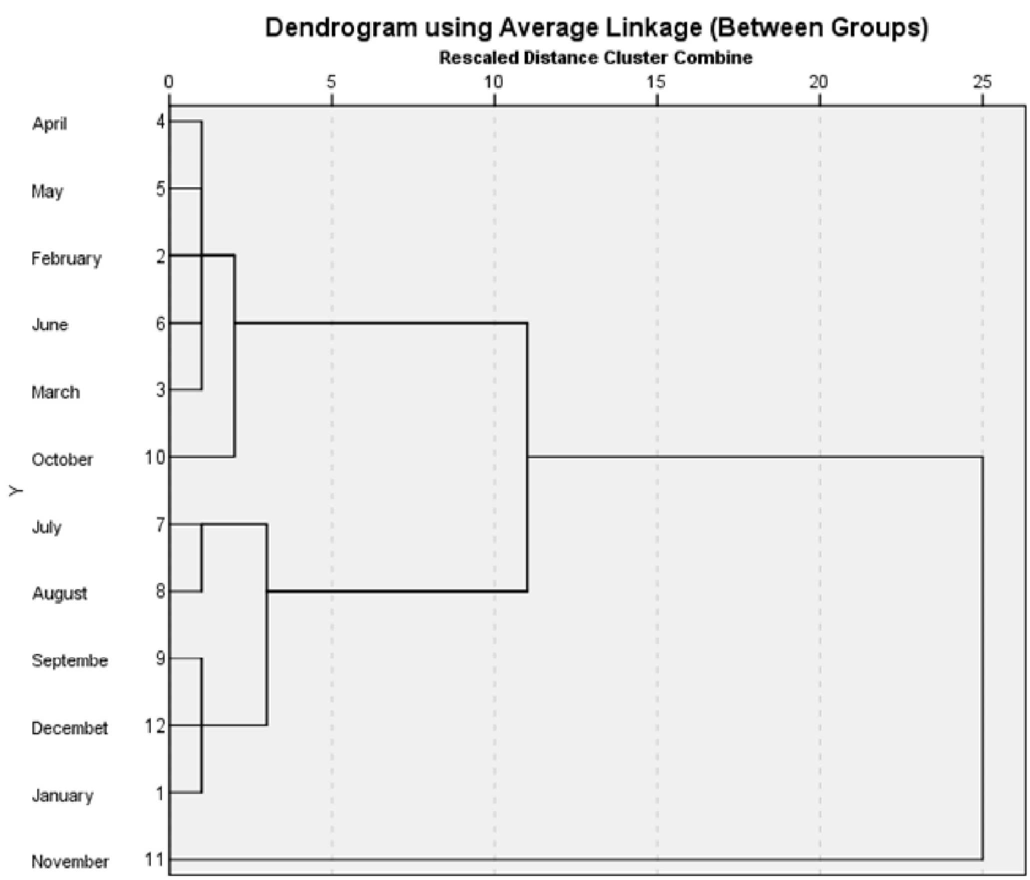

Fig. 6 : Commercial Area

TABLE-7: Correlations of Residential area (R)

Correlations of Residential area (R)				
	SO2	NO2	RSPM	SPM
SO_2	1	.715**	.784**	.795**
NO_2	.715**	1	.624**	.632**
RSPM	.784**	.624**	1	.995**
SPM	.795**	.632**	.995**	1
**. Correlation is significant at the 0.01 level (2-tailed).				

status at different month also present in Figs. 6 and 7.

Gaseous Pollutants

Sulphur dioxide can cause irritation of visibility and respiratory diseases. Healthy persons are mostly affected by broncho-construction at 4540 ìg/m^3 of SO_2 for a few minutes exposure. Throat irritation occurs at 33800 ìg/m^3 level. At 56400 ìg/m^3 SO_2 concentrations may cause immediate cough and eye irritation. Exposure ranges from 400 to 500 ppm of sulphur dioxide even for a few minutes is highly dangerous to human life[2]. The concentration of the SO_2 recorded in the study areas has been ranged between 4.5 to 10.47ìg/m^3. Residential area has lower values of SO_2 (4.5 ìg/m^3) compared to commercial area value of SO_2 (10.47ìg/m^3).

Nitric oxide (NO) and nitrogen dioxide (NO_2) are also of great concern to human health. NO is not irritating and it will not cause any adverse health effects at atmospheric concentrations. But when NO undergoes oxidation to NO_2, it poses health hazards as oxidant. Hemoglobin has 300000 times more affinity for absorbing NO_2 than O_2, which reduce oxygen carrying capacity of the blood. Nitrogen dioxide at high-level exposures in the range of 150 ppm (285 mg/m^3) and above may be fatal to humans [2]. The concentration of the NO_2 recorded in the study areas have been ranged between 13.48 to 29.56 ìg/m^3 . Residential area has lower values of NO_2 (13.48 ìg/m^3) compared to commercial area value of NO_2 (29.56ìg/m^3). The value of NO_2 in the commercial, residential and sensitive areas was within the prescribed value (80ìg/m^3) by the National ambient air quality standards.

SPM and RSPM

When particulate matter of different particle size is inhaled by human beings, it gets deposited in various parts of the respiratory system, with reference to mining and rock crushing areas. If particle size is greater than 10 ìm, they are retained by the cilia of the nose whereas if the size of the particles is less than 10 ìm they may enter the upper respiratory tract. The upper respiratory tract consists of nasal cavity, nasal pharynx, larynx and trachea. The size of the particles ranges from 2 to 10 microns may enter specially into the trachea but the movement of cilia sweep mucus upward, carrying particles from windpipe to mouth, where they can be swallowed. The lower respiratory tract consists of bronchi, bronchioles, alveolar ducts, alveolar sacs and alveoli of the lungs. Particles size less than 2 microns are deposited mostly in bronchioles but few of them may reach the alveolar ducts. A particle size ranges from 0.25 to 1 ìm enter mainly the alveoli of lungs and gets deposited. It reduces the volume of the alveoli thereby causing damage to the lungs by minimizing the oxygen exchange from air to blood. The concentration of the RSPM monitored in the study areas were ranged within 49.38 to 167 ìg/m^3 and SPM is recorded between 108 to 325 ìg/m^3.

Air quality index (AQI):

Air Quality Index (AQI) is developed to provide the information about air quality. Air Quality Index (AQI) was introduced by the Environmental Protection Agency (EPA) in USA to measure the levels of pollution due to major air pollutants. It is one of the important tools available for analyzing and representing air quality status uniformly. The higher value of an index refers to a higher level of air pollution. In the present investigation, the RSPM, SPM, NO_2 and SO_2 levels in different years at both selected sites have been used to calculate AQI.

Site 1 commercial Area showed air quality index (AQI) varied from45.65 (year 2011) to 48.97 (year 2015) and rating scale as FC "Fairly clean", during study period. Site 2 showed air quality index (AQI) varied from 34.67 (2011) to 41.68 (2015) and rating scale as FC "Fairly clean", during study period.

Correlation Analysis

At site 1 (Table VI) correlation of SO_2 with NO_2 (r = .753, p<0.01); SO_2 with RSPM (r = .707, p<0.01); SO_2 with SPM (r = .705, p<0.01); NO_2 with RSPM (r = .696, p<0.05); NO_2 with SPM (r = .704, p<0.01); SPM with RSPM (r = .992, p<0.01); At site 2 (Table VII) residential area correlation of SO_2 with NO_2 (r = .715, p<0.01); SO_2 with RSPM (r = .784, p<0.01); SO_2 with SPM (r = .795, p<0.01); NO_2 with RSPM (r = .624, p<0.05); NO_2 with SPM (r = .632, p<0.05); SPM with RSPM (r = .995, p<0.01);

Cluster analysis

Cluster analysis (CA) was employed to identify groups of similar monitoring months and explore spatial heterogeneity of air quality at different sites. It generated a dendrogram, grouping the 12 months into two distinct clusters. Months 4,5,2,6,3,10 situated in commercial area

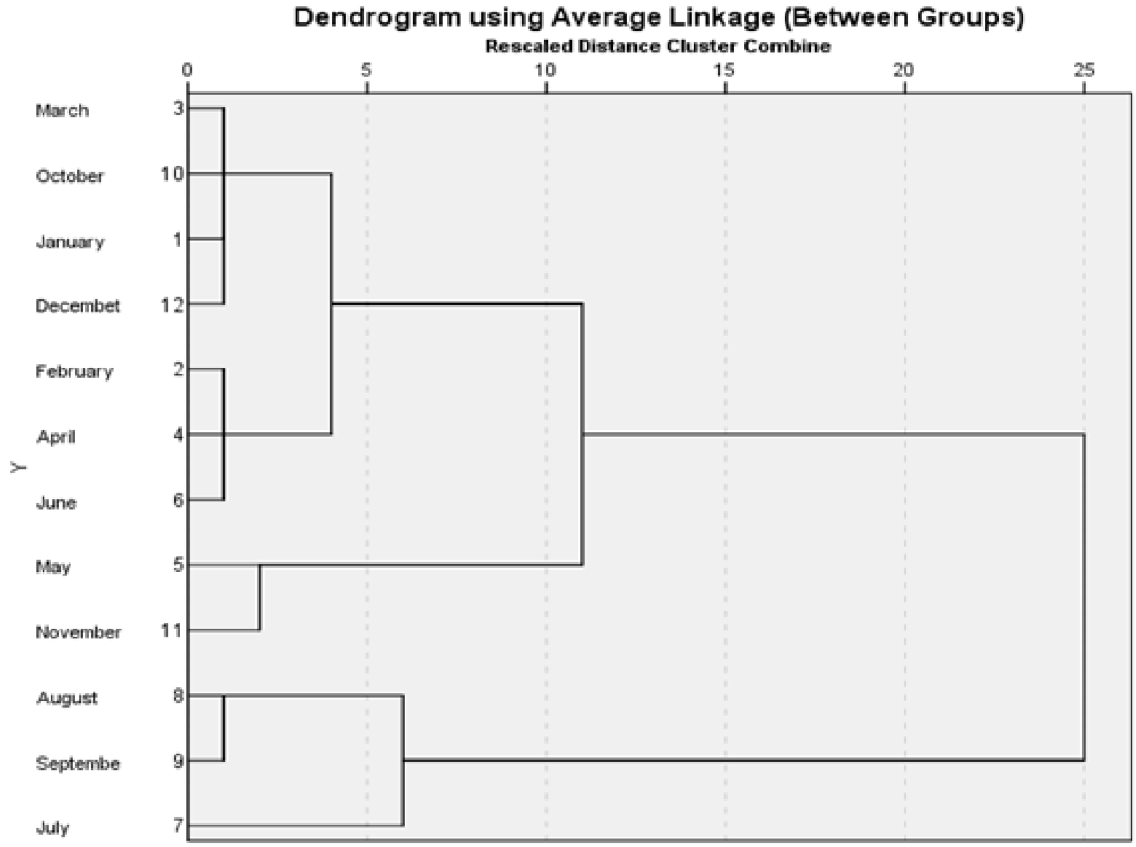

Fig. 7 : Residential Area

classified in similar group and 7 and 8 months in same group 9,12,1,11 in same group which are alike (Fig). Months 3,10,1,12 situated in residential area classified in similar group and 2,4 and 6 months in same group 5,11 and 8,9,7 in same group which are alike (Fig).

Conclusion

In Bundelkhand, especially Jhansi region and its adjoining area are highly affected by the particulate matters and have reached alarmingly at high levels of SO_2 and NO_2 air pollutants due to mining and rock crushing activities over past two decades. Around the mining sites lie within 5 Km radius, a number of private and government hospitals, schools and University are situated which come under the highly dust pollution zone. Analysis of the ambient air quality data monitored over five years since 2011 to 2015 reveal that some of the pollutants, especially particulate matter exceeds the National Ambient Air Quality standards (NAAQS) set by the central pollution control board (CPCB) New Delhi.

The respirable suspended particulate matter and suspended particulate matter (RSPM and SPM) concentration of 49.38 to 167 ìg/m^3 to 108 to 325 ìg/m^3 recorded respectively during investigation. As Indians have short life span, the total impact on life year lost due to air pollution is greater than in developed countries. It is necessary to use a rating system, such as air quality index (AQI) which will provide information about the air quality of concerned area. It is noted that the low the AQI rating scale value 48.57 for commercial area and 34.67 for residential area is good for health. This AQI data will be used to enable the public to take appropriate precautions to safeguard themselves and their families and also communities against exposure to air pollution levels in the granite geo- mining terrains in Jhansi region. For the reduction of air pollution levels, one has to take enforce regulatory measure for local impact.

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