

## Carbonaceous aerosols from biomass burning emissions in Northern India: Chemical characterization and temporal trends

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### Introduction

The impact of biomass burning emissions on atmospheric chemistry and climate has been well recognized in the present-day scenario of rapid increase in the concentration of carbonaceous aerosols. Furthermore, mixing state of carbonaceous aerosols with other chemical species in the atmosphere leads to degradation of regional air-quality. Recent studies from south and south-east Asia have led to diverging views on the sources of carbonaceous aerosols, suggesting dominance of biomass burning emissions vis-à-vis fossil-fuel combustion [1–3]. It is, thus, important to document spatial and temporal variability in the chemical characteristics of carbonaceous aerosols through ground-based measurements from source regions in the Indo-Gangetic Plain (IGP). A large stretch of the IGP in Northern India is influenced by emissions from biomass burning during the wintertime.

### Materials and Methods

PM<sub>2.5</sub> samples were collected (twice a week from October 2008 to May 2009 and from October 2010 to May 2011) from a sampling site (Patiala: 30.2° N, 76.3° E, 250 m asl) using a high-volume sampler. The sampler was operated at a flow rate of ~1.2 m<sup>3</sup>/min for ~12 hours to filter about 1200 m<sup>3</sup> of air through tisuquartz filters (20 x 25 cm<sup>2</sup>). EC and OC were determined on EC-OC analyzer, using a thermal-optical transmittance protocol [3, 4]. PAHs were extracted by accelerated solvent extraction (ASE), followed by matrix purification on a silica cartridge and quantification on GC-MS [4].

### Results and Conclusion

Our comprehensive study on the atmospheric abundances of PM<sub>2.5</sub>, EC, OC, WSOC and PAHs from two distinct post-harvest biomass burning emissions (paddy-residue burning during October–November and wheat-residue burning in April–May) show large temporal and inter-annual variability. This is attributable to the source strength and combustion efficiency of the two biomass burning events in the IGP. Relatively, high mass fraction of OC (Av: 0.33) and low contribution of EC (0.03) in PM<sub>2.5</sub> are associated with the paddy-residue burning (with high moisture content) compared to wheat-residue burning (OC/PM<sub>2.5</sub>: 0.26; EC/PM<sub>2.5</sub>: 0.07). The OC/EC ratio (Av: 10) for paddy-residue burning is about three times higher than that associated with wheat-residue burning emissions. However, the WSOC/OC ratio (range: 0.41–0.91) exhibits similar characteristic for paddy- and wheat-residue burning emissions.

The ΣPAHs/EC ratio of 4.2 mg g<sup>-1</sup> is significantly higher from paddy-residue burning than that from wheat-residue (1.2 mg g<sup>-1</sup>). The particulate concentrations of 5- and 6-ring isomers (normalized to EC) from paddy-residue burning are also about 3–6 times higher. The cross plot of PAHs isomer ratios show distinct dominance of agricultural-waste burning emissions in Northern India [4]. This study brings to focus temporal trends in the dominance of carbonaceous aerosols from biomass burning emissions during the two post-harvest seasons and have implications to atmospheric radiative forcing on a regional scale.

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## Substrates for anaerobic microbial activity in oil sands tailings ponds

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Alberta, Canada, is home to vast fossil energy reserves in the form of heavy oil or bitumen. Surface mining of the oil sands to recover bitumen using a caustic hot water extraction process generates a large volume of solid and liquid waste that is deposited in large storage areas or tailings ponds. The ponds are managed to promote solids densification so that surface water can be recycled. Surface water contains aerobic microbial communities, while the remaining tailings material at depth harbors anaerobic microorganisms. Such microbial communities can potentially affect gas emissions (H<sub>2</sub>S and CH<sub>4</sub>), solids densification, and the biodegradation of oil-associated compounds in the tailings such as bitumen, naphtha (a low molecular weight mixed hydrocarbon diluent), and naphthenic acids (NA). We previously measured sulfate reduction and methanogenesis rates with depth in tailings ponds and found that these activities are ongoing at discrete intervals [1]. Microbial community analysis showed that sulfate reducers and methanogens were abundant along with other anaerobes like nitrate and iron reducers [1]. However, the carbon sources driving such indigenous tailings pond communities remained unknown.

Thus, to determine the key substrates driving anaerobic microbial processes in tailings ponds, we established enrichments under a variety of anaerobic conditions using anaerobic tailings as inoculum. The incubations were amended with either bitumen, naphtha, or NA as potential carbon sources. Concentrations of nitrate, sulfate, Fe(II) and methane were determined over time in the substrate-amended incubations relative to substrate-free controls as indicators of anaerobic microbial activity. In some cases, substrate concentrations were also determined by liquid or gas chromatography.

In laboratory incubations, bitumen did not serve as a carbon source for anaerobic communities. However, naphtha and NA did drive several anaerobic activities. Incubations established under methanogenic conditions with naphtha showed enhanced levels of methane relative to substrate-free controls, and that this activity was ongoing after transfers of the enrichment. Several naphtha components disappeared over time in the naphtha-amended cultures relative to controls. Naphtha components such as low molecular weight alkanes have been shown to drive methanogenesis in samples collected from other tailings ponds [2], thus naphtha is an important carbon source in diverse tailings ponds. Incubations amended with commercially available model NA showed enhanced levels of nitrate reduction, Fe(III) reduction, and methanogenesis relative to substrate-free controls. Natural NA (extracted from tailings pond water) also stimulated Fe(III) reduction and methanogenesis in laboratory incubations. Little is known about the anaerobic transformation of NA in tailings ponds, but our data suggests that in addition to naphtha, NA may also be an important carbon source for the indigenous anaerobic communities.

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