Status of air quality in and around stone crusher at Jhansi Town, U.P. India.

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Abstract:

Bundelkhand is a wealthy economic region of central India and also known as granite mining zone or stone belts. Rapid growing of population poses increasing of industrialization and infra systems with burgeoning infrastructure zone, stone crushing is turning into an essential enterprise. It engaged in generating crushed stone of various sizes as in line with the requirement of respective construction activities including highways, bridges, colonies, production of road, and canals. Stone crusher creates a lot of noise and it emits large and fine particles in surroundings, because of greater attention of respirable particles in air and creates pollution.

During the investigation the samples were amassed from ten distinctive sites for suspended particulate matter (SPM), respirable suspended particulate matter (PM_{10}), oxides of sulfur (SOx) and oxides of nitrogen (NOx) in the period of December 2015 to Novrmber 2016 from residential and industrial areas .It was noticed in this study that the SPM and RSPM levels at all selected sites exceeds the prescribed limits of the NAAQS as stipulated by central pollution control board (CPCB) New Delhi. The average ambient air concentration of SO_x and NO_x were found below the permissible limits of NAAQS of CPCB at all the study sites. This paper present over view on the status of air quality index (AQI) of in and around of stone crusher in Jhansi town by using multivariate statistical techniques. This baseline data can be help governmental and non-governmental organization for the management of air pollution.

Keyword: Air quality, AQI, Stone crusher, Statistical technique

Introduction

In developing countries, the increased levels of pollution are a major environmental problem. Pollution has become a great topic of debate at all levels in India, especially the air pollution because of the enhanced anthropogenic activities (Chauhan et. al. 2016).

Stone crushing in India is basically a labor intensive small scale industry, where most of the operations are performed manually (Aslam et al. 1992). It is estimated that there are over 12,000 stone crusher units in India. The Stone Crushing Industry sector is estimated to have an annual turnover of Rs. 5000 crore (equivalent to over US$ 1 billion) and is therefore an economically important sector. The sector is estimated to be providing direct employment to over 500,000 people engaged in various activities such as mining, crushing plant, transportation of mined stones and crushed products etc. Most of these personnel are from rural and economically backward areas where employment opportunities are limited and therefore it carries greater significance in terms of social importance in rural areas. It is a source of earning for uneducated poor unskilled rural people. The stone crusher is one such industry that exists in the vicinity of almost all major cities/towns throughout the country in all the states because the construction activities go on throughout the country. (CPCB report 2007-08).

It has small scale stone crushers in unorganized sector in different mountainous areas. These crushers provide basic material for road and building construction. They are engaged in highly labor intensive activities. It provides not only raw material for construction of roads, buildings, bridges, etc. but also provides livelihood to the local people. Different stages of stone crushing process involve drilling and blasting of rocks, transportation of the raw material, crushing, screening, size classification, material handling, storage operations and transportation of final product. Mining operations cause significant emissions of suspended particulate matter (SPM) in the atmosphere (Csavina, et al., 2012; Titi et al. 2015). During the stone crushing operation, large size stone, mined from quarries in the size range of 200–300 mm, is crushed to smaller usable sizes, generally 6, 12, or 25 mm. Many crushed stone operations tend to be located relatively near populated areas or on the highways to avoid high transportation costs. This can result in dust associated health problems in addition to automobile pollution problems along the highways (Sivacoumar and Thanasekaran 2001).

The risks of accidents are increased when the crushers are located near the highway. In the absence of proper control devices in these units, the work place can become highly polluted (Central Pollution Control Board 1984).The over hundred stone crusher units established around Jhansi city, Uttar Pradesh, India which was generate high concentration of crushing dust in the locality of the crusher unit/plants and spread out its adjoining areas.

These stone crushers are important for local economy but have adverse effect on air quality due to emission of dust particles in surrounding area. This results in respiratory diseases, low visibility in nearby area and reduction in growth of vegetation. Even though stone crushers are socio-economically important sectors yet they give rise to the quantity of fine dust emission which create health hazard to the workers as well as surrounding population. The dust also adversely affects visibility, growth of vegetation and aesthetic area. The various parameters on considered for the analysis of ambient air quality like Oxides of Sulphur (SO_x), Oxides of nitrogen (NO_x), respirable suspended particulate matter(RSPM)and suspended particulate matter (SPM).

Material and Methods

Study Area: Jhansi is one of the important districts out of the five districts of Bundelkhand massif of Uttar Pradesh occupies almost 70,000 square kilometers of the central plains in India. The Bundelkhand massif covers about 26000 sq. Km of the total area of the southern Uttar Pradesh and north-eastern Madhya-Pradesh in central India and forms the northern fringes of the Peninsular Indian shield. The district Jhansi lies in southwest portion of Jhansi division of Uttar Pradesh state of India between 25º 30' N and 25º 57' N latitudes and 78º 40' E and 79º 25' E longitudes. The present study area of the district according to survey of India is covering 5,024 square kilometers. Jhansi falls under a semi arid climate, with two main seasons specially Monsoon and Dry. Mining and rock crushing are the major essential activities that provide the raw material for society. Also, Jhansi is known one of the important granite mining centers in the Bundelkhand region.

For the five air quality monitoring stations were selected nearby crusher plant while other rest five stations in satellite village of the operational unit.

Table-1: Air Quality Monitoring stations in Jhansi region.

	Name of stone crusher plant	**Village**
1.	**Sri mahamaya Stone Crusher**	**Lakshamanpura (Allahabad Road)**
2.	**Pitambera stone crusher**	**Bijoli (Lalitpur road)**
3.	**Lakshami Stone crusher**	**Goramacchiya (Kanpur road)**
4.	**Mahendra singh Gurjar Stone Crusher**	**Karari (Gwalior Road)**
5.	**Pratappura Industrial Area**	**Pratapura**

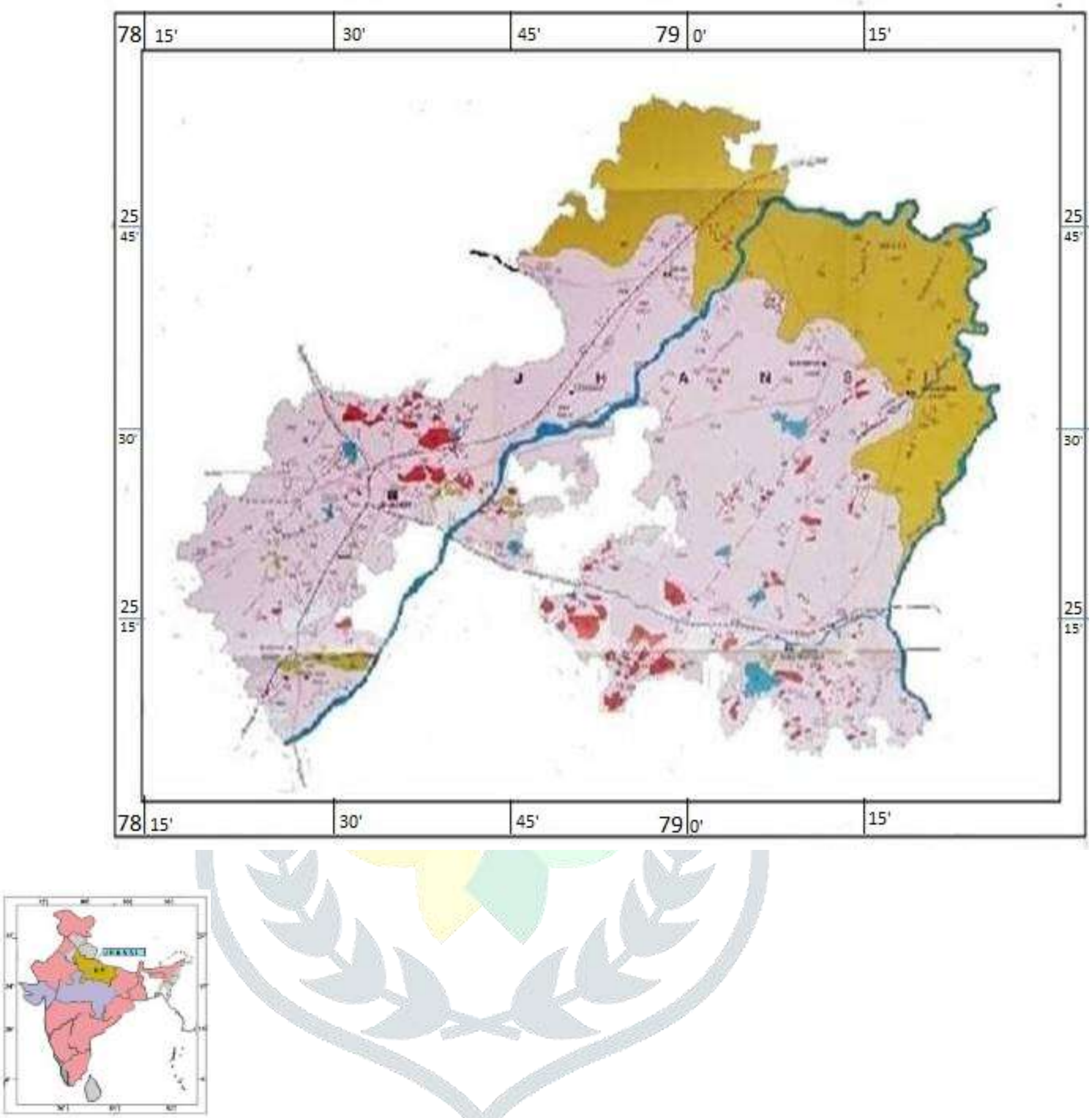

Fig:1- Shows the monitoring station in the study area.

Methodology for Estimation of Air Pollutants: Respirable Dust Sampler (RDS) APM 460 was 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), SOx and NOx gaseous pollutants.

Table-2 : Methodology for Air Quality Monitoring by Respirable Dust Sampler (RDS) APM 460

Particulars	**RSPM**	**SPM**	**SOx**	**NOx**
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
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

Air Quality Index (AQI): AQI is developed to provide the information about air quality. From a series of observation, 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 (Tiwari and Ali, 1987).The categorization of ambient air quality on the basis of AQI is presented in Table 2.

Table 3. Shows the Air Quality Categories Based on AQI

Category	**AQI of Ambient air**	**Description of Ambient air quality**
I	< 10	Very clean
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 suggested by Tiwari and Ali (1987). 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 observed value of the pollutants,
Vs= Standard value recommended for that pollutants.

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

Table 4. Shows the National Ambient Air Quality Standards (NAAQS) for 24 hours time average

Pollutants	**Concentration in Ambient air (µg/m3)**	**Pollutants**
Residential area	**Residential area**	**Industrial area**
SOx	80	80
NOx	80	80
SPM	200	500
RSPM	100	100

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

If total n indicate 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:

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

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 (Belkhiri *et al.*, 2010). The Pearson correlation coefficient (r*xy*) is computed by using the formula as given (Patil and Patil, 2010; Jothivenkatachalam *et. al.*, 2010; Kumar and Singh, 2010). 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.

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 (Shreya and Nag, 2015).

Analysis of variance (ANOVA):

It is used to study the significance of the difference of mean values of a large number of samples at the same time. It can also provide meaningful comparison of sample data. In ANOVA, a total of 'N' observations are divided into 'n' sizes for performing calculations (Mungikar, A. M. (2003). Also, the comparison of observed concentration of pollutants is compared with the CPCB standard AAQM values.

Result and Discussion:

Status of ambient air quality in and around stone crusher plant and its adjoining village of Jhansi city has been monitored for December, 2015 to November, 2016.

RSPM and SPM

When particulate matter of different particles sizes 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 µm, they are retained by the cilia of the nose whereas if the size of the particles is less than 10 µm they may enter into 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 µm enter mainly into 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 average concentration of the RSPM was recorded in monitoring stations ranged from 132 µg/m^3 to 1896 µg/m^3 and SPM in the range of 3817 to 298 µg/m^3. After the comparison from standard values were shown much higher than standard value of RSPM (100 µg/m^3) as well as SPM (200 µg/m^3). Both parameters shows positive correlation show in Fig 12-21 and significant value < .005 in given Table- 15-16, 19-20 and cluster analysis represented in Fig. 2-11.**

Gaseous Pollutants

Sulphur dioxide can cause irritation of visibility and respiratory diseases. Healthy person are mostly affected by experience broncho-construction at 4540 µg/m3 of SO_2 for a few minutes exposure. Throat irritation occurs at 33800 µg/m^3 level. At 56400 µg/m^3 SO_x 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 (Chauhan *et al.,* 2013). **The concentration of the SO_x is recorded in the study areas ranged between 2.7 to 7.5 μg/m^3. After the comparison from standard shows the lower than standard value SO_x (80 μg/m^3). Both parameters shows positive correlation and significant value <.005 and cluster analysis represented in Fig. (2-11).** Nitric oxide (NO) and nitrogen dioxide (NO_2) are also of great to the 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 (Chauhan *et al.,* 2013**). The concentration of the NO_x recorded in the study areas falls between 5.0 to 14.7 μg/m^3 (Table 3). After the comparison from standard value comes under lower than standard value of NO_2 (80 μg/m^3). Both parameters show positive correlation shown in pair graph Fig-12-21 and their significant value <.005 shows in Table (17-18 and 21-22) and cluster analysis in Fig 2-11.**

Conclusion

The preliminary statistical analysis of RSPM, SPM, SO_X and NO_X data collected from the different sampling sites are given in Table 5-14. The annual mean values of RSPM and SPM concentration are higher than recommended values based on NAAQS values throughout the sampling period by shown in very large amount. The SPM concentrations values found in wide range in different seasons. The analysis of variance (ANOVA) test has been applied for the data collected of SPM. 'F' test values calculated based on data shows very low when compared with the standard tabulated value. The high values of SPM concentration are common in the ambient air around of Jhansi city.

Table-5: Air Quality status of Sri mahamaya Stone Crusher Lakshamanpua

		RSPM	Max-Min	SD	SPM	Max-Min	SD	SO_2	Max-Min	SD	NO_2	Max-Min	SD	AQI	Rating
Winter	Dec-15 to Feb-16	1720.66 ±41.69	1798-1655	72.2	3402.66 ±72.12	3545-3308	124.93	3.66 ±0.2	4.0-3.3	0.35	11.29 ±0.36	12.0-10.8	0.62	871	**VII**
Summer	March-16 May-16	1855 ±27.71	1903-1807	48.0	3725.66 ±67.94	3850-3616	117.69	3.13 ±0.06	3.2-3.0	0.11	9.93 ±0.58	11.0-9.0	1.0	955	**VII**
Monsoon	June-16 to Aug-16	806.66 ±75.18	954-707	130.22	1648.33 ±136.14	1908-1442	237.53	2.8 ±0.05	2.9-2.7	0.1	7.16 ±0.44	8.0-6.5	0.76	417	**VII**
Autumn	Sept-16 to Nov-16	1538 ±50.61	1609-1440	87.67	3052.33 ±112.82	3201-2831	195.41	3.43 ±0.26	3.9-3.0	0.45	10.26 ±1.5	13.0-7.8	2.61	776	**VII**
Annual Mean		1480.08±124.02	1903-707	429.61	2957.5 ±242.84	3850-1442	841.23	3.25 ±0.12	4.0-2.70	0.41	9.66 ±0.88	13.0-6.50	2.03	759	**VII**

Table-6: Air Quality status of Lakshamanpura (Village)

		RSPM	Max-Min	SD	SPM	Max-Min	SD	SO_2	Max-Min	SD	NO_2	Max-Min	SD	AQI	Rating
Winter	Dec-15 to Feb-16	232.66 ±17.02	266-210	29.48	468.66 ±20.79	510-444	36.01	6.3 ±0.17	6.6-6.0	0.3	11.33 ±0.28	11.9 - 11	0.49	229	**VII**
Summer	March-16 May-16	326.33 ±17.74	359-298	30.73	653.66 ±27.23	703-609	47.17	7.46 ±0.29	8.0 - 7.0	0.5	15 .0 ± 1.15	17.0-13.0	2.0	324	**VII**
Monsoon	June-16 to Aug-16	158.66 ±30.33	190-98	52.54	332 ± 63.73	405 - 205	110.39	4.46 ±0.37	5.2 - 4.0	0.64	8.93 ± 0.58	10.0-8.0	1	162	**VII**
Autumn	Sept-16 to Nov-16	268.66 ±20.35	299 - 230	35.24	525.66 ±69.65	613-338	120.65	6.13 ±0.94	8.0-4.9	1.64	10.63 ±0.68	12.9 - 9.9	1.18	257	**VII**
Annual Mean		246.58 ±20.58	359-98.0	71.31	495 ±40.88	703-205	141.64	6.09 ±0.39	8.0-4.0	1.37	11.47 ±0.73	17.0-8.0	2.56	245	**VII**

Table-7: Air Quality status of (Pitambra Stone Crusher) Bijoli

		RSPM	Max-	SD	SPM	Max-	SD	SO_2	Max-	SD	NO_2	Max-	SD	AQI	Rating

			Min			Min			Min			Min			
Winter	Dec-15 to Feb-16	1597.66 ± 9.2	1611-1580	15.94	3141.66 ±68.33	3211-3005	118.36	4.2 ±0.17	4.5-3.9	0.3	11 ±0.57	12.0 -10.0	1.0	794	**VII**
Summer	March-16 May-16	1828.66 ±42.99	1911-1766	74.47	3620.66 ±119.52	3829-3415	207.01	5.86± 0.46	6.6-5.0	0.08	11.66 ±0.88	13-10	1.52	912	**VII**
Monsoon	June-16 to Aug-16	1362 ±266.33	1882-1002	461.3	2659.33 ±527.83	3705-2011	914.23	4.36 ±1.26	6.9-3.0	2.19	10.33 ±2.4	15-7.0	4.16	676	**VII**
Autumn	Sept-16 to Nov-16	1546.33 ±53.23	1604-1440	92.19	3080.33 ±92.23	3210-2902	159.66	4.06± 0.4	4.7-3.3	0.7	10.23 ±2.89	16- 6.9	5.01	776	**VII**
Annual Mean		1583.66 ± 77.18	1911-1002	267.39	3125.5 ±156.45	3929-2011	541.95	4.26 ±0.37	6.9-3.0	1.29	10.80	16.0-6.90	2.94	741	**VII**

Table-8: Air Quality status of Bijoli village

		RSPM	Max-Min	SD	SPM	Max-Min	SD	SO_2	Max-Min	SD	NO_2	Max-Min	SD	AQI	Rating
Winter	Dec-15 to Feb-16	235 ±17.55	270-215	30.41	478 ±23.71	525-449	41.07	6.06 ±0.34	6.7-5.5	0.6	11.53 ±0.32	12-10.9	0.56	234	**VII**
Summer	March-16 May-16	349 ±28.93	401-301	50.12	668 ±25.48	710-622	44.13	7.53± 0.23	7.9-7.1	0.4	14.0 ±1.15	16.0-12.0	2.0	339	**VII**
Monsoon	June-16 to Aug-16	275.66 ±17.52	303-243	30.35	497.33 ±106.46	710-382	184.39	4.73 ±0.6	5.9-3.9	1.04	8.33 ±1.45	11.0-6.0	2.51	309	**VII**
Autumn	Sept-16 to Nov-16	398 ±68.39	398-188	118.46	532.66 ±66.06	615-402	114.43	6.06 ±0.87	7.8-5.0	1.51	11.0 ±0.57	12-10	1.0	269	**VII**
Annual Mean		280.25 ±21.0	401.0-188.0	72.76	544.0 ± 35.63	710.0-382.0	123.43	6.1 ±0.38	7.9-3.9	0.38	11.21 ±0.73	16.0-6.0	2.55	269	**VII**

Table-9:- Air Quality status of Lakshami Stone Crusher Goramachhiya (kanpur Road)

		RSPM	Max-Min	SD	SPM	Max-Min	SD	SO_2	Max-Min	SD	NO_2	Max-Min	SD	AQI	Rating
Winter	Dec-15 to Feb-16	1239.66 ±21.98	1279-1203	38.07	2372.66 ±32.86	2408-2307	56.92	2.7 ±0.36	3.2-2.0	0.36	9.66 ±0.88	11.0-8.0	1.52	617	**VII**
Summer	March-16 May-16	1500.33 ±104.53	1709-1385	181.05	3038.66 ±235.57	3495-2709	408.02	4.06 ±0.12	4.3-3.9	0.2	10.0 ±1.15	12-8.0	2.0	776	**VII**
Monsoon	June-16 to Aug-16	1171.33 ±324.64	1819-808	562.28	2294.66 ±710.45	3715-1550	1230.5	2.86 ±0.76	4.4-2.0	1.33	6.66 ±0.88	8.0-5.0	1.52	589	**VII**
Autumn	Sept-16 to Nov-16	1060.66 ±64.34	1189-991	111.28	1954 ±184.38	2249-1650	119.35	3.4 ±0.4	4.2-3.0	0.69	8.0 ±0.57	9.0-7.0	1.0	513	**VII**
Annual Mean		1243 ±88.73	1819-808	307.39	2415.08 ±202.71	3715-1550	702.21	3.25 ±0.25	4.4-2.0	0.25	8.58 ±0.55	12.0-5.0	1.92	617	**VII**

Table-10: Air Quality status of Goramachhiya Village

		RSPM	Max-Min	SD	SPM	Max-Min	SD	SO_2	Max-Min	SD	NO_2	Max-Min	SD	AQI	Rating
Winter	Dec-15 to Feb-16	221 ±15.3	250-198	26.51	469.33 ±28.7	526-433	49.72	6.83 ±0.12	7.0-6.6	0.2	12.16 ±0.16	12.5-12.0	0.2	226	**VII**
Summer	March-16 May-16	311.33 ±19.91	346-277	34.5	670.33 ±25.51	712-624	44.18	7.7 ±0.23	8.1-7.3	0.4	14.73 ±0.99	16.7-13.5	1.72	320	**VII**
Monsoon	June-16 to Aug-16	132.66 ±28.87	190-98	50.01	298 ± 49.9	393-224	86.48	4.63± 0.39	5.4-4.1	0.68	9.6 ±0.7	11.0-8.8	1.21	140	**VII**
Autumn	Sept-16 to Nov-16	270.66 ±21.4	300-229	37.07	526.66 ±74.6	619-279	129.21	5.8± 0.61	7.0-5.0	1.05	9.6 ±0.7	13.0-10.0	1.52	266	**VII**
Annual Mean		233.91 ±22.16	346-98	76.76	491.08 ±45.28	712-224	165.85	6.24 ±0.38	8.1-4.1	1.32	11.95 ±0.64	16.70-8.80	2.23	234	**VII**

Table-11: Air Quality status of ahendra Singh stone crusher Gwalior Road

		RSPM	Max-Min	SD	SPM	Max-Min	SD	SO_2	Max-Min	SD	NO_2	Max-Min	SD	AQI	Rating
Winter	Dec-15 to Feb-16	1734 ±34.42	1788-1670	59.63	3512.66 ±54.14	3602-3415	93.77	3.63 ±0.31	4.0-3.0	0.55	10.0 ±0.57	11.0-9.0	1.0	891	**VII**
Summer	March-16 May-16	1896± 43.15	1974-1825	74.74	3817.66 ±61.54	3910-3701	106.6	3.4 ±0.6	3.9-3.0	0.45	7.33 ±0.88	11.0-8.0	1.52	977	**VII**
Monsoon	June-16 to Aug-16	806 ± 68.88	941-711	119.3	1690.66 ±157.19	2001-1492	272.25	3.83 ±0.6	5.0-3.0	1.04	7.33 ±0.58	8.5-6.6	1.02	513	**VII**
Autumn	Sept-16 to Nov-16	1567.33 ±67.35	1669-1451	109.74	3154 ±122.68	3310-2912	21.48	3.4 ±0.35	4.1-3.0	0.6	9.83 ±1.27	12.0-7.6	2.2	794	**VII**
Annual Mean		1501.25 ±127.83	1974-711	442.83	3043.75 ±250.22	3910-1492	866.78	3.56 ±0.18	5.0-3.0	0.62	9.15 ±0.49	12.0-6.60	1.70	776	**VII**

Table-12: Air Quality status of Karari Village

		RSPM	Max-Min	SD	SPM	Max-Min	SD	SO_2	Max-Min	SD	NO_2	Max-Min	SD	AQI	Rating
Winter	Dec-15 to Feb-16	288.33 ±4.91	298-282	8.5	458 ±21.57	498-424	37.36	5.0 ±0.57	6.0-4.0	1.0	5.0 ±0.57	6.0-4.0	0.9	794	**VII**
Summer	March-16 May-16	338 ±27.5	393-310	47.63	686 ± 21.19	712-644	36.71	3.83 ±0.44	4.5-3.0	0.76	10.23 ±0.98	12.0-8.6	1.74	331	**VII**
Monsoon	June-16 to Aug-16	153.33 ±26.18	188-102	45.35	324.66 ±53.4	391-219	92.5	3.6 ±0.65	4.9-2.9	1.12	7.33 ±0.58	8.5-6.6	1.02	155	**VII**
Autumn	Sept-16 to Nov-16	277.66 ±20.03	310-241	45.35	560.66 ±42.67	623-479	73.92	6.93 ±0.53	7.8-6.0	0.9	10.5 ±1.87	14.0-7.6	3.24	275	**VII**
Annual Mean		264.33 ±22.48	393-102	77.87	507.33 ±43.10	712-219	149.31	4.84 ±0.46	7.80-2.90	1.60	9.75 ±0.64	14.0-6.0	2.22	257	**VII**

Table-13: Air Quality status of Pratappura Stone Crusher

		RSPM	Max-Min	SD	SPM	Max-Min	SD	SO_2	Max-Min	SD	NO_2	Max-Min	SD	AQI	Rating
Winter	Dec-15 to Feb-16	1321 ±13.56	1345-1298	23.5	2586 ±45.54	2660-2503	78.88	4.13 ±0.18	4.5-3.9	0.32	8.6 ±0.88	10.0-7.0	1.52	691	**VII**
Summer	March-16 May-16	1531 ±121.87	1775-1404	211.09	3098 ±196.52	3474-2810	340.38	5.03 ±0.52	6.0-4.2	0.9	10.93 ± 0.52	11.8-10.0	0.9	776	**VII**
Monsoon	June-16 to Aug-16	1036.33 ±390.09	1808-551	675.65	2089.66 ±771.19	3609-1100	1335.7	3.76 ±0.62	5.0-3.0	1.09	7.46 ±1.72	10.8-5.0	2.99	525	**VII**
Autumn	Sept-16 to Nov-16	1020 ±89.59	1188-882	155.19	1939.66 ±175.53	2209-1610	304.02	4.0 ± 0.28	4.5-3.5	0.5	8.6 ±0.3	9.0-8.0	0.52	501	**VII**
Annual Mean		1225.66 ±109.14	1808-551	378.06	2428.5 ±221.57	3609-1100	767.55	4.23 ±0.23	6.0-3.0	0.82	8.91 ±0.57	11.80-5.0	1.99	617	**VII**

Table-14: Air Quality status of Pratappura Village

		RSPM	Max-Min	SD	SPM	Max-Min	SD	SO_2	Max-Min	SD	NO_2	Max-Min	SD	AQI	Rating
Winter	Dec-15 to Feb-16	301.66 ±5.23	310-292	9.07	585.66 ±22.33	622-545	38.68	5.0 ±0.57	6.0-4.0	1.0	10.33 ±0.88	12.0-9.0	1.54	288	**VII**
Summer	March-16 May-16	346.66 ±27.2	401-317	47.12	718.33 ±13.87	743-695	24.02	4.46 ±0.29	5.0-4.0	0.5	10.66 ±1.76	14.0-8.0	3.05	347	**VII**
Monsoon	June-16 to Aug-16	176 ±14.0	202-154	24.24	344 ±41.58	408-266	72.02	4.36 ±0.29	5.8-3.3	1.29	6.6 ±0.7	6.6-8.0	1.21	170	**VII**
Autumn	Sept-16 to Nov-16	288.33 ±7.26	300-275	12.58	591.33 ±14.94	611-562	25.89	6.86 ±0.59	8.0-6.0	1.02	11.0 ±2.8	15.0-8.0	3.60	407	**VII**
Annual Mean		276.33 ±21.20	401-132	73.46	559.83 ±42.28	743-266	146.46	5.17 ±0.82	8.0-3.30	1.35	9.65 ±0.82	15.0-5.80	2.86	275	**VII**

Table-15: Two-way ANOVA analysis of RSPM at Stone Crusher

Source of Variation	*SS*	*df*	*MS*	*F*
Months	5441683	11	494698.4	10.15**
Sites	1262553	4	315638.3	6.47**
Error	2143662	44	48719.58	
Total	8847898	59		

**- Significance level 0.05

Table-16: Two-way ANOVA analysis of SPM at Stone Crusher

Source of Variation	*SS*	*df*	*MS*	*F*
Months	22448040	11	2040731	10.27**
Sites	5714012	4	1428503	7.19**
Error	8735944	44	198544.2	
Total	36897996	59		

**- Significance level 0.05

Table-17: Two-way ANOVA analysis of SO_2 at Stone Crusher

Source of Variation	*SS*	*df*	*MS*	*F*
Months	20.52183	11	1.865621	4.01**
Sites	18.10767	4	4.526917	9.73**
Error	20.45233	44	0.464826	
Total	59.08183	59		

**- Significance level 0.05

Table-18: Two-way ANOVA analysis of NO_2 at Stone Crusher

Source of Variation	*SS*	*df*	*MS*	*F*
Months	141.272	11	12.84291	4.84**
Sites	36.33941	4	9.084852	3.42**
Error	116.6711	44	2.651615	
Total	294.2825	59		

**- Significance level 0.05

Table-19: Two-way ANOVA analysis of RSPM at Village

Source of Variation	*SS*	*df*	*MS*	*F*
Months	231661.8	11	21060.16	12.62**
Sites	18666.77	4	4666.692	2.79**
Error	73425.63	44	1668.764	
Total	323754.2	59		

**- Significance level 0.05

Table-20: Two-way ANOVA analysis of SPM at Village

Source of Variation	*SS*	*df*	*MS*	*F*
Months	912679.7	11	82970.88	16.05**
Sites	45393.6	4	11348.4	2.195
Error	227391.6	44	5167.991	
Total	1185465	59		

**- Significance level 0.05

Table-21: Two-way ANOVA analysis of SO_2 at Village

Source of Variation	*SS*	*df*	*MS*	*F*
Months	64.442	11	5.858364	5.93**
Sites	19.424	4	4.856	4.91**
Error	43.428	44	0.987	
Total	127.294	59		

**- Significance level 0.05

Table-22: Two-way ANOVA analysis of NO_2 at Village

Source of Variation	*SS*	*df*	*MS*	*F*
Months	237.654	11	21.60491	8.96**
Sites	52.74567	4	13.18642	5.46**
Error	106.0743	44	2.41078	
Total	396.474	59		

**- Significance level 0.05

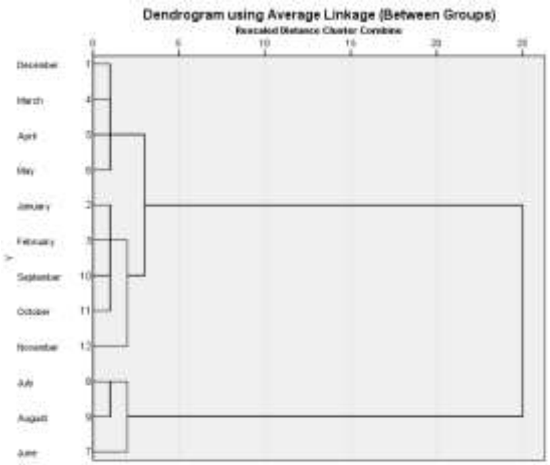

Fig.2- Cluster Analysis of site I at different months

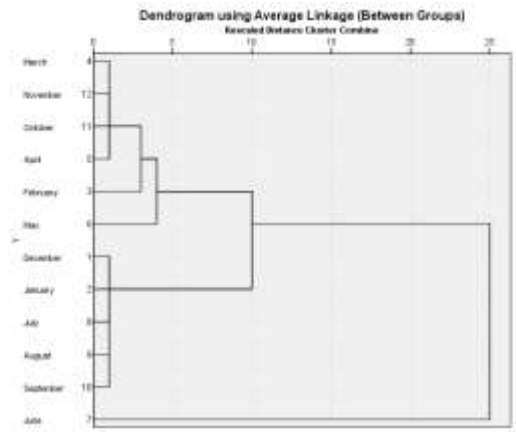

Fig.3- Cluster Analysis of site II at different months

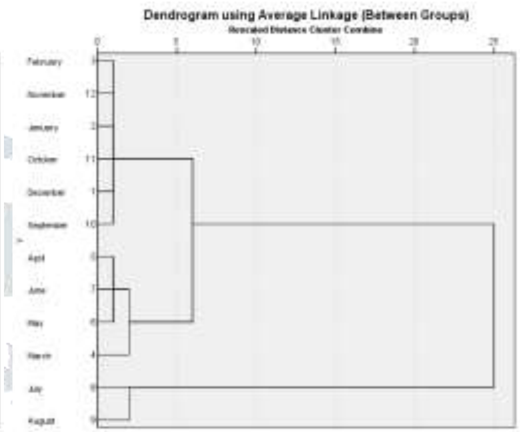

Fig.4- Cluster Analysis of site III at different months

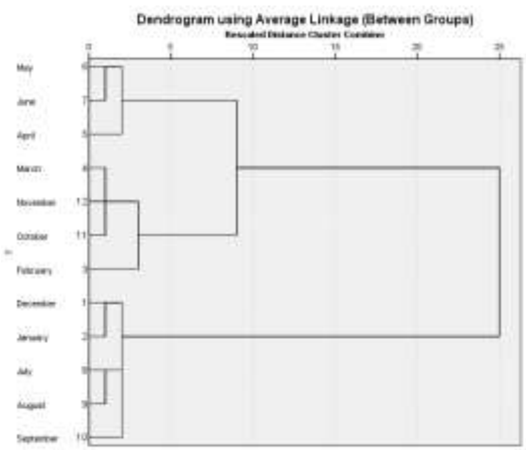

Fig.5- Cluster Analysis of site IV at different months

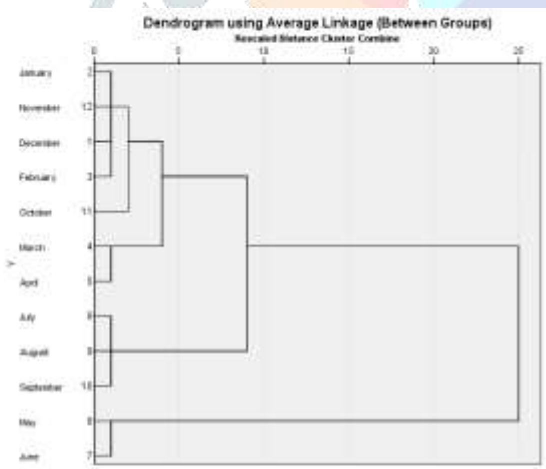

Fig.6- Cluster Analysis of site V at different months

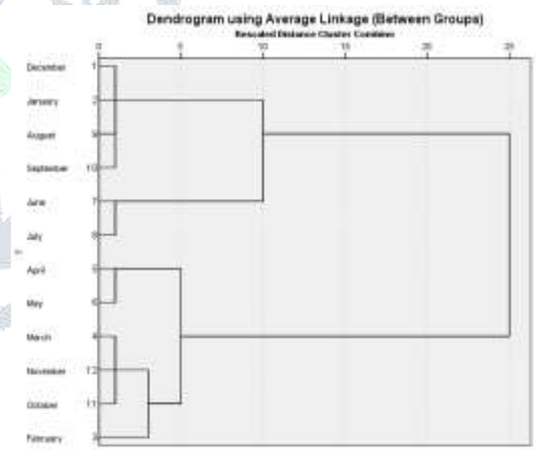

Fig.7- Cluster Analysis of site VI at different months

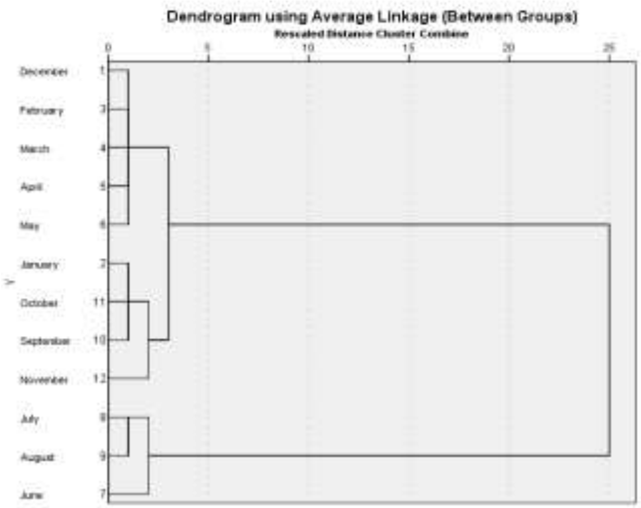

Fig.8- Cluster Analysis of site VII at different months

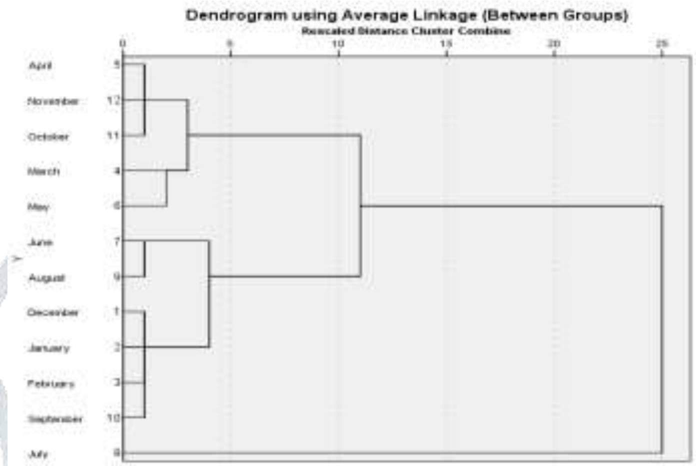

Fig.9- Cluster Analysis of site VIII at different months

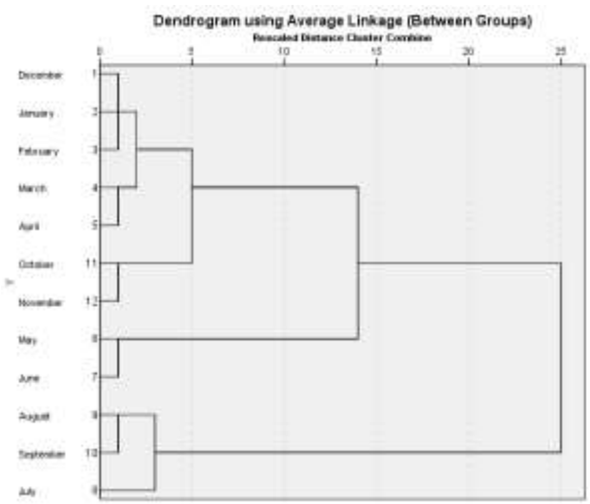

Fig.10- Cluster Analysis of site IX at different months

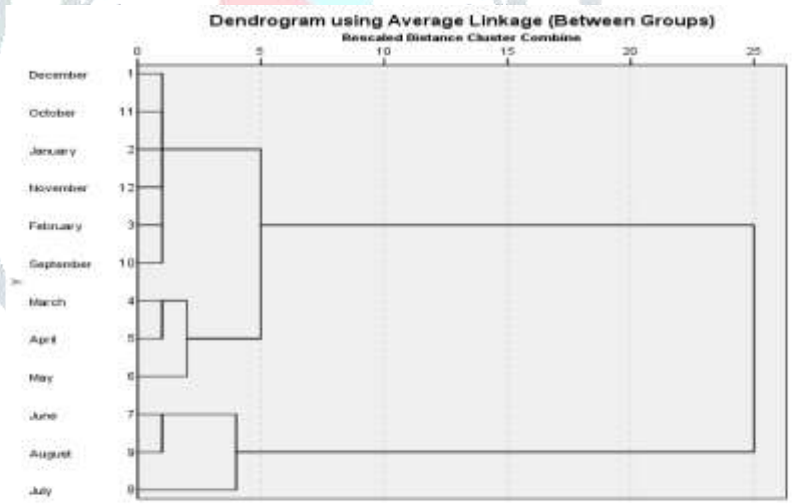

Fig.11- Cluster Analysis of site X at different months

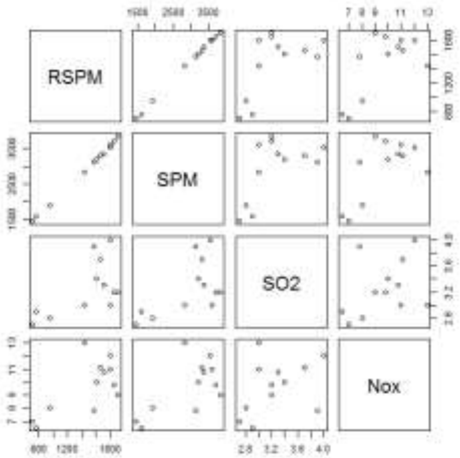

Fig-12. Pair graph of different parameters at site I

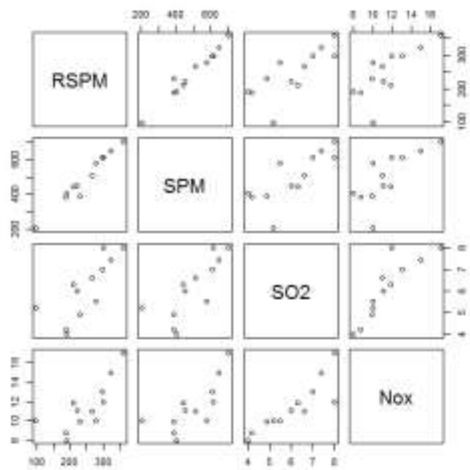

Fig-13. Pair graph of different parameters at site II

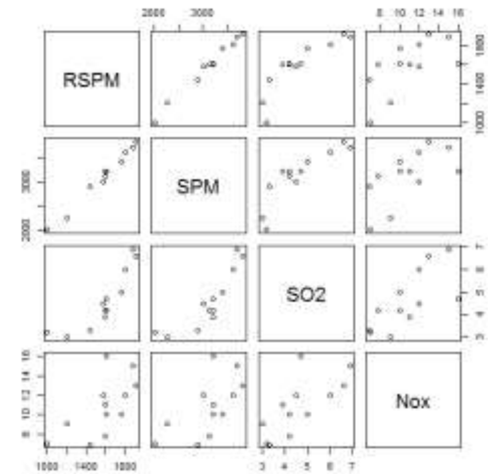

Fig-14. Pair graph of different parameters at site III

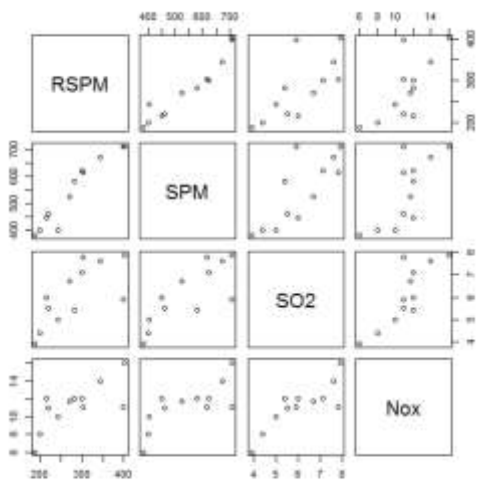

Fig-15. Pair graph of different parameters at site IV

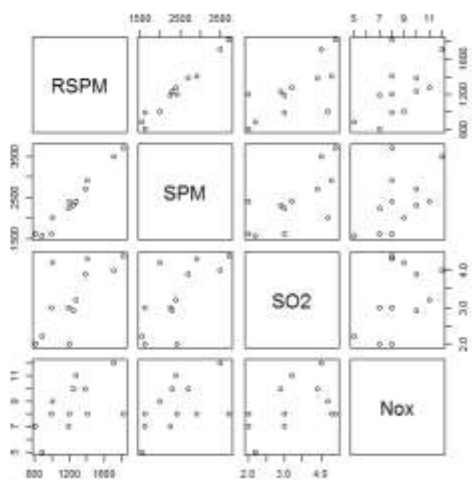

Fig-16. Pair graph of different parameters at site V

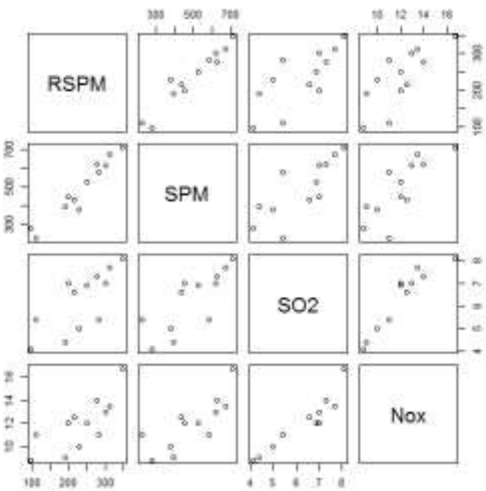

Fig-17. Pair graph of different parameters at site VI

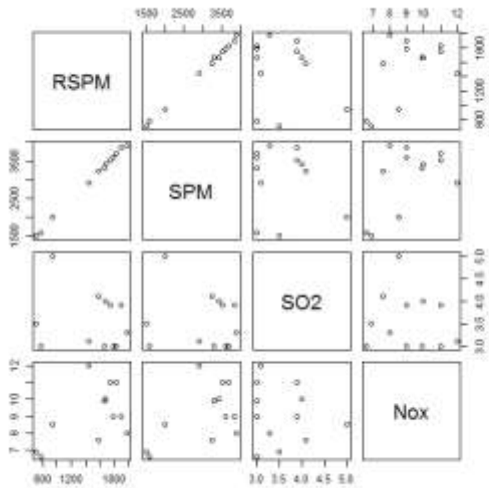

Fig-18. Pair graph of different parameters at site VII

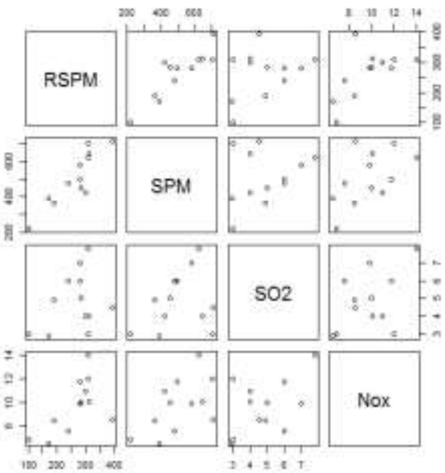

Fig-19. Pair graph of different parameters at site VIII

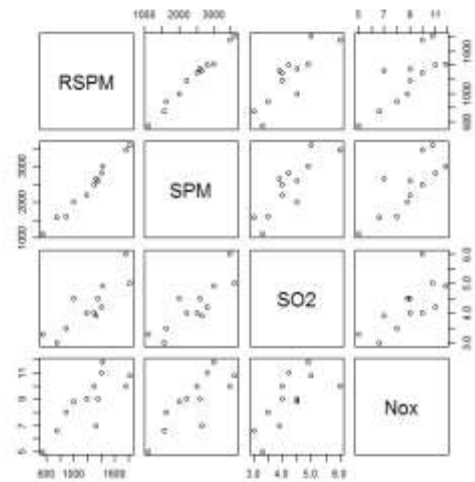

Fig-20. Pair graph of different parameters at site IX

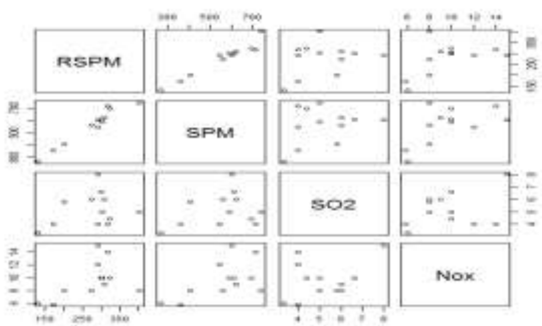

Fig-21. Pair graph of different parameters at site X

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