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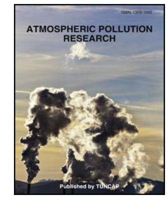

Spatial and temporal variation of respirable particles around a surface coal mine in India

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ABSTRACT

People living around surface mines are exposed to enhanced respirable particle level. Not many studies are available that evaluated the contribution of mining to it. The paper presented the result of study that investigated spatio-temporal variability of particle concentrations around a surface coal mine in eastern part of India. Particle concentration and concurrent meteorological parameters at 24 locations were measured along four sections from the mine boundary up to 500 m using an aerosol spectrometer and portable weather station. SPSS 20.0 was used for statistical analysis. Average PM_{10}, $PM_{2.5}$ and PM_1 concentration varied in the range 212.67 ± 168.76–$524.46 \pm 137.57\,\mu g\,m^{-3}$, and 89.53 ± 77.62–$297.41 \pm 107.10\,\mu g\,m^{-3}$ and 66.22 ± 58.05–$246.66 \pm 84.26\,\mu g\,m^{-3}$ respectively. This is equivalent to 2.74, 1.34 and 2.77 times the background concentration of $PM_{2.5\text{-}10}$, $PM_{1\text{-}2.5}$ and PM_1 respectively. Respirable particles up to 500 m from the mine comprised of 27–73%, 8–12% and 18–61% of $PM_{2.5\text{-}10}$, $PM_{1\text{-}2.5}$ and PM_1. During peak production period, the concentration of respirable particles around the mine increased by a factor 5–15 of the average concentrations. Distance and meteorological parameters explained up to 55% of the variability of particle concentration. Present Indian norm to allow an ambient PM_{10} concentration of $250\,\mu g\,m^{-3}$ at a distance of 500 m is not met, in spite of the study mine is only 10 years old. Extremely limited literature suggests that more studies are required for better understanding and evaluation of mining contribution to the local PM level.

1. Introduction

Several studies have demonstrated health hazards due to exposure to particulate matter (PM) emitted from mining operations (Yudovich and Ketris, 2005; Finkelman et al., 2002; Boyd et al., 1970; Heimann et al., 1953). Some of adverse health effects include asthma (Pless-Mulloli et al., 2000; Banks et al., 1998), coal miners' pneumoconiosis (also known as black lung disease) due to inhalation of coal dust (Davies and Mundalamo, 2010; Hendryx and Ahern, 2008; Donoghue, 2004; Finkelman et al., 2002; Coggon and Taylor, 1998), sinus, mesothelioma, bronchitis, cardiovascular diseases (Hendryx, 2009; Chen et al., 1990), Parkinson's and Alzheimer's disease (Buzea et al., 2007) scleroderma, rheumatoid arthritis due to exposure of silica (Noonan et al., 2006), silicosis (Steenland and Brown, 1995), lung cancer due to exposure of iron ore dust (Wild et al., 2009; Chen et al., 1990), anemia and bone disease due to high exposure to aluminum (Guillard et al., 2004), and neurotoxic effects of manganese (Weiss, 2006). Large-scale operations and use of high capacity heavy machines generate huge quantities of PM leading to enhanced pollution levels in and around surface mines. Unit operations such as drilling, blasting, loading, transport and unloading emit PM in different size ranges directly to the atmosphere worsening human health and surrounding environment (Chaulya et al., 2003; Zhengfu et al., 2010; Heal et al., 2012; Zhang et al., 2013; Kumar et al., 2014; Patra et al., 2016). The particle sizes of concern are PM_{10} (particulate matter having aerodynamic diameter 10 μm or less) which can enter to the gas exchange region of the lung (Heal et al., 2012; Tsiouri et al., 2015) and $PM_{2.5}$ (particulate matter having aerodynamic diameter 2.5 μm or less) that can reach the alveolar region of lungs and thus cause more health damage (Leung and Cheung, 1999). Therefore, recent studies have focused on assessment of fine ($PM_{2.5}$) and coarse ($PM_{2.5\text{-}10}$) fractions of PM_{10} emitted from the mines (Sinha and Banerjee, 1997; Chakraborty et al., 2002; Gautam and

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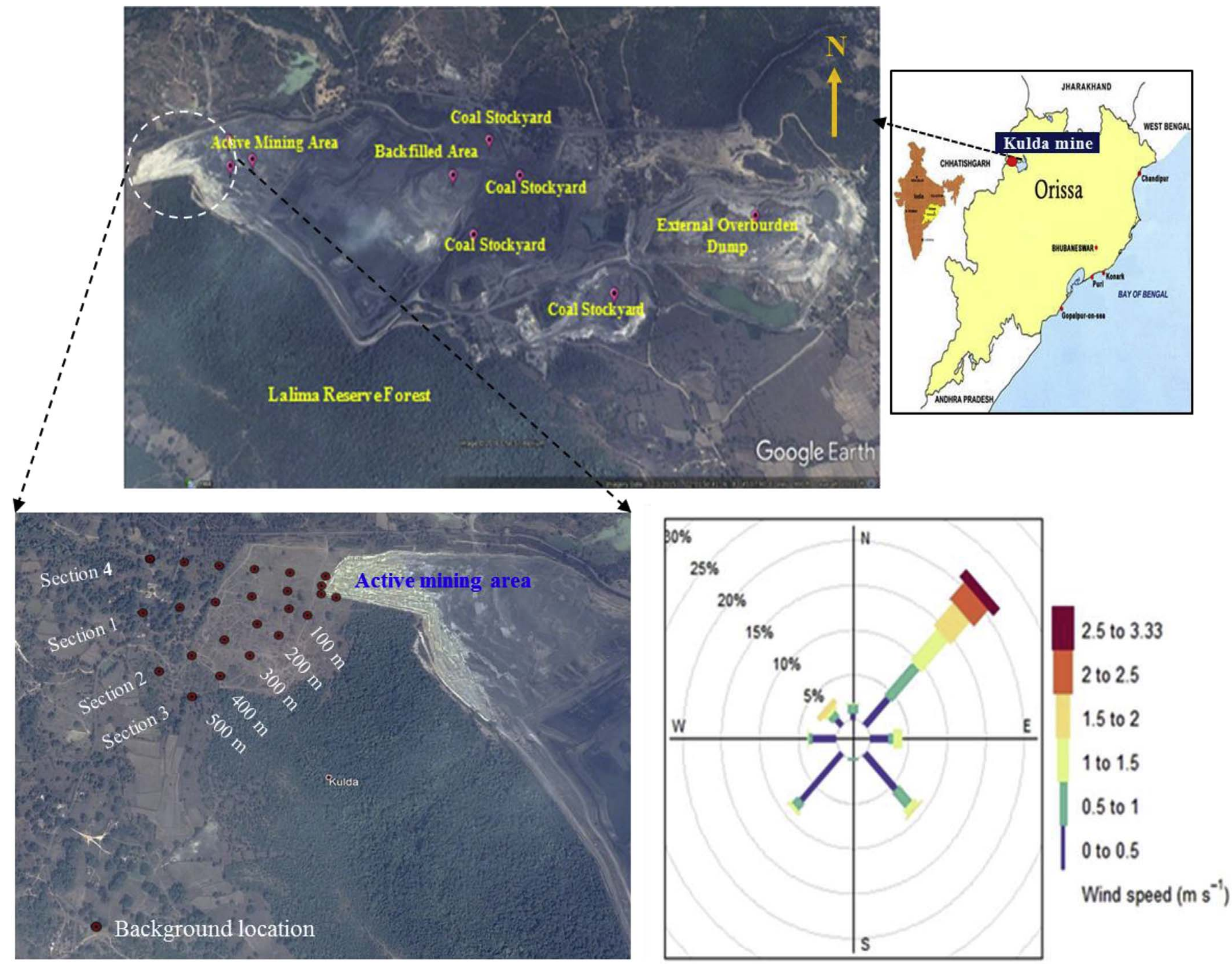

Fig. 1. Kulda surface mine, showing the sampling locations and wind rose during the study period.

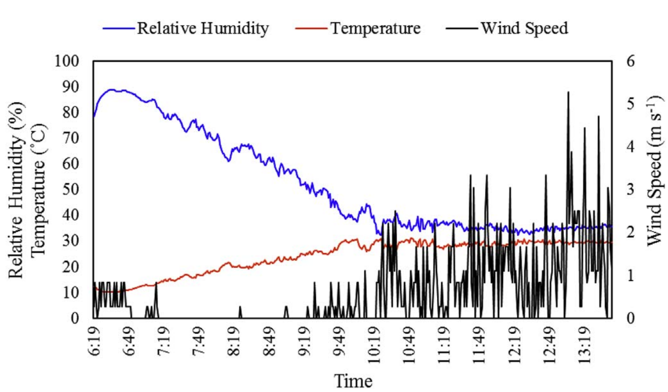

Fig. 2. Relative humidity, temperature and wind speed (Typical meteorological parameter variation in a day).

Patra, 2015). While the health studies have also indicated PM_1 to be an important metric for adverse health (Polichetti et al., 2009), very few studies are available on PM_1 (particulate matter having aerodynamic diameter 1 µm or less) emission from mining operations (Kundu and Pal, 2015; Gautam and Patra, 2015).

Earlier studies on PM emission from mining operations can be grouped into three categories: (1) Estimation of PM generation from different surface mining operations (2) Evaluation of in-pit dispersion of particulate matter; and (3) Assessment of the PM status in mining locality. Studies on operation-wise PM generation involved quantification of PM (mainly Total Suspended PM and PM_{10}) from different mining operations such as top soil removal, drilling, loading, unloading, and transport of material (Tripathy et al., 2015; Mandal et al., 2012; Onder and Yigit, 2009; Chaulya, 2006; Chakraborty et al., 2002). Several studies reported empirical equations for emission rate from different operations in order to assess the individual source potential (Chaulya, 2006; Chakraborty et al., 2002). The main focus of such studies was to evaluate exposure from specific mining operation. The in-pit dispersion studies concentrated on theoretical (Winges, 1981; Fabrick, 1982), CFD modeling (Chinthala and Khare, 2011; Silvester et al., 2009; Bhowmick et al., 2015), physical modeling (Peng and Lu, 1995) and on-site studies (Gautam and Patra, 2015; Gautam et al., 2015) of dispersion of PM of different sizes within the mine boundary. The recent in-pit study in surface mine involved measurement of coarse ($PM_{2.5\text{-}10}$) as well as fine fractions ($PM_{1\text{-}2.5}$ and PM_1) of respirable PM in iron and copper mines at different depths (Gautam and Patra, 2015).