

Estimation of Air Quality in the Opencast Mine of Jharia Coal Field, India

SNIGDHA KUNDU* and ASIM KUMAR PAL

Department of Environmental Science & Engineering,
Indian School of Mines, Dhanbad-826004, Jharkhand, India.

<http://dx.doi.org/10.12944/CWE.10.2.37>

(Received: April 14, 2015; Accepted: May 12, 2015)

ABSTRACT

A systematic air quality assessment study was carried out at Rajapur opencast mine in Jharia Division as per standard guideline. The average concentration of SPM, PM₁₀ and PM_{2.5} concentrations were observed to be in the range of 294 to 965 µg/m³, 100 to 498 µg/m³ and 85 to 296 µg/m³ respectively. The SO₂ and NO_x concentration were in the range of 48.2 to 98.2 µg/m³ and 32.8 to 149.39 µg/m³ respectively. The trace metals concentration in PM₁₀, e.g., lead, nickel, arsenic etc. were also analyzed by Atomic Absorption Spectroscopy technique and were observed to be 0.380 ± 0.009 µg/m³, 0.06 ± 0.02 µg/m³, and 0.00432 ± 0.028 µg/m³ respectively. The observed concentrations were then compared with National ambient air quality standard (NAAQS, 2009) and Ambient Air quality Standard for existing as well as new Coal Mines (CMS, 2000). Most of them were found exceeding the statutory norms.

Key words: SPM; PM₁₀; PM_{2.5}; NAAQS, 2009; CMS, 2000.

INTRODUCTION

Coal mining industry now uses modern technology with powerful and high capacity machinery so as to increase coal extraction capability at the cost of large amount of dust, gases, etc. spewed into the atmosphere, thereby degrading quality of air. These pollutants have harmful consequences not only on the mine workers, but also, depending on the meteorological conditions, on the human settlements, agricultural lands and live stocks in the nearby areas.

Particulate matter is the predominant pollutant connected with the coal mining and its handling operations. The airborne particulates and the associated trace metals were found to be the major cause of both acute and chronic adverse health effects (Prieditis and Adamson, 2002; Magas et al., 2007; Wild et al., 2009). A number of epidemiological studies indicated a significant linkage between airborne particulate matters and elevated rate of mortality (Pope, 2000; Shah, 2009).

The techniques of coal extraction and processing are very specific to the individual site due to difference in geology, mineralogy, terrain and many other factors. Through this research study, emphasis has been made to provide salient information/features of air quality aspects in an open cast mine of Jharia Coalfield.

Description of study area

Rajapur OCP (open cast project) is one of the important OCP in Cluster VII of Bharat Coking Coal Ltd (BCCL) in Jharia Coalfield (Fig 1). BCCL which is a subsidiary of Coal India Limited operates in the state of Jharkhand and West Bengal. Its operation is spread over 305 Km² in the districts of Dhanbad, Bokaro and Burdwan. Mining operation is spread over two coalfields namely Jharia Coalfield and Ranigunj Coalfield. BCCL has produced 29.04 Mt. of coal during 2010-11. Cluster VII covers 12 mining lease holds with 14 underground/opencast mines. The total leasehold of this Cluster is 2127.70 Ha. It is located in the East Central part of JCF. It falls between the latitude 23° 47' 00" to 23° 43' 10"

N and longitudes 86° 22' 54.6" to 86° 24' 45" E. The Cluster has long history of fire and subsidence.

MATERIALS AND METHOD

Ambient air quality monitoring was undertaken at Rajapur OCP of Jharia coalfield during Summer, 2014. The sampling was done for twenty four hours and twice a week and it was continued for four weeks in summer season as per the criteria of IS 5158 Part-XIV, 2006.

Sampling for estimation of SPM and PM₁₀ concentrations were performed with the help of Respirable Dust Sampler with thermo-electrically cooled gaseous sampler attachment (Envirotech make). The flow rate of the sampler was maintained at 1.1-1.3 m³/min for respirable particulate matter and 0.5 and 0.2 lpm for SO₂ and oxides of nitrogen (NOx) respectively. The respirable dust sampler (APM 460 NL) uses an enhanced model of cyclone to separate the coarser particles from the air stream before filtering it on the 0.5 micron glass-fiber pore-size filter which allows a determination of both SPM and the respirable fraction of suspended particulate matter (RPM). The coarse particles collected in the cyclone separator are transferred quantitatively on a petridish and evaluated gravimetrically. Sum of masses of coarse and respirable particles gives the mass of SPM collected during sampling. The SPM concentrations are computed from the mass of SPM and total volume of air sampled. Similarly, for PM_{2.5}, APM 560 Fine Dust Sampler (16.7 LPM) was used. Here, ambient air is allowed to pass through Louvered inlet and WINS Impactor assembly. Particulate matter of size <2.5 microns is deposited on 46.2 mm dia. PTFE filter paper. The difference of final weight and initial weight of filter paper gives the weight of particulate matter of size <2.5 microns. The

concentration of PM_{2.5} is computed as the weight of dust deposited on the filter divided by volume of air sampled. The samplers were installed in the field as per the prescribed sampling siting criteria of IS: 5182 part IV giving a special emphasizes on machine safety and power availability. For analysis of trace metals in ambient air was done according to standard methodology. The acid digestion was performed in Teflon bombs. The filtrates were analyzed using AAS (GBC Avanta) for determination of trace metals. The detection limit for different trace metals for the AAS are as follows Fe (0.005 ppm), Pb (0.01 ppm), Ni (0.009 ppm), Zn (0.005 ppm), Cu (0.001 ppm), Cd (0.004 ppm), Mn 90.0015 ppm and Cr 90.003 ppm). The concentration of an element in the atmosphere is obtained from the following relation,

$$C(\text{ig/m}^3) = \frac{\text{Concentration of the element in digested sample (ig/mL)/volume of the air sample (m}^3) \times \text{Total volume of the sample (mL)/Percent of filter area used for analysis.}}{}$$

RESULTS AND DISCUSSIONS

The average concentration of SPM, PM₁₀ and PM_{2.5} concentrations were observed in the range of 294 to 965 ig/m³, 100 to 498 ig/m³ and 85 to 296 ig/m³ respectively. SO₂ and NOx concentration were in the range of 48.2 to 98.2 ig/m³ and 32.8 to 149.39 ig/m³ respectively. The air quality data are depicted in Table 1. The observed concentrations were then compared with National ambient air quality standard (NAAQS, 2009). Ambient Air quality Standard for existing as well as new Coal Mines (CMS, 2000) laid down and notified by MOEF, GOI in September 2000 was also considered to evaluate the pollution status. The comparisons are presented in Fig 2 to Fig 6. The average PM₁₀ concentration exceeded

Table 1: Air quality data

Parameters	SPM	PM ₁₀	PM _{2.5}	SO ₂	NOx
No. of observations	24	24	24	24	24
Minimum Concentration(ig/m ³)	294	100	85	48.2	32.8
Maximum Concentration(ig/m ³)	965	498	296	98.2	149
Average	743.875	333.2	160.91	79.47	111.39
98th percentile	957.18	492.02	288.18	97.64	148.43



Fig. 1: Site map of Jharia Coalfield

both NAAQS ($100 \mu\text{g}/\text{m}^3$) and CMS ($300 \mu\text{g}/\text{m}^3$). The high concentration of PM_{10} is mainly due to different mining activities as well as running of vehicles on the unpaved road including abrasion of road materials, tires and brake linings as well as re-suspension of soil material because of traffic induced turbulence (Barmpadimos et al., 2011; Bukowiecki et al., 2010). The $\text{PM}_{2.5}$ concentration exceeded NAAQS ($60 \mu\text{g}/\text{m}^3$). The sources of $\text{PM}_{2.5}$ has generally been confined to movement of vehicle on paved/unpaved roads, vehicular exhaust (diesel based), mining activities particularly drilling and blasting of rocks.

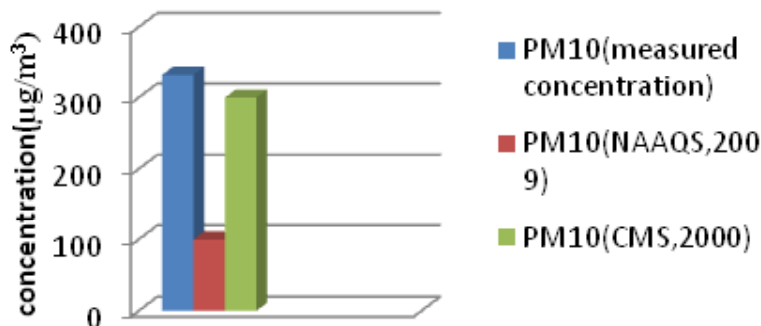


Fig. 2: Status of PM_{10} in comparison with NAAQS, 2009 and CMS, 2000

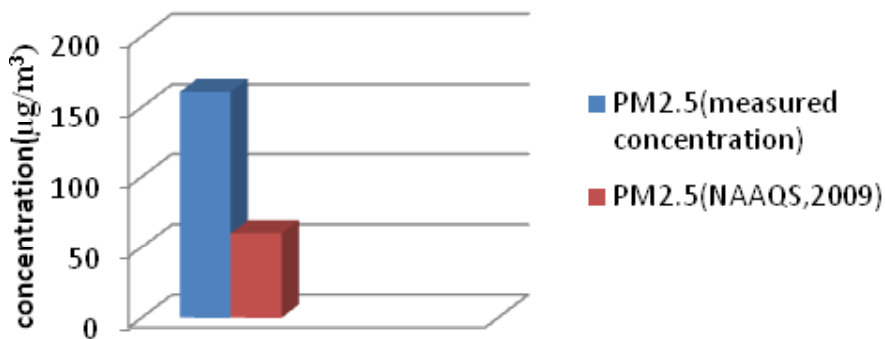


Fig. 3: Status of $\text{PM}_{2.5}$ in comparison with NAAQS, 2009

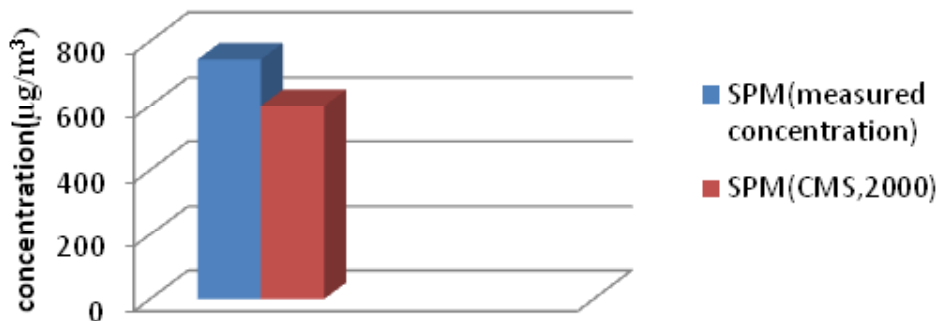


Fig. 4: Status of SPM in comparison with CMS, 2000

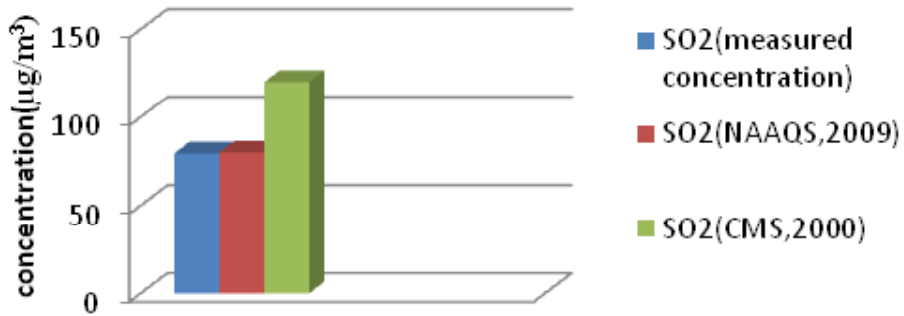


Fig. 5: Status of SO₂ in comparison with NAAQS, 2009 and CMS,2000

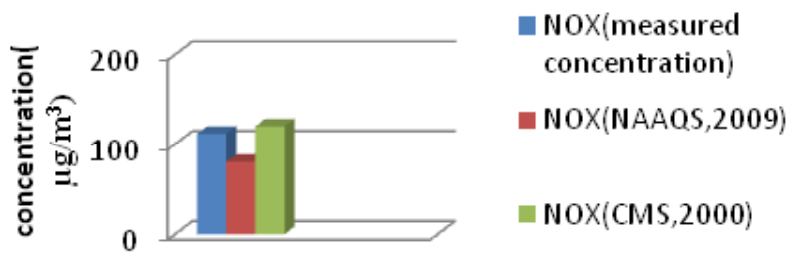


Fig. 6: Status of NO_x in comparison with NAAQS, 2009 and CMS,2000



Fig. 7: Status of Pb in comparison with NAAQS, 2009



Fig. 8: Status of Ni in comparison with NAAQS, 2009

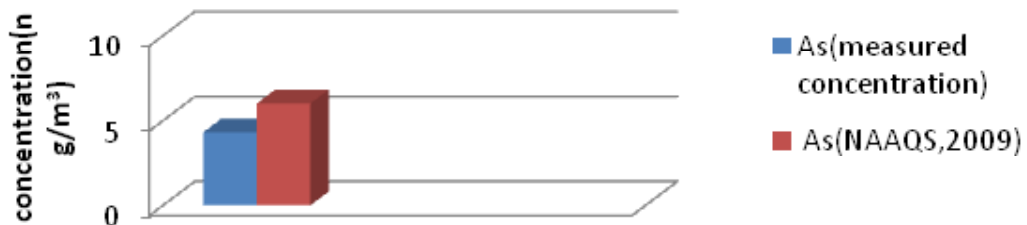


Fig. 9: Status of As in comparison with NAAQS, 2009

Table 2: Trace elements concentration level in summer season

Trace Metal	Concentration in $\mu\text{g}/\text{m}^3$
Pb	0.380 ± 0.009
Ni	0.06 ± 0.02
As	0.00432 ± 0.028
Cu	3.10 ± 0.01
Mn	1.52 ± 0.21
Fe	18.29 ± 0.25
Zn	0.42 ± 0.24
Cd	0.04 ± 0.016
Cr	0.440 ± 0.30

The emission inventory indicates that heavy duty diesel trucks were accountable for majority of the exhaust particulate matter (Sawyer et al., 2000). The SPM concentration exceeded permission level of CMS ($600 \mu\text{g}/\text{m}^3$). The movement of vehicles on the haul road of the opencast mines has been recognized as the major source of fugitive dust emitted from the surface coal mines (Cowherd, 1979). The average SO_2 concentration was below NAAQS ($80 \mu\text{g}/\text{m}^3$) and CMS ($120 \mu\text{g}/\text{m}^3$). The same for NO_x was found above NAAQS ($80 \mu\text{g}/\text{m}^3$) but below CMS ($120 \mu\text{g}/\text{m}^3$). The main source of NO_x in coal mining rejoin are vehicular exhaust, blasting operations, etc. Unpremeditated burning of coal in waste dumps and mine fire release considerable amount of oxides of nitrogen. During combustion process (at high temperature) atmospheric nitrogen combines with oxygen to form NO_x which is aggravated when engine is diesel operated. Tunnel studies indicated that diesel engine produce five times the amount of NO_x per mass of fuel burned when compared to gasoline vehicles (Kirchstetter et al., 1998).

Trace elements analysis of dust samples (PM_{10}) during summer season were done and shown in Table 2. Trace element pollutants in PM_{10} may be natural or anthropogenic. Several trace elements (Pb, Cu, Mn, Co) are considered essential for life. The sources of trace elements may be attributed as discussed below:

Pb (Lead): may be due to higher emissions from vehicular exhausts. This does not rule out the

case of adulteration of fuel for automobiles.

Ni (Nickel): may be due to traffic exhausts, wearing and tearing of vehicular engines parts for old vehicles, etc.

As (Arsenic): Arsenic compounds can be either organic or inorganic. Inorganic arsenic can cause acute, sub acute and chronic effects, which may be either chronic or systematic.

Cu (Copper): this originates from wearing of brake pads of vehicles due to forced deceleration (Hulskotte et al., 2006).

Mn (Manganese): this may be due to crustal dust which includes the suspension of road dusts by vehicles and wind erosion .

Fe (Iron): This is due to the use of iron in brake lining which leads to its emission in ambient air. (Hulskotte et al., 2006)

Zn (Zinc): This is due to tracer of tire wear particles from vehicular movement (Birmili et al., 2006; Wang et al., 2006)

Cd (Cadmium): Cd level may be related due to the composition of gasoline, motor oil, car tires and road side deposition of the residues of those materials as well as traffic density (Sharma and Prasad, 2010)

Cr (Chromium): Chromium is emitted mainly by fumes stainless steel welding (WHO, 2000; Langard, 1994; Danielsen et al., 1993) and from the abrasion of brake lining and tire of the vehicles (Sadasivan and Negi, 1900; Hopke, 1980).

The observed concentrations were then compared with National ambient air quality standard (NAAQS, 2009) (Fig 7-9). The measured concentration of Ni ($0.06 \mu\text{g}/\text{m}^3$) was found more than NAAQS limit concentration ($0.02 \mu\text{g}/\text{m}^3$) whereas measured concentration of Arsenic and lead ($4.320 \text{ ng}/\text{m}^3$ and $0.380 \mu\text{g}/\text{m}^3$ respectively) was found considerably less than NAAQS concentration $6.0 \text{ ng}/\text{m}^3$ and $1.0 \mu\text{g}/\text{m}^3$ respectively.

CONCLUSION

The study reveals the generation of considerable amount of particulate matters due to various mining activities of the concerned opencast mine of the Jharia coalfield. The measured concentration of the particulate matter (SPM, PM₁₀ and PM_{2.5}) exceeded the NAAQS, 2009 and CMS, 2000 standards. Among heavy metals, observed concentration of Ni was found more than NAAQS limit due to vehicular exhausts, wearing and tearing of vehicular engine parts, etc. However, the concentration of Arsenic and lead was found within the permissible limit. The trace metals concentrations

were observed as per following decreasing trend, Fe> Cu> Mn> Cr> Zn> Pb>Ni>Cd> As. For the lack of any existing guidelines, the concentrations of other trace metals could not be compared.

ACKNOWLEDGEMENT

The authors would like to thank the Department of Environmental science and Engineering of Indian School of Mines, Dhanbad for providing necessary facilities to undertake the present research study. We are also thankful to Bharat Coking Coal Ltd for their support and encouragement.

REFERENCES

- Prieditis, H.R., Adamson, I.Y., Comparative pulmonary toxicity of various soluble metals found in urban particulate dust. *Experimental Lung Research*. **28**: 563-576(2002).
- Magas, O.K., Gunter, J.T., Regens, J.L. Ambient air pollution and daily pediatric hospitalizations for asthma. *Environmental Science and Pollution Research*. **14**:19-23(2007).
- Wild, P., Bourgard, E., Paris, C. Lung cancer and exposure to metals: the epidemiological evidence. *Method Molecular Biology*. **472**: 139-167(2009).
- Pope, C.A. Review: epidemiological basis for particulate air pollution health standards. *Aerosol Sci. Technol*, **32**: 4-14(2000).
- Shah, M.H. Atmospheric particulate matter: trace metals and size fractionation, VDM Verlag Dr. Muller, Saarbrücken, Germany, 228(2009).
- NAAQS, National Ambient Air Quality Standard, India, prescribed by Central Pollution Control Board on 18 November(2009).
- Barmapadimos, I., Nuffer, M., Oderbolz, D.C., Keller, J., Aksoyoglu, S., Hueglin, C., Baltensperger, U., Prevot, A.S.H. The weekly cycle of ambient concentration and traffic emission of coarse (PM₁₀ to PM_{2.5}) atmospheric particles. *Atmospheric Environment*. **45**, 4580-4590(2011).
- Bukowiecki, N., Lienemann, P., Hill, M., Furger, M., Richard, A., Amato, F., Prevot, A.S.H., Baltensperger, U., Buchmann, B., Gehrig, R. PM₁₀ emission factors for non-exhaust particles generated by road traffic in an urban street canyon and along a freeway in Switzerland. *Atmospheric Environment*. **44**, 2330-2340(2010).
- Sawyer, R.F., Harley, R.A., Cadle, S.H., Norbeck, J.M., Slott, R., Bravo, H.A. Mobile sources critical review: 1998 NARSTO assessment. *Atmospheric Environment*. **34**, 2161-2181(2000).
- Cowherd, C.Jr. Measurements of fugitive dust emission from haul roads. Report No. EPA600/7-79-181, Research Triangle Park, NC; USEPA, Industrial Environmental Research Lab(1979).
- Chadwick MG, Highton NH, Lindman N. Environmental impacts of The coal mining and utilization. England: Pergamon Press, p. 295(1987).
- Kirchstetter, W.T., Miguel, H.A., Harley, A.R. On road comparison of exhaust emission from gasoline and diesel engines. In: Proceedings of the Eighth CRC On-road Vehicle Emission Workshop, April 20-22, San Diego, CA(1998).
- Hulskotte, J.H.H., Schaap, M., Visschedijk, A.J.H. Brake wear from vehicles as an important source of diffuse copper pollution. 10th international conference on diffuse pollution and sustainable Basin Management, Sept pp.18-22, Istanbul, Turkey(2006).
- Birmili, W., Allen, A.G., Bary, F., Harrison R.M. Trace metal concentrations and water

- solubility insize fractioned atmospheric particles and influence of road traffic. *Environmental Science Technology*.**40**(4): 1144-1153(2006).
15. Wang,X.L.,Sato, T., Xing,B.S. Size distribution and anthropogenic sources apportionment of airborne trace metals in Kanazawa,Japan. *Chemosphere*. 65,2440-2448. 16.Sharma, S., and Prasad, F.M. 2010.Accumulation of lead and cadmium in soil and vegetable crops along major highways in Agra (India).*E-Journal of Chemistry*.**7**(4): 1174-1183(2006).
17. World Health Organisation(WHO).Guidelines for Air Quality.World Health Organisation, Geneva. Retrieved from <http://www.who.int/environmentalinformation/Air/Guidelines/agguide7.pdf>. (2000)
18. Langard,S. Nickle-related cancer in welders. *The science of the total environment*.**148**: 303-309(1994).
19. Danielsen,T.E.,Langard,S.,Andersen,A.,Knu dsen,O. Incidence of cancer among welders of mild steel and other shipyard workers. *British Journal of Industrial Medicine*.**50**: 1097-1103(1993).
20. Sadasivan, S., Negi , B.S.Elemental characterization of atmospheric aerosols. *Science of the Total Environment*. **96**: 269-279(1990).
21. Hopke, P.K. Multielemental characterization of urban roadway dust, *Environmental Science and Technology*, **14**: 164-172(1980).