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Chemical characterization of PM_{10} and $PM_{2.5}$ mass concentrations emitted by heterogeneous traffic

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ABSTRACT

In this paper, the chemical characterization of PM_{10} and $PM_{2.5}$ mass concentrations emitted by heterogeneous traffic in Chennai city during monsoon, winter and summer seasons were analysed. The 24-h averages of PM_{10} and $PM_{2.5}$ mass concentrations, showed higher concentrations during the winter season ($PM_{10}=98\ \mu g/m^3$; $PM_{2.5}=74\ \mu g/m^3$) followed by the monsoon ($PM_{10}=87\ \mu g/m^3$; $PM_{2.5}=56\ \mu g/m^3$) and summer ($PM_{10}=77\ \mu g/m^3$; $PM_{2.5}=67\ \mu g/m^3$) seasons. The assessment of 24-h average PM_{10} and $PM_{2.5}$ concentrations was indicated as violation of the world health organization (WHO standard for $PM_{10}=50\ \mu g/m^3$ and $PM_{2.5}=25\ \mu g/m^3$) and Indian national ambient air quality standards (NAAQS for $PM_{10}=100\ \mu g/m^3$ and $PM_{2.5}=60\ \mu g/m^3$).

The chemicals characterization of PM_{10} and $PM_{2.5}$ samples (22 samples) for each season were made for water soluble ions using Ion Chromatography (IC) and trace metals by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) instrument. Results showed the dominance of crustal elements (Ca, Mg, Al, Fe and K), followed by marine aerosols (Na and K) and trace elements (Zn, Ba, Be, Ca, Cd, Co, Cr, Cu, Mn, Ni, Pb, Se, Sr and Te) emitted from road traffic in both PM_{10} and $PM_{2.5}$ mass. The ionic species concentration in PM_{10} and $PM_{2.5}$ mass consists of 47–65% of anions and 35–53% of cations with dominance of SO_4^{2-} ions. Comparison of the metallic and ionic species in PM_{10} and $PM_{2.5}$ mass indicated the contributions from sea and crustal soil emissions to the coarse particles and traffic emissions to fine particles.

1. Introduction

Particulate matter (PM) is a complex mixture of small and large particles of varying origin and chemical compositions. Exposure to high level ambient PM concentration has been associated with serious health problems (HEI, 2004; WHO, 2004; Pope and Dockery, 2006). PM is broadly classified into coarse particles (aerodynamic diameter $\geq 2.5\ \mu m$) and fine particles (aerodynamic diameter $<2.5\ \mu m$). Coarse particles generally formed by mechanical processes such as fragmentation and re-suspension. It contains high mineral concentrations (Ca, Fe, Si, other naturally occurring earth constituents, and sea salt). The fine particles are usually formed by combustion or gas-to-particle conversions. It is usually rich in carbon, sulphates, ammonium and nitrate ions, as well as trace toxic species/elements (As, Ba, Cd, Cs, Cu, Sr, Zn and Se). In general Ba, Cd, Cu, Fe, Ni, Pb and Zn are emitted from the vehicle's exhaust (Birmili et al., 2006), Zn emits from tyre wear (Li et al., 2001), Cu from brake linings (Adachi and Tainosho, 2004), Pt, Pd, Cr and Rh from catalyst deteriorations (Limbeck et al., 2004). Road dust carries more than 50% of Al, Cr, Fe, K, Mg, Mn and V, and 20% of Cu, Mo, Ni, Pb, Sb and Zn (Pacyna, 1998). In urban areas 55–60% of PM_{10} mass are consists of $PM_{2.5}$ mass (U.S.EPA, 1996, 2004).

The road transport sector is a major source of PM emissions in urban areas. The particles from the vehicles are the result of a combustion process and consist mainly of carbon and unburned or partially burned organic compounds (U.S.EPA, 1996; Gupta et al., 2006). Light duty diesel vehicles emit 4–7 g of PM per litre of fuel; a heavy duty diesel vehicle emits 7–14 g of PM per litre, while conventional gasoline vehicles emit 0.65 g of PM per litre (Pooley and Mille, 1999).

Exposing to toxic substances present in PM is of serious concern to public health (U.S. EPA, 2004). The effects of inhaled particles are determined by the physical and chemical properties of the particles. Chemical properties of the PM also influences many atmospheric processes including cloud formation, visibility, solar radiation and precipitation, and plays a major role in acidification of clouds, rain and fog (Hong et al., 2002; Celis et al., 2004). The relationship between exposing to PM concentration and associated health effects are linked with physical and chemical characteristics of the PM. Therefore, physicochemical characteristics of ambient PM are important for management of PM emissions in the urban area (Braziewicz et al., 2004).

At present, only a limited number of studies have been made in India to analyse the particle composition with emphasis on organic and inorganic species (e.g. Gajghate and Bhanarkar, 2004; Bhanarkar et al., 2005; Karar and Gupta, 2006; Chakraborty and Gupta, 2009;

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Shridhar et al., 2010). In this paper the metallic and ionic species present in PM_{10} and $PM_{2.5}$ mass concentrations at busy urban roadside in Chennai city during winter, summer and monsoon seasons and weekday/weekend were analysed. The sources contribution to PM_{10} and $PM_{2.5}$ mass concentration were also investigated.

2. Study area

2.1. Chennai and its environment

Like in many other developing cities, PM concentration in Chennai city is getting worse due to fast urbanisation and industrialization. The city is located on a flat coastal plain area (known as the Eastern Coastal Plains) having average elevation of about 6.7 m. In 2001 Chennai had approximately 4.56 million inhabitants living in an area of 174 km^2 (CMDA, 2007). At present, city has estimated population of 7.5 million (UN, 2003), making it as the fourth largest agglomeration in India. The city has a diversified economic base anchored by the automobile, software services, hardware manufacturing, healthcare and financial services industries. Chennai is also called as automobile capital of India with the establishments of 30% manufacturing units of India's automobile industry (Sivalingam and Bhaskaran, 2004) and 35% of auto components manufacturing units (GoI, 2007).

The buses run by the Chennai metropolitan transport corporation are the predominant mode of public transport in the city. The city has the total road length of 780.95 km (CMDA, 2007). Bus services in the city are not able to meet the requirements of public transport (overcrowded i.e. increased by 150% of the nominal capacity, infrequent and slow moving, WBR, 2005). This made sharp increase in personal mode of transport vehicle. Motor vehicle ownership in Chennai city has been increasing at unprecedented rates, between 10 and 20% per annum. In 2009, the total number of registered 2-wheelers (scooters, motorcycles and mopeds) was 1.81 million (75.6% of the total vehicle composition) and 0.44 million of cars (18.2% of the total vehicle composition, SHB, 2009). The current ownership level in the city is about 536 vehicles per 1000 populations. The density of motor vehicles per sq. km has increased from 22 in 1996 to 76 in 2009.

2.2. Sampling site

Fig. 1 shows the details of study site. The sampling site is located at 12° 59′ 29.44″ N, 80° 14′ 1.03″ E. The daily average traffic flow on Sardar Patel (SP) road during weekdays and weekends is 0.17 and 0.14 million vehicles, respectively. Two busy traffic intersections are located close to monitoring site (one at 50 m to the west and another at 500 m to the east), hence braking is frequent near the monitoring site. Many premier institutes such as Indian Institute of Technology Madras, cancer hospitals, central leather research institute, Anna University, central polytechnic, software companies and tourist spots (Children's park, Kamarajar mandapam and Gandhi mandapam) are also located in this region. In addition, many heavy industries are located about 30 km away in the north–north–east direction from the monitoring site. In general, the study site is surrounded with dense residential cum commercial areas. Therefore, site has intense human activity and having heavy traffic movement.

The traffic composition at the study site was broadly classified into light and heavy duty vehicles. Further, the light-duty vehicles (LDV) were classified as 2-wheelers (2W), 3-wheelers (3W) and 4-wheelers (4W) and the heavy-duty vehicles (HDV) were classified as light commercial vehicles (LCV) and heavy commercial vehicles (HCV). The movement of LDV on weekdays ranged from 175 to 10,402 vehicles/h and on weekends it ranged from 119 to 9260 vehicles/h. Similarly the movement of HDV on weekdays ranged from 24 to 707 vehicles/h and on weekends it ranged from 17 to 601 vehicles/h. The proportion of HDV on week days and weekends were found to be 6% and 5%, respectively.

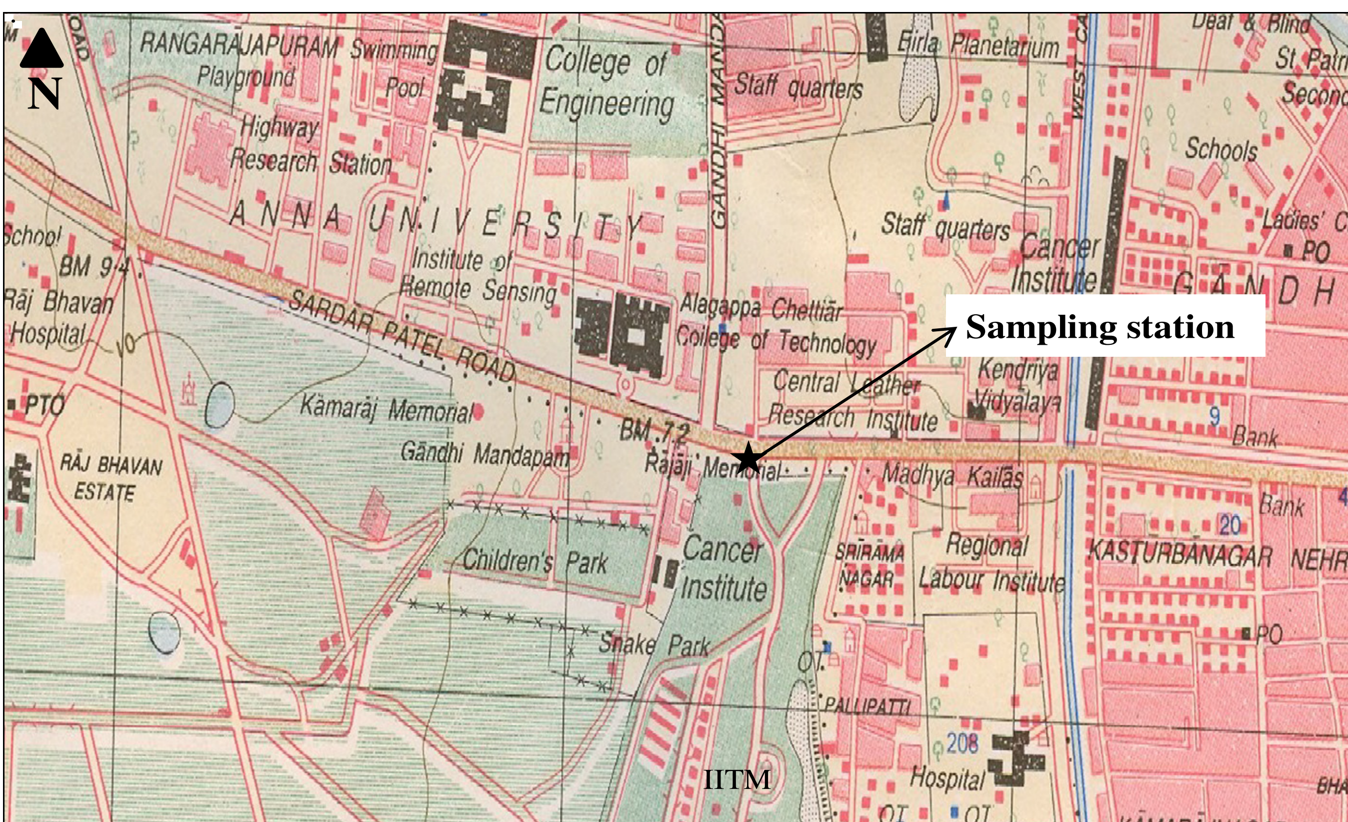

Fig. 1. Location of the study site.