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Aerosol Characteristics and Radiative Forcing over industrial areas of urban environment – A case study from Hyderabad and its Environs

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ABSTRACT

Aerosols play an important role in the radiation budget of earth-atmosphere system and affect climate. Studies on Aerosols with respect to temporal and spatial variations in different environments gains importance. We report the results of diurnal variations in Aerosols and related radiative forcing over one of the industrial areas of Hyderabad, viz., Balanagar, during the February-April. Extensive measurements of aerosol optical properties in six different wavelengths along with UV and PAR measurements have been recorded. Aerosol Optical Thickness (AOT) and columnar ozone have been measured using MICROTOPS-II Sun photometer and UV-radiation from UV-A and SUV meters. Photosynthetic Active Radiation (PAR) in the visible wavelength of 400-700nm has been measured leaf/air temperature sensor. Meteorological parameters on air temperature, wind direction, wind speed and relative humidity have been measured during the course of the study. Results from the aerosol characteristics for different wavelengths suggested a typical pattern of increase in aerosol optical thickness with decrease in wavelength i.e., maximum AOT is observed at 380nm region. Detailed analysis revealed that, maximum values of aerosol optical depth have been observed during afternoon and early evening hours. RH and water vapor showed a positive correlation with aerosol optical depth and air temperature showed a negative correlation with aerosol optical depth in all wavelengths. Total suspended particulate matter showed negative correlation with AOT. Analysis of results from the PAR measurements showed negative correlation with Aerosol Optical Depth in the 500nm region over the study area. SUV values for different days of February suggested clear diurnal trend in minimal erythmal dose. Comparison of SUV values of Hyderabad with Delhi suggested a higher range for Hyderabad when compared to Delhi for the month of April. In the study, an attempt has been made to study the effect of aerosols on the visibility factor at different sites for the years 1999 and 2000. Analysis with respect to visibility for different sites suggested that during the year 1999, Balanagar followed by Charminar, showed a low visibility when compared to other sites. This is mainly attributed to the contribution of aerosols from the industrial sources in the study area.

INTRODUCTION

Aerosols play a pivotal role on the radiation balance of the earth-atmosphere system. Each year increasing amounts of aerosols are released into the atmosphere from biomass burning (Kaufman et al.1998). Aerosol particles have a major influence on global climate and can locally either intensify or moderate the effects of the greenhouse gases through the scattering or absorption of both incoming solar radiation and thermal radiation emitted from earth's surface. Aerosols also act as cloud condensation nuclei (CCN) and thereby modify the radiative properties of clouds. Large uncertainties still exist in the yearly average evaluations of the direct radiative forcing caused by tropospheric aerosols on the global scale due to both aerosol concentration and composition. The regional studies of the direct effects produced by aerosol particles in scattering the solar radiation gains importance (Herbert, Pszenny & Blomquist 1996). The role of aerosols in atmospheric radiation budget and a possible climate impact has been recognized for a long time. Volcanic aerosols can cause warming (of about 3-4°c) in the stratosphere primarily by the absorption by upwelling terrestrial radiation and by reducing the amount of total solar radiation reaching the troposphere; can cause cooling (of about 0.5°C) globally. In the atmosphere, aerosol characteristics are altitude dependent (Subbaraya & Jayaraman 1982) and the stratospheric aerosols are quite different from the lower tropospheric aerosols. Tropospheric aerosols are short-lived due to gravitational settling and rain-wash. So, they produce only local effects. But stratospheric aerosols are long lived and they produce long-term global effects (Aher & Agashe 1998). The forcing due to aerosols is a strong function of their optical, physical and chemical properties, such as spectral optical depth, size distribution and the refractive index. Aerosol properties and their effects show spatial and temporal changes in different scales, most of which are region specific (Moorthy, Nair & Moorthy 1991). Large-scale uncertainties exist in the knowledge of aerosol parameters and their radiative effects, both globally and regionally (Ramanathan et al. 1996). Regional scale studies on the Aerosols and their radiative characteristics depend on the type of aerosols and their chemical constituents. To understand

and evaluate the aerosol behavior and their impact on the local microhabitats, studies on temporal characteristics of aerosols over different time periods is necessary. Hyderabad and its environs are situated in the semi arid region rapidly increasing urban area. The increasing urbanization is causing rapid pollution rates bringing about changes in aerosol and trace gas emission concentrations. In the present study, we evaluate the radiative forcing caused due to urban aerosols from the measurements carried out during February – April.

STUDY AREA

The Hyderabad City is situated in 17° 28'N of the latitude and 78° 27' E longitude and the population according to 1991 census is 31,45,939. The HUDA area is divided into 29 planning zones (11 Zones inside municipal limits and 18 zones with non-municipal limits). The city is located around 580m above mean sea level and experiences a minimum temperature of 11.6°C and a maximum of 40.5°C with an average rainfall of 73.55cm.The city is situated centrally between the other Metropolises of Mumbai, Chennai and Bangalore and is well connected by road, rail and air. The decennial growth of population (1981-91) is 39.76% against the growth rate of 24.20% for the state. Amongst the total population only 0.21% workers relate to Agricultural and allied services and 99.79% belong to workers (Fig.1).

DATA SETS

Measurements of Aerosols with respect to different dates for the months of January to April in the year of 2001 carried out using MICROTOPS -II sun-photometer, which measures the aerosol optical depth in wavelengths viz., 380nm, 440nm, 500nm, 675nm, 870nm and 1020nm. The AOT values are recorded for every 30 minutes interval for each of the day and analyzed for the diurnal variations over a period of time. Using UV-A meter UV-A data on in the range of 320-400nm and Minimal Erythmal Dose (MED) has been counted for January-April, 2001. The CID-301 Photosynthetic System has been used to measure PAR, in synchronous aerosol optical depth measurements. Pollutant data with respect to TSPM has been obtained from AP State Pollution Control Board (APSPCB) for 8 stations in Hyderabad at various locations viz., Banjara hills, Balanagar, Uppal, Punjagutta, Paradise, Charminar and Zoopark. The TSPM measurements were used to estimate the contribution of haze to the visibility in the specified sites of Hyderabad. APPCB using online instrument for measuring air pollutants. CO has been measured from CO11M-CD IR correlation carbon monoxide analyzer.

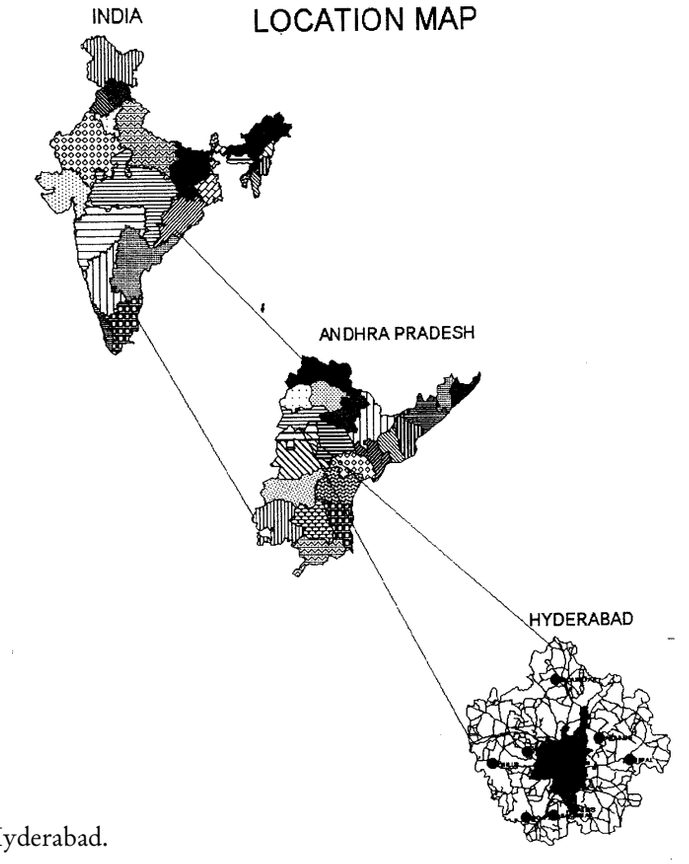

Figure. 1. Study area of Hyderabad.

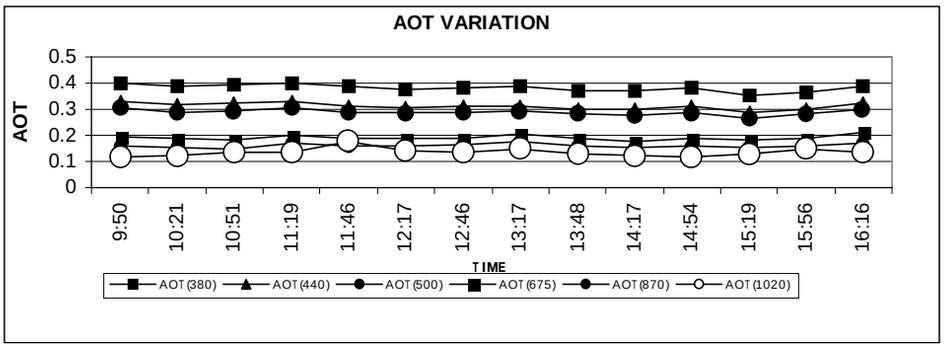

Figure. 2. AOT variations

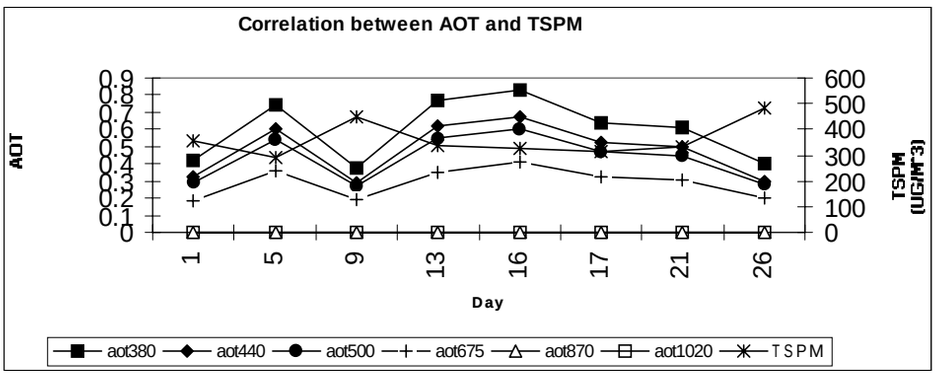

Figure. 3. Correlation between AOT and TSPM

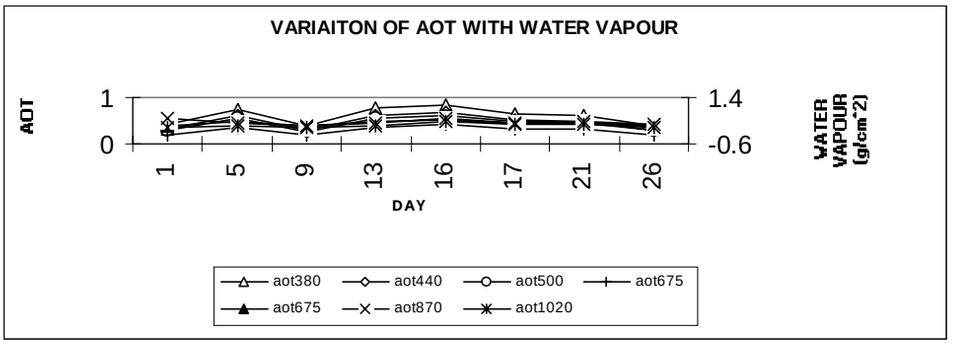

Figure. 4. Variation of AOT with watervapor

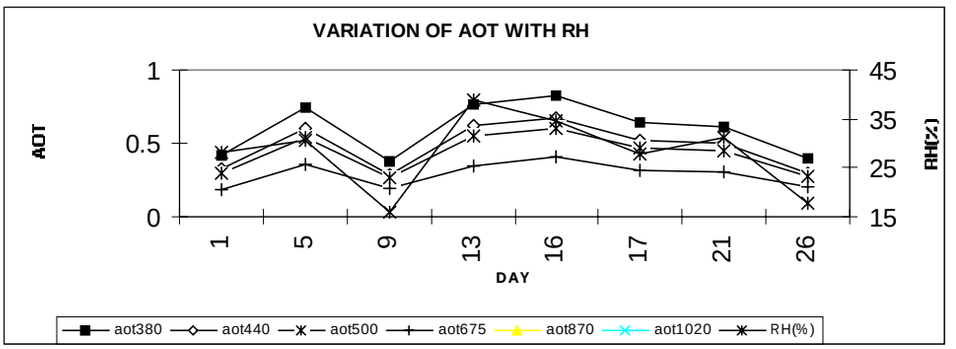

Figure. 5. Variation of AOT with water

RESULTS AND DISCUSSION

The increasing population has also increased the traffic density (Surendra & Viswanadham 1997). Traffic sector contributes 75% of all air pollution in Hyderabad with the automobile population of 8 lakhs (Mimeo 1997). Detailed data with respect to aerosol optical depth measured using MICROTOPS-II sun photometer has been analyzed for one of the industrial sites of Hyderabad namely Balanagar. Diurnal measurements of aerosol optical depth suggested that the values in all wavelengths are high during afternoon hours. Comparison of AOT with that of less industrialized site such as of Anantapur has been done. The AOT variations in different wavelengths for Anantapur suggests (Kant et al. 2000) values of 0.32, 0.25, 0.23, 0.15, 0.12, 0.11 for the wavelength corresponding to 380, 440, 500, 675, 870 and 1020nm. Analysis of the present data sets suggested higher AOT values in the Balanagar region suggesting polluted nature of the region (Fig.2). RH (r^2=0.85) and water vapor (r^2=0.99) showed positive correlation with aerosol optical depth in all wavelengths. Total suspended particulate matter (TSPM) showed negative correlation with aerosol optical depth at 500nm (Figs 3,4 and 5). Ground level ozone measurements suggested high values in afternoon hours (45.7ppb). Increase in UV-B radiation with increase in ground level ozone has been observed. UV-B and aerosol optical depth (500nm) showed positive correlation supporting the role of UV-B radiation (Stefan & Urs 1998) in the oxidation process. Positive correlation between UV-B and aerosol optical depth at 500nm has been observed in Anantapur. UV-B values for different days during the month of March revealed a typical increment from morning with the concentration of 1.16MED/HR to afternoon hours with the concentration of 4.1MED/HR. UV-A also showed a typical increment from morning hours with the concentration of 2.28mw/cm^2 4.3 mw/cm^2 during afternoon hours (Fig.6). PAR values measured in synchronous with AOT values varied from 209.4w/m^2 in the morning to 405.5w/cm^2 in afternoon (Fig.7). High values of CO have been observed in morning hours and evening hours with the values of 0.81ppm and 0.78ppm respectively suggesting vehicular and industrial pollution. Ground level ozone has been observed to be inversely proportional to the CO values revealing a possible loss of tropospheric ozone levels due to heterophase chemistry (Shyam Lal et al. 2000) (Fig 8). EP/TOMS instrument provides measurements on earth's columnar ozone at wavelengths 308.50, 313.50,317.50,322.30,331.20,360.4nm and the data has been compared with sun-photometer derived columnar ozone measurements.

Results suggested 80% correlation with the TOMS data for the period of February to May 2001. The TSPM values have been used to calculate visibility (Upadhyay 1988) for eight sites in Hyderabad for 1998-99 and 1999-2000. During 1999, Zoo park area visibility has been estimated to be 6.09 Km, which is a ten fold lower than the year 2000 (70.7Km). Balanagar study area being an industrial zone showed lower visibility (2.4Km) suggesting high pollution concentration compared to other sites. Similarly Charminar also showed low visibility (2.47Km) among the various sites.

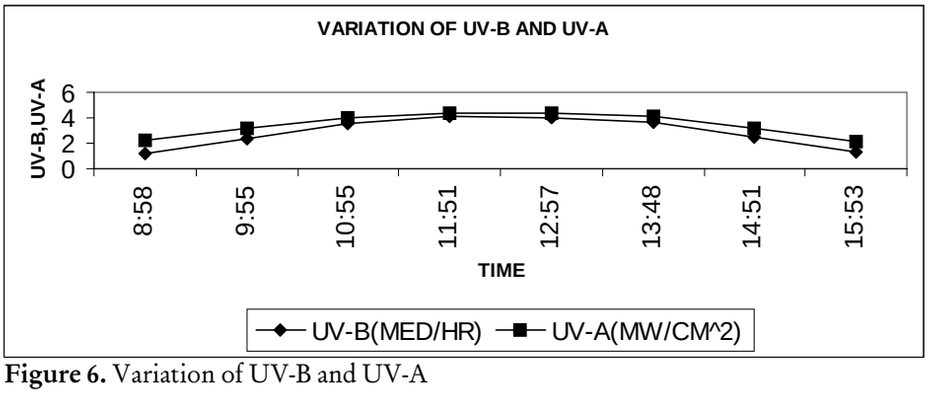

Figure 6. Variation of UV-B and UV-A

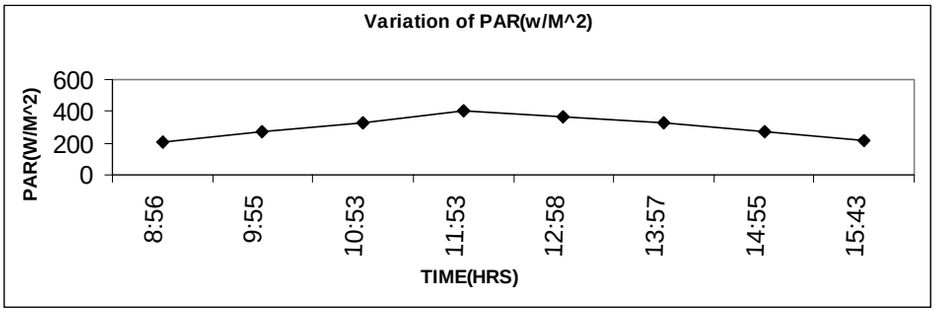

Figure 7. Variation of PAR

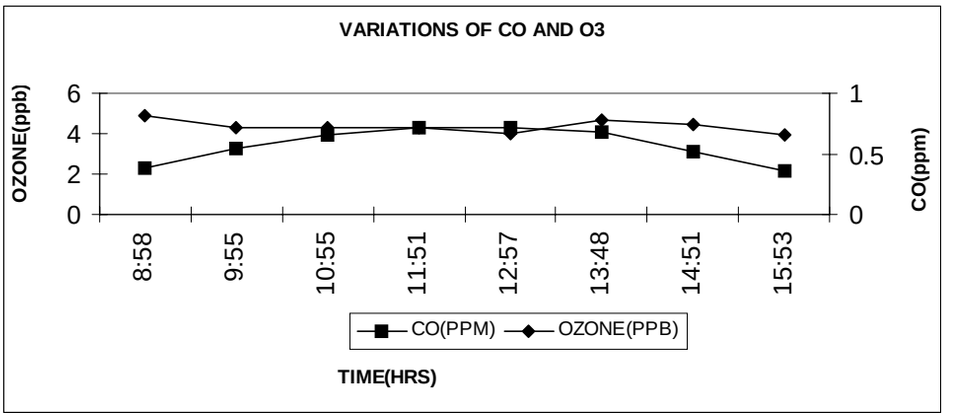

Figure 8. Variation of CO and O3

CONCLUSIONS

Good correlation among aerosol optical depth, columnar water vapor and relative humidity supports the impact of these meteorological parameters on aerosol loading at Hyderabad. Seasonal trends of visibility suggested a typical increase during April to July mainly attributed to dispersal of pollutants due to relatively high wind speed and also low relative humidity during the dry season in the study area. Positive correlation between UV-B and AOT supports the role of UV-B in photochemical processes. The present study reveals low visibility values in industrial area and high visibility in fringe areas suggesting its polluted nature. Aerosols and pollutants in the Hyderabad region are highly varied in nature with respect to diurnal and seasonal patterns and detailed study over a period of time may provide more information with respect to pollution characteristics.

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