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Research Paper

Pattern of aerosol mass loading and chemical composition over the atmospheric environment of an urban coastal station

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ABSTRACT

Aerosol sampling was carried out at four locations in and around Cochin (9°58′ N, 76°17′ E), an urban area, located on the southwest coast of India. The gravimetric estimates of aerosol mass loading showed wide range from 78 $\mu g\, m^{-3}$ to $>450\ \mu g\, m^{-3}$, occasionally reaching values $>500\ \mu g\, m^{-3}$, associated with regional source characteristics. Most of the values were above the air quality standard. Both boundary layer and synoptic scale airflow pattern play role in the temporal features in aerosol mass loading and chemical composition. Chemical analysis of the aerosol samples were done for anionic species viz; F^-, Cl^-, Br^-, NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-} and metallic/cationic species viz; Na, Ca, K, Mg, NH_4^+, Fe, Al, Cu, Mg, Pb, etc using Ion Chromatography, Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma- Atomic Emission Spectroscopy (ICP-AES). At all the locations, extremely high mass concentration of SO_4^{2-} was observed with the mean value of $13 \pm 6.4\ \mu g\, m^{-3}$ indicating the strong anthropogenic influence. Statistical analysis of the chemical composition data was carried out and the principal factors presented. Seasonal variation of these chemical species along with their percentage contributions and regional variations were also examined. Increase in level of Na in aerosol samples indicated the influence of monsoonal activity. Most of the species showed mass concentrations well above those measured over another coastal site Thiruvananthapuram (8°29′ N, 76°57′ E) situated ~220 km south of Cochin revealing the highly localized aerosol features.

1. Introduction

The suspended particulate matter in the atmosphere also called atmospheric aerosols, exert highly uncertain radiative forcing impacts on climate (Forster et al., 2007) and are detrimental to human health (Pope et al., 2002). Atmospheric aerosols also have serious adverse impacts on air quality and visibility (Molina and Molina, 2004). In recent years, air pollution has become a major environmental concern in densely populated urban areas (Andreae, 2007; Chin et al., 2007; Zhang et al., 2012) due to large emissions of air pollutants from anthropogenic activities, like traffic, industry, and power plants. The direct and indirect influence of atmospheric aerosols on the radiation budget of earth-atmosphere system and their role in environmental/pollution-related problems are well recognized (Charlson et al., 1992; Hansen et al., 1988; Tiwari et al., 2011). These problems are further complicated by the prevailing meteorology.

Atmospheric aerosols originate from a wide variety of natural and anthropogenic sources (Prospero et al., 1983). In the atmosphere, aerosols undergo various physical and chemical interactions and transformations. Oceans are the single largest sources of natural aerosols. Through the mechanism of bubble bursting at the surface of the ocean, large amounts of sea-salt particles are injected into the atmosphere (Exton et al., 1985; Fairall et al., 1983; Norris et al., 2013). Another important source contributing to the aerosol loading over oceans is the marine biogenic activity (Charlson et al., 1987). Oxidation of dimethyl-sulfide (DMS) emitted by marine phytoplankton is a major source of non-sea salt aerosols over remote oceanic areas (Kettle et al., 1999; Savoie et al., 1989). Aerosols produced at one station can even reach far-off regions owing to prevailing transport mechanisms (Arimoto et al., 1996; Ayers et al., 1991; Carmichael et al., 1997; Heintzenberg et al., 2000; Krishnamurti et al., 1998; Prospero and Savoie, 1989; Swap et al., 1996). A considerable amount of crustal and other continental aerosols also get transported to the marine environments (Arimoto et al., 1996; Kulshrestha et al., 2001; Marconi et al., 2014; Nair et al., 2004, 2014; Savoie et al., 2002; Swap et al.,

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1996). Presence of oceanic aerosols is seen over the continental regions also (Kapoor and Paul, 1980). In order to assess the effect of these transported anthropogenic/continental aerosols regular/periodic observations on regional scales are essential.

Most of the earlier studies have been conducted over mid-latitudes and/or oceanic environments (Bates et al., 1998; Krishnamurti et al., 1998; Moorthy et al., 2009; Nair et al., 2014, 2004; Raes et al., 2000; Ramanathan et al., 2001; Sarin et al., 1999). However, few studies have been reported from tropical continental sites including Indian region (George et al., 2011, 2008; Kulshrestha et al., 2001; Nair et al., 2006; Rastogi and Sarin, 2005) where spatial in-homogeneities are more pronounced. For a complete characterization of the aerosol system over a region, information on their sources as well as the source strength is essential. While the topography decides the major natural aerosols originating over a region, the anthropogenic contribution is decided by industries/human activities. Long range transport of aerosols caused by the prevailing circulation systems makes the situation even more complex. Knowledge on the chemical composition of aerosols is crucial in identifying the various sources, understanding the role of long-range transport over a region and assessing the health impacts (Carmichael et al., 1997; George et al., 2008; Prospero et al., 1983; Ramanathan et al., 2001; Siefert et al., 1999; Yoon et al., 2007).

The present study focused on the measurement of mass loading and chemical composition of atmospheric aerosols over an industrialized tropical coastal location Cochin, by carrying out in situ sampling and subsequent chemical analysis of the samples. Representative samples collected from few selected near-by locations were also analyzed to bring out the regional heterogeneity. The spatial and temporal variations of the mass loading were investigated. The results on the spatial pattern of water-soluble components and acid-soluble metallic species in atmospheric aerosols are also presented here. This first time study from Cochin, will also contribute to the database on aerosol characteristics over this region. From the results, the seasonal changes in the chemical composition of aerosols over this tropical coastal environment and source characteristics could be understood fairly well.

2. Study region and meteorology

Cochin (9°58′ N, 76°17′ E), located on the southwest coast of India, is a developing urban industrial center. It is a city of about 0.6 million people with 0.2 million within metropolitan area (census 2011). Apart from this, there is a major contribution of floating population. The area is warm and humid, with two monsoon periods annually namely the South-West (SW) monsoon spanning from June to September and the North-East (NE) monsoon from October to November. Total precipitation is about 3000 mm annually, about two third of that from south west monsoon. The average elevation of the city is about 1.5 m, crisscrossed by water bodies called the backwaters. This city is fast developing with increased industrial activities, road traffic and other human activities which lead to degradation of the environment. The major industries of the city comprise an oil refinery and a fertilizer plant located northeast and southeast of Cochin. The city also has several medium and small scale industries. The changes in community behavior, which affects the living environment, must be continuously monitored by measurement on air quality parameters. A reliable and assessable data of pollution status would enable the society to participate in actively reducing urban pollution peak loads and to modify their contributing activities, taking control measures. The shoreline of Cochin is inclined to longitude by about 20° with Arabian Sea on western side and the land on eastern side. This city is well known for its sea port.

Aerosol sampling was carried out at four different close by stations which include coastal and commercial, commercial and sensitive, rural, and mixed category areas. The main study location is a coastal town situated on the coast of Arabian Sea close to Cochin sea port and is right in the middle of commercial activities. This is referred as station 1(coastal town). At station 1, the sources of aerosols are expected to be both from commercial activity and natural sources. Commercial activity is dominated by vehicular traffic and seaport activities. The natural sources of aerosols include sea salt produced from sea spray/white caps through the mechanisms of bubble bursting/jet drops at the sea surface. Large quantities of sea salt aerosols are injected into the air by these processes. Fossil fuel combustion and dust from traffic will be another major contributor of aerosols at this station. For comparison purpose three other stations were also selected. The rural site referred to as station 2 is an inland location ~12 km from station1, with complex terrain and lateritic soil. Even though station 2 is an inland area, it is surrounded by industries ~5 km away. In addition to this, few samples were collected from stations situated within the commercial zone, which are also sensitive areas due to presence of hospitals. They include one within the city and close to a traffic junction referred as station 3 and the other from a highly polluted commercial area, referred as station 4 (Polluted/commercial). Station 3 and 4 are ~1 km and ~9 km from station 1. This site was selected based on the health data collected from public health centers where more number of Acute Respiratory Infection (ARI) cases is reported (Bindu and Kurian, 2014). Fig. 1 shows the study area of Cochin with the sampling stations marked.

Meteorological parameters play a vital role in the dispersion of pollutant gases as well as aerosols in the lower atmosphere. Many of the air quality indicators are raised from the weather conditions prevailing at the area. Wind speed and direction, temperature, mixing height and atmospheric stability are the parameters to be considered in studying the dispersion of pollutants. With a view to understand the effect of synoptic meteorological conditions on the temporal features of aerosol characteristics, the data on temperature, humidity, cloud amount, rainfall and wind speed over Cochin were collected from India Meteorological Department (IMD) for the two years from 2010–2011, the period covering the study period.

2.1. Temperature

Fig. 2a and b shows the monthly mean maximum and minimum temperatures respectively for the two years 2010 and 2011. Seasonal variation is prominent in the case of maximum temperature. The maximum temperature shows peak values during February–April months reaching minimum during south west monsoon months of June–August. During this period, the maximum temperature ranged between 29.4 °C and 35.7 °C and the highest value of 35.7 °C was observed during the month of March in 2010. The minimum temperature reaches peak during March–May and attains minimum during winter months of December to February. But the seasonal variation of minimum temperature is not as prominent as that of maximum temperature. The range of minimum temperature during the two year period is 25.04–20.4 °C with the lowest value of 20.4 °C is observed during February 2011. Year to year variation is not significant.

2.2. Relative humidity (RH)

Fig. 2c shows the variation of monthly mean RH during the period. At this station, monthly mean RH values lie in the range 66–90%. Generally, RH peaks during monsoon months and attains minimum during winter. During 2010, RH shows slightly higher values. The highest value of 90% is seen in the month of June in