Atmospheric Pollution Research 5 (2014) 677-685

Atmospheric Pollution Research

www.atmospolres.com

The traffic linked urban ambient air superfine and ultrafine PM_1 mass concentration, contents of pro–oxidant chemicals, and their seasonal drifts in Lucknow, India

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ABSTRACT

The anthropogenic $PM_{2.5}$ in ambient air is implicated in the increased health risks and morbidities of urban subjects. However in the literature, there is a limited information on mass concentrations and size segregated chemical profile of ultrafine and superfine PM_1 fractions of traffic linked urban ambient air. The size, and the adsorbed chemicals, and response to seasonal change in this submicron range of particles have seldom been studied so far. We have looked into these aspects in urban ambient air of Lucknow Uttar Pradesh India. A 10–stage MOUDI cascade impactor sampled the superfine ($PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$) and ultrafine particles ($PM_{0.1}$, $PM_{0.056}$) distributed in traffic linked ambient air. We studied their morphology, mass concentrations, the adsorbed metal contents and organic chemical moieties using TEM, gravimetric analyses, AAS, and FTIR spectroscopy. A change in their contents and profile with season was also examined. Results revealed spherical and fractal shapes of $PM_{0.1}$, 50 nm–2 µm size range of $PM_{0.56}$ fractions, and 10–100 nm size range of constituent spherules. Gravimetric analyses disclosed mass concentrations and multifold increases in their levels in winter. Cr, Cd, Ni, Pb and transition element Cu, Fe were found to be present in the studied particles. The presence of aliphatic and aromatic hydrocarbons with hydroxyl, carbonyl, and ketone groups were also found and displayed changes in their levels with season. Presence of organonitrate compounds indicated the role of submicron and nanosize particulates in secondary aerosol formation also. Results are important for epidemiological studies and public policy on superfine and ultrafine particulate matter in urban ambient air for identification of toxicity risk or health hazard, air quality monitoring and regulation.

Keywords: *Ultrafine, superfine, nano–particulate matter, carcinogen, transition metal, organonitrate*

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Article History:
Received: 16 December 2013
Revised: 17 April 2014
Accepted: 21 May 2014

doi: 10.5094/APR.2014.077

1. Introduction

The urban ambient atmospheric aerosol in outdoor air pollution is a complex mixture of superfine and ultrafine particulate matter (PM_1), the adsorbed chemicals, and the water vapor (Oberdorster and Utell, 2002; Mauderly and Chow, 2008). Accumulating evidences suggest it to be a perilous or even hazardous factor contributing to increases in cardiopulmonary disorders, skin diseases, lung cancer, and mortality in urban subjects and also to exacerbations of adverse health effects (Dockery et al., 1993; Stone et al., 2007; Strak et al., 2012; Kumar et al., 2013). The contributory role is feared by its greater number concentrations, large surface areas, low mass concentrations, and an array of adsorbed toxicants possibly of pro–oxidant potential present in urban ambient air.

Submicron particulate matter can deposit deep in lower respiratory tract (Kreyling et al., 2006) and escape the natural clearance mechanisms of tissues. This possibility may result in long–term retention of PM_1 and their adsorbed chemicals to present the threat of oxidative damage culminating into risk of toxicity. Respirable particulate matter of relatively larger sizes (PM_{10} and $PM_{2.5}$) and associated trace metals are known to be hazardous to human health. This is mostly due to their potential of generating Reactive Oxygen Species (ROS) and oxidative stress causing DNA damage and cytotoxicity (WHO, 2006; Roberts et al., 2010; Meister et al., 2012; Strak et al., 2012; Deshmukh et al., 2013; Valavanidis et al., 2013).

There is a limited amount of information in literature on mass concentrations, physico–chemical analyses and the hazard analyses of the superfine and ultrafine particulate matter of urban ambient air (Stone et al., 2007; Park et al., 2008; Lu et al., 2011; Deshmukh et al., 2013; Kumar et al., 2013). Presumably, it is due to the apprehension of insufficient mass collection in their sampling from urban ambient aerosol. Sporadic reports reveal only the number concentrations and profile of adsorbed toxic chemicals like metals, hydrocarbons, dioxins, and nitro–PAHs (Voutsa and Samara, 2002; Park et al., 2008). The source of PM_1 pollution in urban ambient air is largely low–mass aerosol from diesel combustion exhausts.

We have investigated the mass concentrations of superfine and ultrafine PM_1 fractions, the adsorbed chemicals and their particulate size based distribution pattern in urban aerosol. We examined also their sensitivity to change in seasons. Affiliation of changes in superfine and ultrafine PM_1 mass concentrations with changes in weather conditions is unknown. We studied the ambient air levels of ultrafine fractions in the urban aerosol of a roadside location in Lucknow, the capital city of Uttar Pradesh (north province) State of India. Its coordinates are 26.847°N 80.947°E as indicated by GEO URI (26°50′ 49.2″N, 80°56′ 49.2″E as indicated by World Geodetic System, WGS 84). The level of auto exhaust pollution could be gauged from the information that (a) city added 186 000 automobiles exclusively in 2009–2011 (GOI, 2013), (b) approximately 4.5 million subjects populated the city, and (c) every day nearly a million commuters sought transport

across the city area of ~300 km^2 (population density 2 011/km^2). Lucknow is largely a residential and commercial city. Industrial establishments are rare and located 10–15 km away from the monitoring point.

2. Materials and Methods

2.1. Sampling and monitoring locations

A high density traffic location (approximately 25 000 vehicles per day) in the urban area of Lucknow was monitored. The aerosol samples were collected in the month of October (autumn) and December (winter) in 2011 and March (spring), April (summer), and May (summer) in 2012. The traffic linked ambient air was sampled in an outdoor area. A roadside location on an arterial street on the river bank was the sampling spot as illustrated in Figure 1 (radial distance of 100 m from the landmark High Court). The sampling station was located at an elevation of 1.5 m above the ground level to simulate the inhalation exposure conditions for humans. Sampling was done in inhalable zone and in non–dusty areas. Outdoor activity included around–the–clock movement of both heavy and light commercial vehicles (more intense during daytime working hours), vehicular traffic (gasoline driven motor-cycles, CNG driven three–wheelers, gasoline/diesel driven four–wheelers) at the sampling location. The automobile exhaust emissions and the roadside kiosk were the major source of pollution, mixed with automobile–tyre scrubs. The air drift of river–bank–dust dispersion was not a contributor to the monitored urban aerosol for the larger size of suspended particulate matter.

Figure 1. *Map of Lucknow (a diagrammatic sketch).*