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Multi-technique study of fly ash from the Bokaro and Jharia coalfields (Jharkhand state, India): A contribution to its use as a geoliner

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ABSTRACT

The chemical, mineralogical, petrographic and textural characteristics of fly ashes from one fluidized-bed and two pulverized-fuel power stations in India, have been evaluated by a range of complementary methods, including optical and electron microscopies, laser granulometry, quantitative X-ray diffraction, X-ray fluorescence spectrometry and inductively-coupled plasma techniques. Mineralogical and geochemical analyses have also been carried out on the feed coals from the respective power stations, and the results were used to evaluate the changes produced during different combustion processes. Differences in particle size and shape for the ashes, and also differences in ash petrology and mineralogy, have been related to differences in the mineral matter of the feed coals, and to the milling characteristics and combustion temperatures in the different power plants.

There is a potential of using these fly ashes as geoliner because of their fine texture and low permeability. Leaching tests have also been carried out on the fly ashes, as a basis for assessing the potential for adverse impacts on groundwater systems.

The materials were blended with bentonite to decrease the permeability further. The major and trace element compositions of these ashes were determined. Most of the elements studied were leached in lower concentrations than averages for the same elements from European fly ashes. It is thus expected that these ashes will not provide significant source of additional contamination to permeating water if they are used with bentonite as geoliner material.

1. Introduction

Large amount of fly ash is generated in India from the coal-based thermal power plants. In 2010–2011, the generation of fly ash was in the tune of 131 MT per year and was expected to increase to 300–400 MT in 2016–17 (Haque, 2013). The Government of India has launched a “Fly Ash Mission” in 1994 to encourage research on various developments in the area of fly ash utilization. In addition, the political will to encourage the use of fly ash has risen perceptibly (DFEE, 2007).

The proportion of the produced fly ash utilized in India has increased from 9.63% in 1996–97 to 54.53% in 2010–11. The usage has increased mainly in the Indian cement industry by 50%. Fly ash is also used in reclamation of low-lying areas, construction of roads and embankments, mine filling, production of bricks and tiles, agriculture and other activities (Haque, 2013). However, additional markets are needed to achieve 95–100% utilization, including the use of fly ash in large scale environmental projects.

One such high volume fly ash utilization can be considered for the construction of geoliner because of its fine texture, large specific surface area, good water holding capacity and relatively less permeability (Blissett and Rowson, 2012).

Since the primary goal of a geoliner system is to reduce the migration of contaminants released from landfilled wastes, clay-based geoliners are widely used and found to be suitable. This is due to their low permeability in the range of ≤10–9 m/s (Kayabah, 1996; Malusis et al., 2003; Rowe and Fraser, 1994) and high ion exchange capacity (Mitchell and Soga, 2005). Clay barriers exhibit membrane behavior, in both vertical and horizontal containment scenarios (Chien et al., 2006; Shackelford et al., 2001). Such geoliners and surface seals have potential to reduce harmful effects from the wastes and create an economically affordable, socially accepted and environmentally effective sustainable landfill system. However, India's clay deposits are rapidly being depleted and substitute materials are needed to reduce the consumption of clays as geotechnical materials. Fly ash can be a good substitute of clay as a constituent material for geoliner.

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Mixing of fly ash with bentonite may possibly provide an impermeable clay-like material. Several studies (e.g. Dixon et al., 1985; Komine, 2004; Rao et al., 2008) have been carried out to assess the suitability of fly ash/bentonite blends as geoliners. It has been found that bentonite can improve the physico-chemical and mechanical strength of the geoliner.

Fly ash has the capacity for use as an economic adsorbent to remove both inorganic and organic pollutants from permeating aqueous solutions because of its potentially reactive nature due to presence of abundant aluminosilicate glass and high internal surface area (Batabayal et al., 1995; Mikendová et al., 2010; Vinay et al., 2008). The low specific gravity, ease of compaction, free draining nature, insensitivity to changes in moisture content, and good frictional properties, as well as, in many cases, the alkaline pH characteristics, are also relevant to the use of fly ash in such applications (Pandian, 2004). However, some of the trace elements that occur in fly ash may also act as pollutants, leading to potential health, environmental and land-use problems (Ayanda et al., 2012; Baba, 2003; Dai et al., 2010; Mandal and Sengupta, 2002).

The properties of coal fly ash are a function of several variables such as coal sources, combustion conditions, the handling and storage methods (Baba, 2003; Creelman et al., 2013; Dai et al., 2014; DFEE, 2007; Mandal and Sengupta, 2002; Valentim and Hower, 2010), and an overall understanding of the fly ash particle size distribution, mineralogy, e.g., the nature and proportion of both the crystalline and non-crystalline components (Hower and Mastalerz, 2001; Hower, 2012; Hower et al., 2005; Lester et al., 2010; Suárez-Ruiz and Valentim, 2007; Suárez-Ruiz and Ward, 2008; Suárez-Ruiz et al., 2008a, 2008b; Vassilev and Vassileva, 2005; Ward and French, 2006), geochemistry and leaching behavior (Xie et al., 2007; Izquierdo and Querol, 2012; Kim and Hesbach, 2009; Li et al., 2014), and in predicting the environmental impacts associated with ash disposal (EPA, 2000; Liu et al., 2009; Praharaj et al., 2002; Ward et al., 2009) should be obtained to complement the feasibility of fly ash in geotechnical applications.

In this study, the granulometry, mineralogy, petrography, chemical and leaching characteristics of several different Indian fly ashes were investigated to assess their potential for effective use in geoliner materials. Fly ash samples were collected from three different thermal power plants, and analyzed by laser granulometry, reflected light optical microscopy, scanning electron microscopy and X-ray microanalysis, powder X-ray diffraction, and X-ray fluorescence spectrometry; the solids and eluate from leaching tests were also analyzed by ICP-MS techniques.

2. Study area

2.1.1. Bokaro coalfield

The Bokaro coalfield is located in Jharkhand state, Eastern India (Fig. 1). It covers an area of 572 km^2, and includes a narrow belt of Gondwana coal-bearing strata extending 65 km from east to west and 10 to 16 km north to south. The coalfield is topographically separated by the Lugu hill into the East Bokaro and the West Bokaro coalfields (Casshyap and Tewari, 1987; Chatterjee et al., 1990; Fox, 1930; Verma et al., 1989).

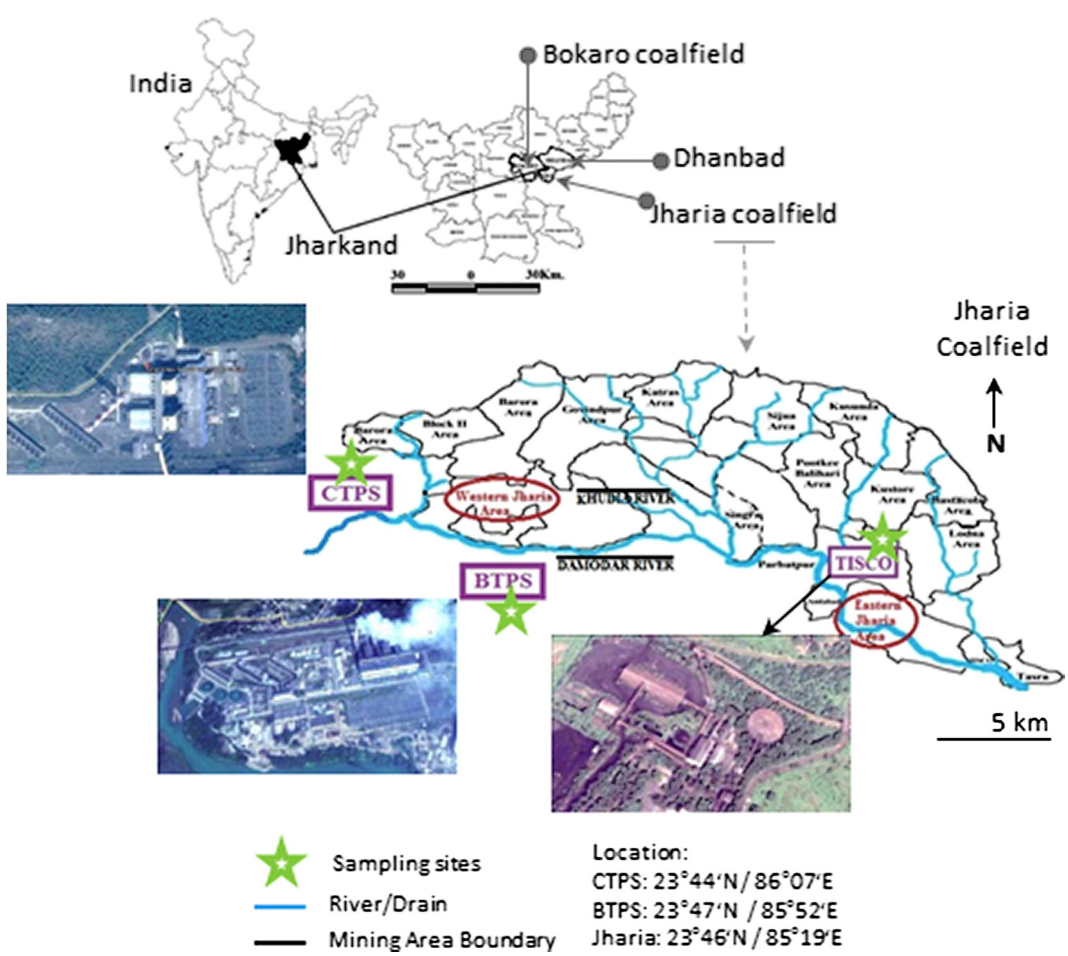

Fig. 1. Geographical location of Bokaro and Jharia coalfields, and Bokaro, Chandrapura and Jharia Thermal Power Plants (Jharkhand state, India). Adapted from Saikia and Sarkar, 2013.