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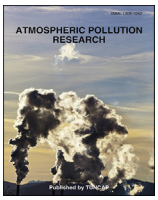

Original Article

Micro-structural analysis of individual aerosol coarse particles during different seasons at an eastern coastal site in India

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ABSTRACT

Micro-structural analysis of PM samples collected during various seasons (from July-2012 to August-2013) were carried out by Field Emission Scanning electron microscopy (FESEM), Transmission Electron Microscope (TEM) coupled with Energy Dispersive X-Ray Analysis (EDX) and Selected area electron diffraction (SAED) image for in-depth analysis of their morphology, elemental composition and crystal pattern. Significant variation was observed in the particle size and surface morphology during the different seasons of a year. Four different types of particles were commonly observed among which the carbonaceous particles, mainly the soot aggregates were found to be the most abundant species in the PM samples. Few biogenic particles were observed, mostly during post-monsoon period, with distinct microstructure in comparison to other particles. Micro-structural analysis also gives an indication about their post-production history e.g., the age of aerosol particles, turbulence of the air, agglomeration etc. that influences aerosol microstructure. Most of the elements including transition metals were observed to be present in the form of metal oxides from their EDX pattern. Key source of the aerosol particles were from crustal, industrial, biological, and marine or sometimes from long range transport.

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1. Introduction

Atmospheric Particulate Matter (PM) mass concentration depends on a series of anthropogenic as well as natural processes like vehicular emission, industrial and agricultural activities, volcanic eruption, soil dust, sea salt, gas-to-particle formation etc (Pant and Harrison, 2013; Westerdahl et al., 2005). and contribute to the ambient air as primary or as secondary pollutant. In 1987, the U.S. Environmental Protection Agency (USEPA) included the particulate matter having aerodynamic diameter 10 μm (PM_{10}) as one of the five criterions air pollutants and for the first time publicized National Ambient Air Quality Standards (NAAQS) for PM_{10}. These particles have been reported to impair the human population by causing various respiratory and pulmonary diseases including lung cancer, asthma, cardiovascular disorder etc. (Pascal et al., 2014; Strak et al., 2012; Murr and Garza, 2009; Goo and Kim, 2003). Atmospheric PM also have a great influence on meteorology by acting as Cloud Condensation Nuclei (CCN) (Ram et al., 2014; Posfai et al., 2013) and play a crucial role in earth's radiation balance by absorbing or scattering the incoming solar radiation. Moreover, the aerosol particles catalyze various atmospheric chemical reactions through their surface morphology (Vione et al., 2006). Pertaining to their origin from various sources, PM show a discrepancy in their size; surface properties and chemical compositions which further affects the related atmospheric phenomenon. Physical properties of PM also vary greatly with the local meteorological conditions like temperature, rainfall, wind speed and relative humidity (RH) etc. (Tiwari et al., 2014). Study of surface properties also provides an overall idea regarding the age of the particles. Thus in the current scenario, it is important to understand the morphology and size distribution of atmospheric PM through micro-structural analysis of individual particles.

There is a plethora of information on the characteristics of atmospheric PM over the Indian sub-continent, however, recent publications focus mainly on chemical composition and mass balance studies (Safai et al., 2010; Das et al., 2010, 2011; Ram and Sarin, 2011; Pandey and Venkataraman, 2014; Misra et al., 2014). Besides,

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information regarding morphological properties of the individual atmospheric PM, over this region is rare (Agarwal et al., 2011; Pachauri et al., 2013a, 2013b; Pipal et al., 2014; Pipal and Satsangi, 2015). Single-particle analysis would provide in-depth information about various physical and chemical features of the particles, crucial for health risk assessment and would also act as fundamental substantiation for policy makers. Investigating the presence of particular elements in a particle, through analytical techniques like EDX, gives an overview of the particle type. Further the surface morphology of individual particles also gives an impression about their post-production history i.e. whether these particles arise from local anthropogenic origin or are carried through long distance transport. A seasonal analysis of the particle morphology would also provide vital information about the effect of meteorology e.g. temperature, wind speed, rainfall, humidity on the physical and chemical properties of the particles. Considering the graveness of situation with regard to PM pollution and dearth of information on microstructural analysis of the individual PM over the Indian sub-continent, an attempt has been made to study the morphological and elemental composition of the individual as well as aggregate airborne PM. The resulting information through micro-analytical techniques like Field Emission Scanning Electron Microscope (FESEM) followed by Transmission Electron Microscope (TEM) coupled with Energy Dispersive X-ray spectrometer (EDX) has been used to understand the nature of the particles as well as to trace their sources. Selected Area Electron Diffraction (SAED) pattern has also been studied to comprehend the crystal structure and crystalinity of the collected samples.

2. Experimental

2.1. Description of sampling site

The sampling site (Fig. 1) is on the roof (at a height of 10 m from ground level) of CSIR-Institute of Mineral and Material Technology in Bhubaneswar (21°15′ N, 85°15′ E) which is the capital of Odisha state. It is situated at an altitude of 45 m a.s.l. and is considered to be one of the fastest growing cities in the eastern part of the country. The average temperatures of the city ranges between a minimum of around 10 °C during winter to a maximum of 40–45 °C during summer. The city has a population of 1.2 million and the nearest major city is Kolkata, ~440 km away towards north. The sampling equipment is placed around 200 m away from National Highway (NH-5) dominated by vehicular emissions and is surrounded by small townships (approximately within 100 km) where various coal based thermal power plant, mining and fertilizer based

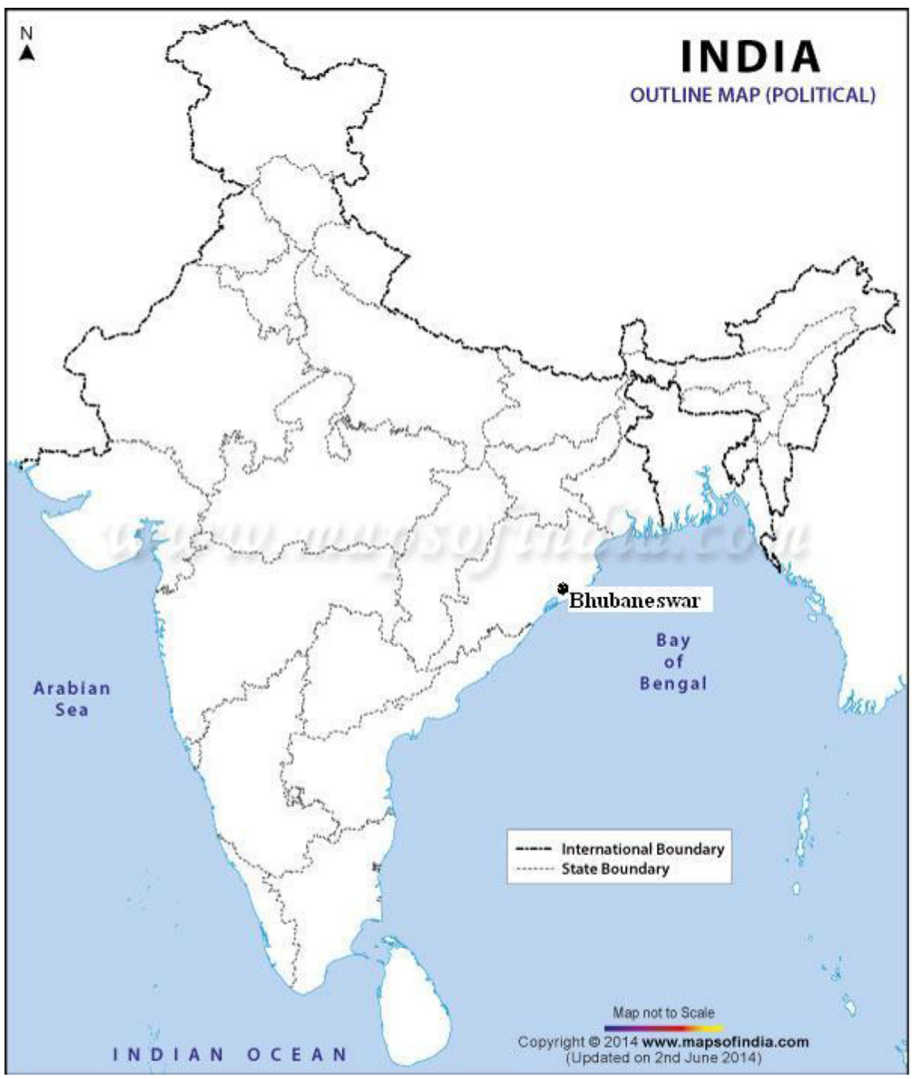

Fig. 1. India map showing the sampling site.

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