CONCENTRATION AND DISTRIBUTION OF PARTICULATE MATTER IN SUBBARAYANAHALLI IRON ORE MINE, SANDUR, KARNATAKA, INDIA - A CASE STUDY

A Jaswanth Gowda[1], K M Sham Sundar[2], D P Nagarajappa[3], Ashok Kusagur[4], B Lokeshappa[5]

[1]*Post Graduate Student, Department of Civil Engineering, University BDT College of engineering, Davanagere-577004, Karnataka, India.*

[2]*Professor, Department of Civil Engineering, University BDT College of engineering, Davanagere-577004, Karnataka, India.*

[3]*Professor, Department of Civil Engineering, University BDT College of engineering, Davanagere-577004, Karnataka, India.*

[4]*Associate Professor, Department of Electrical and Electronics Engineering, University BDT College of engineering, Davanagere-577004, Karnataka, India.*

[5]*Associate Professor, Department of Civil Engineering, University BDT College of engineering, Davanagere-577004, Karnataka, India.*

Abstract

Particulate matter is a major air pollutant in open cast mining areas. The activities of Subbarayanahalli iron ore mine contribute to air pollution in and around the mine areas. The ambient air quality monitoring was conducted for suspended particulate matter (< 10 micron) and respirable suspended particulate matter (< 2.5 micron) at 8 locations considering various activities in the core zone and haul roads of villages in the buffer zone during summer, rainy and winter of 2014. The results showed that SPM varied from 23 $\mu g/m^3$ to 113 $\mu g/m^3$ and RSPM varied from 13 $\mu g/m^3$ to 56 $\mu g/m^3$ with maximum at haul road followed by crushing and weighing bridge locations. In summer the values are very high and low in the rainy season due to the variations in rainfall, humidity, temperature, wind velocity and direction. Compared with meteorological conditions it is observed that humidity levels higher than 65% in mining region maintain safe air quality conditions. The various mining activities such as loading and unloading, drilling, crushing, blasting and unpaved haul roads are the major sources of particulate matter. The particle sizes 0-2.5 µm were found in the range of 45.65% to 63.41% in the core zone and 34.11% to 56.52% in the buffer zone of the total SPM.

Keywords: *Suspended Particulate Matter, Respirable Particulate Matter, Fugitive Dust, Core Zone, Buffer Zone.*

---***---

1. INTRODUCTION

Particulate matter is a major air pollutant in open cast mining areas. Air pollution problems vary with respect to area and the pollutant's behaviour [1,4]. The movement of vehicles carrying iron ore is contributing high suspended particulate matter in the region apart from the unpaved haul roads. This particulate matter affects the health of mine workers and residents in the buffer zone as well as the inhabitants of the region. The airborne dust arises from working with machineries and iron ore benches, crushing and screening plants, transporting equipment and having unpaved haul roads [6,9]. The traffic of vehicles on an unpaved haul road contributes to fugitive dust into atmosphere. The uncontrolled airborne dust creates health hazards as well as less visibility; the distribution of fugitive dust travels over long distances causing deterioration of ambient air quality in and around the mining site. The size and silica content of the dust are important parameters influencing the dispersion as well as health effects [9]. The Government of Karnataka has identified a number of environmental problems in and around the Sandur region. The region has been identified as one of the major environmental hotspots of the state due to problems arising out of mining [8]. A study was made in the Subbarayanahalli Iron Ore Mine (SIOM), a hilly iron ore deposit of M/s Mysore Minerals Limited (Sandur, Karnataka) for a period of three seasons in 2014 to understand how the emission rate of particulate matter varies with weather conditions.

2. MATERIALS AND METHODS

The study area, the sampling locations, the sampling procedure and the meteorology are described in detail.

2.1 Study Area

Subbarayanahalli iron ore mine is one of the leading iron ore mines of M/s Mysore Minerals Limited in the Hospet-Bellary sector. The mine has an area of 80.93 hectares. The area falls in the survey of India toposheet No.57A/12 and lies inside the Kumaraswamy Betta Forest. It is approachable by good road from Sandur town to Devagiri at a distance of about 12 km towards Subbarayanahalli village. The total area lies between 76^{0}32'45" and 76^{0}33'48" in longitude and between 15^{0}00'58" and 15^{0}01'55" in latitude. Toranagallu is the nearest railway station at a distance of 40 km in the NNE direction. Figure 1 shows the map of study area with sampling Locations.

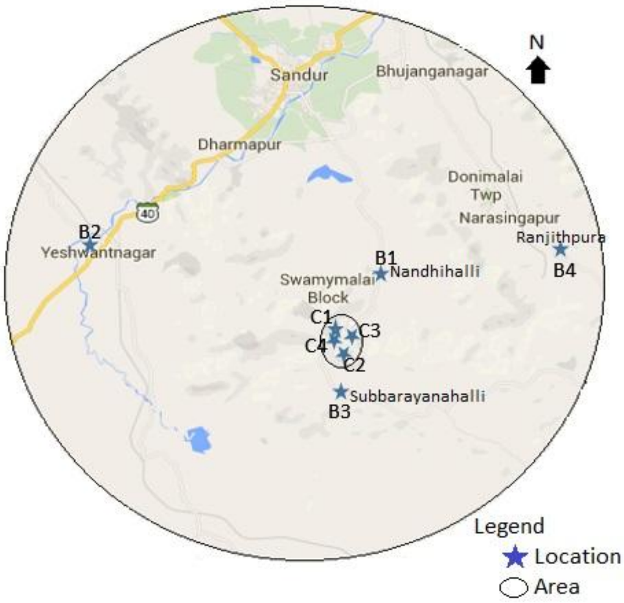


Fig 1 Map showing the location of Subbarayanahalli Iron Ore Mine and the sampling stations.

2.2 Sampling Locations

In this study, eight sampling stations have been selected based on the emission of particulate matter considering the (i) traffic density in unpaved road, (ii) wind direction and (iii) site activities. Sampling selection criteria plays an important role in the developmental activity as it provides an outlook on the type of environmental compliance and management to be adopted by the project proponent [7,9]. Locations detailed report is tabulated in Table 1.

2.3 Sampling Procedure

Fine particulate samplers of Model APM 550 of ENVIROTECH Instruments were used for monitoring Suspended Particulate Matter and Respirable Particulate Matter fraction. Sampling and analysis of Particulate Matter in ambient air were implemented by the Gravimetric method. Air was sucked through a size selective inlet and a filter at a flow rate of 1132 L/min. Particles with aerodynamic diameter less than 10 µm and 2.5 µm were collected by the respective filter paper. The mass of these particles was determined by the difference in filter paper weights before and after sampling. The concentration of PM_{10} and $PM_{2.5}$ was calculated by dividing the weight gain of the filter paper by the volume of air sampled [2,3]. Sampling was conducted on 16 hourly basis at each station during the study period. The concentrations of SPM and RSPM were measured in µg/m^3. Guidelines of Central Pollution Control Board, New Delhi on National Ambient Air Quality Standards-2009 were followed for undertaking the monitoring [2].

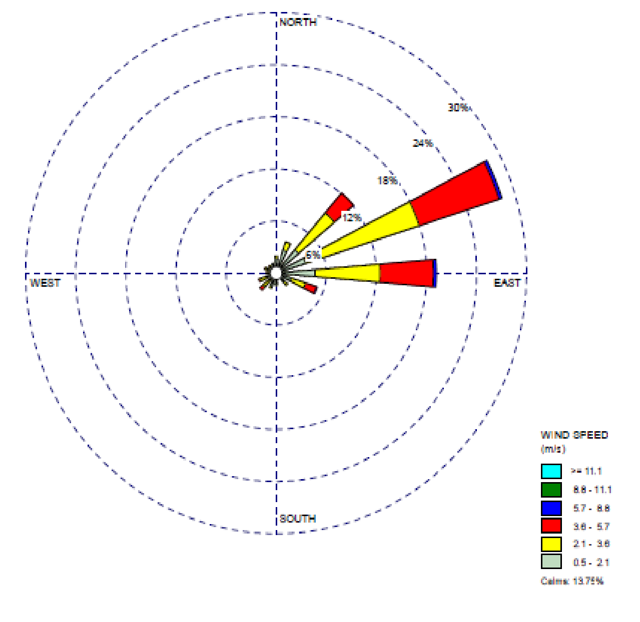
2.4 Meteorology

Air quality monitoring at 8 stations was conducted in the study area during summer (March to June), rainy (July to October) and winter (November to February) of 2014. The meteorological data have been collected from Indian Meteorological Department. During summer the temperature goes up to 42.2º C and in winter season it falls as low as 5.5º C. The number of rainy days in 2014 was 56; the rainfall amount and intensity were maximum in the month of September (181 mm). The annual relative humidity in the study area ranges from 38% to 95%. During the rainy season the humidity is maximum compared to summer and winter and it is observed that it is higher in the morning and less in the evening [5]. The wind rose diagram for the study area has been plotted for one month in the three different seasons.

Table 1: Location Report of Ambient Air Monitoring Stations

Sl.No.	Sampling Location	Code	Source Type	Longitude E	Latitude N	Surface above mean sea Level (m)	Direction to Mine Area
1	Crushing/Screening	C1	Area	76º 33' 15.1"	15º 01' 23.4"	966	---
2	Weighing bridge	C2	Point	76º 33' 20.7"	15º 01' 01.9"	987	---
3	Office area	C3	Line	76º 33' 29.3"	15º 01' 17.9"	915	---
4	Haul Road	C4	Line	76º 33' 18.2"	15º 01' 09.2"	1001	---
5	Nandhihalli Village	B1	Line	76º 34' 05.1"	15º 02' 11.9"	633	NNE
6	Yeshwanthnagar	B2	Line	76º 29' 57.9"	15º 02' 37.1"	601	W
7	Subbarayanahalli	B3	Line	76º 33' 16.2"	15º 00' 38.1"	1015	S
8	Ranjithpura	B4	Line	76º 36' 33.5"	15º 02' 44.3"	638	NEE

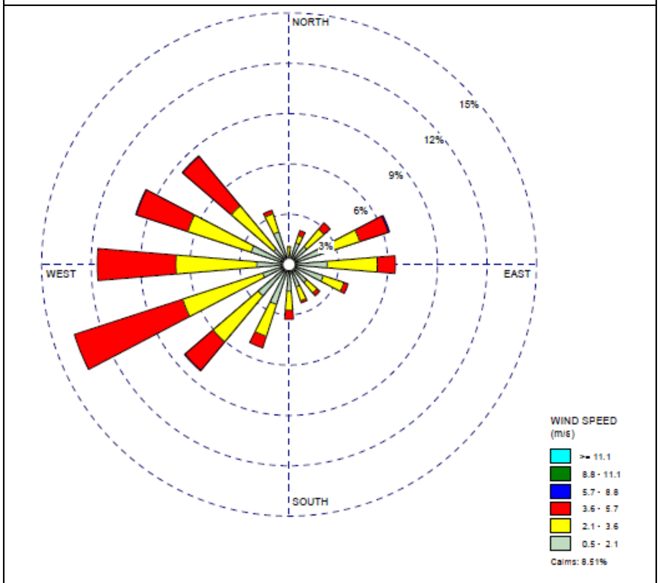
WIND ROSE PLOT Winter Season Direction (blowing from)	DISPLAY Wind Speed



COMMENTS	DATA PERIOD	CALM WIND	AVG. WIND SPEED
	January 2014	13.76%	2.38 m/s

Fig 2 Wind rose diagram for winter

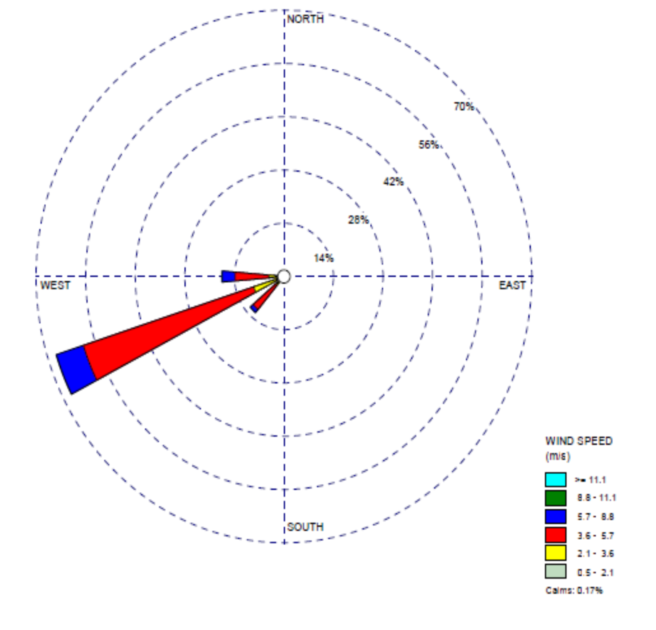
WIND ROSE PLOT Summer Season Direction (blowing from)	DISPLAY Wind Speed



COMMENTS	DATA PERIOD	CALM WIND	AVG. WIND SPEED
	May 2014	8.51%	2.60 m/s

Fig 3 Wind rose diagram for summer

WIND ROSE PLOT Rainy Season Direction (blowing from)	DISPLAY Wind Speed



COMMENTS	DATA PERIOD	CALM WIND	AVG. WIND SPEED
	September 2014	0.17%	4.57 m/s

Fig 4 Wind rose diagram for the rainy Season

During winter the predominant wind direction is from north to east with average velocity of 2.38 m/s and calms in the morning. Figure 2 shows the wind rose diagram for the month of January 2014. In summer the predominant wind blows from southwest to northwest with an average velocity of 2.6 m/s. Figure 3 shows the wind rose diagram for the month of May 2014. In the rainy season the predominant wind blows from south to west with average velocity of 4.57 m/s. Figure 4 shows the wind rose diagram for the month of September 2014.

3. EXPERIMENTAL RESULTS

The SPM and RSPM concentrations obtained during the three seasons are summarized and tabulated in Table 2. The concentrations of SPM and RSPM were found to be higher in the summer and minimum in the rainy season due to the variation in rainfall, humidity, temperature, wind speed and direction. The percentage contribution of RSPM in SPM was found to be higher at the locations in the core zone compared to the ones in the buffer zone in the rainy season, the values ranged from 45.65% to 63.41% and 34.11% to 56.52%, respectively.

From the obtained results the higher concentrations of particulate matter arise from the haul roads, crushing/screening plants and weighing bridge due to their continuous activity at these locations.

Table 2 SPM and RSPM concentration at the sampling locations

Sl.No.	Code	SPM (µg/m³)			RSPM (µg/m³)			% RSPM in SPM	
		Jan 2014	May 2014	Sep 2014	Jan 2014	May 2014	Sep 2014	Max	Min
1	C1	101	110	41	50	54	23	56.09%	49.09%
2	C2	107	104	44	50	52	21	50%	46.72%
3	C3	92	103	39	42	49	20	51.28%	45.65%
4	C4	106	113	41	49	56	26	63.41%	46.22%
5	B1	75	83	31	29	32	16	51.61%	38.55%
6	B2	83	92	37	35	39	20	54.05%	42.16%
7	B3	73	85	23	26	29	13	56.52%	34.11%
8	B4	82	88	31	33	40	17	54.83%	40.24%
Mean		89.88	97.25	35.88	39.25	43.88	19.5	---	---

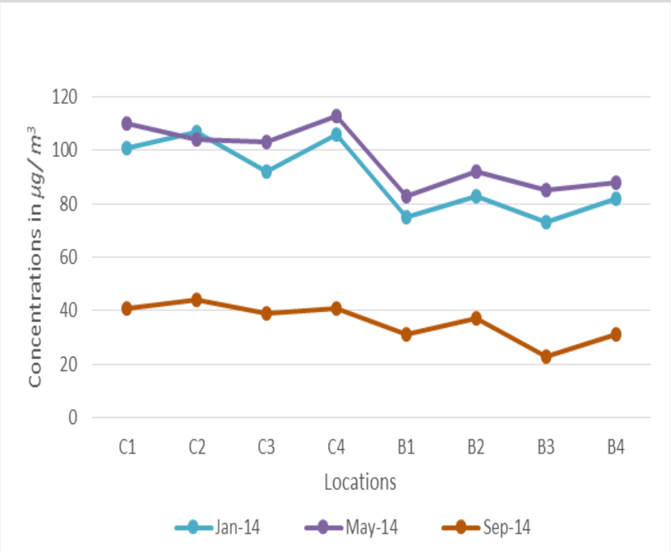


Fig 5 SPM concentration variation at the sampling locations

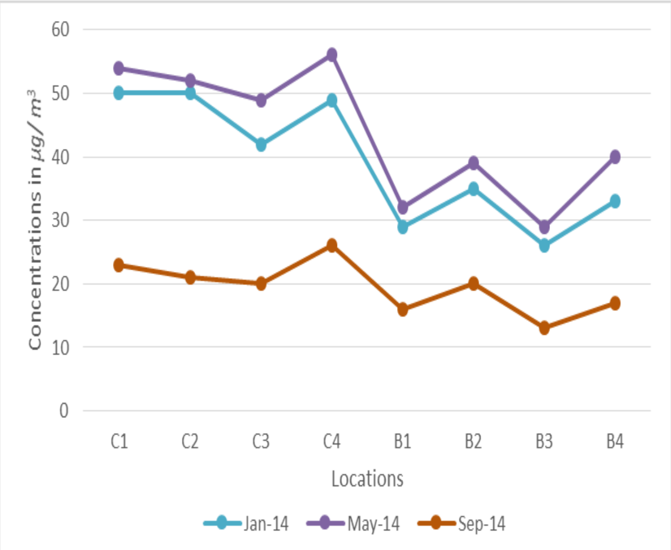


Fig 6 RSPM concentration variation at the sampling locations

4. CONCLUSION

Particulate Matter concentrations for all the eight locations have been interpreted. It is inferred that the values in the core zone are higher while in buffer zone the concentrations are within the National Ambient Air Quality Standards. In the summer the values are very high, they are low in the rainy season due to the variations in the rainfall, humidity, temperature, wind velocity and direction. Compared with meteorological conditions it is observed that humidity higher than 65% in mining region maintain safe air quality conditions. The various mining activities such as loading and unloading, drilling, crushing, blasting and unpaved haul roads are the major sources of particulate matter. The particle sizes of 0-2.5 µm in diameter were found in the range of 45.65% to 63.41% in the core zone and 34.11% to 56.52% in the buffer zone of the total SPM. The unpaved haul roads of the villages have been identified as the major source of fugitive dust. The vehicles carrying iron ore on unpaved haul roads of villages contributes the particulate matter which causes health effects to the residents and inhabitants of the surrounding area.

ACKNOWLEDGEMENTS

The authors are thankful to the authorities of Subbarayanahalli Iron Ore Mines for permission to carry out monitoring; Indian meteorological department for providing meteorological data. The authors extend thanks to authorities of Department of Studies in Civil Engineering, University B D T College of Engineering, Davanagere.

REFERENCES

[1] Banerjee G K, Srivastava K K, Chakraborty M K and Sundararajan, "An approach towards the estimation of emission rate from various activities of noamundi iron ore mine – A Case Study," Journal of Scientific and Industrial Research, Volume 62, 339-343, 2003.

[2] Central Pollution Control Board. (2011), "Guidelines for the Measurement of Ambient Air Pollutants," Volume-I, available from: http://www.cpcb.nic.in
[3] Chakraborty M K, Ahmad M, Singh R S, Pal D, Bandopadhyay C and Chaulya S K, "Determination of the emission rate from various opencast mining operations," Environmental Modelling & Software 17, 467–480, 2002.
[4] Huertas J I, Huertas M E, Cervantes G and Díaz J, "Assessment of the natural sources of particulate matter on the opencast mines air quality," Science of the Total Environment 493, 1047–1055, 2014.
[5] Indian Meteorological Department, available from: http://www.imd.gov.in
[6] Kiran Kanti Panda, Akhila Kumar Swar, Rahas Bihari Panda and Meikap B.C, "Distribution of Respirable suspended particulate matter in ambient air and its impact on human health and remedial measures in Joda-Barbil region in Odisha," South African Journal of Chemical Engineering,vol.18, no. 1, 18-29, 2011.
[7] Panda S.R and Anil Barik, " Impact of iron ore mines generated pollutants on peripheral environment and its effective management—A case study of Koira Region, Odisha," Proceedings of the XI international seminar on mineral processing technology, 1147-1156, 2010.
[8] State of Environment Report and Action Plan, (2003), Published by Government of Karnataka.
[9] Subrato Sinha and Banerjee S P, "Characterization of haul road dust in an Indian opencast iron ore mine", Atmospheric Environment vol. 31, no. 17, 2809-2814, 1997.