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Ambient air quality and emission characteristics in and around a non-recovery type coke oven using high sulphur coal

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HIGHLIGHTS

- Gaseous species and aerosols are investigated around coke oven.
- SO_2, NO_2, NH_3, PM_{10}, and $PM_{2.5}$ concentrations are dependent upon the feed coal used.
- Principal Component Analysis (PCA) is reported.

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ABSTRACT

The objective of this study is to determine the concentrations of gaseous species and aerosols in and around a non-recovery type coke making oven using high sulphur coals. In this paper, physico-chemical properties of the feed coal sample are reported along with the collection and measurement of the emitted gases (SO_2, NO_2, and NH_3) and aerosol particles ($PM_{2.5}$, PM_{10}) during the coal carbonization in the oven. The coals used are from northeast India and they are high sulphur in nature. The concentrations of the gases e.g., SO_2, NO_2 and NH_3 emitted are observed to be within the limit of National Ambient Air Quality Standard for 24 h. The mean PM_{10} and $PM_{2.5}$ concentrations are found to be 125.4 μg/m^3 and 48.6 μg/m^3 respectively, as measured during three days of coke oven operations. About 99% of the SO_2 in flue gases is captured by using an alkali treatment during the coke oven operation. A Principal Component Analysis (PCA) after Centred Log Ratio (clr) transformation is also performed to know the positive and negative correlation among the coal properties and the emission parameters.

1. Introduction

The rapid industrialization and urbanization in developing countries such as India have resulted in an increase in the consumption of commercial energy in the last decade with coal being one of the major sources in India. It is also the world's second largest source of primary energy (World Energy Council, 2013). The coal-based industries are considered to be among the main industrial emitters of particulate matter (Ayub and Sharma, 2011). The coke making process emits various air pollutants including particulate matters (PMs) (0.7–7.4 kg per MT of coke produced), volatile organic compounds (VOCs) (3.0 kg per MT of coke produced), poly-nuclear aromatic hydrocarbons (PAHs), methane (0.1 kg per MT of coke produced), carbon monoxide (0.050–0.080 kg per MT of coke produced), hydrogen sulphide (0.050–0.080 kg per MT of coke produced), ammonia as well as oxides of sulphur and NOx (CPCB, 2011). The particulate matter (PM) is commonly classified in three different types namely ultrafine (nucleation and aitken mode, diameter less than 0.1 μm), fine (mainly accumulation mode, aerodynamic diameter between 0 and 2.5 μm) and coarse having aerodynamic diameter between 2.5 and 10 μm (Taiwo et al., 2014). In non-recovery types of coke ovens, all these pollutants are released into the environment directly if emission controls are not put into place for treating the flue gas. Thus, these coke ovens are considered to be major air polluting industries. Both stack and fugitive emissions from coke oven plants contribute significantly towards air pollution. These pollutants from the coke oven contribute to the formation of aerosol concentration in the atmosphere, which can create adverse effects to the environment and mankind (Sharma et al., 2013). The atmospheric burden of aerosols has also the effects towards the radiation balance (IPCC., 2013).

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Fig. 1. Map showing the location of the study site.

High-sulphur coal resources are abundant in India, China and other countries, from both practical and academic perspectives (e.g., coal forming origin and related geological aspects). The North-East region (NER) of India is endowed with a good reserve of about 1 billion metric tons of high sulphur coals (Khare et al., 2013). These coals have indifferent characteristics with high organic sulphur, low inorganic sulphur, low ash, high volatile matter and are mostly caking in nature. Presently, NER coals are mostly used in coke-oven industries and utilization in the power sector apart from brick, ferrosilicon, cement and tea industries (Khare et al., 2013). The majority of the coke oven industries in NER are of conventional type that release pollutants directly into the environment. According to a study conducted by Khare and Baruah (2011), it was found that 40–80% of sulphur remains in the coke and 20–60% is released with coke oven flue gases during the pyrolysis of this type of coals. Emission of SO_2 has serious impacts on the environment and human health and its removal from the flue gas before being released into the environment has gained increasing attention all over the world. The studies on the emission profile of coke ovens using high organic sulphur NER coals and the controlling of harmful gases such as SO_2 released from its operation are utmost important for this region.

Thus, the prime objective of this investigation is to study the variability of the concentrations of flue gases emitted during the coke oven operation and the ambient air quality (including PM) around the coke oven and also to see the effect of alkali solution to control the harmful flue gases.

1.1. Study site

The study site comprises of a non-recovery type of experimental (200 kg/batch) pilot plant coke oven unit in CSIR-NEIST, Jorhat (North East India). The site is surrounded by various types of deciduous trees and residential settlements. A national highway is about 1 km away from the study site. Map in Fig. 1 illustrates the location of the study site.

The study area has a humid subtropical climate with a temperature range between 33 and 36 °C during the summer period (May–August) and 9–11 °C in winter (November–February). The southwest monsoon in the region begins to blow from the middle of June and continues up to September. In the period considered in this study, the meteorological conditions were similar to a normal winter season, with a minimum temperature of 8.4 °C and a maximum of 27.9 °C. During the period of sampling, the average wind speed and temperature were 1.5 m/s and 9.5 °C respectively.

The high organic sulphur coals were obtained from the Tirap colliery of Makum coalfield, Assam (Northeast India). Makum coalfield, the largest of all the coalfields of North eastern region (latitude 27°15′–27°25′ N and longitude 95°40′–95°50′ E) is located along the outermost northern flank of the Naga–Patkai range and is disposed as detached, isolated

Fig. 2. Coke oven unit used for the study.