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Characterization of $PM_{2.5}$ generated from opencast coal mining operations: A case study of Sonepur Bazari Opencast Project of India

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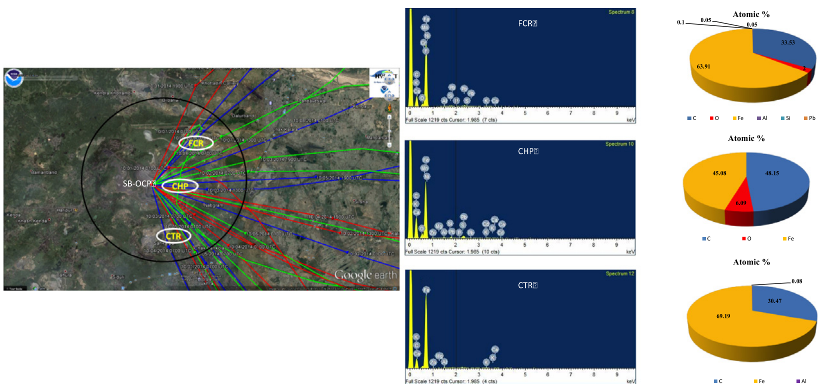
HIGHLIGHTS

- $PM_{2.5}$ concentration is measured at three strategic locations in an OCP.
- EDX analysis for $PM_{2.5}$ elemental composition is carried out.
- Carbonaceous species (OC, EC, OC/EC and TCA) are calculated.
- $PM_{2.5}$ levels, 2–3 times of the national permissible limit, are recorded.
- Fe content (∼45–70%) in $PM_{2.5}$ is very high for a coal mine area.

GRAPHICAL ABSTRACT



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ABSTRACT

Opencast coal mines, a major source of airborne particulate matter (PM), is widespread in India. The health impacts are primarily associated with the concentration and composition of the PM inhaled. A study aimed at characterization of the airborne $PM_{2.5}$ at a coal mine was carried out during 01–07 October 2014 in the Sonepur Bazari Opencast Project in India. Samples were collected at three different locations at the mine using $PM_{2.5}$ samplers.

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Air mass trajectory

Collected $PM_{2.5}$ samples were characterized in terms of surface elemental composition using Energy Dispersive X-ray (EDX) spectroscopy. The $PM_{2.5}$ levels were 2–3 times of the permissible Indian limits. Surface elemental composition analysis indicates that Fe (∼45–70%) and C (∼30–50%) as the dominant elements amongst all elements present in $PM_{2.5}$. An average organic carbon (OC) to elemental carbon (EC) ratio of 3.5 indicated diesel vehicle and coal smoke from stockyard as the sources, which is typical to opencast coal mining activities. Forward air mass trajectory analysis using HYSPLIT4 model showed that in addition to the locations nearby the mine getting affected by the $PM_{2.5}$ emitted from the mine, places as far as 200 km from the mine can also receive the traces of $PM_{2.5}$. More studies on elemental species characterization of $PM_{2.5}$ in different coal mining areas will provide better understanding of occupational health hazards to which mine workers exposed due to inhalation of airborne PM.

1. Introduction

The number of opencast coal mine has increased globally since 30 years (Gautam et al., 2012). The growth of coal production in India was very slow before nationalization of coal mines. After the nationalization of the coal mines in 1975–76, the coal production has significantly increased (i.e. 100 million tonne (Mt) in 1977–78, 200 Mt in 1989–90, 300 Mt in 1999–2000, 400 Mt in 2005–06 and 613 Mt in 2013) (WCA, 2015; Dixit, 2009). The coal mining operations (i.e. drilling, blasting, loading/unloading of coal/material and transportation of coal/material, etc.) generate significant amount of total particulate matter (PM) that disperses in the surrounding atmosphere (Kurth et al., 2014a; Gautam et al., 2012; Chaulya, 2006, 2004; Chakraborty et al., 2002). Several studies have reported adverse health effects due to increased PM concentration from the mining operations (Pless-Mulloli et al., 2001; Ramanathan and Subramanian, 2001; Love et al., 1997). Inability of the body to remove progressive build-up of coal dust leads to inflammation, fibrosis and in the worst case, necrosis (Davis and Mundalamo, 2010). Respiratory diseases i.e. black lung, asthma and cardiovascular diseases are a very common health problem in and around coal mining area (Banks et al., 1998; Hendryx, 2009; Hendryx and Ahern, 2008; Yudovich and Ketris, 2005; Finkelman et al., 2002).

The occupational exposure to PM and its adverse effect on human health depend on the size of the particle (Li et al., 2014; Fernandez-Navarro et al., 2012; Pless-Mulloli et al., 2000; Goix et al., 2011; Finkelman et al., 2002; Pless-Mulloli et al., 2001; Seaton et al., 1995; Boyd et al., 1970; Kurth et al., 2014a) as well as chemical/mineralogical composition of the particles (Aneja et al., 2012; Poschl, 2005). Medical evidence suggests that $PM_{2.5}$ (Particles with equivalent diameter up to 2.5 μm), also referred to as respirable particles, can easily penetrate through the respiratory system to the deeper parts of the lung and therefore, it can cause the respiratory diseases (Poschl, 2005; Flemming et al., 2011; Kurth et al., 2014b). As a result, studies on PM emission from mining operations are mostly focused on estimating the concentration of PM of different sizes emitted from the mining operations (Chaulya, 2004; Chakraborty et al., 2002; Ghose and Majee, 2001; Tripathy et al., 2009). Some studies (Gautam et al., 2016; Gautam and Patra, 2015; Onder and Yigit, 2009; Tecer et al., 2008) reported that among the respirable particles, mining operations generate more coarse particles ($PM_{10-2.5}$) then fine particle ($PM_{2.5}$). Limited studies are available in literature on the characterization of PM emitted from coal mining operations and relate it to the health effects. Aneja et al. (2012) reported presence of antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium in airborne PM around the coal mining area of Appalachia. It has been reported that the quantity of arsenic is high in atmosphere in coal mining areas of Coal basins of Western Kentucky (USA) (Yudovich and Ketris, 2005) and China (Finkelman et al., 2002). Huang et al. (2004) reported that the pyrite content of coal is associated with the occurrence of coal miner's pneumoconiosis. Association of rank of coal with coal miners' pneumoconiosis has also been reported (Bennett et al., 1979; Christian and Nelson, 1978). Presence of toxin and impurities in coal dust has been ascribed to the kidney diseases and cardiovascular problems among the coal miners (Hendryx and Ahern, 2008; Finkelman et al., 2002). While the mineralogical characterization of PM is an important tool to understand the health effect, not many studies have been carried out on it. Limited studies (Roy et al., 2015; Pandey et al., 2014; Tecer et al., 2008) are available on the elemental composition of PM in and around the opencast coal mines. Therefore, the chemical assessment of air borne $PM_{2.5}$ in and around the opencast coal mines is required. The paper presents the findings of a study aimed at mineralogical/chemical characterization $PM_{2.5}$ emitted form an opencast coal mine in India.

2. Methodology

2.1. Experimental

The study was conducted at Sonepur Bazari Opencast Coal Project (SB-OCP), India, during 01–07 October 2014. The mine is located 10 km away from Grand Trunk Road that connects two major cities (Kolkata and Delhi) of India (Fig. 1). Administratively, it falls under the Eastern Coalfields Limited, which is a subsidiary of Coal India Limited, the nationalized coal company of India. The present production of the SB-OCP is 6.5 million tons (Mt) with an average stripping ratio of 1:4.72. As on 01-04-2010, the mineable reserve is 141.90 Mt with an estimated life of 46 years.