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Soil Physical Conditions for an Open Cast Coal Mining Area

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ABSTRACT

A study for the assessment and management of the Soil quality was carried out around Jayant open cast coal mining situated at Jayant in Sidhi district of Madhya Pradesh, India from Jan. 2007 to Dec 2008. the 24 hour average concentration of total suspended particulate (TSP) matter, dust fall rate, sulphur dioxide (SO) and oxide of nitrogen (NO) were monitored 2 year period, sampling were done at a regular interval through out the year at five monitoring station in the residential area mining area & industrial areas. Air quality date at Jayant coal mining indicated that the concentration of SO , NO , TSP and dust fall rate and air borne trace metals were highest at S2 sites, although it vary in few cases, S1 site also showed highest concentration of pollutant. Concentration of SO_2 and NO_2 were high during winter season and minimum during rainy season. The particulates (TSP and dust fall rate) were found to be maximum in summer season. Diurnal pattern of gaseous pollutant showed peak during winter. In Jayant coal mines suspended area the concentration of SO_2 and NO_2 were below the NAAQS and CPCB India at all the monitoring station but TSP and settled dust concentration were well above the limit. Zinc and Maganese were present in highest qualities in both TSP and settled dust. In settled dust Zn showed maximum concentration followed by Mn, Pb, Cd, Ni and minimum in Cr however in TSP, Zn in followed by Mn Pb Cr Ni and minims Cd.

***Keywords*— :** Soil pollution, Nitrogen oxide (NO), Sulphur dioxide (SO), TSP (Total Suspended Particulate), dust fall rate

I. INTRODUCTION

Coal mining is one of the core industries in India . Its environmental impact cannot be ignored but, to some extent is unavoidable (Chaulya, 2004). Most major mining activities contribute directly or indirectly air pollution. There air pollutant reduce air quality and their ultimately affects people flora and fauna in and around mining areas (Nanda and Tiwari, 2001). Major air pollutant due to open cast mining are total suspended particles matter (TSP) and settled dust matter. The concentration of particulate matters varies with the meteorological parameters and a relation also exists between TSP settable dust matter. The dispersion of particulate matter follows the annual predominant wind direction of the area Detailed studies of air quality are required to assess the environmental impact of a coal mining area. Analysis of temporal and spatial variation of air pollutant concentration is also essential (Chaulya, 2004) discussed the air pollution problem in Indian open cast coal mine. The present study was conducted in the Jayant open cast coal field limited NCL India.

II. STUDY AREA

The experimental sites were situated at Jayant open cast coal mine of Singrauli coal mine fields in India between 24 05'55" to 24, 11" N latitudes 82 38'10" to 82 40' 45"E longitudes and elevation of 300-500m above MSL Singrauli is one of the most polluted industrial sites of Asia. The coal field experiences a tropical monsoon type of climate with their distinct reason ie a mild winter (Nov. – Feb.) a hot summer (April- June) and a warm rainy season (July - Sept). The average climatologically data of the area from 2007-2008 are given in the (table-1). Average minimum temperature ranged from 13.1°C to 33.4°C and average maximum temperature from 19.5°C to 44.5°C. The rains falls in the area varied between 2.6 mm to 770.0 mm during different month. Maximum rain fall was recorded in the month of September (770 mm) and minimum in month of February (2.6 mm) relative humidity varied between 30.4% to 87.5% wind speed in the area varied between 3.3 to 12.6. During summer the prominent wind direction were W, SW and NW, during winter E and SE and during rainy season NE, SE and SW (Fig. 1).

III. GENERAL GEOLOGY AND SOIL

The Singrauli lies at the northern extremely of the Son- Mahanadi Master Gondwana basin, which stretches from the east coast to the heart of the peninsular India. The nature of the parent material is carboniferous. The Jayant block is located in the middle part of the Mohar Sub basin. The present study was conducted in the area affected by Jayant opencast coal mine for the purpose of the present study, the whole area was divide into four zones and five

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major sites (Fig. 1 and Table-2). For each major site three micro sites was selected on basis of identical activities location of different study sites. Air monitoring was done at all major sites.

IV. MATERIALS AND METHODS

For air quality monitoring initially several monitoring site were selected in different direction and distances around OCP Singrauli, Sidhi (M.P). Finally on the basis of accessibility of terrain and prevailing wind direction for the maximum time in a year Jan. 2007 study sites were selected for intensive air quality monitoring. A control site was selected at 50 Km. of the Jayant OCP. Characterization of monitoring site is detailed in Table-2. The data on meteorological parameter during the study period were collected from Jayant coal mines authorities concerned with collecting such information.

V. AIR MONITORING

The air quality for total suspended particulate (TSP) sulphur dioxide (SO_2) Nitrogen dioxide (NO_2)and settled dust were monitored for two consecutive years at different study site from 2007-2008. Air monitoring for SO_2, NO_2 and TSP was done for 24 hrs., once every 15 days at each sites and concentration were expressed as µm-^{3} Mean value for pollutant were calculated on 24 hrs. sampling basis. Where as peak value denoted 4 hrs. average concentration. Air borne sulphate level was quantified in TSP sample. Metals such as Calcium Ca. Maganese (Mn) Lead (Pb), Iron (Fe),Copper (Cu) Cadmium (Cd) and Nickel (Ni) were also determined in TSP and settable dust sample.

Total Suspended Particulates:

For the sampling of particulate matter HVS (High Volume Sampler) was used. Samples were collected for two years using glass fiber filter paper on fort nightly basis. 24hrs. Concentration of TSP were determined gravimetrically. The mass concentration of suspended particulate matter in µg/m-3 is computed by measuring the mass of collected particles and volume of the air sampled. Sulphur dioxide (So2) and oxide of Nitrogen (NO2) are the main acidic gaseous pollutants. The sampling and analysis for the concentration of SO2 in the ambient air was done by improved (West and Gaeke,1956). Nirogen dioxide Nitrogen dioxide was absorbed by bubbling air through NAOH solution taken in the impinger. Nox has been sampled as NO2 by modified method Merryman et al. (1973) Harrison (1986). The settle settable dust was collected in settling jar of known area by placing them at a height of 3 meter at different site for known period. The dust fall rate was calculate using formula. Air borne sulphate determined by the method of Rossum and Villarryz (1961).

Air Borne Metals

For the determination of air borne metals (Ca, K, Na, Ni, Cr, Zn, Pb, Mn and Cd) in TSP. The filter paper was cut into fine pieces and digested for 30 minutes in 100 ml of Conc, HCL. The metals in the pooled filtrate were analysed on Atomic Absorption Spectro photometer (Model 2380, Perkin Elmer, U.S.A.). For the determination of metals in settled dust, 2 g of sample was digested in 20 ml ternary acid. Data was subjected to analysis of variance test using SPSS/PC programme for micro computer (SPSC/PC/1986).The 24 hr average samples were obtained following the NAAQS Protocol of the Central Pollution Control Board, New Delhi.

VI. RESULTS

Spatial and temporal variation in concentration of gaseous and particulate pollutants were observed during both the year of air monitoring. Mean annual concentration of gaseous and particulate pollutants were generally maximum at site S2 followed by S1,S3,S4 and minimum at control site(Fig. 2). Annual average SO_2 concentration was 41.52, 46.5, 22.9,16.48and 13.0µgm $^{-3}$ at site S1 S2 S3 S4 and S5 respectively in year 2007. More or less similar levels of SO_2 recorded during 2008. TSP concentration was maximum at S2 sites followed by S1 S3 S4 and S5 the value being 949.76,639.13 299.17,181.42 and 36.73 µgm^{-3} respectively in 2007.Temporal variation in SO_2 concentration was recorded during winter the value being 46.50, 52.00,27.97,19.78 and 15.75µgm^{-3}at S1,S2,S3,S4 and S5 respectively during 2007. Minimum concentration of SO_2 was recorded during rainy season. Diurnal pattern of SO_2 showed two peaks during winter. The first peak concentration (106µgm^{-3}) was recorded between 4 to 8 am while the second 100.6µgm^{-3} was recorded between 4 to 8 pm in the late evening. Spatial and temporal variation in concentration of gaseous and particulate pollutants were observed during both the years of air monitoring. Mean annual concentration of gaseous and particulate pollutants were generally maximum at site S2 followed by S1, S3, S4 and minimum at control site (Figure 1,2). Annual average So_2 concentration was 41.52, 46.5, 22.9, 16.48, and 13.0!gm^{-3} at sites S1, S2, S3, S4 and S5 respectively during 2007 (Figure 1). More or less similar levels of SO_2 were recorded during 2008. TSP concentration was maximum at S2 site followed by S1, S3, S4 and then S5. Temporal variation in SO_2 concentration were also obvious (Table-3). Maximum SO_2 concentration was recorded during winter, the value being 46.50, 52.00, 27.97, 19.78 and 15.75 !gm^{-3}at S1, S2, S3, S4 and S5 respectively during 2007. Minimum concentration of So_2 was recorded during rainy season, the respective value being, 35.8, 40.5, 19.32, 13.4 and 13.1 !gm^{-3} during 2007. Maximum SO_2 concentration was recorded during winter, the value being 46.50, 52.00, 27.97, 19.78, and 15.75!gm^{-3} at S1, S2, S3, S4, and S5, respectively during 2007. Minimum concentration of So_2 was recorded during

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rainy season, the respective value being 35.8, 40.5, 19.32, 13.4, and 13.1!gm^{-3} during 2007. However, the variation due to site season interaction was found to be insignificant. Diurnal pattern of So_2 showed two peaks during winter. The first peak concentration (106.!gm^{-3}) was recorded between 4 to 8 AM, while the second (100.6!gm^{-3}) was recorded between 4 to 8 PM in the late Evening maximum mean annual No_2 concentration was

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recorded at S2 (35.16!gm), followed by S1 (30.13!gm),

S2 (35.16 55!gm^{-3}), S3 (18.16!gm^{-3}), S4 (13.55!gm^{-3}) and minimum at control site i.e. S5 (10.44 !gm^{-3}) during 2007 (figure 2) concentration of No_2 showed more or less similar spatial variation during 2008 also (figure 2). No_2 concentration also showed seasonal variation. Variation in No_2 concentration were found to be significant due to sites and seasons. Diurnal variation in No_2 concentration was also recorded. The first peak of No_2 recorded between 4 to 8 AM reached to 78.5 !gm^{-3} while the second of 73.2 !gm^{-3} was recorded between 4 to 8 PM. Maximum TSP was recorded during summer, the value being 888.87, 1513.16, 380.63, 236.37, and 44.89!gm^{-3} followed by winter the value being 651.4, 881.66, 311.47, 182.9 and 39.13 and minimum during rainy season, the value being 377.13, 454.26, 205.42, 125.0 and 26.17!gm^{-3} at sites S1, S2, S3, S4 and S5 respectively for year 2007. Similar pattern of variation was observed for 2008. Total suspended particulates showed maximum concentration between 8 AM to 4 PM in 24 hr cycle during summer maximum concentration 1989!gm^{-3} was observed between 8 AM to 12 Noon . Spatial and temporal variation in TSP were also observed. Mean annual TSP was 639.13, 949.69, 299.17, 181.42 and 36.73!gm^{-3} at site S1, S2, S3, S4 and S5 respectively in the year 2007. Similar pattern in mean TSP was recorded during 2008. Spatial and Temporal variation in dust falls rate were also observed. Mean annual dust falls rate was 7.77, 13.92, 2.39, 2.67 and 1.81!gm^{-2} day^{-1} at sites S1, S2, S3, S4 and S5 respectively for the year 2007 (Table-6). The mean annual dust falls rate was also recorded for the year 2008. Similar pattern in mean annual dust falls rate was observed. Maximum dust rate was measured at site S2 15.57gm^{-2} day^{-1} followed by S1 (9.38 gm m^{-2}day^{-1}), S3 (3.18gm^{-2}day^{-1}), S4 (2.54 gm^{-2} day^{-1}) and S5 (1.31gm^{-2}day^{-1}) during summer in the year 2007 (Table-6). Minimum dust falls rate was recorded during rainy season similar seasonal pattern was also observed for the year 2008 also. Season and site wise variation in dust falls rate was found to be significant. Concentration of toxic trace metals (Cd, Ni, Mn, Cr, Pb and Zn) were also determined in the particulates. In settled dust as well as in TSP, all the metals were present in maximum concentration at S2 site followed by S1, S2, S3, S4 and S5 (i.e. control site). In settled dust, Zn showed maximum concentration (530.15!gm^{-1}) followed by Mn (164.70 !gm^{-1}) , P6 (44.89 !gm^{-1}), Cd (41.17 !gm^{-1}) Ni (36.65 !gm^{-1}) and minimum in case of Cr (30.32!gm^{-1}) at site S2 (Table-7). All the metals showed significant site wise variation in TSP as well as in settled dust. Na, K, Ca and $SO4^{-2}$-S were also estimated in particular matter. The maximum concentration of metals reported at S2 and minimum at control site i.e S5(Table-8). In settled dust Ca concentration was higher as compared to that in TSP (Table-7) significant site wise variation were observed in case of Ca, K, Na, SO4-2-S in TSP as well as in settled dust.

VII. DISCUSSION

Gaseous pollutant showed maximum concentration along major road sides followed by minor road side, over burden that in the residential area. High level of SO_2 and NO_2 at road site may be attributed to continuous movement of heavy duty vehicle for transporting coal from the mining place to distribution or dumping. Concentration of primary pollutants in the ambient air are generally proportionally to the frequency of emission sources (Pandey, 1992). Further more the building ratio plays important role in or dispersion of air pollutants. The SO_2 in the residential area derived from open burning of raw coal and other domestic and commercial activity. SO_2 and NO_2 showed maximum concentration during winter followed by during rainy season. (Table-4) A similar pattern of seasonal variation in gaseous concentration around OCP mine was reported by (Jamal et al 1992) in the Singrauli coal field area. High concentration of SO_2 and NO2 during winter may be due to frequent temperature inversion, especially during night and early morning hour which restrict pollutant dispersion and the increase the pollutant at ground level. Further the undulating topography of area with medium sized hills also tend to chanalize and concentrate pollutant at the site of emission. The present study showed higher annual average compared to the value recorded by around coal mines in Singrauli field. 24 hr. and annual average concentration of SO_2 (residential 20.5-24.3µm^{-3}) industrial 15.3-30.8 µm^{-3} and non residential 19.7-25.3 µm^{-3} residential 14.3-33.5µm^{-3} were will with the prescribed limits on the NAAQS at all the monitoring station on diurnal scale, two peak were observed for NO_2 and SO_2 are during forenoon or and other during evening hours. Peak of SO_2 and NO_2 occurred simultaneously. Highest concentration of gaseous pollutant at zone S2 were done due to high frequency accountable for high concentration of SO_2 and NO_2 in zone S2. Chaulya (2003) reported annual average SPM concentration in the industrial/ mining area were 455.2 and 502.0µm^{-3}. at the monitoring station respectively and there were both higher then the thresold limit of 360µm^{-3} of the NAAQS protocol. The 24hr. average SPM concentration ranged from 312.7µm^{-3}. Maximum concentration as SPM in the mining area and levels gradually diminished with increasing distance due to transportaion deposition and dispersion of particle. Chaulya et al. 2001. the dispersion of particulate matter tended to be towards the annual predominant wind direction of the area.

During the process of open cast coal mining on

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variety of rock type with different composition are exposed to atmospheric condition and under accelerated weathering. As heavy metals are the important constituent of coal and existing parent rock, mining operation may lead to substantial increase in the amount of toxic substance in the environment (Rimmer 1982,) The sources of heavy metals in the mining area are (i) Soil dust in which the element such as Mn, Ni, Zn etc. and present in the solid form and (ii) Emission by combustion process add in the environment. Some trace metal such as Ni, Pb and Cd, are present in the gaseous form also (Kumar and Ratan 2003). The concentration of heavy metals in the air environment were closely associated with the variation in the emission Source. The air sample along the road sides showed maximum concentration of heavy metal. Air sample collected from over burden i.e S1 sites the area situated in close proximity of mining area showed comparatively low level of heavy metals because of their situation from the mining area and also due to the presence of plant patches of green belt that acts as a sink for particulate and heavy metals at these sites. In the air sample Zn showed maximum concentration followed by Mn, Pb, Cr, Ni, and all the minimum. Zn and Mn are the constituent of parent rock and are commonly parent in soil dust Cr, Ni, and Cd concentration were low in comparison to Zn and Mn and Pb in the TSP. this is because these metals have no specific source in the mining area other than emission from combustion of coal oil etc. In settled dust, concentration of metal were in the following order Zn>Mn>Pb>Cd>Ni>Cr>. Unlike TSP in settled dust concentration Cd was more than those of Ni and Cr. This is probably due to difference in the particle size of there metals. Concentration of Ca, K, Na, and $SO4^{-2}$-S in the TSP have being found in the following order $SO4^{-2}$-S>Ca>K>Na. However, in settled dust calcium showed more concentration than SO_4^{-2}-S. It is well known that ion like SO_4^{-2}-S are directly emitted in the atmospheric conversion of SO_2 in SO_4^{-2}-S (Dams et al. 1975).

Table 1: Climatological date of study area (Average of 3 year 2006-2008)

Months	Average Temperature (°C)		Rainfall (mm)	Relative Humidity (%)	Wind Speed ($Kmhr^{-1}$)	Predominant wind direction
	Max	Min				
January	21.3	13.1	5.1	35.5	5.5	SE, E
February	25.5	17.7	2.6	36.0	7.2	SE
March	35.0	22.6	22.4	50.5	8.0	SW
April	40.5	28.0	12.2	40.2	8.7	SW, W
May	44.5	33.4	4.6	30.4	10.5	W, SW
June	42.0	32.5	170.0	61.2	12.6	W, NW
July	31.6	30.0	329.5	80.0	8.8	NW, SE, SW
August	35.5	27.5	273.5	69.8	8.5	NW, SE, SW
September	37.1	26.3	770.0	87.5	8.6	SW, NW
October	29.4	22.1	131.0	70.0	4.9	SE, SW
November	24.3	18.5	4.8	39.3	4.3	SW, SE
December	19.5	14.8	3.9	37.9	3.3	SE, E

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Table 2: Characterization of monitoring site

Zone	Zone/Site Name	Direction	Description
A	**S1**	**SE, E, SW**	Working places in the mine, where actual mining operation such as drilling, crushing, handling, transportation and excavation etc are done. This site includes the entire area of overburden where plantation is developed. This zone considered highly Pollution generating source.
	S2	**S**	This zone occupies the area along the road side where heavy duty vehicles ply for transportation of coal. The area around narrow roads where light vehicle ply also included in this zone. This zone may be considered o f pollution generating source.
B	**S_3**	**S**	This site is more close to the road where a number of transport vehicle stop. In this zone plantation have been developed. This zone may be considered as mining sites of non dust generating nature in the area.
C	**S4**	**SE**	This is primarily a residential locality mainly with office building day garden and a small market.
D	**S5**	**NW**	This site is 30 km north west from the mining area covered with thicket forest.

Table 3 : Seasonal variations in mean So (mg m^{-3}) concentration at selected sites around 2

Sites	2007			2008		
	S	R	W	S	R	W
S_1	42.22 ± 5.8	35.86 ± 3.2	46.50 ± 5.5	42.21 ± 6.9	37.07 ± 3.5	47.15 ± 4.7
S_2	47.23 ± 5.9	40.53 ± 2.7	52.00 ± 5.1	47.52 ± 4.7	40.52 ± 3.3	51.91 ± 6.0
S3	21.51 ± 1.8	19.32 ± 3.6	27.97 ± 1.7	22.26 ± 3.0	18.14 ± 1.8	27.67 ± 2.7
S_4	16.27	13.4	19.78	17.90	15.5	19.32

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	± 1.6	± 1.4	± 2.5	± 1.1	± 1.4	± 3.6
S_5	10.36 ± 1.1	13.17 ± 1.7	15.75 ± 1.5	13.17 ± 1.7	12.53 ± 1.5	16.94 ± 3.4

Table 4: Seasonal variation in mean TSP (mg m^{-3}) concentration at selected sites around Jayant opencast mine

Site	2007			2008		
	S	R	W	S	R	W
$^{S}1$	888.87 ± 47.6	377.13 ± 106.8	651.4 ± 49.5	881.66 ± 45.3	388.13 ± 94.6	668.66 ± 49.1
S_2	1513.16 ± 122.5	454.26 ± 124.3	881.66 ± 45.3	1524.3 ± 109.2	434.13 ± 101.0	888.87 ± 47.6
S_3	380.63 ± 16.8	205.42 ± 8.1	311.47 ± 15.7	378.5 ± 16.3	208.13 ± 5.4	310.53 ± 13.3
S_4	236.37 ± 19.1	125.0 ± 44.1	182.9 ± 51.0	208.13 ± 5.4	134.17 ± 352	188.63 ± 52.3
S_5	44.89 ± 2.4	26.17 ± 2.3	39.13 ± 3.6	44.42 ± 3.2	28.43 ± 4.7	39.5 ± 3.2

Table 5: The mean value of NO (mg m^{-3}) concentration during seasonal variation at selected sites around Jayant coal mine during 2006-2008

Site	2006-2007			2007-2008		
	S	R	W	S	R	W
$^{S}1$	32.22 ± 3.5	21.58 ± 0.9	36.6 ± 2.4	31.18 ± 3.4	20.19 ± 1.2	36.6 ± 2.4
S_2	39.5 ± 3.2	24.58 ± 0.9	44.42 ± 3.2	39.13 ± 3.6	24.93 ± 2.6	44.89 ± 2.4
S_3	18.89 ± 1.7	14.89 ± 1.7	20.7 ± 2.1	19.26 ± 2.3	15.57 ± 2.5	21.89 ± 2.0
S_4	13.52 ± 1.6	11.56 ± 1.0	15.57 ± 1.4	13.83 ± 0.9	12.11 ± 1.1	15.56 ± 0.9
$^{S}5$	10.04 ± 1.1	7.88 ± 1.1	13.4 ± 0.6	9.57 ± 1.4	8.29 ± 1.5	13.83 ± 0.9

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Table 6 : Seasonal variation in dust fall rate (mg m^{-3} day^{-1}) at selected sites around Jayant opencast coal mine during 2006-2008

Site	2006-2007			2007-2008		
	S	R	W	S	R	W
S_1	9.38 ± 1.42	6.02 ± 1.10	7.91 ± 0.99	9.09 ± 0.93	5.65 ± 1.35	8.25 ± 1.18
S_2	15.57 ± 1.4	13.52 ± 1.6	12.67 0.98	15.56 ± 0.4	12.68 ± 1.4	13.52 ± 1.6
S_3	3.18 ± 0.52	1.36 ± 0.26	2.63 ± 0.37	3.24 ± 0.37	1.42 ± 0.26	2.70 ± 0.39
S_4	2.54 ± 0.57	1.30 ± 0.38	1.88 ± 0.19	2.58 ± 0.46	1.36 ± 0.26	1.91 ± 0.23
S_5	1.31 ± 0.31	0.55 ± 0.7	0.90 ± 0.22	1.34 ± 0.32	0.50 ± 0.07	0.80 ± 0.18

Table 7: Average heavy metal concentration (mg g^{-1}) in settled dust at selected site around Jayant opencast coal mine during 2006-2008

Sites	Heavy Metal					
	Cd	Ni	Mr	Cr	Pl	Zn
	33.40 ± 0.05	30.32 ± 0.60	132.45 ± 1.17	24.26 ± 0.63	41.27 0.57	500.2 ± 5.71
	41.27 ± 0.57	36.65 ± 0.90	164.70 ± 2.36	30.32 ± 0.60	44.89 ± 2.4	530.15 ± 20.85
	26.73 ± 0.33	21.41 ± 0.56	10.52 ± 1.07	18.50 ± 0.50	34.30 ± 0.63	450.46 ± 5.83
	20.3 ± 0.05	22.27 ± 2.22	118.29 ± 0.03	17.16 ± 2.08	17.16 ± 2.08	420.47 ± 1.06
	8.37 ± 0.58	8.60 ± 0.15	57.27 ± 0.7	6.23 ± 0.56	8.16 ± 0.60	121.07 ± 6.39

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Sites	Ca	K	Na	So_4^{2}-5
S_1	21.73 ± 0.14	6.57 ± 0.42	4.6 ± 0.20	23.33 ± 1.92
S_2	29.80 ± 0.65	8.47 ± 0.08	7.87 ± 0.06	30.32 ± 0.60
S_3	16.7 ± 0.70	4.6 ± 0.20	0.81 ± 0.08	7.87 ± 0.06
S_4	8.40 ± 0.26	1.37 ± 0.06	0.54 ± 0.005	4.6 ± 0.20
S_5	3.83 ± 0.49	0.87 ± 0.13	0.41 ± 0.012	4.43 ± 0.43

Figure 1: Average annual So and No concentration during 2007 and 2008
2

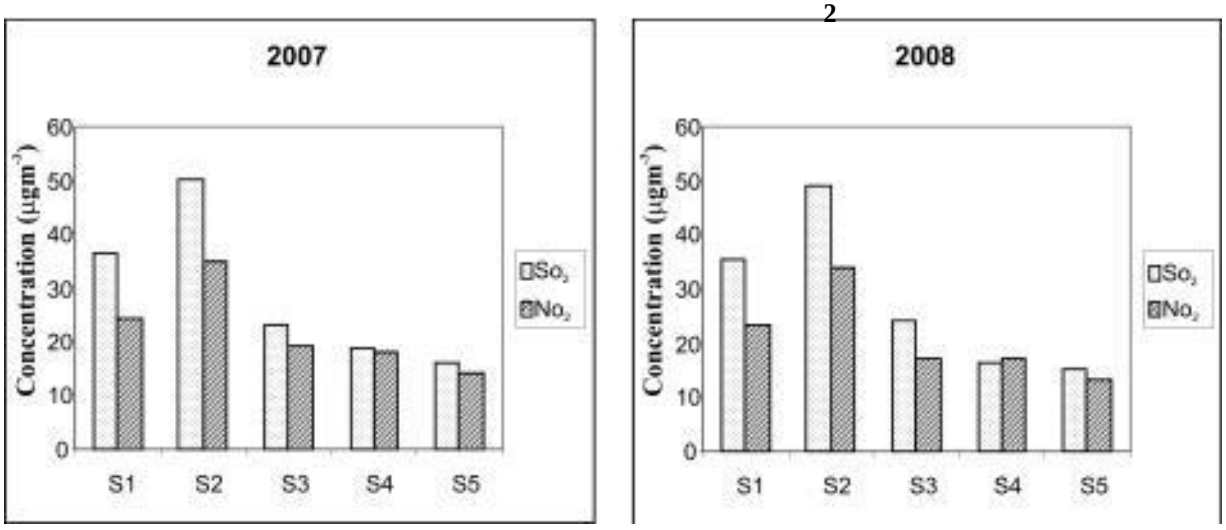
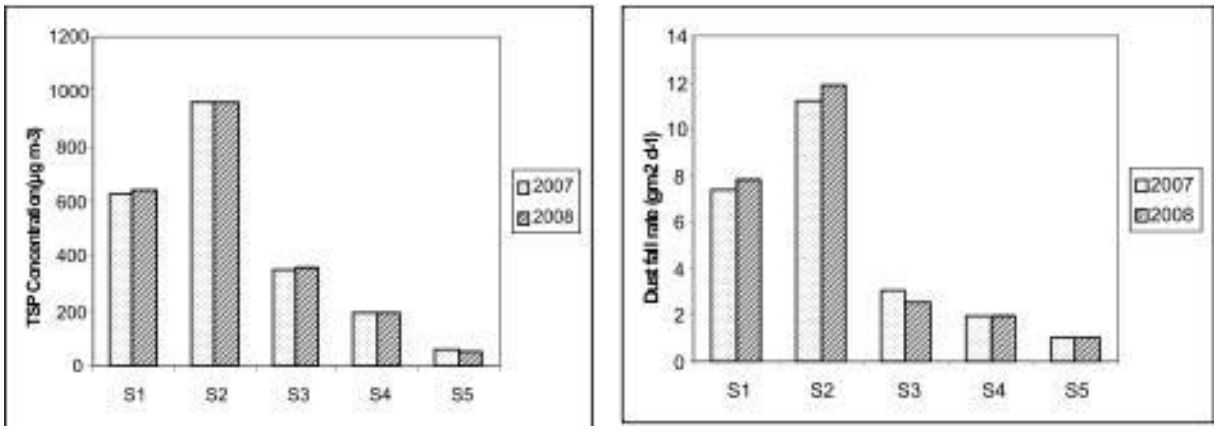


Figure 2: Average concentration of total suspended particulates (TSP) and dust fall rate during 2007 and 2008



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