IJEP 30 (3) : 198-206 (2010) (Received on August 31, 2009)

A Study of Air Pollution Load Assessment Around Opencast Coal Project in India

Ratnesh Trivedi, M. K. Chakraborty, A.G. Sangode and B.K Tewary
Central Institute of Mining and Fuel Research, Dhanbad - 826 015

Opencast mining technology results in the release of a huge amount of air borne dust. The air borne dust peculiarly below 100 micron in size, are environmentally nuisance and cause health hazards. Total suspended particulate matter (TSPM) and respiratory particulate matter (PM_{10}) are the major pollutants in the air environment of opencast coal mines. Therefore, dust generation, its dispersion, and pollution load assessment have been found to be major concerns in air quality modeling of opencast coal mines. The present paper focuses on the quantification of sourcewise emission inventory for different point, area and line sources considering the background dust concentration at one of opencast coal project (OCP), namely Hindustan Lalpet of Western Coalfields Limited (WCL). The 24 hr average concentrations of TSPM and PM_{10} were monitored at three monitoring stations during winter season. On an average the PM_{10} concentration in the ambient air constituted 17.00 to 60.03 % of TSPM concentration. TSPM concentration ranged from 313.11 to 565.57 $\mu g/m^3$ and 79.48 to 270.61 $\mu g/m^3$.

KEYWORD

Air borne dust, Total suspended particulate matter, Respiratory particulate matter, Dust emission, Dispersion, Emission rates, Open cast coal mine.

INTRODUCTION

Air pollution includes one or more contaminants or pollutants, in the outdoor atmosphere in such quantities and of such duration that may be injurious to human, plant or animal life. Once these contaminants enter in the atmosphere, either in gaseous form or as particulate matters, these cannot escape and keep circulating and deteriorating the air quality. The mining activities contribute to the problem of air pollution directly or indirectly (Trichy,1996; Corti and Senatore, 2000; Baldauf *et al.*, 2001; Collins *et al.*, 2001). The primary source of fugitive dust at fully operational surface mine may include overburden(OB) removal, blasting, haulage, mechanical handling operations, minerals stockpiles and site restoration (Appleton *et al.*, 2006).

Mining activities, such as drilling, blasting, loading, transporting, crushing, screening, overburden dumping, etc., release particulate matter and gaseous pollutants, such as CO, NO_x, SO_2, etc. Since the magnitude of emissions of gaseous pollutants is small and concentration of such pollutants is generally much lower than the prescribed threshold limit values. Hence the air quality modeling is restricted to the determination of particulate matter concentration (Sinha and Banerjee, 1997; CMRI, 1998; Banerjee, 2006; Trivedi *et al.*, 2007).

Coal dust is the major pollutant in the air of opencast coal mining areas (Vallack and Shillito, 1998; CMRI, 1998). Dust generated from surface mining sites is the result of a force applied to bulk material which acts to reduce the size of that material for the purposes that include easier and sometimes even more economical extraction, handling, processing, storage, transportation (Appleton *et al.*, 2006). The vehicle haul road intersection has been identified as the most critical source producing as much as 70% of total dust emitted from surface coal mines

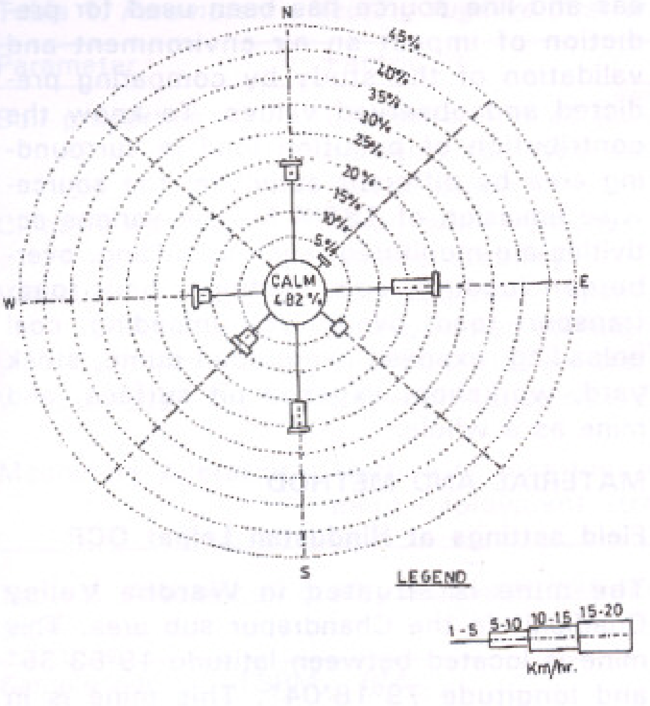

Figure 1. *Wind rose diagram at Hindustan Lalpet OCP*

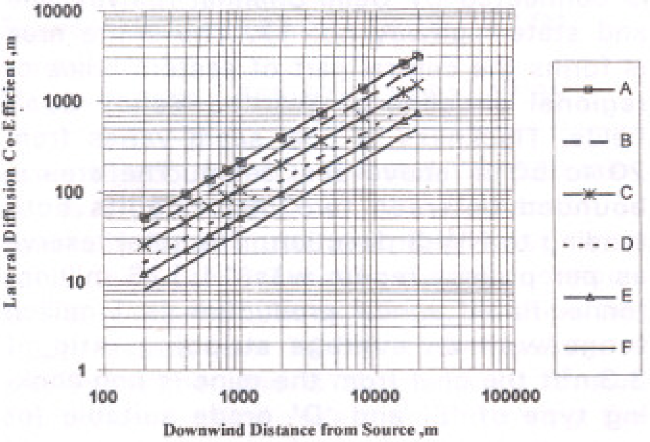

Figure 2. *Lateral diffusion co-efficient vs downwind distance from source* (Turner, 1970)

(Muleski and Cowherd, 1987), while it was accounted to be 80-90% of the PM_{10} emission (Cole and Zapert, 1995). Such a large amount of dust generated cause safety and health hazards, such as poor visibility, failure of mining equipment, increased maintenance cost, etc., that ultimately lowers the productivity (Prabha and Singh, 2005).

Air pollution effects encompass those that are health related as well as those associ-

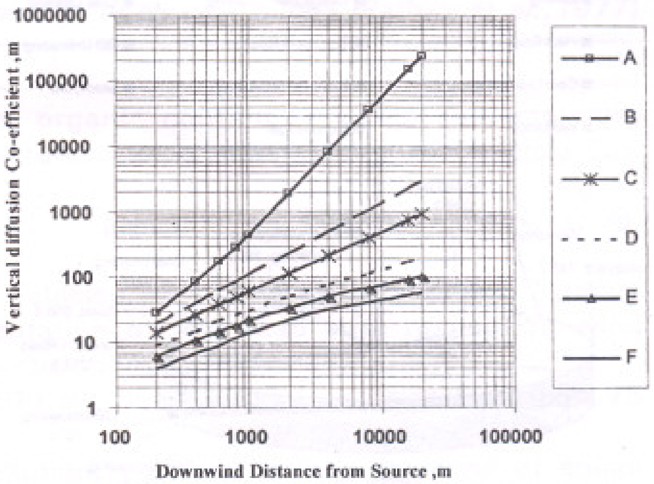

Figure 3. *Vertical diffusion co-efficient vs downwind distance from source* (Turner, 1970)

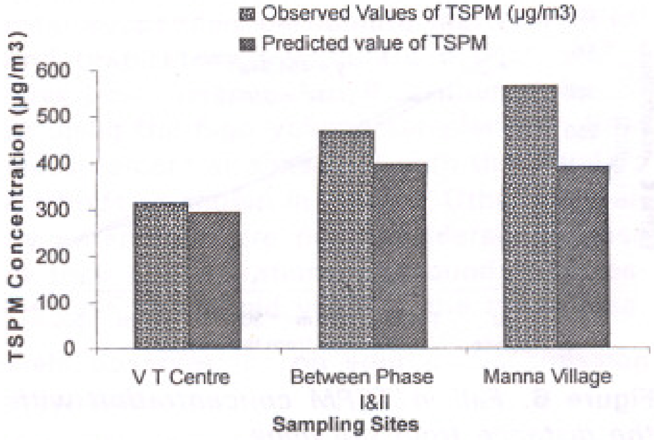

Figure 4. *Comparision between observed values and predicted values of TSPM*

ated with damage to property or which cause decreases in atmospheric aesthetic feature. A prolonged exposure to air borne dust may cause to damage of lung tissues of the miners which may further lead to pneumoconiosis or black lung disease. The maximum tissue damage is caused by the dust of 5 microns lesser sizes since such particles reach the alveoli of the lung (Peavey *et al.*, 1985). Fugitive emission from various source in opencast mines depend upon many parameters as presented in table 1.

In the present study, an attempt has been made to generated ambient air quality data, micro-meteorological data, and dust material quality data for the Hindustan Lalpet

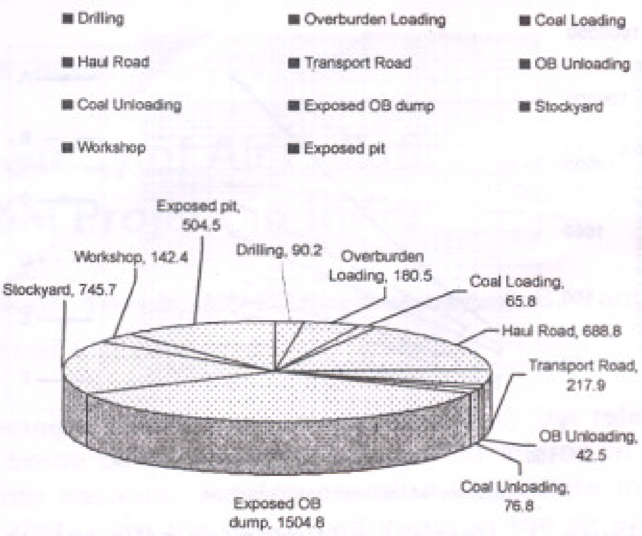

Figure 5. *Air pollution load assessment in the OCP*

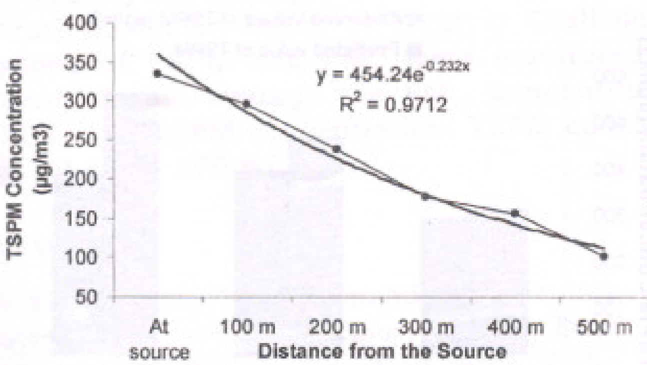

Figure 6. *Fall in TSPM concentration with the distance from the mine*

Opencast Coal Project (OCP) of Western Coalfields Ltd., (WCL). Micro-meteorological parameters, namely wind speed, wind direction and ambient temperature were collected from the nearest meteorological studies form Indian Meteorological Department (IMD), Nagpur. In the light of activitywise and sourcewise emission data along with the micro-meteorological data, such as wind speed stability class, etc., dispersion coefficients of the dust for vertical as well as horizontal direction have been estimated. Air quality modeling has also been attempted using air pollution model fugitive dust model (FDM) developed by United States Environment Protection Agency (USEPA). FDM is a fugitive dust model based on steady state Gaussian dispersion model for multiple areas and line source has been used for prediction of impact an air environment and validation of the study by comparing predicted and observed values. To know the contribution of pollution load in surrounding area by different activities, the sourcewise emission of TSPM for the various activities are monitored, such as drilling, overburden loading, coal loading , haul road, transport road, overburden unloading, coal unloading, exposed overburden dump, stock yard, workshop, exposed pit surface, and mine as a whole.

MATERIAL AND METHOD

Field settings at Hindustan Lalpet OCP

The mine is situated in Wardha Valley Coalfields in the Chandrapur sub area. This mine is located between latitude 19°53'35" and longitude 79°18'04". This mine is in Chandrapur district of Maharashtra State, 3 km away from Chandrapur town. The mine is connected by Delhi-Chennai railway line and state highway no. 17. The entire area is forms the central part of eastern limes of regional anticline of Wardha Valley Coalfields. Thickness of coal seam varies from 20 to 50 m above coal seam. The area is bounded between two major faults both tending to NW-S direction. The total reserve as per project report was 11.126 million-tonne. Rated annual production is 1 million tonne with an average stripping ratio of 3.3m^3/t the coal from the mine is non-cooking type of 'E' and 'D' grade suitable for cement plants, thermal power plants and paper plants. Topsoil upto a depth of 10m is removed by scrapers. Shovel and Dumper are used to excavate coal. Simultaneous backfilling is practiced with exploitation of coal.

A weather monitoring station and SODAR has been installed at study site. The climate of the area is tropical. Summer is well defined from April to June, followed by rainy season from July to September and winter from December to February. May is the hottest month with temperature rising to a maximum of around 48°C. December is the coldest month when the temperature falls

Table 1. *Parameters affecting fugitive dust emission in open cast mines (*Pathak *et al.,*1977)

Parameter	Factor
Soil properties	Characteristic of particle, organic content, average soil, moisture content, soil type and texture. Erosion characteristics, particle size distributions
Climatic conditions	Mean wind velocity, humidity, precipitation, net solar index, atmospheric stability
Vehicular traffic	Traffic density, speed of vehicles, size/capacity of vehicles. Number of types per vehicle orientation of haul-road with respect to wind direction, design and construction of haul-roads
Wind forces	Saltation (dust size 75-500 μ), Suspension (dust size less than 75 μ).
Machinery operations	Method of rock-tool interaction, type/size/capacity/location of equipment deployment strategy

Table 2. *Ambient air quality around H. Lalpet OCP*

Sample site	TSPM,	PM_{10}	
	$\mu g/m^3$	$\mu g/m^3$	%of TSPM
VT Centre	313.11	187.95	60.03
Between Phase I and II	467.62	79.48	17.00
Manna Village	565.57	270.61	47.85

down to about 10°C. The mean annual rainfall is around 1250mm. Wind direction is generally from north and northwest, with velocities upto 6-7 km/hr during monsoon and about 3-4 km/hr in winter. Relative humidity varies from 74-83 % during August and September and is about 15-20 % during summer. Wind rose diagram during the study period is illustrated in figure 1.

Ambient air quality status around OCP

The ambient air quality status in the impact zone was assessed through a network of ambient air quality monitoring locations. The studies on air environment include identification of specific air pollutants for assessing the impacts of proposed mining projects including other activities. Accordingly, air quality monitoring was carried out in winter season. Accordingly, three ambient air quality stations have been selected to know the air quality of the area. The measured data of SPM, RPM and TSPM are shown in table 2.

Amount the ambient air quality parameters, total suspended particulate matter (TSPM) and respiratory particulate matter (PM_{10}) have been measured at 8 hr interval for 24 hr using the high volume sampler with RPM measurement arrangement with the standard methods as shown in table 3. Other air quality parameters are not considered because of their concentrations are found much below the threshhold value in the study area.

Field observations on sourcewise emission inventory

A fugitive dust model based on steady state Gaussian dispersion model for multiple areas and line source was used for prediction of impact on air environment which uses the modified Pasquill and Gifford formula for ground level emission has been used to calculate the emission rate.

$$C\ (x,O) = \frac{Q}{\Pi\ u\ \sigma y\ \sigma z}$$

Where, C (x, O) is difference in pollutant concentration, g/m^3, that is C(x,O) = DN max-UP; DN max is maximum concentration in downwind direction; UP is back ground concentration in upwind direction; Q is pollutant emission rate, g/s; Π 3.14159; u is mean wind speed, m/s; σy is standard deviation of horizontal plume concentration, evaluated

Table 3. *Air pollutant analysis methods : Coal mine standards* (CPCB, 1994)

Parameter	Time weighted avg.	Concentration in ambient air, $\mu g/m^3$	Method	Instrument
TSPM	Annual	430	IS-5182	High volume sampler with RPM
	24 hr	600	Part XIV	Measurement arrangement (Av. flow rate not<σ1.1 m^3/min)
PM_{10}	Annual	215	IS-5182	High volume sampler with RPM
	24 hr	300	Part XIV	Measurement arrangement (Av. flow rate not<1.1 m^3/min)

Table 4. *Activitywise TSPM emission inventory at Hindustan Lalpet OCP*

Source of TSPM	TSPM con., $\mu g/m^3$				Wind velocity, m/s	Diffusion coefficent		Emission rate
	DN, Min	DN, Max	UP	C(x,0)		σy,m	σz,m	
Drilling, g/s	1235	1663	1048	615	1.5	18	12	0.6257
Overburden loading, g/s	1368	1706	1080	626	21.9	14	8	0.4176
Coal loading, g/s	1430	1814	1162	652	2.6	14	8	0.5733
Haul Road, g/m	1741	2120	1098	1022	2.3	14	8	0.0085
Transport Road, g/m	1592	1984	1024	960	2.5	14	8	0.00844
Overburden unloading, g/s	1281	1693	1041	652	2.6	20	12	2.2775
Coal unloading, g/s	1420	1895	1133	762	2.3	14	8	0.6164
Exposed overburden dump, g/m^2	932	1178	848	330	2.8	30	20	0.0003 87
Stockyard,g/m^2	1198	1612	975	637	1.5	18	12	0.000 60
Workshop,g/m^2	1040	1258	866	392	1.6	26	16	0.0000 82
Exposed pit surface,g/m^2	976	1205	890	315	1.5	26	16	0.0000 154
Overall mine,g/s	510	730	395	335	2.2	120	65	20.5121

in terms of downwind distance x, m (Figure 2); σz is standard deviation of vertical plumes concentration, evaluated in terms of downwind distance x, m (Figure 3).

Emission inventory details have been collected by installing a set of high volume samplers at down wind sides as well as upwind side of different point, area and line sources. In order to measure the contribution of TSPM by the source two high volume samplers are placed, namely one at downwind side at a distance nearly 100m from the source and one at upwind side to know the back ground concentration. Emission data have been generated for various mining activities, such as overburden loading, mineral loading, haul road transportation, unloading of overburden, unloading of minerals, stock yard, exposed overburden dumps, mineral handling plant, exposed pit face and workshop. Blasting being an instantaneous source was monitored separately, which is not included in the present study. Sourcewise emission inventory has been shown in table 4 and source wise emission properties, such as moisture content silt content, etc., have been measured from the samples collected during field study. Frequency of vehicle movement on the haul road and transport road per day, and fre-

Table 5. *Sourcewise TSPM emission properties*

Source	Source type	Moisture content, %	Silt content, %	Remark
Drilling	Point	7.2	39.2	Hole dia 160 mm; 80 hole/day
Overburden loading	Point	8.7	13.5	Drop height 1.6 m; frequency 24 no/hr
Coal loading	Point	8.2	10.5	Drop height 0.9 m; frequency 24no/hr
Haul Road	Line	22.3	29.00	Frequency 22 no/hr; average speed 2.7m/sec
Transport Road	Line	20.5	26.0	Frequency 28 no/hr; Average speed 11 m/sec
OB unloading	Point	7.8	14.5	Frequency 14 no/hr ;drop height 15.0 m
Coal unloading	Point	8.0	10.8	Frequency 11 no/hr; drop height 2.6 m
Exposed OB dump	Area	7.1	8.5	Dump area 0.045 km²
Stockyard	Area	8.4	10.0	Unloading freq. 5 No/hr; loading freq. 20 No/hr
Workshop	Area	14.4	30.0	Area 10000 m²
Exposed pit	Area	7.1	7.9	Exposed area 0.04 km²

Table 6. *Air pollution load assessment in Hindustan Lalpet OCP*

Source	Source type	Emission rate	Kg per day	Remark
Drilling,g/s	Point	0.6257	90.2	Hole dia 160 mm; 80 hole/day
Overburden loading, g/s	Point	0.4176	180.5	Drop height 1.6 m; frequency 24 no/hr
Coal loading, g/s	Point	0.5733	65.8	Drop height 0.9 m; frequency 24 no/hr
Haul Road, g/m	Line	0.0085	688.8	Frequency 22 no/hr; average speed 2.7m/sec
Transport Road, g/m	Line	0.00844	217.9	Frequency 28 no/hr; Average speed 11 m/sec
OB unloading, g/s	Point	2.2775	42.5	Frequency 14 no/hr ;drop height 15.0 m
Coal unloading, g/m²	Point	0.6164	76.8	Frequency 11 no/hr; drop height 2.6 m
Exposed OB dump, g/m²	Area	0.000387	1504.8	Dump area 0.045 km²
Stockyard, g/m²	Area	0.000160	745.7	Unloading freq. 5 No/hr; loading freq. 20 No/hr
Workshop, g/m²	Area	0.000082	142.4	Area 10000 m²
Exposed pit, g/m²	Area	0.0000154	504.5	Exposed area 0.04 km²

quency of drilling operation per day, etc., secondary data have also been generated during field study as shown in table 5.

Utilizing the mine plan for locating different activities, activitywise emission rate and meteorological data, fugitive dust model (FDM) has been run FDM is a computerized Gaussian plume air quality model, specifically designed for the estimation of the concentration and deposition impacts from fugitive dust sources. FDM employs an advance transfer particle deposition algorithm. Air quality modeling has been exercised with the help of fugitive dust model (FDM). The model can process upto 1200 receptors and upto 121 sources (USEPA, 1987). FDM represents the behaviour of particles in the atmosphere most accurately since terrain features are not included in FDM, it can be used only for local scale.

Table 7. *Comparison between observed and predicted values of TSPM*

Sample site	Observed values of TSPM	Predicted value of TSPM	
	TSPM, $\mu g/m^3$	$\mu g/m^3$	Percent of observed value
V. T Centre	313.11	295	94.21
Between Phase I and II	467.62	396	84.68
Manna Village	565.57	390	68.95

RESULT AND DISCUSSION

In order to run the FDM the various air pollution sources have been located on the mine plan. Sourcewise emission rates have been calculated as shown in table 4. Meteorological data, activitywise and sourcewise emission rates and other parameters, such as moisture content, silt content, etc., as shown in tables 4 and 5, have been used as input parameters to run the fugitive dust model. From the modeling exercise, TSPM concentrations at certain receptor locations have been predicted. The receptor locations have been selected such that these are exactly same of one where ambient air quality measurement with similar regional background levels to get the total predicted TSPM concentration. Regional background data are the average of the monitored data in activity zone. The predicted and observed TSPM concentrations at receptor locations for different mines are listed in tables 7 and 8.

Field observations of ambient air quality of Hindustan Lalpet OCP have been placed in the table 2. The higher value of TSPM and PM_{10} at Manna Village may be contributed by the presence of main transport road and other industries nearby yet it is almost touching the limit prescribed by Indian Standards for coal mines IS:5182 Part XIV. Sourcewise emission inventory data placed in table 4. Atmospheric Pasquill Gifford Stability classes have been found to be B and C during the air quality monitoring programme. It is clearly evident from the table 4 that among the point sources, namely drilling, overburden loading, overburden unloading and coal unloading highest value of emission rates (g/s) has been found in case of unloading of overburden. Among the line sources, emission rates have been in case of Haul found and transport road to be 0.0085 gm/m/sec and 0.0084 gm/m/sec, respectively which is more than the emission rates of area sources, but less than the emission rates of point sources. Emission rate for whole mine is found 20.5121 gm/sec. With the help of source-wise emission rates and secondary data generated for the mining activities including heavy earth moving machineries, air pollution load in terms of kg air pollutants mainly TSPM emission per day has been computed and shown in table 6 and figure 5. It can be clearly seen from the figure 5 that exposed overburden (OB) dump, Stock Yard, Haul Roads are the major contributor of TSPM emission per day.

The variation between measured and predicted values as shown in figure 4 may be due to non-accountability of emission from various other sources, like non-mining area activities, domestic use of fuels, transportation network nearby thermal power plant, etc. With the help of FDM, TSPM concentration has been calculated at various distances in down wind direction as shown in table 8. It is clearly evident from the table that dust generated due to mining activities does not contribute to ambient air quality in surrounding areas beyond 500 m in normal meteorological condition and an exponential fall in the TSPM concentration with the distance from the OCP with the coefficient of correlation (R^2) equals to 0.9712 can be clearly seen in the figure 6. The value of coefficient of correlation between predicted value by FDM and observed value have been calculated to be 0.781. They show a fairly less agreement between measured and predicted values. The values of index of agreement (IA) show the extent to which the model performs. Here, the average IA value for FDM has been calculated to be 0.665, which indicates the contribu-

Table 8. *Fall in TSPM concentration with the distance from the OCP*

Study site	Predicted values, μg/m^3					
	At source	100 m	200 m	300 m	400 m	500 m
H. Lalpet Mine as a whole	335.00	295.89	237.42	177.98	156.94	102.33

tion from other sources.

CONCLUSION

It can be safely concluded that TSPM and PM_{10} are the major sources of air pollution in and around the OCP. 24 hourly measurements of TSPM and PM_{10} indicate higher values than prescribed in Indian standards IS-5182, Part XIV at some places around the OCP which may affect the health and property of homeowners living adjacent to the OCP. In addition, dust emission associated with the OCP has been modeled using the fugitive dust model (FDM). The ground level dust concentration has been predicted for each of the three monitoring stations as well as for the mine as a whole and compared with actual values. In general, the FDM results tended to under-predicted the measured concentrations. However, the results of the comparison showed that FDM performed well in predicting dust concentrations and that the model was adequate for application at the OCP. Accordingly, the FDM was used for the purpose of simulating the spatial distribution of dust in and around the OCP as a whole by which a air pollution dispersion modeling has been attempted. As far as dispersion pattern of dust is considered, it is heavily dependent on the dispersion coefficients in horizontal and vertical direction, stability class of prevailing meteorological conditions, wind speed and its direction. Again from the dispersion modeling using FDM indicates that dust generated due to mining activities does not contribute to ambient air quality in surrounding area beyond 500 m in normal meteorological conditions.

From the study of emission inventory, it is quite clear that haul road and transport road are the major contributor to the pollution load. Therefore, proper dust suppression arrangement is to be made. The prevailing practice of water sprinkling does not seem to be adequate. Therefore, the installation of continuous atomized spraying system for haul roads should be used. Exposed overburden dump is another major contributor of pollution load. These dumps not only contribute to air pollution by way of wind erosion but also spread the dump itself. Therefore, judicious, plantation on these dumps is highly recommended. These plantations will not only stabilize the dump but also attenuate the dust emission.

ACKNOWLEDGEMENT

Authors are thankful to Director, Central Institute of Mining and Fuel Resrach, Dhanbad for giving his consent for this publication. Authors are also grateful to Western Coalfields Limited for providing financial assistance to conduct the study.

REFERENCE

Appleton, T.J., *et al.* 2006. The development of a modeling strategy for the simulation of fugitive dust emissions from in-pit quarrying activites: A UK case study. *Int. J. Mining, Reclamation and Env.,* 20 : 57-82.

Banerjee, S.P. 2006. TSP emission factors for different mining activities for air quality impact prediction as collated from different sources. *Minetech.,* 27:3-18.

Baldauf, R.W., D.D Lane and G.A. Marote. 2001. Ambient air quality monitoring network design for assessing human health impacts from exposures to air-borne contaminants. *Env. Monitoring Assess.,* 66 : 63-76.

CMRI. 1998. Determination of emission factor for various opencast mining activities. *Report* GAP/9/EMG/MOEF/97. Central Mining Research Institute, Environmental Management Group, Dhanbad.

Chaulya, S.K. 2004. Assessment and management of air quality for an opencast coal mining area. *J. Env. Manage.*, 70 (1): 1-14.

Cole, C.F. and J.C. Zapert.1995. Air quality dispersion model validation at three stone quarries. National Stone Association, Washington DC.

Collins, M.J., P.L. Williams and D.L. MacIntosh. 2001.Ambient air quality at the site of a former manufactured gas plant. *Env. Monitoring Assess.,* 68 : 137-152.

Corti, A. and A. Senatore. 2000. Project of an air quality monitoring network for industrial site in Italy. *Env. Monitoring Assess.,* 65 : 109-117.

CPCB. 1994. National ambient air quality standards. Central Pollution Control Board, New Delhi.

Muleski, G.E. and C. Cowherd. 1987. Evaluation of the effectiveness of chemical dust suppressants on unpaved roads. EPA/600/2-87.102. U.S. Environmental Protection Agency, Research Triangle Park, N.C., 27711.

Pathak, K., I.N Singh and M.E. Murkute. 1997. A new approach to study the generation of dust over surface mining haul roads. *Indian J. Env. Prot.,* 17 : 761-766.

Peavy, H.S., D.R. Rowe and G. Tech Obanoglous. 1985. Environmental Engineering. Mcgraw Hill, New York. pp 668-670.

Prabha, J. and G. Singh. 2005. A review on emission factor equations for haul roads: The Indian perspective. *Indian Mining Eng. J.*, 44: 11-16.

Sinha, S. and S.P. Banerjee. 1997. Characterisation of haul road in Indian open cast iron ore mine. *Atmos. Env.,* 31 : 2809-2814.

Tichy, J. 1996. Impact of atmospheric deposition on the status of planted Norway space stands : A comparative study between sites in Southern Sweden and the North Eastern Czech Republic. *Env. Poll.,* 93 : 303-312.

Trivedi, R., *et al.* 2007. A study of source-wise emission inventory for air quality modeling in Padampur opencast coal project of Western Coalfields Limited, India. *Mining Engineers' J.,* 9 : 20-27.

Turner, D.B. 1970. Workbook of atmospheric dispersion estimates. USEPA, Washington, DC.

USEPA. 1994. User's guide for the fugitive dust model (FDM). Vol. 1. User instructions. United States Environmental Protection Agency, Region 10, 1200 sixth Avenue, Seattle, Washington.

Vallack, H.W. and D.E Shillito. 1998. Suggested guidelines for deposited ambient dust. *Atmos. Env.,* 32 (16) : 2737–2744.