

POLLUTION DUE TO PARTICULATE MATTER FROM MINING ACTIVITIES

Sneha Gautam[#], Basanta Kumar Prusty, Aditya Kumar Patra

Department of Mining Engineering, Indian Institute of Technology, Kharagpur, India

Received: 11. April 2012.

Accepted: 30. November 2012.

ABSTRACT - This paper focuses on generation and dispersion of particulate matter (PM) during mining operations. The paper starts with a brief introduction to health effects of PM and effect of different size of PM on respiratory system of human being. Surface mines, due to their very nature of exposure to ambient atmosphere, release PM directly to the atmosphere. The dust particle sizes of interest from health point view are $PM_{2.5}$ & PM_{10} which can penetrate to the deeper parts of the respiratory system. Several earlier studies have indicated that the pollution due to PM is very high in working areas of opencast mines. Along with the quantity of PM generated, the nature of dispersion plays an important role as far as human exposure to particulate matter is concerned. Therefore, it is needed to carry out studies to measure and understand the nature of dispersion of PM from open cast mines.

Key words: Air pollution, Particulate matter, Opencast mines, Modelling, Health effects

1. INTRODUCTION

Particulate matter is a term used for solid particles or a mixture of solid particles and liquid droplets suspended in the air. Impact of particulate matter on health depends on age and health status of a human being [1, 2]. Particulate matter is a common pollutant in mining areas because the mining activities (i.e. overburden removal, drilling, blasting, transportation, loading and unloading, etc.) produce different size of particulate matter with different concentration [3]. Particle size is mainly described by the diameter of particles. Particulate matter is composed of both coarse particles (PM_{10} ; Particulate matter having aerodynamic diameter below $10\ \mu\text{m}$) and fine particles ($PM_{2.5}$; Particulate matter having aerodynamic diameter below $2.5\ \mu\text{m}$). Movement and deposition of particulate matter depend on size, shape and density. Fine particle penetrate into deeper parts of the lungs and get deposited

there. Figure 1 shows the particle deposition in respiratory system according to their size.

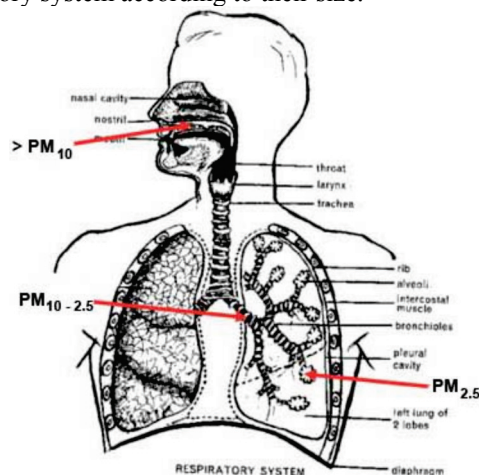


Figure1. Deposition and effects of particulate matter on human health [4, 5]

[#] Corresponding author: S. Gautam, Department of Mining Engineering, Indian Institute of Technology, Kharagpur, India.
E-mail: snehagautam_goni@yahoo.co.in

2. PARTICULATE MATTER AND MINING

The degradation of air quality is major problem in mining areas [2]. Generation of particulate matter is a concern in all type of mining activities. Mining activities which consist of unit operations like drilling, blasting, loading, transport, unloading, etc produce particulate pollutants that are very harmful for human health and surrounding environment [3, 7, 8]. There are several sizes (i.e. PM_{10} , $PM_{2.5}$, PM_{10} etc.) of particulate matter which are responsible for reduced air quality that results in adverse effect on human health. As far as human health is concerned, dispersion of particulate matter in air plays an important role on health (i.e. illness, asthma, mortality, lungs cancer, skin problem, etc.) of mine workers. The movement and spread of PM in surrounding depends on size, shape density, nature of particles and as well as meteorology of the locality [9]. Particulate matter, especially $PM_{2.5}$ size, can be suspended in air for a longer time and transported to long distances. If inhaled, it goes directly to the deeper parts of the lungs and affects respiratory system. Some diseases common in mine workers such as asthma, black lungs, silicosis, asbestosis, berylliosis, inflammation, bauxite fibrosis and siderosis, etc. happen due to exposure to particulate matter. Therefore, the modelling

and measurement of particulate matter is required to predict the amount of dust inhaled by a person and deterioration of air quality due to surface mining activities.

Different mining activities and PM pollution

The economic progress of particular country depends on the production and consumption of minerals, including fuel minerals (i.e. coal, iron, etc.). For this, expansion of mining activities is needed [10]. Mining consist of mainly two process i.e. surface mines and underground mines. Surface mine is the most important contributors to modern societies. It is a type of mining in which soil and rock materials are removed to get economic minerals. This mining method is applicable to minerals located at shallow depth. Surface mining consist of different unit operations which are described below.

Overburden removal: Overburden removal is first unit operation in surface mining. During this activity, overlying materials are removed to expose the mineral. Air pollution is a major concern during the removal and transports of the overburden materials. This operation therefore, is the first stage of PM production for a surface mine.



Figure 2. Overburden removal in surface mining [11]

Drilling: Drilling is second step of unit operation of surface mining. Drilling produce significant amount of PM. Depend on size, shape and dispersion parameter,

then PM may remain in atmosphere for a very long time. Drill holes are then charged with explosives and blasted to loosen the mineral.



Figure 3. Drilling operation in surface mining [12]

Blasting: blasting is third step of unit operations of surface mining by which the overburden and minerals is loosened so that these can be excavated by excavations and loaded on to dumpers or other transport system. Blasting results in short term exposure of particulate pollutant, but the concentration of pollutant is very high.



Figure 4. Blasting operation in surface mining [13]



Figure 5. Loading of material in surface mining [14]

Loading of material: this process involves loading of blasted material onto the transporting mechanism. Material is composed of particles of sizes. Depending on air velocity these particles become airborne.

Transport: Ore from mine site is transported to processing site by transport machines. The pollution is very high at the point of loading and unloading point. During transport, hauls road becomes a major source of airborne particle due to road-tyre interaction. For friable material, if uncovered, direct emissions during transport also contribute to air pollution.



Figure 6. Transportation in surface mining operations [15]

Unloading of material: When the material is unloaded from dumpers, depending on the height of discharge and air current, the severity of air pollution varies. Transfer points in conveyor system are the locations where dust generation is maximum.





Figure 7. Unloading of material in surface mining [16]

3. MEASUREMENT TECHNIQUES

The measurement techniques for assessment of PM level in air ambient environments are summarised below.

Table 1. Different Instruments for measurement of dispersion of particulate matter

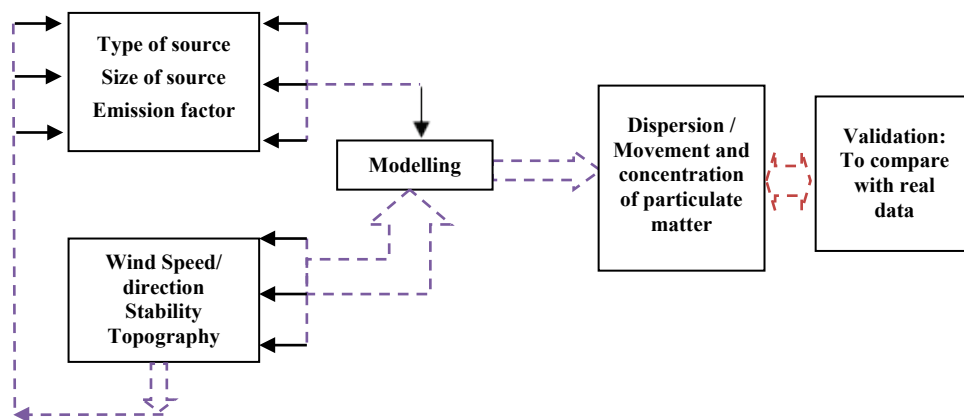
Sl. No.	Instruments	Figure	Purpose of Instruments
1	Respirable Dust Sampler		To collect suspended particulate matter (SPM) and respirable particulate matter (RPM) from the open atmosphere.
2	Dust Trak		It gives PM concentrations for PM ₁ , PM _{2.5} , PM ₁₀ (RPM) and Suspended Particulate Matter (SPM)

The relevant meteorological data that include wind speed, humidity are collected by anemometer and hygrometer respectively. Dilution and dispersion of PM in a surface mine is a function of design of mine working and local meteorological condition. Several earlier studies have indicated that the pollution due to PM is very high in working areas of opencast mines. With increase in depth of mines, effective vertical movement and final dispersion of PM away from mine working becomes difficult. It is therefore needed to carry out studies to measure and understand the nature of dispersion of PM from deep surface mines.

4. MODELLING

The modelling of the particulate matter is the most important step to identify the origin and dispersion

behaviour of particulate matter. Modelling of particulate matter provides some information about the particle such as mass concentration with size range. In Figure 8, shows procedure of modelling of particulate matter. Air pollution modelling consist of some stages (i.e. data input, data processing, result output, result analysis) to ensure a reliable assessment of the significance of any potential adverse effects and dispersion of particulate matter. Meteorology is fundamental for the dispersion of pollutants because it is the primary factor determines the diluting effect of the atmosphere [17]. The movement and dispersion of pollutant is varying from season to season. Many studies indicated that meteorological condition is the most important for controlling the levels of air pollutant such as ozone, SO₂, CO₂, and particulate matter (PM₁, PM_{2.5}, PM₁₀), etc.

**Figure 8.**Flow diagram of procedure of modelling of particulate matter

Particle always moves downwind along the wind direction. The dispersion model is a mathematical simulation and being used to determine the generation, movement and dispersion of pollutant. It is basically computer programmes using some mathematical

equation for simulate the pollutant dispersion. A number of models are created for simulation of particulate matter in opencast mines by researchers. A list of dispersion model shown in below table 2.

Table 2: Summary of dust dispersion models for mining operations [21]

Sl. No.	Model	Algorithm Type	Tested at mine site	EPA-approved
1	AERMOD (Huertas, 2012; Zou, 2010)	Gaussian	Yes	Yes
3	CALPUFF (Anfossi et al., 2010)	Lagrangian	No	Yes
5	ISC3 (Huertas, 2012)	Gaussian	Yes	Yes
6	Fugitive Dust Model (Chaulya, 2004; Trivedi, 2008,2009; Wings, 1990)	Gaussian	Yes	No
7	Dynamic Component Programm (Reed 2003)	Gaussian	Yes	No
8	Box Model (Coal & Fabrick, 1984)	Gaussian	No	No

Modelling is a simplified picture of reality. Models are widely used to make predictions, to solve problems and to identify the best solutions for the management of specific environmental problems.

5. CONCLUSION

This review presents the adverse effects of a particulate matter on human health. Increasing level of particulate matter is the most serious problem in mines area. The degree of impact is also dependent on the size of the particulate matter. Coarse particle result in adverse effect on lung system while fine particles are deposited in the deeper parts of the lungs and can diseases on health of mine workers. Meteorology is fundamental for the dispersion of pollutants because it is the primary factor determining the dilution of the pollutant. Some meteorological data is required for accuracy of prediction. Models like AERMOD, ISC3, etc. adopt a more simple approach to describe dispersion with the help of some fundamental information about the atmospheric properties. This enables for better results of different situation such as complex terrain. Therefore, the modeling is needed to predict and analyze the movement/ dispersion and concentration of particulate matter due to mining activities. Models results are analyzed to understand the controlling parameters of PM dispersion. Thus models assist in better air pollution management.

REFERENCES

- Carlton, A.G.; Turpin, J.B.; Johnson, W.; Buckley, B.T.; Simcik, M.; Eisenreich, S.J.; Porcja, R.J. Microanalysis Methods for characterisation of personal aerosol exposures. *Aerosol Science Technology* **1999**, *31(1)*, 66 – 80.
- Ghose, M.K.; Majee, S.R. Air pollution caused by opencast mining and its abatement measures in India. *Journal of Environmental Management* **2001**, *63(2)*, 193 – 202.
- Chaulya, S.K. Assessment and management of air quality for an opencast coal mining area. *Journal of Environmental Management* **2004**, *70*, 1–14.
- <http://www.cenvironment.blogspot.com>, Overtaken 23.02.2012.
- <http://www.home-air-purifier-expert.com> overtaken 23.02.2012.
- Hopke, P.K. Contemporary threats and air pollution. *Atmospheric Environment* **2009**, *43(1)*, 87–93.
- Ghose, M.K.; Majee, S.R. Characteristics of hazardous airborne dust around an Indian surface coal mining area. *Environmental Monitoring and Assessment* **2007**, *130(1-3)*, 17– 25.
- Trivedi, R.; Chakraborty, M.K.; Tewary, B.K. Dust dispersion modeling using fugitive dust model at an opencast coal project of western coalfields limited, India. *Journal of Scientific and Industrial Research* **2009**, *68*, 71– 78.
- Vesovic, V.; Auziere, A.; Calviac, G.; Dauriat, A. Modelling of the dispersion and deposition of coarse particulate matter under neutral atmospheric conditions. *Atmospheric Environment* **2001**, *35 (1)*, S99 – S105.
- Kan, H.; Chen, R.; Tong, S. Ambient air pollution, climate change, and population health in China. *Environmental International* 2011, doi: 10.1016/j.envint.2011.03.003.
- <http://www.louishelbig.com> overtaken 25.02.2012.
- <http://www.miningweekly.com> overtaken 25.02.2012.
- <http://www.algor.com> overtaken 25.02.2012.
- <http://www.ceforum.co.uk> overtaken 25.02.2012.
- <http://www.bestcoaltrading.blogspot.in> overtaken 25.02.2012.
- <http://www.mining-technology.com> overtaken 25.02.2012.

17. Pang, X.; Mu, Y.; Lee, X.; Zhang, Y.; Xu, Z. Influences of characteristic meteorological conditions on atmospheric carbonyls in Beijing, China. *Atmospheric Research* **2009**, *93* (4), 913 – 919.
18. Reed, R.W. Significant dust dispersion models for mining operations **2005**, U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory.