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Emissions estimates of PAH from biomass fuels used in rural sector of Indo-Gangetic Plains of India

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HIGHLIGHTS

- Determination of EF of PAHs from biomass fuels in the laboratory.
- Simultaneous determination of gaseous and particulate phase PAHs.
- State-wise EF of total PAHs from residential fuels over IGP, India.
- Budget estimates of PAHs from residential fuels over six states in IGP, India.

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ABSTRACT

Polycyclic aromatic hydrocarbons (PAHs) are of special interest due to their carcinogenicity, and ubiquitous presence in the environment. Emissions of PAH vary with use of biomass fuels. In this study, the experimentally determined emission factors and emission estimates of PAH emitted from biomass fuels (dung cake, fuelwood and crop residue) from rural household of six states (Delhi, Uttar Pradesh, Punjab, Haryana, Uttarakhand and Bihar) over the IGP, India, are presented. The gaseous phase and particulate phase PAHs emissions are simultaneously determined from various biomass fuels. The average emission factors of total PAHs from dung cakes, fuelwood and crop residue over the IGP, India are estimated as 59.5 ± 19.9 mg kg^{-1}, 52.5 ± 19.6 mg kg^{-1} and 40.9 ± 15.2 mg kg^{-1} respectively. The emission factor of particulate phase PAHs (56.5 mg kg^{-1}, 45.3 mg kg^{-1} and 35.8 mg kg^{-1}) was found higher as compared to gaseous phase PAHs (3.1 mg kg^{-1}, 7.2 mg kg^{-1} and 5.1 mg kg^{-1}) from dung cakes, fuel-wood and crop residue, respectively. Anthracene, fluoranthene, pyrene, benzo[a]anthracene and chrysene are predominant PAHs in all biomass fuels. The emission estimates of PAH over IGP are determined as 2.95 ± 0.98 Gg yr^{-1}, 3.13 ± 1.08 Gg yr^{-1} and 0.66 ± 0.26 Gg yr^{-1} from dung cakes, fuelwood and crop residue, respectively.

1. Introduction

About half of the world's rural population relies on unprocessed biomass fuels (dung cake, fuelwood and crop residues) as the primary source of energy; nearly 2 billion kg of biomass are burnt every day in developing countries (Reddy et al., 1996). In rural India, nearly 94% of primary energy use is accounted for by biomass (fuelwood, 56%; dung, 22%; crop residues, 16%) (TEDDY, 2007). These fuels are inexpensive and readily available as compared to electricity and LPG (Liquefied petroleum gas). In India especially in rural areas, fuelwood, crop residue and dung cake are burnt in traditional domestic stoves (*chulha*) with low combustion efficiency for space heating and food preparation. Biomass combustion is a major source of indoor air pollution and a major public health concern globally (Bhargava et al., 2004; Brauer et al., 1996; Bruce et al., 2000; Smith, 2002) and it is an important source of trace gases and aerosols which affect the atmospheric chemistry and radiation budget of the earth (Andreae and Merlet, 2001). Besides morbidity, indoor air pollution from biomass burning in developing countries is believed to be responsible for an estimated 2.2–2.5 million premature deaths every year (WHO, 1997). India alone registers over 0.6 million premature deaths per year that can be attributed to use of biomass fuel (Smith, 2002).

Polycyclic aromatic hydrocarbons (PAHs) form a particular set of Hydrocarbons, which are semi-volatile compounds containing 2 or more aromatic rings. The sources, formation and profiles of PAHs

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emitted from different biomass burning have received major attention in the past two decades. Several studies have reported high exposure levels of the organic compounds such as PAHs and TSP particularly in poorly ventilated houses (Nguyen et al., 2002; Naumova et al., 2002; Ohura et al., 2004). Low-temperature biomass fuel combustion has the potential to result in higher emissions of PAH than high-temperature industrial sources (Smith, 2002). Every kilogram of wood burnt emits 1 mg of benzo[a]pyrene (Smith and Harrison, 2000). The exposure to PAHs, especially benzo [a]pyrene, can cause immune suppression in both animal and humans (Hall, 1989). Much of the population in the developing Asian countries uses unvented stoves for cooking and heating in poorly designed kitchens. As a result, the air pollution levels in Asian homes often exceed World Health Organization standards for ambient outdoor as well as that for typical indoor levels in developing countries (UNEP, 1991).

The present study has been carried out across the Indo-Gangetic Plains (IGP) of India. The IGP is major source of pollutants over India due to the usage of biomass fuels as energy. Moreover, due to rapid urbanization and industrialization over this region, geographical distribution of pollutants has changed. These pollutants affect the air quality as well as climate of the region. Availability of large amount of fuelwood, crop residues and dung cakes over the IGP due to large forest cover, high agricultural activities with varieties of crop production and larger proportion of cattle in this area has enabled the population to use these various biomass fuels as a source of energy. Consumption pattern and usage of these biomass fuels in IGP have already been published (Saud et al., 2011a). This study is unique and probably the first of its kind as it presents total (gaseous-phase and particulate-phase) PAHs concentration over IGP from burning of biomass fuels used in rural sector of IGP. Similar studies carried out in India have shown that there is an elevated incidence of chronic lung disease, asthma and bronchitis in non-smoking women who cook food by burning biomass in the homemade clay stoves (Bhargava et al., 2004). It also would provide useful information for educational purposes, public awareness and development of database for their emission inventory concerning smoke emissions from domestic combustion in India. This would serve as a tool for air quality management vis-à-vis health aspects.

2. Experimental

2.1. Sampling area and description

The IGP is a great alluvial crescent stretching from the Indus River system in Pakistan to the Punjab Plain (in both Pakistan and India) and the Haryana Plains to the delta of the river Ganga in Bangladesh. Topographically the plain is homogeneous, with only floodplains and other related features of the river erosion and changes in river channels forming important natural features. IGP, India comprises the states of Uttarakhand, Punjab, Haryana, Delhi, Uttar Pradesh (UP) and Bihar. Samples of domestic biomass fuels have been collected at district level in rural areas of Uttarakhand, Punjab, Haryana, Delhi, Uttar Pradesh and Bihar of IGP. The map showing sampling areas is given in Fig. 1. The household biomass fuels have been categorized into three different types: residues of all agricultural biomass as crop residue, all types of wood used as fuelwood and faeces of domestic animals used as dung cakes. Details of sampling methodology and distribution of biomass fuel over this region are discussed in Saud et al. (2011a). After extensive survey based on biomass fuel usage and variety, the samples of different biomass fuels were collected. The consumption pattern of biomass fuel over IGP has been discussed in our previous study (Saud et al., 2011a).

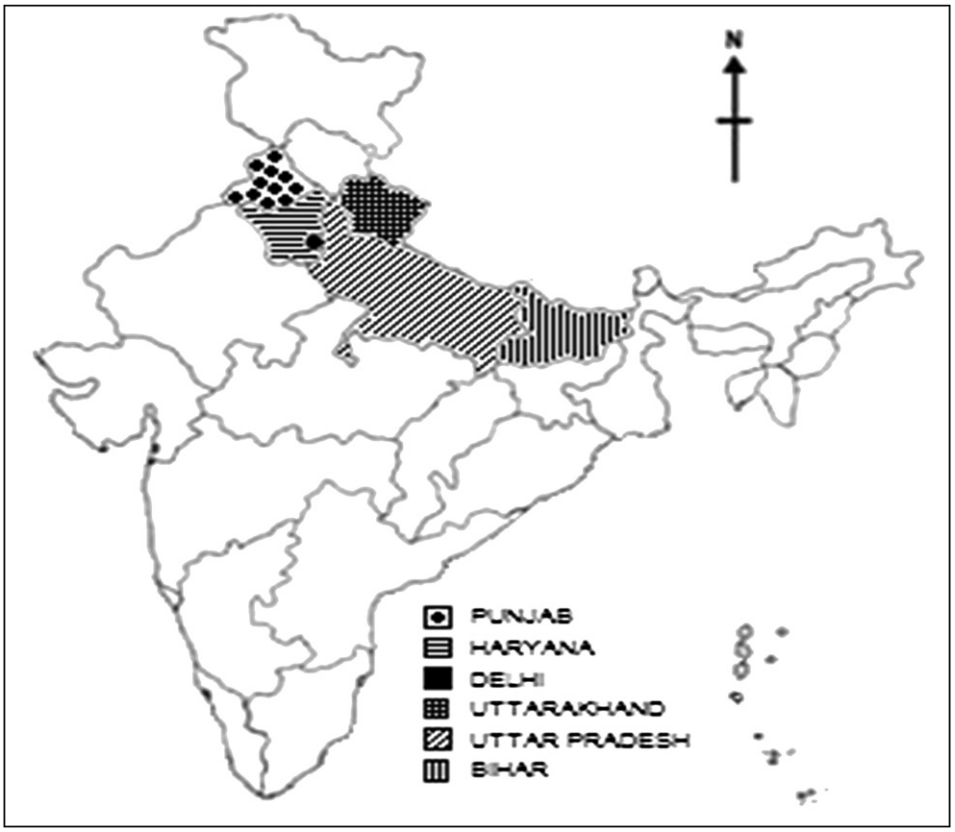

Fig. 1. Sampling locations at Indo-Gangetic Plains of India.