Aerosol behaviour in Kanpur during Diwali festival

Aerosols are important in local and regional climatology through different direct and indirect atmospheric processes[1]. During the Diwali festival period, people play with crackers and fireworks. A high concentration of anthropogenic aerosols is injected into the atmosphere due to the burning of crackers and fireworks especially in urban regions. Diwali was celebrated on 4 November 2002 and on 14 November 2001. Anthropogenic contribution of aerosols during the Diwali festival has been studied earlier by Babu and Moorthy[2] in Thiruvananthapuram city, where a large increase of aerosol black carbon has been observed after the event. Central Pollution Control Board (www.cpcb.nic.in) maintains regular monitoring of air quality in seven major Indian cities, where one of the parameters measured is Respirable Suspended Particulate Matter (RSPM). Monitoring of aerosols at Delhi during Diwali festival has been carried out by Jain *et al.*[3]; but no measurement is being done for aerosols in the size range of 0.01 to 5 μm in northern cities, especially those lying in the Indo-Gangetic basin where the pollution level is increasing, affecting climatic conditions. Efforts have been made to study the behaviour of aerosol optical depth (AOD) in Kanpur (26.45°N and 80.23°E; 128 m mean sea level), a north Indian city, at 340, 500 and 1020 nm wavelengths during Diwali festival periods of the year 2001 (November 11 to 16) and of the year 2002 (November 1 to 7).

Figures 1 *a*, *b* show the behaviour of AOD during the Diwali festival period over Kanpur for the years 2001 and 2002. AOD increases from the preceding days of the festival which is normal since people start playing with crackers and fireworks about two days prior to the main Diwali day especially in urban cities. These fireworks and crackers invariably contribute to the anthropogenic aerosols. During 2001, the increase of AOD was found to be 16.25% at wavelength 340 nm, 17.7% at 500 nm and 12.7% at 1020 nm wavelengths on Diwali day (14 November 2001). AOD shows continuous increase on the next day with a maximum value 0.688 at 500 nm wavelength (Figure 1 *a*). During the Diwali festival period in the year 2002, the maximum increase of AOD is found to be 5.7% at 340 nm, 5.52% at 500 nm and 2.4% at 1020 nm wavelengths on Diwali day (4 November 2002), afterwards the trend of AOD is found to decrease (Figure 1 *b*). The increase of AOD at all the wavelengths from 2 to 3 November 2002 (Figure 1 *b*) is quite consistent with the celebration practice. At 1020 nm wavelength, AOD is found to increase ~ 0.1 on 6 November 2002 (Figure 1 *b*). At this wavelength, the role of water vapour becomes important. It has been observed that from 6 November onwards, the water vapour content in the atmosphere is found to increase (from 2.001 cm to 3.13 cm) (www.iitk.ac.in/aeronet) over Kanpur. The AOD increase on 6 November 2002 may be attributed to the local seasonal influence.

The monthly average of AOD values at Kanpur has been considered and the seasonal effect has been removed from the AOD values measured during the Diwali festival period for the years 2001 and 2002 to study the characteristics of AOD. AOD is found to increase by 0.055 at 340 nm, 0.033 at 500 nm and 0.01 at 1020 nm wavelengths on Diwali day (14 November 2001). In the year 2002, AOD is found to increase by 0.061 at 340 nm and 0.038 at 500 nm wavelengths on Diwali day (4 November).

The persistence of higher AOD values after the Diwali festival is likely to be attributed to the presence of soot particles and organic carbon compounds injected to the atmosphere due to the burning of different types of crackers and fireworks[3].

Such aerosols interact in the shorter wavelengths of the visible spectrum. As a result, larger variations of AOD for 340 and 500 nm wavelengths have been found compared to the variations at 1020 nm wavelength.

The particle size distribution of the submicron aerosols during the Diwali festival for the years 2001 and 2002 are shown in Figure 2 *a*, *b* and Figure 3 *a*, *b*. The size distribution data have been

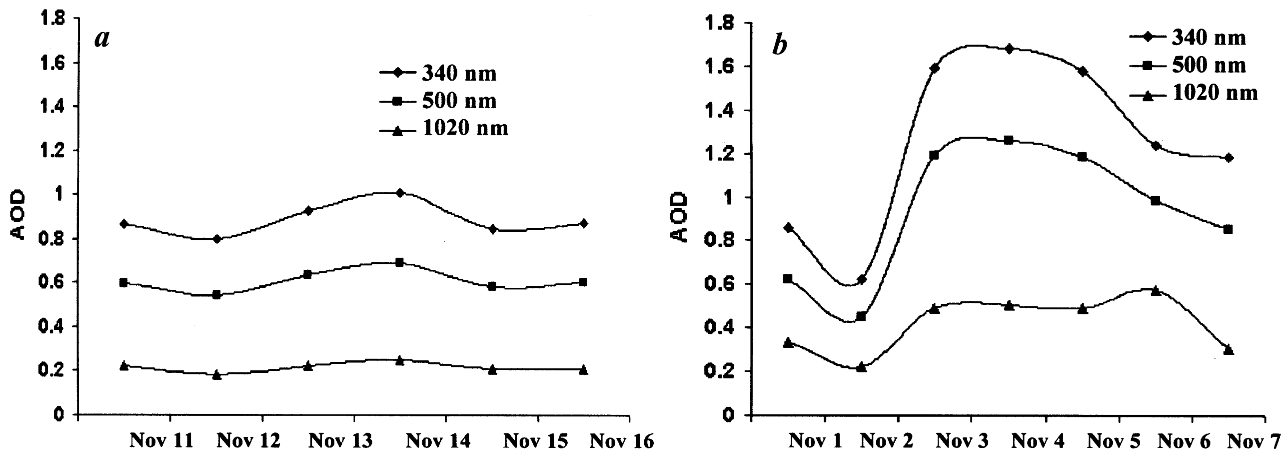

Figure 1. Variations of AOD during the Diwali week in (***a***) 2001; (***b***) 2002.

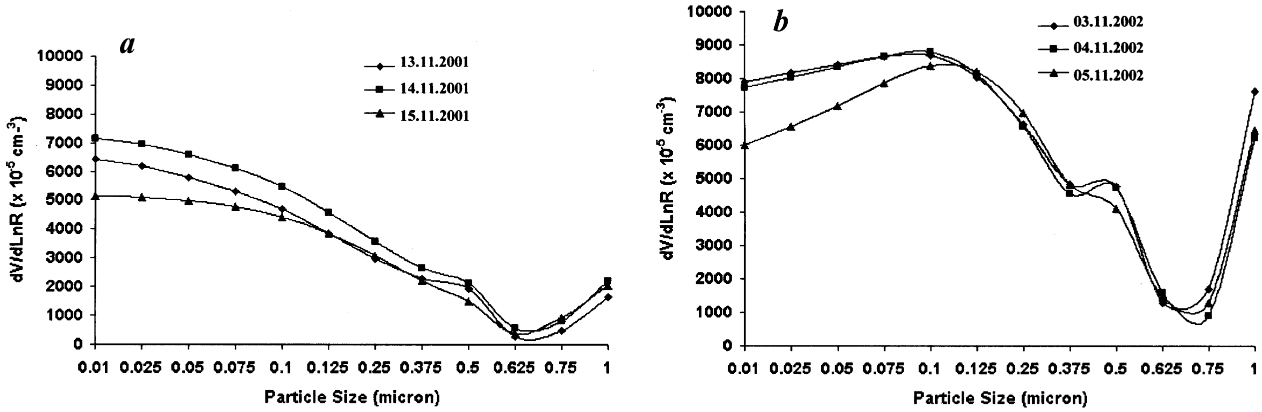

Figure 2. Size distribution of sub-micron aerosols during Diwali of the year (***a***) 2001; (***b***) 2002.

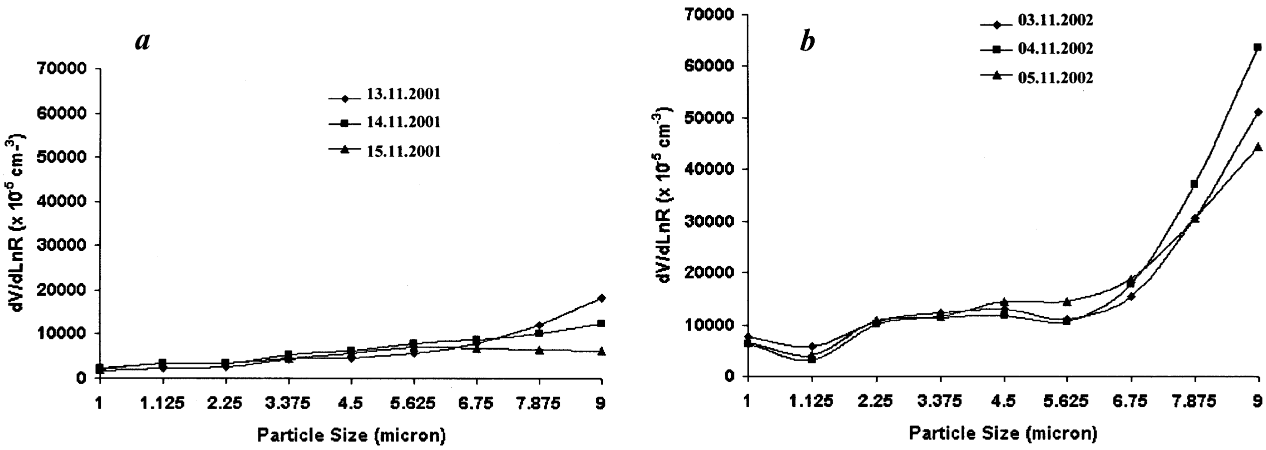

Figure 3. Size distribution of super-micron aerosols during Diwali festival of the year (***a***) 2001; (***b***) 2002.

taken from the Kanpur Aeronet station (Station number 184) deployed under NASA AERONET program[4], which maintains a global database of aerosol parameters measured using the CIMEL sun and sky scanning radiometer in various stations in the world. Three types of data on aerosols are available from the Aeronet site. We have used level 1.5 data (cloud screened), which has accuracy of AOD of ± 0.01. Significant difference in size distribution has been found in the volume distribution of the aerosols for the years 2001 and 2002. The volume distribution of the aerosols is found to increase on Diwali day for the years of 2001 and 2002. Also, the size distribution during 2002 shows large variations compared to that during 2001. This corresponds well with the observed spectral variations of AOD during 2001 and 2002. The large increase of AOD at 340 nm during 2002 compared to those during 2001 is reflected in the submicron particle size distribution curves (Figure 2 *a*, *b*).

The aerosol size distribution shows distinctly sub-micron and super-micron aerosols, where the size distribution is found in the range 0.6–0.8 μm for both the years (Figure 2 *a*, *b*). The size distribution curves clearly show that the volume concentrations of the aerosols of super-micron size (1–10 μm) are larger compared to the sub-micron aerosols (0.01–1 μm) (Figure 3 *a*, *b*). The concentration of aerosols is found to increase from the year 2001 to 2002. Large increase in concentrations of aerosols larger than 6 μm is seen during the year 2002 compared to those during 2001 (Figure 3 *a*, *b*). The super-micron aerosols generally stay at the lower level of the atmosphere close to the ground as they settle quickly. Their abundance in the aerosol size distribution indicates increase in the level of pollution at Kanpur from 2001 to 2002. The higher increase in the AOD at 340 nm and 500 nm compared to that at 1020 nm during the Diwali festival has been found due to the higher concentrations of the aerosols at these sizes. The large increase in the AOD values in the year 2002 from 3 November is reflected in the size distribution curves where higher concentrations are seen compared to those for the year 2001.

Efforts have been made to analyse single scattering albedo (SSA) data available from the Aeronet station at Kanpur during Diwali festival periods of the years 2001 and 2002. The SSA data (quality level 1.5) of 4 wavelengths 440, 675, 875 and 1020 nm have been considered. The SSA is very significant and characteristic (SSA 0.95 or less) of anthropogenic nature of the aerosols (black carbon is mostly common) which shows

Table 1. The SSA at Kanpur during the week of the Diwali festival

	Single scattering albedo (SSA)							
	Year 2001				Year 2002			
Days from Diwali	440 nm	675 nm	875 nm	1020 nm	440 nm	675 nm	875 nm	1020 nm
–1	0.89	0.883	0.866	0.861	0.909	0.861	0.855	0.85
0	0.917	0.913	0.912	0.91	0.869	0.867	0.85	0.874
1	0.902	0.88	0.872	0.865	0.85	0.843	0.805	0.855
2	0.875	0.874	0.852	0.846	0.852	0.804	0.849	0.859
3	0.872	0.87	0.865	0.85	0.855	0.771	0.828	0.842
4	0.90	0.899	0.894	0.891	0.863	0.81	0.853	0.861

absorbing characteristics[5]. During 2001, the SSA is found to decrease by 0.05 after the Diwali festival and during 2002 the SSA is found to decrease by 0.07. The decrease of SSA is found from 15 November in 2001 (one day after the main Diwali day) and from 5 November in 2002 (one day after the main Diwali day), which is due to the higher concentrations of absorbing aerosols. The higher change in SSA after the Diwali festival during the year 2002 compared to those from the Diwali festival of the year 2001 may be attributed to the prevailing meteorological conditions and the background aerosol concentrations. The values of SSA at 440, 675, 875 and 1020 nm wavelengths are shown in Table 1. The decrease of SSA with higher wavelengths (Table 1) is due to the higher absorption by smaller particles. But during the year of 2002, SSA at 1020 nm is found to be higher compared to those at other wavelengths which is attributed to the large increase in the volume concentrations of the aerosols around 1 μm size range (Figure 2 *b*) compared to the year 2001. The maximum decrease in SSA after the Diwali festival is found at 675 nm wavelength for both the years.

The increase of aerosols during the Diwali festival period, especially in urban areas is very common due to fireworks and crackers. Such increase in concentration of the aerosols has been found[3] over Delhi. The present results show that the AOD increase during Diwali festival period is reflected in the size distribution curves. In view of the increasing population and the use of fireworks and crackers in major urban areas, the routine measurements of aerosols using sunphotometers will help in guiding people and local administrators for the use of fireworks and crackers during Diwali festival period and also in understanding the changing climatology of Indo-Gangetic basin.

1. Parameswaran, K., *Proc. Indian National Science Academy*, 1998, **64**, 245–266.
2. Suresh Babu, S. and Krishna Moorthy, K., *Curr. Sci.*, 2001, **81**, 1208–1214.
3. Jain, S. L., Arya, B. C., Kumar, A., Singh, P., Tiwari, M. K. and Garg, S. C., *IASTA Bull.*, 2002, **14**, 146–148.
4. http://aeronet.gsfc.nasa.gov:8080/.
5. IPCC, *Climate Change: A Scientific Basis* (eds Houghton, T. *et al.*), Cambridge University Press, UK, 2001, p. 944.

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Baseline resistance to Cry1Ac toxin in cotton bollworm, *Helicoverpa armigera* (Hubner) in south Indian cotton ecosystem

Insecticidal protein genes coding for crystal (Cry) toxins of Cry1A group from the bacterium *Bacillus thuringiensis* (*Bt*) have been transferred to and expressed in a number of crops in order to confer resistance against lepidopteron insect pests[1–3]. Several transgenic crop species incorporating *cry1A* genes have been commercialized and cultivated in a number of countries over the past few years. *Bt* transgenic cotton was cleared by the Department of Biotechnology, Government of India for commercial cultivation from the year 2002, after a long debate and discussion. The primary target pest of this technology in India and several other countries is the cotton bollworm, *Helicoverpa armigera* (Hubner). It is a polyphagous pest with a wide host range of 181 plant species including cotton, pigeonpea, tomato, chickpea, maize, sun-