Diurnal and Seasonal Characteristics of Aerosol Ionic Constituents over an Urban Location in Western India: Secondary Aerosol Formation and Meteorological Influence

A.K. Sudheer*, Ramabadran Rengarajan, Dipjyoti Deka, Ravi Bhushan, Sunil Kumar Singh, Mohammed Yusuff Aslam†

Geosciences Division, Physical Research Laboratory, Ahmedabad, 380 009, India

ABSTRACT

Water-soluble ionic constituents (Cl\(^-\), NO\(_3\)\(^-\), SO\(_4\)\(^2-\), Na\(^+\), NH\(_4\)\(^+\), K\(^+\), Mg\(^{2+}\) and Ca\(^{2+}\)) of PM\(_{2.5}\) were measured using Ambient Ion Monitor coupled-to Ion Chromatography (AIM-IC) with a time resolution of one hour at Ahmedabad (an urban location in a semi-arid region of western India) during summer and winter to study the diurnal and seasonal variations. Maximum abundances of most of the species were observed during afternoon hours in summer, whereas minimum concentrations were found during winter at the same local time. During summer, the concentration levels of most of the constituents in a diurnal cycle are largely influenced by variations in the ambient relative humidity. During winter, the emission strength and boundary layer dynamics impact the diurnal cycle. Secondary inorganic species like NH\(_4\)\(^+\), NO\(_3\)\(^-\) and SO\(_4\)\(^2-\) exhibit significant differences in their relative abundances during winter and summer. Four factors have been derived by Positive Matrix Factorization (PMF) analysis of the water-soluble ionic constituents. These are secondary, sea-salt, mineral dust sources, while the fourth factor is associated with K\(^+\), which is likely to be due to emissions related to biomass burning.

Keywords: Aerosol chemistry; PM\(_{2.5}\); Secondary aerosol; GEOTRACES.

INTRODUCTION

One of the major uncertainties in quantitative assessment of climate change is the influence of atmospheric aerosol on global climate by direct and indirect effects (IPCC, 2007). Aerosol, mainly fine aerosol (PM\(_{2.5}\), particles < 2.5 µm aerodynamic diameter) are also responsible for reduction in visibility and have adverse health effects (Nel, 2005). Fine particles are formed from a variety of natural and anthropogenic sources and can be primary or secondary in nature. In urban areas, large fraction of fine particulate is water-soluble, where in inorganic ionic constituents comprise a major portion. Inorganic constituents are generally responsible for the hygroscopic nature of aerosol and influences CCN activation, thereby having profound impact on hydrological cycle on a regional scale. Major water-soluble ionic species such as SO\(_4\)\(^2-\), NO\(_3\)\(^-\) and NH\(_4\)\(^+\) are secondary in nature, produced from precursor gases, viz., SO\(_2\), NO\(_x\) and NH\(_3\). Formation of secondary aerosol, both organic and inorganic, has been recognized as a major factor for air pollution over mega-cities (Guo et al., 2010; Zhang et al., 2010).

Several studies addressing the chemical composition of atmospheric particulate matter over Indian sub-continent, a potential hot-spot region in terms of aerosol and pollutant emission, have been reported (Ram et al., 2008; Kulshrestha et al., 2009; Rengarajan et al., 2011; Ram et al., 2012). This region is characterized by high loading of both natural and anthropogenic aerosol during different seasons. In addition, this region is a potential source for variety of constituents transported to surrounding remote oceanic regions under favourable meteorological conditions (Kumar et al., 2008; Cherian et al., 2010; Kumar et al., 2012), which have significant impact on surface ocean biogeochemistry. Northwestern arid and semi-arid regions of India are known for high amount of mineral aerosol, especially during summer (Kumar and Sarin, 2009). During summer monsoon (June–September), most of the continental region is influenced by sea-salt aerosol transported by trade winds. During winter (December–January), anthropogenic emission from various sources is enhanced and surface meteorological condition is conducive for entrainment of pollutants in a shallow