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Biomass burning is a major source of particulate matter in Indian cities

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ABSTRACT

Biomass burning is found to be reported as major source of particulate matter in several places in India, which includes surprisingly both small and mega cities. This study, which is based on the recent reports, suggest that about half of the atmospheric aerosol loading in several places in India is due to incomplete combustion of fuel, which includes domestic cooking (biomass/bio-fuel), open burning practices (of garbage, garden-waste/tree leaves, agriculture-waste, etc.), burning of biomass in brick clinkers (especially in small scale), biomass and waste burnings for heating purposes especially in winter season, etc. These biomass burnings are largely responsible for particulate bound organics (many toxicants in air, such as polycyclic aromatic hydrocarbons (PAHs), nitro-organics, organic acids, alcohols, ketones, etc.) and bulk water-soluble organic carbon (WSOC), organic carbon (OC), elemental carbon (EC) and inorganic ions. More studies especially long-term are needed to better know the sources of bulk biomass burning types in different places/cites in India A policy/regulation should be in place to control such biomass burning practices in India.

Keywords: Biomass burning, Source of Particulate matter.

INTRODUCTION

Aerosols are tiny particles suspended in air. Depending on size, chemical composition and concentration, aerosols affect the health, climate and ecology in a complex manner (IPCC, 2007). Aerosols have both anthropogenic and natural sources. Anthropogenic sources include emissions from traffic, industries, construction work, land-use pattern and combustion sources (biomass, bio-fuel, waste, etc.), whereas sea-bubble bursting, volcano emission and dust events are the major natural sources of aerosol particles. Apart from the direct emissions, there are secondary aerosols, which form by condensation, coagulation and photochemical reactions which are also influenced by natural and anthropogenic sources. Contribution of anthropogenic sources has increased manifolds since pre-industrial era. Sources in urban areas are so much intermingled that it has become extremely difficult to identify and estimate the key sources. To better understand the effect of aerosols on the health, climate and ecology, the chemical and physical properties of aerosols, their sources need to be known with great precision. However, to estimate the chemical composition is a challenging task, and needs state of art instrumentation and very skilled and experienced human resource. The chemical characterization data may be used as source signatures and can be implemented as a useful tool for modelling studies. Such studies are needed for making control policies and regulations.

In this work, we have categorized the particulate sources in small and mega cities and found that about half of the aerosol loading in these places is because of biomass burning practices. However, data are not available to quantify the biomass source types, such as domestic cooking, biomass/bio-fuel, open burning practices of garbage, garden-waste/tree leaves, agriculture-waste, burning of biomass in brick clinkers (especially in small scale), biomass and waste burnings for heating purposes especially in winter season, etc. Study on the focus on the source apportionment of combustion sources, especially biomass burning sources should be given more attention for making better policies and assessment of the health effects.

MATERIALS AND METHODS

In this work a review has been done on the recent report on aerosols' chemical characterization, which were collected in several megacities and small cities of India. In the reports, authors have apportioned the sources of particulate matter based on source marker.

RESULTS AND DISCUSSION

Number of reports on Delhi aerosols has increased significantly in recent years especially within last five years. Myazaki et al., [1] analyzed aerosol samples collected in Delhi for bulk as well as molecular level composition. Total suspended particulate matter was studied for low molecular weight dicarboxylic acids and related compounds, as well as total water-soluble organic carbon (TWSOC). High concentrations of diacids (up to 6.03 mg m^3), TWSOC, and OC were obtained, which are substantially higher than those previously observed at other urban sites in Asia. Daytime TWSOC/OC ratio (37%) was on average higher than that in nighttime (25%). In particular, more water-soluble OC (M-WSOC) to TWSOC ratio in daytime (50%) was twice higher than in nighttime (27%), suggesting that aerosols in New Delhi are photochemically more processed in daytime to result inmorewater-soluble organic compounds. Oxalic acid (C2) was found as the most abundant dicarboxylic acid, followed by succinic (C4) and malonic (C3) acids. Contributions of C2 to M-WSOC were greater (av. 8%) in nighttime than daytime (av. 3%). Positive correlations of C2 with malic acid (hC4), glyoxylic acid (wC2), and relative humidity suggest that secondary production of C2 probably in aqueous phase is important in nighttime via the oxidation of both longer-chain diacids and wC2. C2 also showed a positive correlation with potassium (K^+) in nighttime, suggesting that the enhanced C2 concentrations are associated with biomass/biofuel burning. More tight, positive correlation between less water-soluble OC (L-WSOC) and K^+ was found in both day- and nighttime, suggesting that L-WSOC, characterized by longer chain and/or higher molecular weight compounds, is significantly influenced by primary emissions from biomass/biofuel burning.

Kirillova et al., [2] reported that water-soluble organic carbon (WSOC) is a major constituent (~ 20–80%) of the total organic carbon aerosol over the Indian subcontinent during the dry winter season. Due to its multiple primary and secondary formation pathways, the sources of WSOC are poorly characterized. They present radiocarbon constraints on the biomass versus fossil sources of WSOC in $PM_{2.5}$ for the 2010/2011 winter period for the megacity Delhi, situated in the northern part of the heavily polluted Indo-Gangetic Plain. The fossil fuel contribution to Delhi WSOC (21 ± 4%) is similar to that recently found at two South Asian background sites. In contrast, the stable carbon isotopic composition of Delhi WSOC is less enriched in ^{13}C relative to that at the two receptor sites. Although potentially influenced also by source variability, this indicates that near-source WSOC is less affected by atmospheric aging. In addition, the light absorptive properties of Delhi WSOC were studied. The mass absorption cross section at 365 nm (MAC_{365}) was 1.1–2.7 m^2/g with an Absorption Ångström Exponent ranging between 3.1 and 9.3. Using a simplistic model the relative absorptive forcing of the WSOC compared to elemental carbon in 2010/2011 wintertime Delhi was estimated to range between 3 and 11%. Taken together, this near-source study shows that WSOC in urban Delhi comes mainly (79%) from biomass burning/biogenic sources. Furthermore, it is less influenced by photochemical aging compared to WSOC at South Asian regional receptor sites and contributes with a relatively small direct absorptive forcing effect.

Aggarwal et al. [3] reported sources of the Mumbai aerosols. In their study, to better understand the sources of PM10 samples in Mumbai, India, aerosol chemical composition, i.e., total carbon (TC), organic carbon (OC), elemental carbon (EC), water-soluble organic carbon (WSOC), and inorganic ions were studied together with specific markers such as methanesulfonate (MSA), oxalic acid (C2), azelaic acid (C9), and levoglucosan. The results revealed that biofuel/biomass burning and fossil fuel combustion are the major sources of the Mumbai aerosols. Nitrogen-isotopic (δ15N) composition of aerosol total nitrogen, which ranged from 18.1 to 25.4 ‰, also suggests that biofuel/biomass burning is a predominate source in both the summer and winter seasons. Aerosol mass concentrations of major species increased 3–4 times in winter compared to summer, indicating enhanced emission from these sources in the winter season. Photochemical production tracers, C2 diacid and SO_4^{2-}, do not show diurnal changes. Concentrations of C2 diacid and WSOC show a strong correlation (r2 = 0.95). In addition, WSOC to OC (or TC) ratios remain almost constant for daytime (0.37 ± 0.06 (0.28 ± 0.04)) and nighttime (0.38 ± 0.07 (0.28 ± 0.06)), suggesting that mixing of fresh secondary organic aerosols is not significant and the Mumbai aerosols are photochemically well processed. Concentrations of MSA and C9 diacid present a positive correlation (r2 = 0.75), indicating a marine influence on Mumbai aerosols in addition to local/regional influence. Backward air mass trajectory analyses further suggested that the Mumbai aerosols are largely influenced by long-range continental and regional transport. Stable C-isotopic ratios (δ13C) of TC ranged from −27.0 to −25.4 ‰, with slightly lower average (−26.5 ± 0.3 ‰) in summer than in winter (−25.9 ± 0.3 ‰). Positive correlation between WSOC / TC ratios and δ13C values suggested that the relative increment in 13C of wintertime TC may be caused by prolonged photochemical processing of organic aerosols in this season. The study suggested that in winter, the tropical aerosols are more aged due to longer residence time in the atmosphere than in summer aerosols.

In a study carried out by Hegde et.al., [4] aerosol samples were collected from a high elevation mountain site (Nainital, India; 1958m a.s.l.) in the central Himalayas, a location that provides an isolated platform above the planetary boundary layer to better understand the composition of the remote continental troposphere. The samples were analyzed for water-soluble dicarboxylic acids (C2-C12) and related compounds (ketocarboxylic acids and α-dicarbonyls), as well as organic carbon, elemental carbon and water soluble organic carbon. The contributions of total dicarboxylic acids to total aerosol carbon during wintertime were 1.7% and 1.8 %, for day and night, respectively whereas they were significantly smaller during summer. Molecular distributions of diacids revealed that oxalic (C2) acid was the most abundant species followed by succinic (C4) and malonic (C3) acids. The average concentrations of total diacids (433±108 ngm^{-3}), ketoacids (48±23 ngm^{-3}), and α-dicarbonyls (9±4 ngm^{-3}) were similar to those from large Asian cities such as Tokyo, Beijing and Hong Kong. During summer most of the organic species were several times more abundant than in winter. Phthalic acid, which originates from oxidation of polycyclic aromatic hydrocarbons such as naphthalene, was found to be 7 times higher in summer than winter. This feature has not been reported before in atmospheric aerosols. Based on molecular distributions and air mass backward trajectories, they have concluded that dicarboxylic acids and related compounds in Himalayan aerosols are derived from anthropogenic activities (largely biomass burning practices) in the highly populated Indo-Gangetic plain areas.

On the other hand, Pavuluri et al.[5] studied coastal aerosols**.** To better characterize the tropical aerosols in Indian region, PM10 samples collected from Chennai, India (13.04º N; 80.17 º E) were analyzed for carbonaceous and water-soluble ionic components. Concentration ranges of elemental carbon (EC) and organic carbon (OC) were 2.4–14 $\mu g\ m^{-3}$ (ave. 6.5 $\mu g\ m^{-3}$) and 3.2–15.6 $\mu g\ m^{-3}$ (ave. 9.1 $\mu g\ m^{-3}$) in winter samples whereas they were 1.1–2.5 μgm^{-3} (ave. 1.6 μgm^{-3}) and 4.1–17.6 μgm^{-3} (ave. 9.7 $\mu g\ m^{-3}$) in summer samples, respectively. Concentration of secondary organic carbon (SOC) retrieved from EC-tracer method was 4.6±2.8 µg m^{-3} in winter and 4.3±2.8 µg m^{-3} in summer. OC accounted for 38.5±14% (n = 49) of combined concentrations of carbonaceous and ionic components in PM10. We also found that OC concentrations are generally higher than those of SO_4^{2-} (8.8±2.5 µgm^{-3} and 4.1±2.7 µg m^{-3} in winter and summer, respectively), which was the most abundant ionic species (57 %) followed by NH_4^+ (15 %)>NO_3^- >Cl^->K^+>Na^+>Ca^{2+}>MSA^->Mg^{2+}. The mass fractions of EC, organic matter (OM) and ionic species varied seasonally, following the air mass trajectories and corresponding source strength. Based on mass concentration ratios of selected components and relations of EC and OC to marker species, we found that biofuel/biomass burning is a major source of atmospheric aerosols in South and Southeast Asia. The high concentrations of SOC and WSOC/OC ratios (average 0.45; n=49) as well as good correlations between SOC and WSOC suggest that the secondary production of organic aerosols during long-range atmospheric transport is also significant in this region. This study provides the baseline data of carbonaceous aerosols for southern part of the Indian subcontinent.

APPLICATIONS

The results provide the baseline data of carbonaceous aerosols for southern part of the Indian subcontinent and suggests that biomass burning is a major source of aerosol loading in several megacities and small/remote sites of India.

CONCLUSIONS

This study suggests that biomass burning is a major source of aerosol loading in several megacities and small/remote sites of India. Literature survey suggest that these biomass burning sources could be included domestic cooking (biomass/bio-fuel), open burning practices (of garbage, garden-waste/tree leaves, agriculture-waste, etc.), burning of biomass in brick clinkers (especially in small scale), biomass and waste burnings for heating purposes especially in winter season, etc. These biomass burnings are largely responsible for particulate bound bulk water-soluble organic carbon (WSOC), organic carbon (OC), elemental carbon (EC) and inorganic ions and many organics/metals at molecular level. However more studies especially long-term are needed to better know the sources of bulk biomass burning types in different places/cites in India. A policy/regulation should be in place to control such biomass burning practices in India.

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