Atmospheric Environment 96 (2014) 370–379

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Observations of new particle formation at two distinct Indian subcontinental urban locations

V.P. Kanawade [a, *], Sachchida N. Tripathi [a, *], Devendraa Siingh [b], Alok S. Gautam [b], Atul K. Srivastava [c], Adarsh K. Kamra [b], Vijay K. Soni [d], Virendra Sethi [e]

[a] Department of Civil Engineering, Indian Institute of Technology, Kanpur, India
[b] Indian Institute of Tropical Meteorology, Pune, India
[c] Indian Institute of Tropical Meteorology (Branch), Prof Ramnath Vij Marg, New Delhi, India
[d] India Meteorological Department, Lodhi Road, New Delhi, India
[e] Center for Environmental Science and Engineering, Indian Institute of Technology Bombay, Mumbai, India

HIGHLIGHTS

- New particle formation was observed at both urban locations in India.
- The properties of ultrafine particles during new particle formation were studied.
- Particle formation and growth rates showed different patterns at these urban sites.
- The particle mode diameter at Kanpur was larger than at Pune.

ARTICLE INFO

Article history:
Received 24 March 2014
Received in revised form
30 July 2014
Accepted 1 August 2014
Available online 1 August 2014

Keywords:
Particle size distribution
Ultrafine particles
Formation rate
Growth
Urban

ABSTRACT

While the formation of new atmospheric aerosol particles and their subsequent growth have been observed under diverse environmental conditions globally, such observations are very scarce over Indian subcontinent. Here, we present the systematic analysis for new particle formation (NPF) from two distinct urban locations in India during April–May of two consecutive years. Particle size distributions were measured at Pune (18.53°N, 73.85°E) during 16 April–23 May, 2012 and at Kanpur (26.46°N, 80.32°E) during 16 April–23 May, 2013. The campaign mean total particle number concentration in the similar size range of 4–135 nm at Pune (12.2×10^3 cm^{-3}) was higher than at Kanpur (7.9×10^3 cm^{-3}), whereas the estimated total condensation sink (CS_{4-750}) at Pune (16.2×10^{-3} s^{-1}) was lower than at Kanpur (33.3×10^{-3} s^{-1}). Despite lower particle number concentrations at Kanpur, larger particle sizes resulted in higher condensation sink than at Pune. The mean particle mode diameter at Kanpur was found larger by a factor of ~1.8 than at Pune. NPF events were observed commonly at both sites, with lower frequency at Kanpur (14%) than that at Pune (26%). The derived particle growth rates, *GR*, and the formation rates of 5 nm particles, J_5, ranged from 3.4 to 13.3 nm h^{-1} and 0.4 to 13.9 cm^{-3} s^{-1}, respectively, which are generally comparable to typical values reported in previous studies. Generally, the particle growth rates were found higher at Kanpur, whereas the formation rates were higher at Pune. It appears that the presence of pre-existing large particles at Kanpur than at Pune suppressed formation rates and favored particle growth. Overall, NPF occurred at lower condensation sink, lower RH, higher solar radiation, and higher temperature.

1. Introduction

Atmospheric aerosols influence the climate directly by scattering and absorbing incoming solar radiation (Schwartz, 1996), and indirectly by modifying cloud microphysical properties and lifetime via cloud condensation nuclei (CCN) activation (Twomey, 1991), thus affecting the Earth's radiation budget. One of the

* Corresponding authors.
E-mail addresses: vijaykanawade03@yahoo.co.in, vijaypk@iitk.ac.in (V.P. Kanawade), snt@iitk.ac.in (S.N. Tripathi).

http://dx.doi.org/10.1016/j.atmosenv.2014.08.001
1352-2310/

leading reasons for uncertainty in the aerosol indirect effect is ambiguity in the CCN budget (Pierce and Adams, 2009). The formation of aerosol particles (via gas-to-particle conversion) is one of the predominant sources for new particles in the atmosphere and thus is an important process that controls total aerosol number concentration and cloud abundance. New particle formation (NPF) is a global phenomenon, with newly formed particles accounting in the range of about 3–70% of CCN production in the troposphere (Merikanto et al., 2009; Pierce and Adams, 2009; Spracklen et al., 2008). Regional NPF events take place frequently in the continental boundary layer, wherein NPF occurs over a large spatial scale (Kulmala et al., 2012). Such events have been reported in numerous studies at diverse locations, including several urban locations (McMurry et al., 2005; Stanier et al., 2004; Yue et al., 2009). Despite these extensive studies, the processes involved in NPF are still not well understood.

The first direct observation of atmospheric nanoparticles and clusters down to 1 nm diameter only recently revealed that NPF occurs by forming stable critical cluster (diameter of 1.5 ± 0.3 nm), followed by subsequent growth of clusters to 2 and 3 nm (Kulmala et al., 2013). Sulfuric acid (H_2SO_4) is thought to be the primary vapor responsible for NPF because of its low vapor pressure (Sipilä et al., 2010). However, H_2SO_4 alone does not form stable clusters to initiate nucleation and other additional base compounds are necessary to stabilize these H_2SO_4 clusters, such as organic molecules (Schobesberger et al., 2013), ammonia (NH_3) (Kirkby et al., 2011) and amines (Paasonen et al., 2012), and facilitate them to grow into particles. Previous laboratory experiments have also revealed that NH_3 (Ball et al., 1999) and amines (Almeida et al., 2013; Dawson et al., 2012; Yu et al., 2011) play a crucial role in NPF and growth processes at atmospheric conditions. Further, organic acids and their low-volatility oxidation products (Metzger et al., 2010; O'Dowd et al., 2002; Zhang et al., 2004) and charged ion clusters (Kanawade and Tripathi, 2006; Lee et al., 2003; Yu and Turco, 2008) have also been suggested to initiate particle formation, though the latter component has a minor role in the boundary layer (Kirkby et al., 2011).

Most of the studies reported to date were conducted in the temperate regions where distinct and definitive seasonal variations in climatic conditions can be observed (Cheung et al., 2011; Kulmala et al., 2004; Mejía and Morawska, 2009; Vakkari et al., 2011). However, studies in tropical regions are still very limited (Betha et al., 2013; Iida et al., 2008; Kanawade et al., 2014; Siingh et al., 2013), where the climatic conditions are much different. In particular, over the Indian subcontinent, the systematic analysis for NPF are limited to only a few locations; New Delhi (Mönkkönen et al., 2005), Pune (Siingh et al., 2013), Gual Pahari (Hyvärinen et al., 2010), Gadanki (Kanawade et al., 2014), Kullu-Manali in the Western Himalaya (Sharma et al., 2011), Mukteshwar (Komppula et al., 2009; Neitola et al., 2011), and Hanle in the Trans-Himalayas (Moorthy et al., 2011). Therefore, we measured particle size distributions in the diameter range of 4–135 nm at Pune during April–May 2012. We have also conducted analogous measurements, for the first time, at Kanpur that show strong seasonality in climatic conditions, but in the size range of 4–750 nm and during April–May 2013. The objective of this study is to examine NPF characteristics at two distinct urban locations that have different climatic conditions and emission sources.

2. Experimental setup and methods

2.1. Measurement sites

Measurements were made at two distinct urban locations (Pune and Kanpur) in India (Fig. 1). While observations of NPF have only recently been reported from Pune (Siingh et al., 2013), there are currently no published reports from Kanpur. In Pune, the measurements were carried out from the second floor of the Indian Institute of Tropical Meteorology building (IITM, 18.53°N, 73.85°E, 573 m amsl). In Kanpur, these were carried out from the second floor of the Center for Environmental Science and Engineering building in Indian Institute of Technology campus (IIT, 26.46°N, 80.32°E, 125 m amsl).

The Pune site is located on the outskirts of Pune city (~5 km away from the city center to the northwest) with a population of ~9 million as per 2011 census report. This site is surrounded by hillocks about 500–800 m high amsl on three sides, forming a valley-type configuration. A road with moderate traffic is located about 100 m to the North of the site. This site has no major industrial

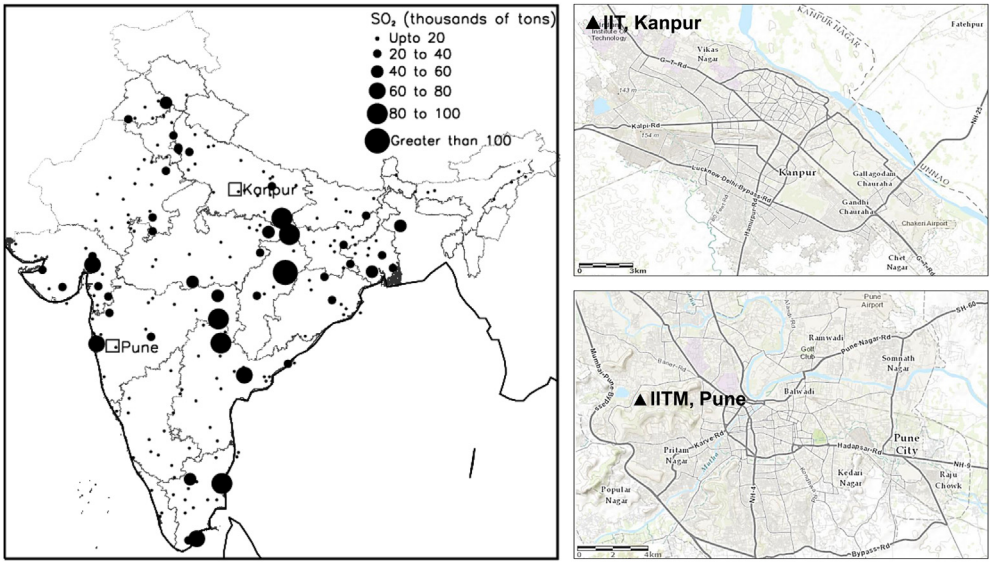

Fig. 1. Regional map showing location of the measurement sites, Pune and Kanpur (left panel). The industrial facilities SO_2 emissions for the year 2002 (dots) (Garg et al., 2002) are also indicated. The size of a dot corresponds to the emissions of the facility (in thousands of tons). The right panels show major road map in the immediate vicinity of each site (courtesy: www.arcgis.com).