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Multi element exposure risk from soil and dust in a coal industrial area

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A B S T R A C T

Coal mining and processing have profound environmental concerns, where large quantities of mine spoil and dust particles are generated. Potentially toxic elements dispersed in the dust and soils in coal mining ecosystem may have adverse health impacts to the nearby inhabitants. Dust and soil samples collected from Jharia coal mining area, India were analysed for As, Cd, Co, Cr, Cu Ni, Pb, V, and Zn. With respect to crustal abundance, As, Cd, and Pb were enriched in the soil, whereas Pb, and As were enriched in the dust. The geo-accumulation index (I_{geo}) was <0 for most of the elements, except for Zn (I_{geo} 1.07), and Pb (I_{geo} 0.9). Pollution load index was higher for soil (1.3) than dust (1.2), and both were categorized as moderately polluted. Exposure risk assessment showed that, ingestion is the main route of exposure to potentially toxic elements present in soil/dust followed by dermal exposure. Exposure risk was higher for child than adult. Though the hazard index (HI) was <1.0 for all the elements, the contents of Cr, As, Pb, and V were close to the permissible exposure limits. The carcinogenic risks associated with As, Cd, Co, Cr, and Ni were also less than the permissible limits.

1. Introduction

Globally, coal is one of the most abundant and important energy resource. It plays an imperative role in defining the economy of a nation. Coal is also used as a reducing material (in the form of coke) in iron and steel industries. It is relatively an inexpensive fuel that enables developing countries to strengthen their economies and improve the standard of living of their citizens. Coal mining involves excavation of the earthly bound coal by removing overburdens using mechanical devices. This process is associated with the release of large quantities of mine spoil and dust particles. Open cast coal mining is associated with large quantities of emissions (dust and gases) that are potentially hazardous to the local community (Masto et al., 2010). Metal pollution from coal is of concern because some of the elements have high enrichment factors. Bi is considered as highly enriched in coal with a factor of 10, whereas As, Cd, B, Sb, Mo, and Hg are less enriched (factor, 2–10) (Masto et al., 2007). Dusts from coal mines contain metal species and organic pollutants that settle down to the nearby soils and other structures. Soil is an important natural resource which supports plant growth and other human needs. But, the presence of pollutants can affect soil quality and impair its life sustaining capacity.

Coal mining is one of the significant causes of environmental pollution, as large quantities of coal dust particles are emitted (León-Mejía et al., 2011). Exposure to coal dust has been associated with different chronic diseases and mortality risk (Guerrero-Castilla and Olivero-Verbel, 2014). Exposure to high levels of heavy metals can result in acute and chronic toxicity, leading to the damage of central and peripheral nervous systems, blood composition, lungs, kidneys, liver, and even death. Local communities in coal mining areas are exposed to heavy metals in dust and soil through exposure routes like ingestion, inhalation, and dermal absorption (Li et al., 2014). In rural communities typical of coal mining areas, the level of exposure is usually higher for children than adults because of pica and other play behaviours.

Elemental composition in dust and soil samples can reflect the characteristics of short- and long-term activities in that area. It can also provide information about the levels of human exposure to heavy metals pollution from coal mining activities. However, systematic studies on heavy metals in dust and soil and their combined impact on human health especially in coal mining areas are very few. Caravanos et al. (2013) emphasized on the need of tools for rapid assessment of exposure risks in mining industries, especially for the Initial Site Screening (ISS), to quickly identify key site criteria including human exposure pathways, estimated populations at risk, sampling information, etc. Exact exposure assessment is important for risk estimation and regulation (Pesch et al., 2004).

In a small mining town (Gaungxi Zhuang Autonomous Region in southern China), Zhang et al. (2009), found that the heavy metals were associated with significant human health effects ranging from reduced intelligent quotients (IQs) in children (from Pb exposure) to

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cancer (Cd and As). In Colombia, León-Mejía et al. (2011) observed genotoxic effect in humans due to coal mining. Continuous input of some toxic metals from coal-mining operations to agricultural lands in the region of Cam Pha (Vietnam), enhanced absorption of metals by rice plant, which may lead to metal accumulation (especially Cd) in human organs (Martinez et al., 2013). Risk assessment studies near the Shuoli coal mine (China), showed that the contents of As, Cu, and Zn in wheat grains were much higher than the exposure limits. The hazard indices of aggregate risk through consumption of wheat grains were 2.3–2.4 for rural inhabitants and 1.4–1.5 for urban inhabitants (Shi et al., 2013). Cr, Mn, Pb, As and Sb exposure risks to children near a large coking plant (China) were 3 to 10 times higher than the acceptable levels (Cao et al., 2014). Arsenic exposure of residents of Changqing (Guizhou, China) was linked to coal burning (Shraim et al., 2003). A systematic review of data from 72 Chinese mining areas revealed that the soils surrounding the mining areas are seriously polluted by heavy metals emitted from mining activities and pose health risks to the public, especially to children (Li et al., 2014).

These direct health problems due to coal mining may be severe (leading to death), widespread (affecting many millions of people), and complex (requiring a multidisciplinary research approach) (Finkelman et al., 2002). Dust and soil are the complex heterogeneous media that may directly affect the health of the inhabitants due to the presence of heavy metals in them. Studies on the combined exposure risk from these two media are limited. Thus, this study was carried out in the Jharia coal mining area (India) to assess the potential human exposure risks due to heavy metals in the soil and dust.

2. Materials and methods

2.1. Site description

The study was conducted in Jharia, Dhanbad district, India. Jharia town located in the eastern part of Jharkhand state of India (Fig. 1), between latitudes 23°44′53″ N and 23°44′02″ N and longitudes 86° 25′13″ E and 86° 24′54″ E, with an average elevation of 202 m. Jharia is actively associated with coal mining activities for more than a century. There are many active opencast and underground mines, abandoned coal mines, natural coal fires, and overburden dumps. The site has congested roads for local commuters and for transportation of coals from the mines.

2.2. Sample collection and analysis

Settleable dust samples were collected from 20 different spots using wooden trays covered with stainless steel plates (60 × 40 cm, height 10 cm). All the sampling spots were located within 1 km from coal mining activity. Dust samples were collected for a 15 days interval during winter season of 2012. Dust particles were wiped off from the bottom of plates with a camel hair brush, and were collected in polyethylene containers. Soil samples were also collected from the places where dust samples were collected. The dust and soil samples were dried to constant weight in a hot air oven at 105 °C and sieved.

The methods described by Tandon (1993) and Baruah and Barthakur (1999) were used to determine the following soil properties: bulk density (BD) (soil core method), maximum water holding capacity (by equilibrating the soil with water), pH and EC in water (1:2.5, soil/water ratio), soil organic carbon (by potassium dichromate oxidation), loss on ignition, and soil N (alkaline permanganate method). Heavy metals from the soil and dusts were extracted using USEPA method 3051A (USEPA, 2007), in a microwave system (Milestone, Italy) and analysed through ICP-OES (ICAP 6300 Duo, Thermo Fisher Scientific, UK). Multi elemental standard solution (CertiPUR) (1000 mg/l) procured from Merck, Germany was used for the development of calibration curves. Yttrium was used as internal standard for consistency in sample measurement. NIST coal fly ash (NIST 2689) and loamy sand soil (CRM024-05, RTC, Laramie, WY) certified reference materials (CRM) were used for quality assurance. The percentage recovery of elements from CRM ranged from 93.8% for Ni to 118% for As. The blank reagent and standard reference material were analysed intermittently, to verify the accuracy and precision of the digestion procedure. After every tenth sample during analysis, the calibration standards were analysed to check the analytical accuracy. The analytical variations of these repeated standard samples were within 5%. All the samples were digested and analysed in triplicate and the coefficient of variations (CV) was within 7%.

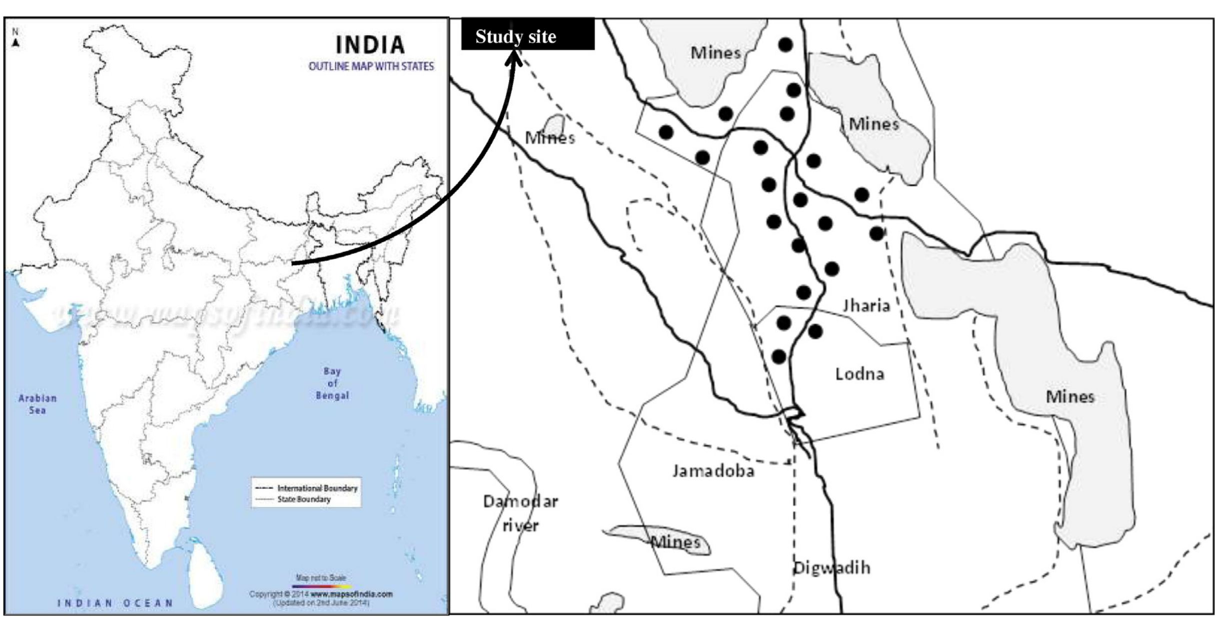

Fig 1. Location of the study area.

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