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Monitoring of arsenic fate with proximate parameters and elemental composition of coal from Thar coalfield, Pakistan

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ABSTRACT

It was extensively studied that combustion of coal for power generation is an important anthropogenic contributor of toxic elements to the environment. In present study the exposure of arsenic (As) from coal samples collected from two sites (III and V) of Thar coalfield before and after burning were evaluated. Meanwhile the proximate parameters and elemental composition of collected coal samples were also studied in detail. The quantitative analysis of As in coal samples and their ash were achieved by microwave-assisted acid digestion methods prior to analyze by MHS-15 hydride generation atomic absorption spectrometry. The contents of As in coal samples of site-III of Thar coalfield was found to be higher as compared to site-V, it may be due to difference in geochemical mineral composition. The resulted data of ash indicated that during combustion of coal >88.5% of As can be released into the atmosphere. The evaluated moisture contents in coal samples of Thar coalfield indicated that the direct use of coal is not suitable for power generation and other activities.

1. Introduction

Nowadays, Pakistan is facing energy crises due to unusable natural energy resources even in the presence of its huge amount. With grace of Almighty Allah, Pakistan has the largest natural lignite coal depositions in district Tharparkar, Sindh, Pakistan (Imran et al., 2014; Khurshid et al., 2013; Rafique et al., 2008; Tahir and Rauf, 2006). However, coal is one of the most important energy resources in developing countries (Liu et al., 2000). Unfortunately, explored coal in Pakistan has not been properly developed for power generation due to insufficient financing and lack of technological and human recourses (Gunter et al., 1997; Siddiqui, 2007). At the movement, the Government of Pakistan is focused on foreign private investors for the development of coal mining and application of it as a cheap indigenous energy resource (Zaigham, 2003; Zaigham and Nayyar, 2005). The use of coal for power and heat generation can produce significant amounts of toxic elements such as arsenic, mercury and other toxicants (Matschullat, 2000). The high contents of As in coal was also reported by other workers, which is considered to be a serious matter of concern for scientific community (Gemici et al., 2008; Imran et al., 2014; Keimowitz et al., 2005). The burning of coal is also highlighted as a cause of As contamination of surface and groundwater in different areas (Singh et al., 2012; Tuzen et al., 2010).

The As in coal occurs in two major forms, bounded with organic and inorganic phases as oxygenated sulfide complexes (Guo et al., 2004). During coal combustion, As can vaporize and condense homogeneously/heterogeneously to adsorb on the surface of fine fly ash particles (Vejahati et al., 2010; Yan et al., 2000). The As released into the environment due to burning of coal, may be responsible to create several kinds of health consequences (Larios et al., 2012; Melamed, 2005; Morin and Calas, 2006). It was studied that the coal mining activities create environmental health impacts. (Li et al., 2011). The main task of a hydrogeochemical study is to identify the process responsible for the evolution of As.

The present study has been carried out for the first time on Thar coalfield, where the open pit coal mining will be started soon with the collaboration of Australian Engineering company and Engro chemical (Pvt. Limited) Pakistan, whereas preliminary operational condition of underground coal gasification is in progress. A systematic work is urgently needed to understand the composition of coal in newly developed mining area of Pakistan, as well as the fate of As following environmental release.

In the present study, the content of As in coal and its residual ash samples were obtained from two sites, at four different depths of Thar coalfield (a largest natural coal basin of Pakistan), to check the available and exposure route of As into the environment. The As in coal samples and their ash were extracted by acid digested in a microwave oven. The proximate parameters (sulfur, moisture and ash) and elemental composition of coal samples were also analyzed. The correlation between different elements and As in coal samples has been studied.

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The accuracy of the methodology has been validated by the standard addition method. The concentrations of As in coal samples before and after burning were measured by MHS-15 hydride generation atomic absorption spectrometry (HG-AAS).

2. Materials and methods

2.1. Description of study area

Thar coalfield is located in the south-eastern part of Sind province in Pakistan on the stable western margin of the Indian plate and positioned between 24°45′–24°80′ N and 70°05′–70°30′ E as shown in Fig. 1 (Ali et al., 2015). The study area has a tropical desert climate (Imran et al., 2014). The temperatures during summer and winter remain between 24°C to 48°C and 9°C to 28°C respectively, rainfall varies from year to year, but average annual rainfall is 200 to 300 mm.

The geological survey of Pakistan has discovered a huge deposit of coal in 1992 at Thar during the research program assisted by United States geological survey. The Thar coalfield is spread over an area of more than 9100 km^2 with dimensions of 140 km (north–south) 65 km (east–west) with estimated reserves of 175 billion tones. (Ali et al., 2015). Thar coalfield is divided into twelve blocks according to the private power and infrastructure board, federal ministry of water and power government of Pakistan. The number of coal seams varies from hole to hole, and a maximum of 20 seams have been logged in some of the drill holes. The thickness of coal seams varies from 0.20 to 22.8 m.

Thar coalfield is covered by dunes with an average depth varying from 14 to 93 m. At the depth of >275 m the basement rock is generally granite (Fig. 2). The granitic rocks of the Thar coalfield may belong to the proterozoic malani magmatism of western Rajasthan, India (Ahmad and Chaudhry, 2007). The basement rocks comprised of epidote amphibolite facies of metamorphic rocks ranging from mafic to granite composition. The kaolin deposits are generally covered by thick sand dunes and alluvium extending down to an average depth of 30 m. The depth of the kaolin pockets is estimated to be 2 to 8 m below the surface (Naseem et al., 2010). The paleocene–ecocene coal bearing horizons of claystone, carbonaceous claystone, sandstone and siltstone occur with interlaminated coal beds shown in Fig. 2. The sandstone is very fine to coarse grained and consists of ferromagnesium mineral grains. The met basalts are medium to coarse grained volcanic and plutonic rocks that have metamorphosed to epidote amphibolites and contain acidic dykes of rhyolite to quartz trachyte composition (Naseem et al., 2010). The coal bearing horizon of the Paleocene-Eocene sediments above the basement complex is designated as baraformation and has highly altered kaolinite (Choudry et al., 2010; Malkani, 2012). It was reported in literature that geoelectrical drilling and geophysical log data indicate four major divisions of lithological sequences in the whole Thar coalfield shown in Fig. 2. These zones are sand dune, sub-recent deposits, coal-bearing formations of Paleocene, igneous and bfement complex of Precambrian age (Rafique et al., 2008; Zaigham, 2003).

2.2. Sampling

For the current study, coal samples were collected from four coal seam (n = 5 per seam) of each sites-III (n = 20) and V (n = 20), with the assistance of the Sindh coal authority. The drilling of the coalfield in site-III and V occurred at the time of sampling in 2014. The coal samples were collected by using core sampling method at different depths, ranging from 120 to 280 m. The collected coal samples were

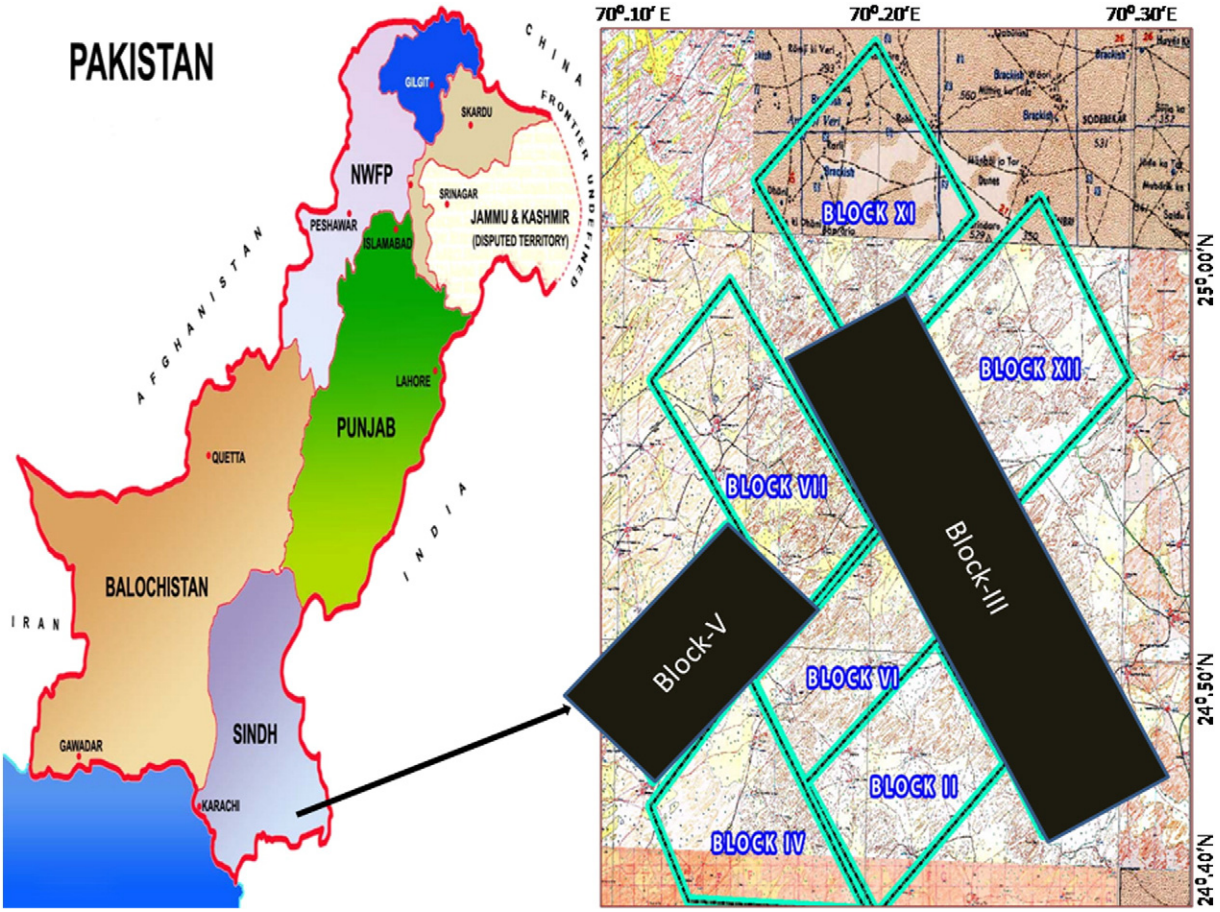

Fig. 1. Study map of blocks-III and V (black shaded), Thar coalfield, Pakistan.