Seasonal variations of atmospheric aerosols and its association with the optical properties of aerosols in Varanasi at middle Indo-Gangetic plain

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Air pollution is the most important environmental issue for the human health, climate change as well as for the agricultural production. So it becomes necessary to assess the seasonal variability of particulate matter (PM: $PM_{2.5}$, PM_{10}). It has been observed that the air pollution is increasing day by day and cross the standard level in Varanasi, India. In the present study, measurements of particulate matter were made using two high volume sampler installed at the roof of the Department of Physics, Institute of Science, Banaras Hindu University, Varanasi, India from November 1, 2016 to June 7, 2017. Space-borne passive (MODIS-Terra) daily observations were simultaneously used with ground based aerosol mass measurement for the winter (November-February) and summer (March-June) months. Exceptionally high aerosol mass loading was recorded for both PM_{10} and $PM_{2.5,}$ typically exceeding national standard. Also, coarse mode particulate matter ($PM_{10–2.5}$) mass was estimated as the difference between the mass of PM_{10} and $PM_{2.5}$. The seasonal mean concentrations such as summer (March - June) and winter (November - February) were computed and compared. High concentration of $PM_{2.5}$ (134.18 ± 47.16 μg m^{-3}, range 42.83 – 257.76 μg m^{-3}), PM_{10} (211.89 ± 79.02 μg m^{-3}, range 123.23 – 464.52 μg m^{-3}) and $PM_{10–2.5}$ (77.71 ± 54.15 μg m^{-3}, range 3.66 – 206.76 μg m^{-3}) were observed during winter season while low concentration of $PM_{2.5}$ (39.05 ± 26.98 μg m^{-3}, range 4.33 – 105.41 μg m^{-3}), PM_{10} (135.95 ± 49.57 μg m^{-3}, range 2.55 – 212.04 μg m^{-3}) and $PM_{10–2.5}$ (96.90 ± 55.55 μg m^{-3}, range -102. 86 ± 175.93 μg m^{-3}) were found during summer season. The correlation coefficient (R = 0.74) was found between $PM_{2.5}$ and PM_{10} in the winter season however R = 0.04 was found in the summer season. During summer months dust storms and transboundary emissions are prevalent resulting into persistence of mixed type of aerosols. During winter season due to poor dispersion, the aerosol contribution from fossil fuel and increase usage of biomass burning might have caused higher loading of fine particle into the atmosphere. The high $PM_{2.5}/PM_{10}$ ratio was recorded in the winter (0.63) season while low $PM_{2.5}/PM_{10}$ ratio was recorded in the summer (0.29) season. The mean $PM_{2.5}/PM_{10}$ ratio was ~63% in the winter season, is the indicative of a higher loading of the fine aerosol particles compared to the coarser aerosols in Varanasi. The Angstrom exponent values ($\alpha > 1.0$) over winter season indicating that in winter small aerosols particle are dominant. However, in summer season $\alpha < 1.0$ indicates the existence of bigger size of aerosol particles. A significant correlation between $PM_{2.5}$ and MODIS-aerosol optical depth (AOD) ie.0.70 and between PM_{10} and MODIS-AOD i.e. 0.48 was found in the winter season. However a poor correlation was found in the summer season. Concentration Weighted Trajectory analysis show that $PM_{2.5}$ and PM_{10} levels at the land stations were influenced by weak to moderate contributions from Arabian Sea, Tropical Indian Ocean and the arid South-west Asia and North-west India, peninsular India and from the polluted Indo Gangetic Plain region. Major source reasons were determined for the winter and summer seasons using back trajectory cluster analysis. Outcomes of the present study may be helpful to improve regional air quality and also for the other particulate source apportionment studies.

Keywords: Indo Gangetic Plain, $PM_{2.5}$, PM_{10}, MODIS, AOD