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Quarrying induced particulate air pollution in Jaipur City, western India

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ABSTRACT

Jhalana hills, fringing the northern and northeastern periphery of the Jaipur City in Rajasthan, western India, form a part of Aravalli hill Range. Stratigraphically, they belong to the Middle Proterozoic, Delhi Supergroup of rocks, predominantly comprising of quartzite indicating arenaceous facies sedimentation. Signatures of polyphase deformation are manifested as tight to isoclinal folds and steep dips. On account of its close vicinity to the city and conforming to various structural engineering standards, the Jhalana Quartzite has been a source of construction material for the last two centuries for all types of civil engineering activities in and around Jaipur.

Rapid and unplanned urbanisation of Jaipur and the hinterland areas has resulted in urban sprawl and industrialisation. Increased demand for construction material has resulted in multifold rise in quarrying operations, without taking into account of the consequent adverse impacts. This has led to alarming increase in suspended particulate matter (SPM) in air as one of the three major air pollutants in Jaipur, besides sulphur dioxide (SO_2) and nitrogen oxides (NO_x). The present work focuses on monitoring and quantitative evaluation of air quality in relation to quarrying activity. The observed values have been compared with the prescribed SPM limits for impact assessment.

The air quality monitoring has been carried out by establishing three observation sites at different directions from the source of pollution (quarries and stone crusher sites). The prevailing wind direction has been taken into account while synthesising the SPM data. Sampling for twenty-four hour duration with a frequency of twice a week has been done for a period of five months (October, 1996 to February, 1997). For impact assessment modelling, the data were converted into monthly mean concentrations.

The observed exceedence in SPM varies from 118.2 to 278.3%, 13.12 to 163.3% and 15.87% at different monitoring sites. An inverse relationship of distance from quarrying and crusher sites with SPM exceedence levels in air is also well documented.

INTRODUCTION

The Jhalana stone quarries located on the western flanks of the Jhalana hills to the southeast of the Jaipur city in Rajasthan have remained the main source of building stones for more than two centuries. The hills with precipitous slope on either side and flattened tops are the outcrops of the main Aravalli ranges further extending to Alwar in the northeast direction. These ranges offer a variety of building stones, which have been extensively used in erecting the monumental palaces, garrisons, forts and buildings of the Jaipur City.

During last two decades, the Jhalana area has witnessed a constant increase in quarrying operations due to incessant flow of migrants and their demands for housing. As a result, the Jhalana area was exposed to particulate formed due to quarrying operation and running of stone crushers.

However, till the early part of the last decade, it did not pose any environmental threat as the quarrying was at a slow pace. The problem of air and noise pollution has acquired alarming dimensions only during the last ten years. Considering the importance of the area and the gravity of the pollution problems, the study was taken up and the observations and results on air quality monitoring of the region have been embodied in the present paper. The location of quarrying sites in relation to the Jhalana hills is given in Fig. 1.

The specific objectives of this paper is to present:

a) To monitor SPM levels (respirable and non-respirable ranges) in the area, since quarrying operations are expected to produce only particulate rather than gases, and,
b) To compare the observed SPM levels with the prescribed limits.

BACKGROUND INFORMATION

Geomorphic Setting

The rocks of the Jhalana area occurring as quartzite hills and ridges form a part of the NE-SW trending Aravalli Mountain Belt. The quartzites belonging to the Alwar Group of rocks (Delhi Supergroup) overlie a basement of schists and gneisses. The whole region, in turn, is covered by a Quaternary mantle. Some exposures of impure marble, exposed to the north of Jaipur have been ascribed to Raialo age. The quartzites have predominant quartz showing interlocking arrangement with minor abundances of muscovite and feldspar and ferrugineous material. The cementing material in most of the cases is siliceous. The quartzite shows considerable variation in the grain size, at places, attaining conglomeratic nature. Well-preserved relict structures like cross-stratification are quite common. Signatures of polyphase deformation are manifested in tight isoclinal folding and steep joints.

The Jhalana hills rising above the alluvial tract represent the most significant geomorphic feature of the region. The maximum height is approximately 200 m above the surrounding plains. A dendritic network of ephermal streams drains the slopes. The streams on the western flank of the hill join together and flow southward along the base of the hill and ultimately join the Amanishah Nalah. The streams on the eastern slopes join and follow an easterly flow as the Gogado Nadi. The western side of the hills has been greatly modified into steep slope due to quarrying operations. This has also initiated extensive sheet and gully erosion and deforestation.

Meteorology

Atmospheric motion plays an important role in air pollution phenomenon. In general, the pollutants are dispersed in the environment by the process of molecular diffusion and transportation that arises due to change in concentration and depends upon a number of factors, namely, meteorological condition (e.g., wind direction and velocity), topography, etc. Fig. 1 presents the Wind Rose Diagrams of the Jaipur City. As evident, the general winds are predominant in northwest sector with the velocity ranging from 1 to 12 km/hr.

Prescribed Air Quality Standards

The Central Pollution Control Board (CPCB) has laid down standards for permissible SPM levels (Central Pollution Control Board, 1996) as shown in Table 1.

METHODOLOGY

Period of Study

The air quality monitoring in the Jhalana area for present investigation, was carried out from September, 1996 to February, 1997 during which Respirable Suspended Particles (RSP) and Total

Table 1: Standards prescribed for permissible SPM level (Central Pollution Control Board, 1996)

S.N.	Area Category	RSP (μg/m^3)	TSP (μg/m^3)
1	Industrial and mixed landuse pattern	250	500
2	Residential	100	200
3	Sensitive	50	100

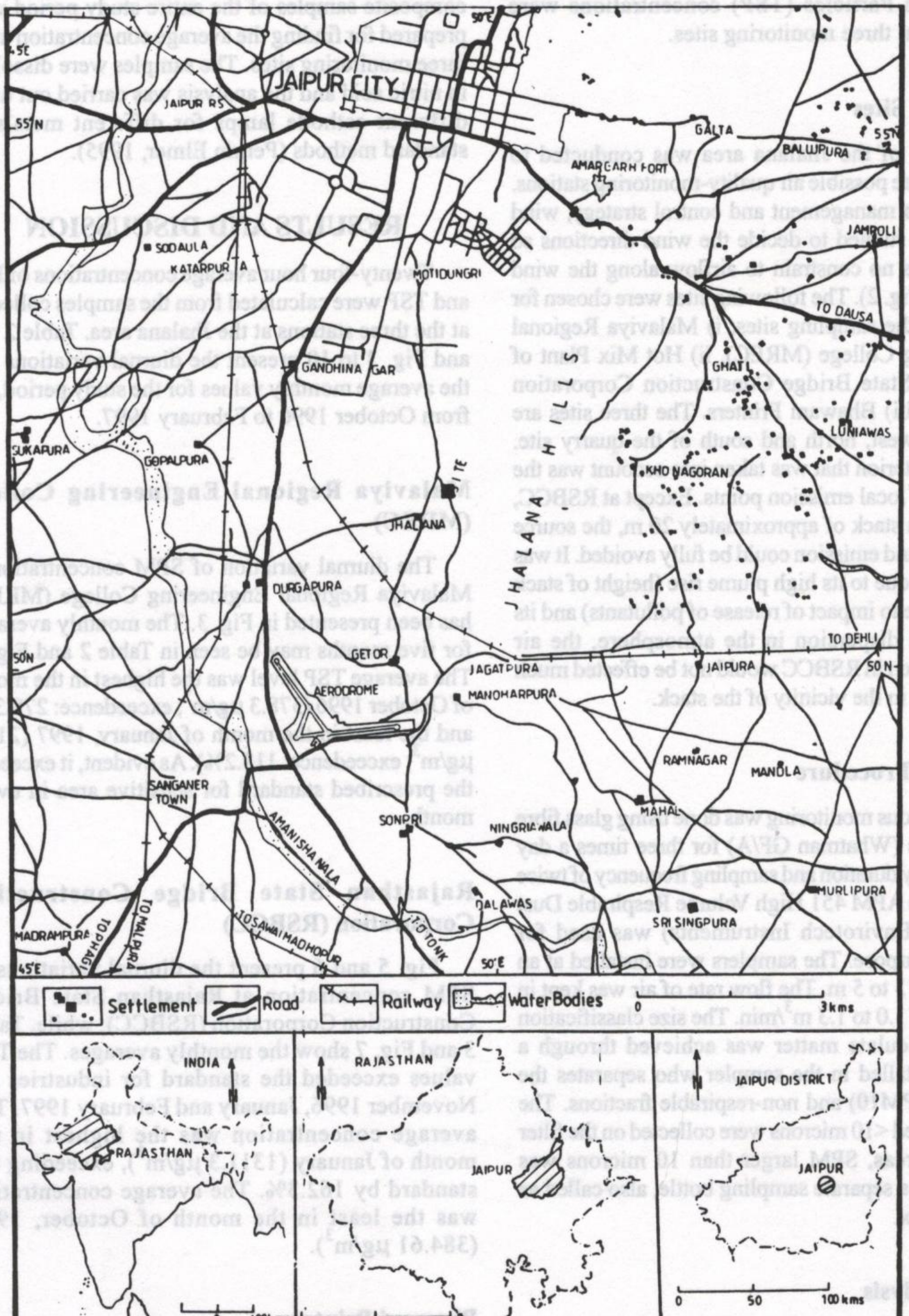

Fig. 1: Map of Jaipur region showing locations of sampling site along the western fringe of Jhalana hills.

Suspended Particles (TSP) concentrations were measured at three monitoring sites.

Sampling Sites

Survey of the Jhalana area was conducted to identify three possible air quality-monitoring stations. To evolve a management and control strategy, wind roses were studied to decide the wind directions so that there is no constrain to airflow along the wind direction (Fig. 2). The following sites were chosen for setting up the sampling sites: i) Malaviya Regional Engineering College (MREC), ii) Hot Mix Plant of Rajasthan State Bridge Construction Corporation (RSBCC), iii) Bhawani Printers. The three sites are located at west, north and south of the quarry site. Another criterion that was taken into account was the presence of local emission points. Except at RSBCC, which has a stack of approximately 20 m, the source of background emission could be fully avoided. It was argued that due to its high plume rise (height of stack + height due to impact of release of pollutants) and its subsequent dispersion in the atmosphere, the air samples taken in RSBCC would not be effected much when taken in the vicinity of the stack.

Sampling Procedure

Continuous monitoring was done using glass fibre filter papers (Whatman GF/A) for three times a day with 8 hourly duration and sampling frequency of twice a week. The APM 451 High Volume Respirable Dust Sampler (Envirotech Instruments) was used for sampling purpose. The samplers were installed at an elevation of 3 to 5 m. The flow rate of air was kept in the range of 1.0 to 1.3 m^3/min. The size classification of the particulate matter was achieved through a cyclone installed in the sampler who separates the respirable (PM10) and non-respirable fractions. The particles sized <10 microns were collected on the filter paper; whereas, SPM larger than 10 microns was collected in a separate sampling bottle, also called as dust collector.

Metal Analysis

Quantitative metal analysis was carried out by atomic absorption spectrophotometer (PERKIN ELMER, AAS 311). As prescribed by Katz (1977), composite samples of the entire study period were prepared for finding the average concentration at the three monitoring sites. The samples were dissolved in nitric acid and the analysis was carried out using different cathode lamps for different metals by standard methods (Perkin Elmer, 1995).

RESULTS AND DISCUSSION

Twenty-four hour average concentrations of RSP and TSP were calculated from the samples collected at the three stations at the Jhalana area. Table 2 to 4 and Fig. 3 to 10 present the diurnal variations and the average monthly values for the study period, i.e. from October 1996 to February 1997.

Malaviya Regional Engineering College (MREC)

The diurnal variation of SPM concentration at Malaviya Regional Engineering College (MREC) has been presented in Fig. 3. The monthly averages for five months may be seen in Table 2 and Fig. 4. The average TSP level was the highest in the month of October 1996 (378.3 $\mu g/m^3$; exceedence: 278.3%) and the least in the month of January, 1997 (218.2 $\mu g/m^3$; exceedence: 118.2%). As evident, it exceeded the prescribed standard for sensitive area in every month.

Rajasthan State Bridge Construction Corporation (RSBCC)

Fig. 5 and 6 present the diurnal variations of SPM concentration at Rajasthan State Bridge Construction Corporation (RSBCC); while, Table 3 and Fig. 7 show the monthly averages. The TSP values exceeded the standard for industries for November 1996, January and February 1997. The average concentration was the highest in the month of January (1311.3 $\mu g/m^3$), exceeding the standard by 162.3%. The average concentration was the least in the month of October, 1996 (384.61 $\mu g/m^3$).

Bhawani Printers

The diurnal variations of SPM at Bhawani Printers have been presented in Fig. 8 and 9, while

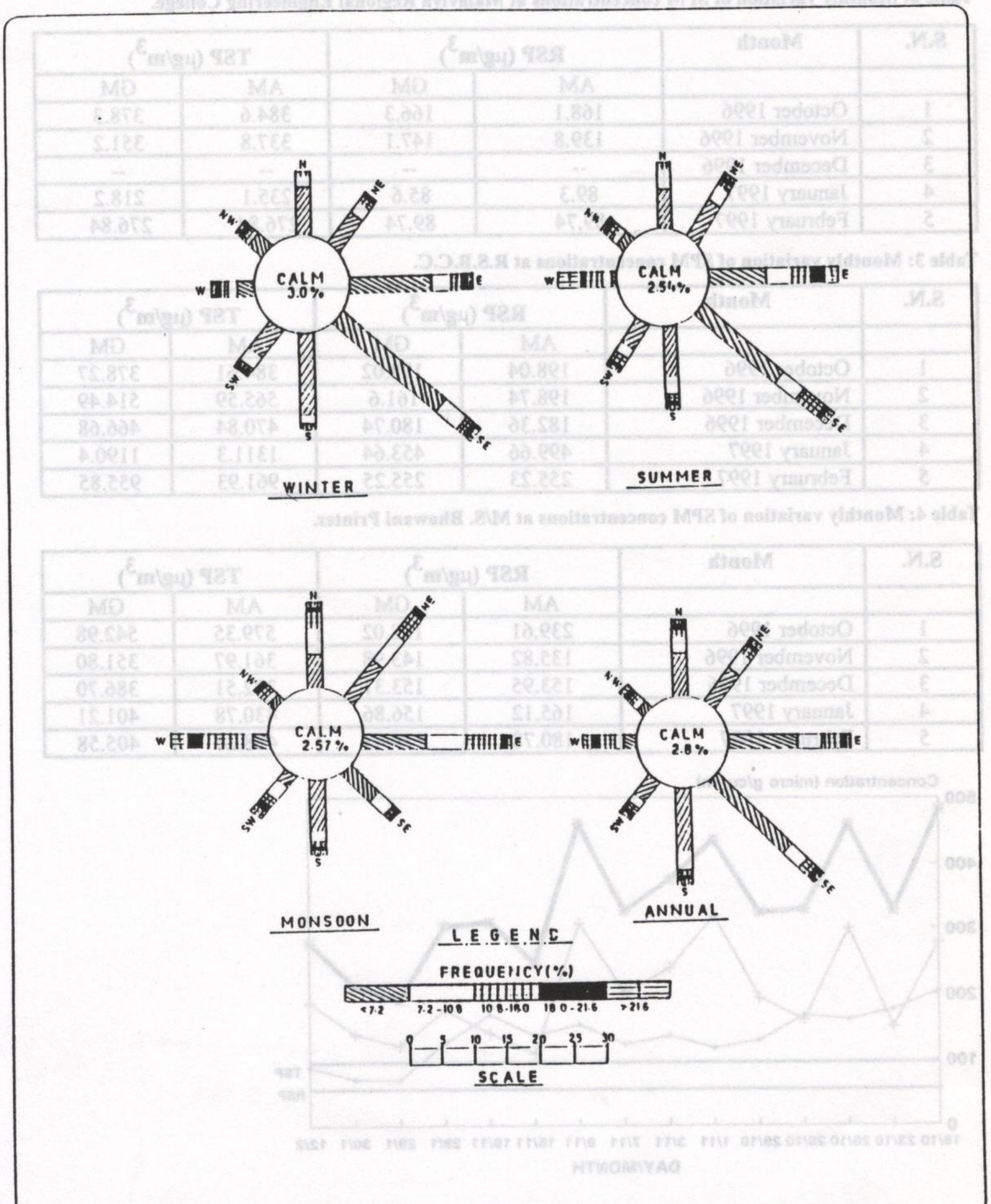

Fig. 2: Wind rose diagram.

Table 2: Monthly variation of SPM concentrations at Malaviya Regional Engineering College.

S.N.	Month	RSP ($\mu g/m^3$)		TSP ($\mu g/m^3$)	
		AM	GM	AM	GM
1	October 1996	168.1	166.3	384.6	378.3
2	November 1996	139.8	147.1	337.8	351.2
3	December 1996	--	--	--	--
4	January 1997	89.3	85.6	235.1	218.2
5	February 1997	89.74	89.74	276.84	276.84

Table 3: Monthly variation of SPM concentrations at R.S.B.C.C.

S.N.	Month	RSP ($\mu g/m^3$)		TSP ($\mu g/m^3$)	
		AM	GM	AM	GM
1	October 1996	198.04	198.02	384.61	378.27
2	November 1996	198.74	161.6	565.59	514.49
3	December 1996	182.36	180.74	470.84	466.68
4	January 1997	499.66	453.64	1311.3	1190.4
5	February 1997	255.23	255.25	961.93	955.85

Table 4: Monthly variation of SPM concentrations at M/S. Bhawani Printer.

S.N.	Month	RSP ($\mu g/m^3$)		TSP ($\mu g/m^3$)	
		AM	GM	AM	GM
1	October 1996	239.61	188.02	579.35	542.98
2	November 1996	135.82	143.98	361.97	351.80
3	December 1996	153.95	153.31	392.51	386.70
4	January 1997	165.12	156.86	430.78	401.21
5	February 1997	180.78	179.43	408.26	405.58

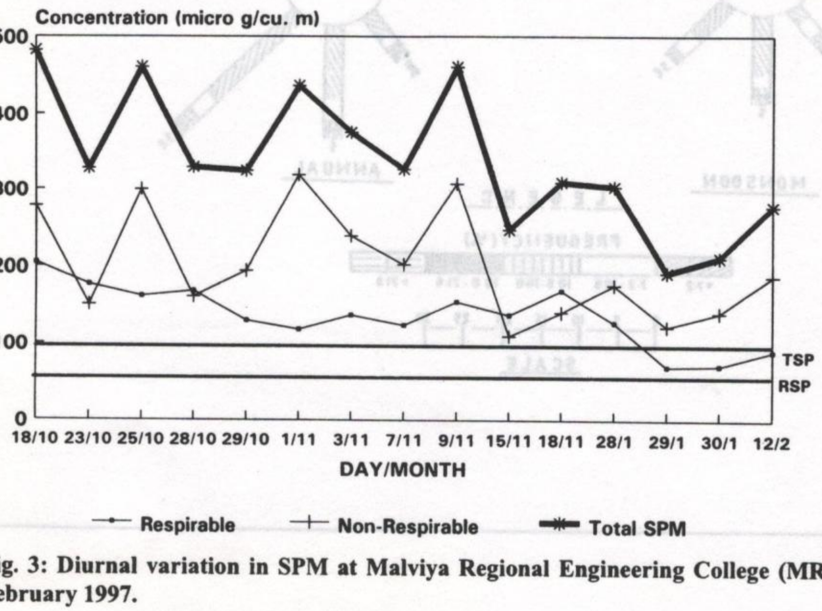

Fig. 3: Diurnal variation in SPM at Malviya Regional Engineering College (MREC) during October 1996 – February 1997.

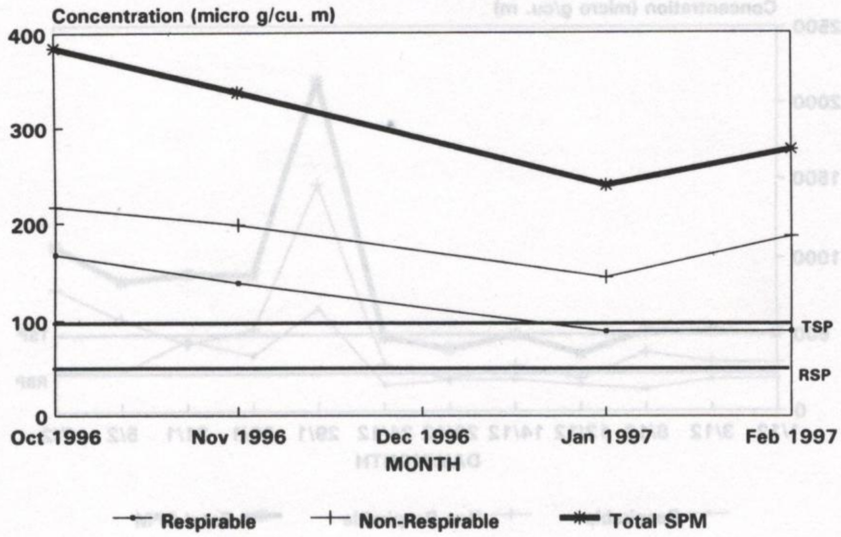

Fig. 4: SPM Concentration at MREC during October 1996 – February 1997.

Fig. 10 and Table 4 give the monthly variations. The SPM levels were the maximum in the month of October, 1996 (579.35 g/m^3) and the least in November, 1996 (361.97 g/m^3). TSP concentrations were generally low in all the months and were within the safe limit, except, in October, 1996 when an exceedence limit of 15.87% was found.

Metal Analysis

Average metal concentrations of zinc, iron, cadmium, copper and lead at the three stations for the entire sampling duration have been presented in Table 5. The metals have mostly originated from the quarrying sites and stone crushers, and have dispersed with the wind. The origin and presence of metals at

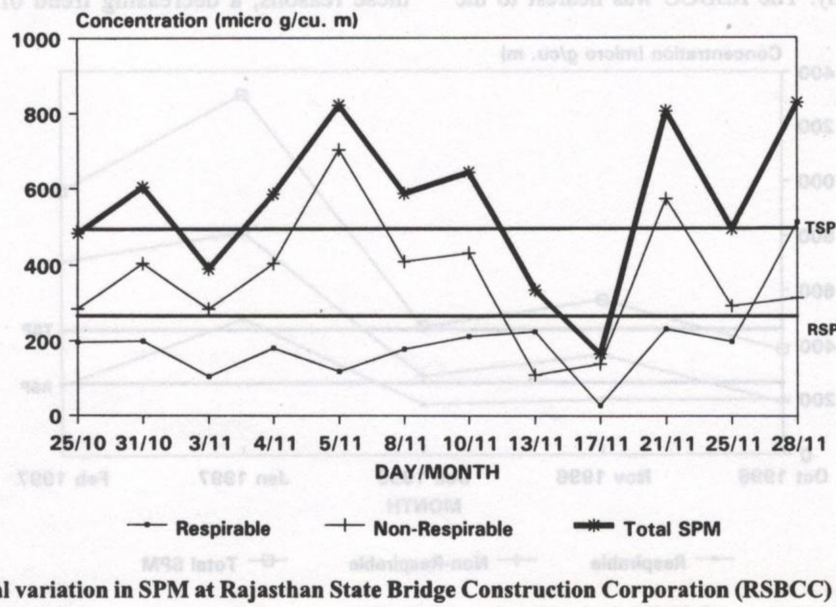

Fig. 5: Diurnal variation in SPM at Rajasthan State Bridge Construction Corporation (RSBCC) during October 1996 –November 1996.

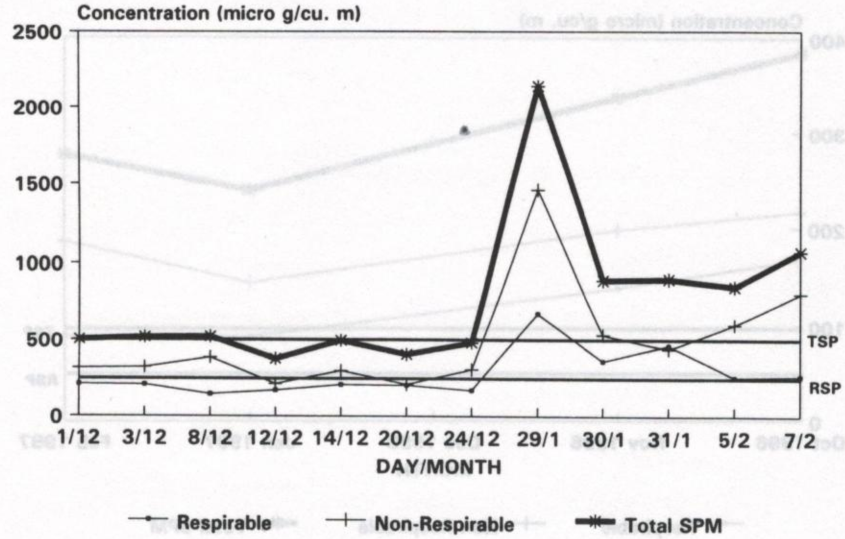

Fig. 6: Diurnal variation in SPM at RSBCC during November-December, 1996.

the quarrying sites have been confirmed by an optical study of sample rocks from the Jhalana area. As evident from the Table 5, the concentration of all the metals was highest at the MREC, followed by the Rajasthan State Bridge Construction Corporation (RSBCC) and Bhawani Printers. The trend is attributed to the prevailing wind direction, distance of the location from the quarrying sites and localised generation of pollutants, if any. The RSBCC was nearest to the blasting sites, whereas, Bhawani Printers was at the farthest distance. During the months of October to February, predominant wind sector is mostly south-easterly and blows over the RSBCC towards the Jhalana hill, further reflected by the hill it blows over the MREC and Bhawani Printers due south-west. Of these two sites, the MREC encounters the maximum frequency of wind from the Jhalana area (Fig. 2). For these reasons, a decreasing trend of metals was

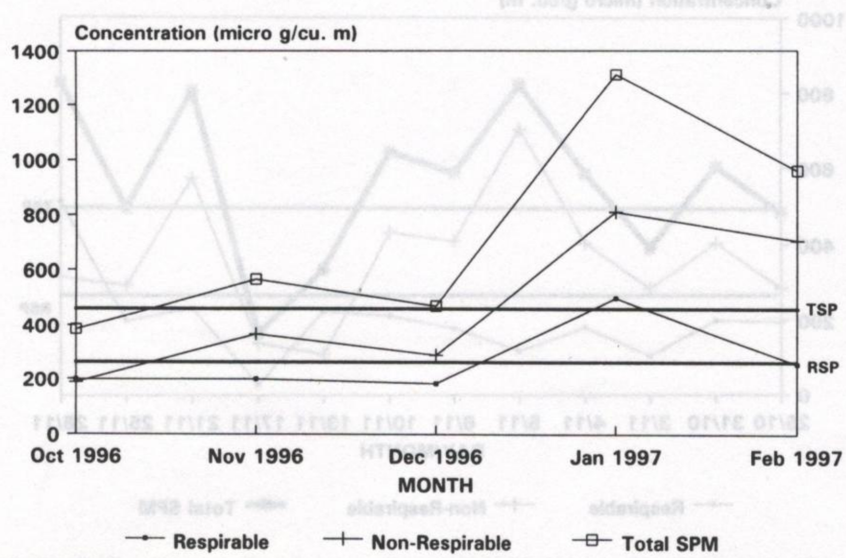

Fig. 7: SPM concentration at RSBCC during October 1996 – February 1997.

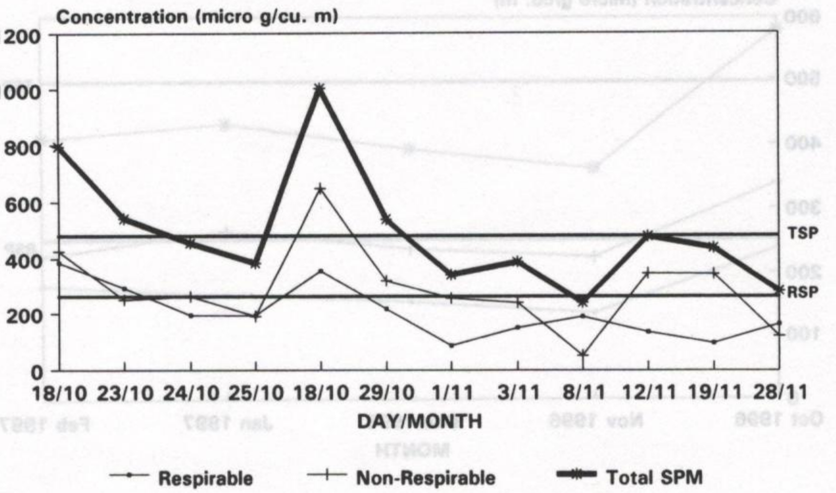

Fig. 8:Diurnal variation in SPM at Bhawani Printers during October-November 1996.

expected in the order of the MREC, Bhawani Printers and RSBCC, respectively. However, due to presence of localised pollutants, concentrations at the RSBCC was found higher than at the Bhawani Printers.

CONCLUSION AND RECOMMENDATION

The foregoing discussion establishes that the quarrying operations are responsible for particulate and heavy metal air pollution in the Jhalana region. Although no independent mineral phases containing Cd could be identified, its source in the Jhalana quartzite has been established on the basis of dispersion pattern. The TSP values at the MREC in all the months from October, 1996 to February, 1997 exceeded the standard. The RSBCC was the site of maximum pollution and the TSP level was within the limit in only two months. In the other three months,

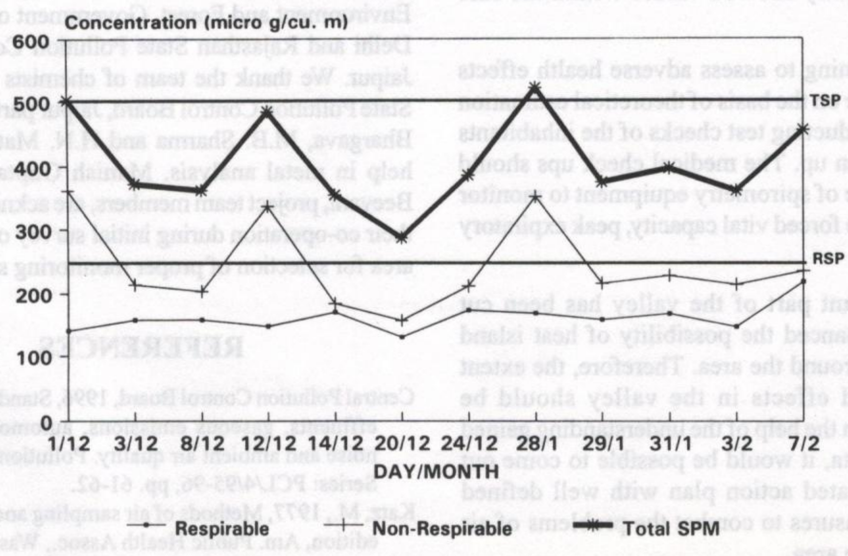

Fig. 9:Diurnal variation in SPM at Bhawani Printers during December 1996 – February 1997.

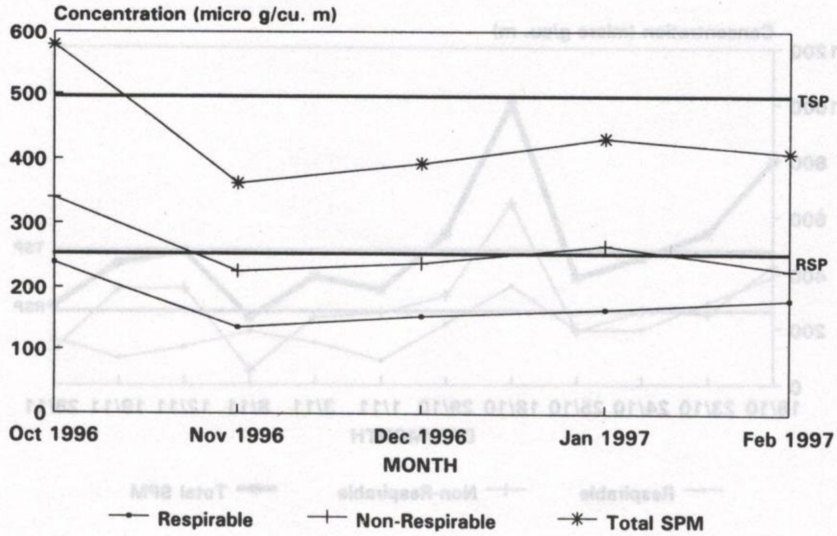

Fig. 10 SPM concentration at Bhawani Prtinters during October 1996 – February 1997.

Table 5: Average metal concentrations (PPM) for five months.

S.N.	Metals→	Zn	Cu	Fe	Pb	Cd
1	MREC	1.5567	0.4572	16.8287	0.1389	3.0500
2	Bhaw. Print.	1.0645	0.3310	14.2188	0.0925	0.0121
3	RSBCC	1.0641	0.3269	11.0769	0.0908	0.0103

the SPM level was very high and the exceedence limit of more than 200% was found. The Bhawani Printers generally showed values within the safe limit.

Studies aiming to assess adverse health effects on local people on the basis of theoretical estimation as well by conducting test checks of the inhabitants should be taken up. The medical check ups should involve the use of spirometry equipment to monitor parameters like forced vital capacity, peak expiratory flow rate, etc.

A significant part of the valley has been cut which has enhanced the possibility of heat island effect in and around the area. Therefore, the extent of heat island effects in the valley should be measured. With the help of the understanding gained from above data, it would be possible to come out with an integrated action plan with well defined mitigating measures to combat the problems of air pollution in the area.

ACKNOWLEDGEMENTS

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REFERENCES

Central Pollution Control Board, 1996, Standards for liquid effluents, gaseous emissions, automobile exhaust, noise and ambient air quality. Pollution Control Law Series: PCL/4/95-96, pp. 61-62.

Katz, M., 1977, Methods of air sampling and analysis. 2nd edition, Am. Public Health Assoc., Washington.

Perkin Elmer, 1995, Operating Manual.