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Review

Opencast mines: a subject to major concern for human health

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Presently India ranks third amongst the coal producing countries in the world after China and USA. Sustainability of present growth rate around 9% in the Indian economy depends largely in accelerating growth in mining sector, especially the coal mining. Country's demand of coal has increased manifold requiring adoption of appropriate technology in the industry. Enhancement of combustion fuel / minerals is mainly responsible for the degradation of air quality in mines area. Some activities (i.e. drilling, blasting, loading-unloading of materials, overburden etc.) in mines area created some fine particles which can suspended in air and caused of respiratory diseases. These all effects on human health through particulates matter are follow the time of exposure and quantity of particle in such type of concentration. Here we undertake the simplistic review of particulate matter which is generated due to mining activities and creates adverse impact on human health.

Keywords: Air pollution, Particulate matter, Opencast mines, Modeling, Health effects.

INTRODUCTION

Growth in coal production in India in first 25 years of independence was very slow, from around 30 million tonnes (Mt) in 1947 to 73 Mt in 1970-71. However, post nationalization period experienced a rapid growth in coal production from 81 Mt in 1973-74 to 493.90 Mt in 2008-09 (Table 1). Coal production crossed 100 Mt in 77-78, 200 Mt in 89-90, 300 Mt in 99-2000 and 400 Mt in 05-06 (Dixit, 2009).

Table 1 shows the shift of share of coal production from opencast mines from below 30% until nationalization to above 88% in 2008-09. And this trend is expected to remain heavily tilted towards opencast mines because of higher demand of coal in future to support the growth of the economy. As projected in "Coal Vision 2025" document, based on approach made by The Energy and Research Institute (TERI), demand at 8% Gross Domestic Product (GDP) will be 1267 Mt and at 7% GDP will be 1147 Mt by 2025 (MOC, 2005).

This has resulted in and will continue to result in opening up of huge opencast mines with very high production capacity. Presently Coal India Ltd. has very high capacity opencast mines like Dudhichua, Jayant and Nigahi in NCL, Gevra in WCL and Rajmahal in ECL, producing more than 10 Mt coal per annum. Similar large capacity mines with high degree of mechanisation are proposed in several areas and some of the existing mines will undergo production capacity enhancement, e.g. ECL is in the final stage of implementing a project to enhance the production of Rajmahal open cast mine from 11.5 Mt to 17.5 Mt high ash thermal coal (E and F grade) in 2012 (Bose, 2009).

Increase in depth of surface mining

The sharp augmentation of coal production through commissioning of large opencast mines is leading the opencast mines to go deeper, i.e. deep opencast mines are going to come up more and more in future. The Rajmahal opencast mine is planned for a depth of up to 150 m. Similar situation, although not as sharp increase of production as coal, is also going to happen in case of opencast non-coal mines. Malanjkhand Copper Project (MCP), the single largest copper deposit of India with nearly 70% of the country's reserve and contributing around 80% to total copper production of Hindustan Copper Limited (HCL), have a reserve of 221 Mt with a grade of 1.31% copper and now have an annual

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Table 1. Coal production in India

	Coal Production (Mt)			% Share	
	Underground (UG)	Opencast (OC)	Total	UG	OC
At the time of Independence (1947)	28.20	7.80	30.00	94	16
At the time of Nationalisation (1970-71)	59.95	21.05	81.00	74	26
2010-11	58.89	529.11	588.00	10.015	89.984

production of 2 Mt (MCP, 2009).

It is proposed to increase the production of mine which will necessitate the opencast mine to go as deep as 300m from the surface (The surface Reinforcement Learning (RL) is 580m, RL of presently working is 200m and extraction of the entire reserve will necessitate the mine to go deep up to a RL of 280m.). Similar is the case with the three big opencast iron ore mines of Steel Authority of India Limited (SAIL) at Kiriburu, Meghahatuburu and Bolani having annual production of about 4.20 Mt. Each of them has been planned to go for higher production with increase of depth of working.

Share of opencast mines increases

Opencast mines and underground mines are the most important and common methods of extraction of minerals / coal from the earth, but choice of methods is totally depends on economic cost of minerals, depth of minerals and quantity of minerals. In India, the quantity of opencast mines has increased because of opencast mines is only methods to extract the minerals with 100% possibility. The results of this scenario, Indian Coal/ Minerals mines sector both have large no. of opencast mines.

Air pollution and Health

“Air pollution may be defined as any atmospheric condition in which certain substances are present in such concentration that they can produce undesirable effects on man and his environment” (Rao, 1998). Some of these pollutants are sulphur dioxide, nitrogen dioxide, carbon monoxide, particulate matter (PM_{10} and $PM_{2.5}$), ozone, lead, ammonia, benzene, arsenic and nickel (NAAQS, 2009). Both indoor and outdoor pollution can have effects not only on human health but also on surrounding environment (Adgate et al., 2003; Chunlei et al., 2005; Kamens et al., 1991; Koponen, et al., 2001; Reshetin and Kazazyan, 2004; Ruth, 2007; Saxena, 1997; Sivacoumar et al., 2001; Smith et al., 2005).

Both developed and developing countries have been facing the air pollution problem (Chan et al., 2001; Kan et al., 2009; Gupta et al., 2006; Kim et al., 2006; Tsai and Chen, 2006). Huge amount of pollutant are emitted by fossil fuel combustion in vehicles, industries and other production sites (Abdul-Wahab, 2006; Ashbaugha et al., 2003; Kan et al., 2011; Laden et al., 2000; Moreno et al., 2007; Mukhopadhyay and Forssell, 2005). The enhanced concentration of pollutants in the atmosphere due to anthropogenic activity has significant impact on health of human being (Bond et al., 2004; Braun et al., 1992; Maantay, 2002; Ramanathan and Carmichael, 2008; Stieb et al., 2002; Wilson and Spengler, 1996). The emitted particulate matter in the atmosphere leads to the increasing mortality and morbidity through the respiratory disease (Abbey et al., 1998; Anderson et al., 2004; Arbex et al., 2009; Beverland et al., 2002; Brunekreef and Holgate, 2002; Castillejos et al., 2000; Dockery et al., 1993; Dockery and Pope, 1994; Guo et al., 2009; Halliday et al., 1993; Hopke 2009; Kan and Chen, 2004; Kjellstrom et al., 2002; Lebowitz, 1996; O'Neill et al., 2008; Ostro, 2004; Pan et al., 2007; Pope at al., 2002; Pope III et al., 2002; Qian et al., 2007; Salter and Parsons, 1999; Samet et al., 2000; Schwartz et al., 1996; Spix et al., 1993; Vedal, 1995; Wilson and Spengler, 1996).

Among all air pollutant, the impact of particulate matter on health is the most important one (ApSimon et al., 2001; Braun et al., 1992; Brunekreef et al., 1997; Harrison et al., 2001; Kamens et al., 1991; Kulkarni, 2006; Nel, 2005; Pillai et al., 2002; Schwartz et al., 1996; Smith and Jantunen, 2002; Wilson and Suh, 1997). Many studies have shown that the particulate matter generated through urban pollution (vehicle, industries etc.) leads to the adverse impacts on health (Arbex et al., 2009; Cooper et al., 2009; Harrison and Yin, 2000; Kamens et al., 1991).

Air Pollution and Surface Mining

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 stratified minerals deposit close to the surface. Opencast mines are the most important and common methods of extraction of minerals / coal from the earth, but choice of methods is totally depends on economic cost of minerals, depth of minerals and quantity of minerals. It is totally opposite of underground mining. Surface mining is predominant

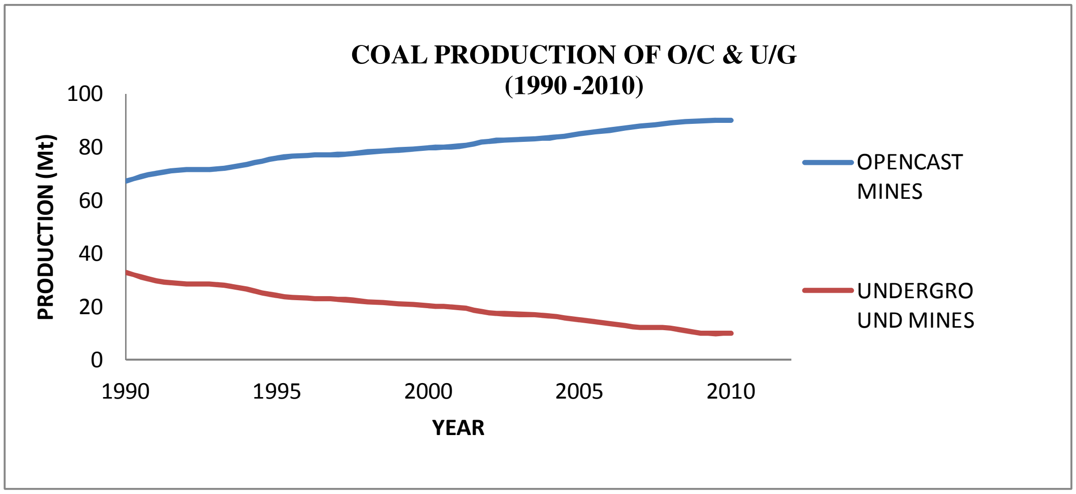

Figure 1. Coal Production in Opencast (OC) and Underground (UG) mines
Source: Ministry of Coal & Mines, Govt. of India

exploitation procedure for minerals. Almost all metallic ore, non-metallic ore and other materials are mined using surface mining. In World, the quantity of opencast mines has increased because of opencast mines is only methods to extract the minerals with 100% possibility. In India, the ratio of underground mining and surface mining is 10% and 80% respectively.

Surface mines generally result in high productivity and low operation cost therefore; deep opencast mines are going to come up more and more in future. Surface mining are among the most economical of all mining methods but can only be applied to limited categories of mineral deposits. Surface mining Therefore, are gradually increasing time by time. In India, several examples are present to indicate that increases the depth of opencast mines for higher production such as Rajmahal opencast coal mines, Malanjkhand Copper Project (MCP) and Steel Authority of India Limited (SAIL) at Kiriburu, Meghahatuburu and Bolani opencast mines. Each of them has been planned to go for higher production with increase of depth of working.

Surface mines is a direly related to surrounding environment. Some unit operation of surface mining (i.e. drilling, blasting, crushing and loading – unloading, etc) are directly emitted pollutant to the atmosphere (Chaulya, 2004; Cowherd, 1979; Ghose, 1989; Ghose and Majee, 2000; Ghose and Majee, 2001; Ghose and Majee, 2007; Jacko, 1983; Kumar et al., 1994; Mirmohammadi et al., 2009; Pandey et al., 2008; Silvester et al., 2009; Sinha and Banerjee, 1994; Sinha, 1995; Soni and Agarwal, 1997; Trivedi et al., 2009; Chengdu et al., 2010). Some other pollutant (gaseous) is concerned to major pollutant in mining areas such as oxide of nitrogen, oxide of sulphur, carbon monoxide and hydrocarbon, etc. (Almbaucer et al., 2001; Chakraborty et al., 2002; Ghose and Majee, 2001; Zhengfu et al., 2010).

A surface mine has been responsible for creating impact on surrounding environment as compare to other mining methods. Mining activities are not only reducing air quality but also disturbing natural environment such as fauna and flora, etc. (Chaudhari and Gajghate, 2000; Chaulya, 2004; Crabbe et al., 2000; Nanda and Tiwary, 2001; Wheeler et al., 2000). However, many environmental impacts are at maximum in surface mining areas including air blast, visual intrusion, noise and vibration, air and water pollution and dereliction.

Modelling of particulate matter

In recent, the particulate matter is the most significant source of air pollution in mega cities (Chan et al., 2001; Kan et al., 2009; Gupta et al., 2006; Kim et al., 2006; Tsai and Chen, 2006). The source of particulate matter are very common either urban areas activities such as factories, chimneys, and exhaust from vehicles, etc. (Abdul-Wahab, 2006; Ashbaugha et al., 2003; Kan et al., 2011; Laden et al., 2000; Moreno et al., 2007; Mukhopadhyay and Forssell, 2005) or mining activities such as drilling, blasting, crushing, transporting of material, loading- unloading point, overburden, and haul rods, etc.(Chaulya, 2004; Cowherd, 1979; Ghose, 1989; Ghose and Majee, 2000; Ghose and Majee, 2001; Ghose and Majee, 2007; Jacko, 1983; Kumar et al., 1994; Mirmohammadi et al., 2009; Pandey et al., 2008; Silvester et al., 2009; Sinha and Banerjee, 1994; Sinha, 1995; Soni and Agarwal, 1997; Trivedi et al., 2009; Zhengfu et al., 2010). Due to these all activities the concentration of particulate matter leads to gradually high in the atmosphere. At this stage, the precaution is the most important not only for human life but also for the surrounding environment (plant, buildings, and natural habitat, etc.). All mega cities of India are also affected by the increase of air pollution levels as a result of activities from urbanisation and industrial/mining activities (Molina and Molina, 2004; Oanh et al., 2009). The increase rate of pollutant has driven for modelling and measurement of air quality. The modelling of particulate matter is the most important to identify the origin and dispersion behaviour of particulate. Modelling of particulate matter is also provided some information about the particle such as mass concentration with size range. Modelling gives some information about how much concentration of pollutant substances at a particular location but it can not be gives information about the future concentration of pollutant. The pollutant can be controlled by meteorological condition (Pang et al., 2009; Sezer et al., 2005; Silva et al., 2007).

DISCUSSION

The aim of this study was to assess respirable dust exposure in opencast coal mines. Predominant dust types include the ore/mineral mined, exhausts from the mining machineries and dust types in the nearby locality that is carried by wind and tyres of the vehicle to the mine working environment. 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. Determination of the respirable dust exposure of coal miners will help to investigate relationships between such exposures and respiratory diseases. This will give an estimate of PM in different horizons of a deep surface mine that the persons working are exposed to. This will serve as an input to the scientists who are working on areas to interpret the impact of workplace environment on the health of a worker.

REFERENCES

(http://www.indianjournals.com/ijor.aspx?target=ijor:jeohandvolume=9andissue=1and2andarticle=009)

Abdul-Wahab SA (2006). Impact of fugitive dust emissions from cement plants on nearby communities. Ecological Modelling 195: 338-348.

Adams SJ (1997). Dust deposition and measurement: a modified approach. Environ. Technol. 18: 345–350.

Adgate JL, Ramachaandran G, Pratt GC, Waller LA, Sexton K (2003). Longitudinal variability in outdoor, indoor and personal $PM_{2.5}$ exposure in healthy non-smoking adults. Atmospheric Environ. 37: 993-1002.

Alves CA (2008). Charaterisation of solvent extractable organic constituents in atmospheric particulate matter: an overview. Anais Da Academia Brasileira De Ciencias 80:21-82.

Anderson HR, Atkinson RW, Peacock JL, Marston L, Konstantinou K (2004). Meta-analysis of time-series studies and panel studies of particulate matter (PM) and ozone (O_3): Report of a WHO task group, Copenhagen, WHO Regional Office for Europe, document EUR/04/5042688.

ApSimon HM, Gonzalez del Campo MT, Adams HS (2001). Modelling long-range transport of primary particulate material over Europe. Atmospheric Environment 35: 343-352.

Arbex MA, de Souza Conceicao GM, Cendon SP, Arbex FF, Lopes AC, Moyses, EP, Santiago SL, Saldiva PH, Pereira LA, Braga ALF (2009). Urban air pollution and chronic obstructive pulmonary disease-related emergency department visits. J. Epidemiol. Community Health 63: 777-783.

Argenbright LP (1971). Smelter pollution control. Mining Congress J. 57 (5): 24-28.

Ashbaugha LL, Carvachoa OF, Browna MS, Chow JC, Watson JG, Magliano K C (2003). Soil sample collection and analysis for the fugitive dust characterization study. Atmospheric Environment 37:1163-1173.

Baldauf RW, Lane DD, Marote GA (2001). Ambient air quality monitoring network design for assessing human health impacts from exposures to airborne contaminants. Environmental Monitoring and Assessment 66: 63-76.

Beverland IJ, Heal MR, Agius RM, Hibbs KR, Elton RA, Fowler D (2002). The metal contents of airborne particles in Edinburgh: application to epidemiology. Technical report, Department of Health, London.

Bose PR (2009). Business Line (Business Daily from the Hindu group of publications); Wednesday, Feb 25, 2009. http://www.thehindubusinessline.com/2009/02/25/stories/ 2009022551190300.htm (last accessed on 14 September, 2009).

Braun C, Ackermann U, Schwartz J, Gnehm HP, Rutishauser M, Wanner HU (1992). Air pollution and respiratory symptoms in preschool children. Am. Rev. of Respiration 145: 42–47.

Brooks K, Schwar MJR (1987). Dust deposition and the soiling of glossy surfaces. Environ. Pollution 43: 129–141.

Brunekreef B, Holgate ST (2002). Air pollution and health. The Lancet 360: 1233-42.

Carlton AG, Turpin JB, Johnson W., Buckley, B. T., Simcik, M., Eisenreich, S. J., and Porcja, R. J. (1999). Methods for characterisation of personal aerosol exposures. Aerosol Sci. Technol. 31: 66–80.

Castillejos M, Borja-Aburto VH, Dockery DW, Gold DR, Loomis D (2000). Airborne coarse particles and mortality. Inhalation Toxicol. 12: 61-71.

Chakraborty MK, Ahmad M, Singh RS, Pal D, Bandopadhyay C, Chaulya S K (2002). Determination of the emission rate from various opencast mines operations. Environ. Modeling and Software 17: 467-480.

Chan LY, Kwok WS, Lee SC, Chan CY (2010). Spatial variation of mass concentration of roadside suspended particulate matter in metropolitan Hong Kong. Atmospheric Environ. 35: 3167-3176.

Chaudhari PR, Gajghate DG (2000). Assessment of air pollution effect on plants- a review. Indian J. Environ. Protection 20: 925-933.

Chaulya SK (2004). Assessment and management of air quality for an opencast coal mining area. J. Environ. Manage. 70: 1-14.

Chunlei L, Jiamo F, Guoving S, Xinhui B, Yongmei H, Xinming W, Bixian M (2005). Vertical distribution of PAHs in the indoor and outdoor ($PM_{2.5}$) in Guangzhou, China. Building and Environment 40: 329-341.

Cooper CF, Kjellstrom J, Smith KR (2009). Asthma in Latin Ameria: a public health challenge and research opportunity. Allergy 64: 5-17.

Cowherd C (1979). Measurements of fugitive dust emission from haul roads, Report No. EPA 600/7–79–182.

Davis CT, Mundalamo RH (2010). Environmental health impacts of dispersed mineralization in South Africa. J. Afr. Earth Sci. 58: 652-666.

DeGaetano AT, Doherty OM (2004). Temporal, spatial and meteorological variations in hourly $PM_{2.5}$ concentration extremes in New York City. Atmospheric Environ. 38: 1547–1558.

Dhar BB (1994). Changing environment scenario in mining industry. J. Mines, Metals and Fuels, pp. 309–314.

Dixit MP (2009). Coal mining technology and its strategic planning for the days to come in Indian coal mining industry and the role of coal in

global scenario. Guest lecturer at Department of Mining Engineering, Indian Institute of Technology, Kharagpur. 11th September 2009.
Dockery DW, Pope CA (1994). Acute respiratory effects of particulate air pollution. Annual Review of Public health 15: 107-32.
Dockery DW, Pope CA, Xu XP, Spengler JD, Ware JH, Fay ME, Ferris BG, Speizer FE (1993). An association between air-pollution and mortality in six United States Cities. New Engl. J. Med. 329: 1753-1759.
Elliot S, Blake DR, Rowland FS (1999). New directions: rapid industrialization in developing countries: the challenge to earth system, research for the new millennium. Atmospheric Environ. 33 (4): 683–684.
Fan S, Wang B, Tesche M, Engelmann R, Althausen A, Liu J, Zhu W, Fan Q, Li M, Ta N, Song L, Leong K (2008). Meteorological conditions and structures of atmospheric boundary layer in October 2004 over Pearl River Delta area. Atmospheric Environ.42: 6174–6186.
Farhat SCL, Silva CA, Orione MA, Campos LMA, Sallum AME, Braga ALF (2011). Air pollution in autoimmune rheumatic diseases: A review. Autoimmunity Rev. doi:10.1016/j.autrev.2011.06.008.
Gao Y, Fan SM, Sarmiento JL, (2003). Aeolian iron input to the ocean through precipitation scavenging: a modeling perspective and its implication for natural iron fertilization in the ocean. J. Geophysical Res. 108 (D7), 4221.
Ghose MK (1989). Pollution due to air borne dust particles in coal mining, its monitoring and abatement measures. Mine Tech 6 (1): 186-190.
Ghose MK, Majee SR (2000). Assessment of the impact on the air environment due to opencast coal mining- an Indian case study. Atmospheric Environ. 34: 2791-2796.
Ghose MK, Majee SR (2001). Air pollution caused by opencast mining and its abatement measures in India. J. Environ. Manage. 63: 193-202.
Ghose MK, Majee SR (2007). Characteristics of hazardous airborne dust around an Indian surface coal mining area. Environmental Monitoring and Assessment, 130: 17–25.
Godish T (1985). Air Quality, Lewis publishers, Inc., Chelsea, Michigan, 39-51.
Guo J, Miao X (1999). Dust suppression at the fully mechanized top-coal caving face, Mining Science and Technology' 99, A. A. Balkema, Rotterdam, Netherlands (ISBN 9058090671): 105-106.
Guo Y, Jia Y, Pan X, Liu L, Wichmann H (2009). The association between fine particulate air pollution and hospital emergency room visits for cardiovascular diseases in Beijing, China. Science of the Total Environment 407: 4826-4830.
Gupta P, Christopher SA, Wang J, Gehrig R, Lee Y, Kumar N (2006). Satellite remote sensing of particulate matter and air quality assessment over global cities. Atmospheric Environ. 40:5880-5892.
Hall JV (1996). Assessing health effects of air pollution. Atmospheric Environment 30: 743–746.
Harrison RM, Yin J (2000). Particulate matter in the atmosphere: which particle properties are important for its effects on health? The Science of the Total Environment 249: 85–101.
Harrison RM, Yin J, Mark D, Stedman J, Appleby RS, Booker J, Moorcroft S (2001). Studies of the coarse particle (2.5 - 10 µm) component in UK urban atmosphere. Atmospheric Environment 35, 3667–3679.
Hopke PK (2009). Contemporary threats and air pollution. Atmospheric Environment 43: 87-93.
Irvine KN, Murray SD, Drake JJ, Vermette SJ (1989). Spatial and temporal variability of dry dust fall and associated trace elements: Hamilton, Canada. Environmental Technology Letters 10: 527–540.
Jacko RB (1983). Air quality in surface mining. In: Sendlein, L.V. A.,
Hasan, Y, Carlson C. L., editors. Environmental Monitoring and Reclamation Handbook. New York: Elsevier Science Publishing.
Jeffrey LS (2005). Characterization of the coal resources of South Africa. J.the South Afr. Instit. of Mining and Metallurgy, pp. 95-102.
Jones T (1993). The role of environmental impact assessment in coal production and utilization. Natural Resource Forum 17 (3): 170–180.
Kamens R, Lee CT, Weiner R, Leith D (1991). A study to characterize indoor particles in three non-smoking homes. Atmospheric Environment 25: 939-948.
Kan H, Chen B (2004). Particulate air pollution in urban areas of Shanghai, China: health based economic assessment. Science of the Total Environment 322: 71-79.
Kan H, Chen R, Tong S (2011). Ambient air pollution, climate change, and population health in China. Environmental international: doi: 10.1016/j.envint.2011.03.003.
Kapoor RK, Gupta VK (1984). A pollution attenuation coefficient concept for optimization of green belt. Atmosphere Environment 18: 1107-1117.
Kim KH, Mishra VK, Kang CH, Choi KC, Kim YJ, Kim DS (2006). The ionic compositions of fine and coarse particle fractions in the two urban areas of Korea. J. Environ. Manage. 78: 170-182.
Kjellstrom TE, Neller A, Simpson RW (2002). Air pollution and its health impacts: the changing panorama. Med. J. Australia 177: 604-608.
Koponen IK, Asmi A, Keronen P, Puhto K, Kulmala M (2001). Indoor air measurement campaign in Helsinki, Finland 1999- the effect of outdoor air pollution on indoor air. Atmospheric Environment 35: 1465-1477.
Kulkarni MM (2006). Source apportionment of human exposure to particulates in Mumbai, India. Aerosol Air Quality and Res. 6: 281–294.
Kumar CSS, Kumar P, Deshpande VP, Badrinath SD (1994). In: Khuntia, G.S., (Ed.), Fugitive dust emission estimation and validation of air quality model in bauxite mines, Proceedings of International Conference on Environmental Issues in Minerals and Energy Industry, IME Publications, New Delhi, India, 77–81.
Laden F, Neas LM, Dockery DW, Schwartz J (2000). Association of fine particulate matter from different sources with daily mortality in six U.S. Cities. Environment Health Perspective 108: 941-947.
Lebowitz MD (1996). Epidemiological studies of the respiratory effects of air pollution. Eur. Respiratory J. 9: 1029-1054.
Maantay J (2002). Mapping environmental injustices: pitfalls and potential of geographic information systems in assessing environmental health and equity. Environmental Health Perspectives 110:161–171.
MCP (2009). Malanjkhand copper project. http://www.hindustancopper.com/MCCPlant.asp?lnk=1 (last accessed on 15 September 2009).
Mirmohammadi M, Gholamnejad J, Fattahpour V, Seyedsadri P, Ghorbani Y (2009). Designing of an environmental assessment algorithm for surface mining projects. J. Environ. Management 90: 2422-2435.
MOC (2005). Report (Part I): The expert committee on road map for coal sector reform. Ministry of Coal, Government of India. http://coal.nic.in/expertreport.pdf (last accessed on 15 September 2009).
Molina MJ, Molina LT (2004). Critical review: megacities and atmospheric pollution. J. the Air and Waste Management Assoc. 54: 644–680.
Monn Ch, Braendly O, Schaeppi G, Schindler Ch, Ackermann-Liebrich U, Leuenberger Ph, Sapaldia T (1995). Particulate matter <10 µm (PM_{10}) and total suspended particulates (TSP) in urban, rural and alpine air in Switzerland. Atmospheric Enviro. 29: 2565–2573.
Moorcraft JS, Laxen DPH (1990). Assessment of dust nuisance. Environmental Health, pp. 215–217.
Moreno T, Alastuey A, Querol X, Font O, Gibbons W (2007). The identification of metallic elements in airborne particulate matter derived from fossil fuels at Puertollano, Spain. Int. J. Coal Geol. 71: 122-128.
Mu YJ, Pang XB, Quan JN, Zhang XS (2007). Atmospheric carbonyl compounds in Chinese background area: a remote mountain of the Qinghai–Tibetan Plateau. J. Geophysical Res. 112: D22302. doi:10.1029/2006JD008211.
Mukhopadhyay K, Forssell O (2005). An empirical investigation of air pollution from fossil fuel combustion and its impact on health in India during 1973–1974 to 1996–1997. Ecological Economics 55: 235 – 250.
NAAQS (2009). National Ambient Air Quality Standard. Central Pollution Control Board, India. www.cpcb.nic.in (last accessed: 24 August 2011).
Namdeo AK, Colls JJ, Baker CJ (1999). Dispersion and re-suspension of fine and coarse particulates in an urban street canyon. The

Science of the Total Environment 235: 3-13.

Nanda SN, Tiwary SN (2001). Concentration of SPM in the Burla-Hirakud -Sambalpur region (Orissa). Indian J. Environ. Protection 21: 193-202.

Nel A (2005). Atmosphere, Air pollution –related illness: effects of particles. Science 308: 804-806.

O' Neill MS, Bell ML, Ranjit N, Cifuentes LA, Loomis D, Gouveia N, Borjaaburto VH (2008). Air pollution and mortality in Latin America: the role of education. Epidemiol. 19: 810-819.

Oanh NTK, Pongkiatkul P, Upadhyay N, Hopke PP (2009). Designing ambient particulate matter monitoring program for source apportionment study by receptor modelling. Atmospheric Environment 43: 3334-3344.

Ostro B (2004). Outdoor air pollution: assessing the environmental burden of disease at national and local levels. WHO Environmental Burden of Disease Series, No.5. Geneva: World Health Organization.

Pan X, Yue W, He K, Tong S (2007). Health benefits evaluation of the energy use scenarios in Beijing, China. Science of the Total Environment 374: 242- 251.

Pandey SK, Tripathi BD, Mishra VK (2008). Dust deposition in a sub-tropical opencast coal mine area, India. J. Environ.Manage. 86: 132-138.

Pang X, Mu Y, Lee X, Zhang Y, Xu Z (2009). Influences of characteristic meteorological conditions on atmospheric carbonyls in Beijing, China. Atmospheric Res. 93: 913–919.

Pateraki S, Maggos T, Michopoulos J, Flocas HA, Asimakopoulos DN, Vasilakos C (2008). Ions species size distribution in particulate matter associated with VOCs and meteorological conditions over an urban region. Chemosphere 72: 496–503.

Pillai PS, Suresh Babu S, Krishna Moorthy K (2002). A study of PM, PM_{10} and $PM_{2.5}$ concentration at a tropical coastal region. Atmospheric Res. 61: 149–167.

Pope III CA, Burnett RT, Thun MJ, Calle EE, Krewski D Ito K, Thurston GD (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. J. Am. Med. Assoc/.287 (9): 1132–1141.

Powell RA (1972). The growth of an iron ore dust problem- part Hedland, Western Australia in International Clean Air Conference, Melbourne, Australia, pp. 146-151.

Pudasainee D, Sapkota B, Shrestha ML, Kaga A, Kondo A, Inoue Y (2006). Ground level ozone concentrations and its association with NOx and meteorological parameters in Kathmandu valley, Nepal. Atmospheric Environment 40: 8081–8087.

Rao CCV (1996). Air quality modelling — research needs. In: Dhar, B. B., Charkraborty, M. K., Chaulya, S. K., Singh, R. S (Eds.), Proceedings of Workshop on Air Quality Modelling and Atmospheric Acidification. Commonwealth Science Council, Dhanbad, India, pp. 1–27.

Rao CS (1998). Environmental Pollution Control Engineering, New Age International (P) Limited, publishers, New Delhi, India, pp. 30.

Reshetin VP, Kazazyan VI (2004). Public-health impact of outdoor air pollution in Russia. Environmental Modelling and Assessment 9: 43-50.

Reynolds L, Jones TP, Berube Wise H, Richards R (2005). Toxicity of airborne dust generated by opencast coal mining. Geoscience 67 (2): 141.

Ruth AE (2007). Indoor and outdoor air pollution: Tobacco, smoke, moulds and diseases infants and children. Int. J. Hygiene and Environ. Health 210: 611-616.

Rybicka EH (1989). Metals and their chemical and mineralogical forms in industrial pollutants of the atmosphere. Environ. Technol. Letters 10: 921–928.

Salter LF, Parsons B (1999). Field trials of the TEOM and partisol for PM_{10} monitoring in the St Austell Chaina clay area, Cornwall, UK. Atmospheric Environ. 33: 2111-2114.

Samet JM, Dominici F, Curriero FC (2000). Fine particulate air pollution and mortality in 20 US cities, 1987-1994. New Engl. J. Med. 343: 1742–1749.

Saxena VK (1997). Impact of stratospheric volcanic aerosols on climate: evidence for aerosol short-wave and long-wave forcing in the southeast US. Atmospheric Environ. 31: 4211.

Schwartz J, Dockery DW, Neas LM (1996). Is daily mortality associated specifically with fine particles? J. the Air and Waste Management Assoc. 46: 927–939.

Seto S, Hara H (2006). Precipitation chemistry in western Japan: its relationship to meteorological parameters. Atmospheric Environ. 40: 1538–1549.

Sezer TF, Nuhoglu A, Bayraktar H (2005). Impacts of some meteorological parameters on SO_2 and TSP concentrations in Erzurum, Turkey. Chemosphere 59: 1633–1642.

Shannigrahi AS, Agrawal KM (1996). An overview on optional green belt development around industrial porject. Indian J. Environ. Protection 17: 253-261.

Sharma SC, Roy RK (1997). Green belt- an effective means of mitigating industrial pollution. Indian J. Environ. Protection 17: 724-727.

Silva PJ, Vawdrey EL, Corbett M, Erupe M (2007). Fine particle concentrations and composition during wintertime inversions in Logan, Utah, USA. Atmospheric Environment 41: 5410–5422.

Silvester SA, Lowndes IS, Hargreaves DM (2009). A computational study of particulate emissions from an open pit quarry under neutral atmospheric conditions. Atmospheric Environ. 43: 6415–6424.

Singh G, Pal A, Khoiyanbam RS (2009). Impact of mining on human health in and around Jhansi, Bhundelkhand region of Uttar Pradesh, India. Journal of Ecophysiology and Occupational Health 9 (1 and 2).

Sinha S (1995). Quantification of fugitive particle emission from line source in surface coal mine-an approach. Indian J. Environ. Protection 15: 339-343.

Sinha S, Banerjee SP (1994). A method for estimating fugitive particulate emission from haul roads in opencast coal mines and mitigative measures. In: Banerjee, S. P., (Ed.), Proceedings of Second National Seminar on Minerals and Ecology, Oxford and IBH, Dhanbad, India, pp. 217-227.

Sivacaumar R, Bhanarkar AD, Goyal SK, Gadkari SK, Aggarwal AL (2001). Air pollution modelling for an industrial complex and model performance evaluation. Environmental Pollution 111: 471-477.

Slack AV, Falkenberry HL, Harrington RE (1972). Sulphur oxide removal from waste gases. Journal of Air Pollution Control Association 22 (3): 159-166.

Smith KR, Jantunen M (2002). Why particles?. Chemosphere 49 (9): 867–871.

Smith KR, Mehta S, Maeusezahl-Feuz M (2004). Indoor air pollution from household use of solid fuels. Environmental and occupational risk factors. World Health Organization, pp. 1435-1493.

Soni DK, Agarwal A (1997). Characterisation of dust emission in coal mining activities - a case study. Indian J. Environmental Protection 17: 80-814.

Spix C, Heinrich J, Dockery DW, Schwartz J, Volksch G, Schwinowski K, Collen C, Wichmann HE (1993). Air pollution and daily mortality in Erfurt, East-Germany, 1980-1989. Environmental Health Perspectives 101: 518-526.

Stieb DM, Judk S, Burnett RT (2002). Meta-analysis of time-series studies of air pollution and mortality: effects of gases and particles and the influence of cause of death, age and season. J. the Air and Waste Manage. Assoc. 52: 645-646.

Tayanc M (2000). An assessment of spatial and temporal variation of sulphur dioxide levels over Istanbul, Turkey. Environ. Pollution 107: 61–69.

Triantafyllou AG (2003). Levels and trends of suspended particles around large lignite power station. Environmental Monitoring and Assessment 89: 15–34.

Triantafyllou AG, Kassomenos PA (2002). Aspects of atmospheric flow and dispersion of air pollutants in a mountainous basin. The Science of the Total Environment 297: 85–103.

Tripathi BD, Chaturvedi SS, Tripathi RD (1996). Seasonal variation in ambient air concentration of nitrate and sulphate aerosols in a tropical city, Varanasi. Atmospheric Environment 30 (15): 2773–2778.

Trivedi R, Chakraborty MK, Tewary BK (2009). Dust dispersion modeling using fugitive dust model at an opencast coal project of western coalfields limited, India. J. Scientific and Industrial Res. 68: 71-78.

Tsai YI, Chen CL (2006). Atmospheric aerosol composition and source apportionments to aerosol in southern Taiwan. Atmospheric Environment 40: 4751–4763.

Vallack HW, Shillito DE (1998). Suggested guidelines for deposited ambient dust. Atmospheric Environment 32 (16): 2737–2744.
Vedal S (1997). Ambient particle and health: lines that divide. Journal of the Air and Waste Management Association 47: 551-581.
Wanquan T, Honglang X, Jianjun Q, Zheng X, Gensheng Y, Tao W, Xiaoyou Z (2004). Measurements of dust deposition in Gansu Province, China, 1986–2000. Geomorphol. 57: 41–51.
Wheeler AJ, Williams I, Beaumont RA, Manilton RS (2000). Characterization of particulate matter sampled during a study of children's personal exposure to air borne particulate matter in a UK urban environment. Environment Monitoring and Assessment 65: 69-77.
Wilson R, Spengler J (1996). Particles in our air: Concentration and health effects. Harvard University Press, Boston.
Wilson WE, Suh HH (1997). Fine particles and coarse particles: concentration relationships relevant to epidemiological studies. J. the Air and Waste Management Assoc. 47: 1238-1249.
Yudovich EY, Ketris MP (2005). Arsenic in coal: a review. International Journal of Coal Geol. 61: 141-196.
Zhengfu B, Hilary I, John DL, Frank O, Sue S (2010). Environmental issues from coal mining and their solutions. Mining Science and Technol. 20: 215-223.