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Carbon Monoxide Pollution Levels at Environmentally Different Sites

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ABSTRACT
Environmental characteristics such as topography, altitude, anthropogenic activity such as traffic, industrial gaseous effluents, proximity to all sources of pollution etc., have considerable influence on the abundance, residence time and retention of tropical trace gases over a locale. When the trace gas is toxic with its source at the surface of the Earth and has residence time of the order of several days, like in the case of carbon monoxide (CO), this trace gas becomes a criteria pollutant. Under the ISRO Geosphere Biosphere Programme (ISRO-GBP), a scientific study was initiated with a view to studying CO baseline at a tropical coastal station (Thiruvananthapuram) and to compare short-term CO measurements carried out in different environments such as a metropolis, a mining site and a pristine midland environment. CO is an air pollutant and is being monitored at a tropical coastal station Thiruvananthapuram since 2003 using an infrared analyzer. Also, for short durations CO was measured at three other environmentally different sites viz., Palode (near Thiruvananthapuram, a midland hill station with dense vegetation at an altitude of 140m ASL on Western Ghats), New Delhi (metropolitan city) and at Jaduguda (a mining site in Jharkhand state) near Kolkatta. From these measurements, the behaviour of CO at different environments was studied. Ambient CO at these sites, their diurnal patterns and the effect of vehicular emission inferred from weekday-weekend behaviour was delineated. This study revealed that Palode has the lowest ambient CO, followed by Thiruvananthapuram, Jaduguda and then New Delhi. Modulation of ambient CO by the vehicular emissions was observed at New Delhi, Thiruvananthapuram and Palode, but was absent at Jaduguda. The results of the characteristic CO levels encountered at different environmental locations, the response to traffic, the main anthropogenic activity that affects CO levels, are presented in detail and discussed in the manuscript.

INTRODUCTION

One of the significant sources of air pollution in urban areas, towns and cities of the developing countries is the emissions from motor vehicle exhausts (Mayer 1999). India, one of the fast developing countries of the world, has registered a sharp increase in vehicular pollution, particularly, in the urban area (CPCB 1999). Review of earlier work indicates that pollution studies in major cities, particularly New Delhi, the capital city of India, have been carried out (WHO/UNEP 1998; CPCB 1999). In vehicular emissions CO, hydrocarbons (HC), oxides of nitrogen (NOx), sulphur dioxide (SO2), Pb and particulates are the main pollutants. Recently, a few studies were carried out where in the investigators analyzed the diurnal and seasonal variations of O3, SO2, and NOx (Mondal et al., 2000; Pandey et al., 1992).

CO is a colourless, odourless and chemically stable, but relatively inactive gas that has molecular weight close to that of air. At the surface of the Earth, CO is produced in all forms of burning of biotic material at insufficient oxygen levels. In the atmosphere, natural production to the extent of 50% of the total atmospheric CO load is by the interaction of solar radiation with methane. In the urban centers, developing towns and cities vehicular exhaust is the major anthropogenic source for CO (Environmental Health Criteria 1999). In rural areas, biomass burning associated with agricultural practices is a major contributor. An important loss process for CO is through respiration by warm-blooded animals at the surface and at higher altitudes till tropopause, CO is mainly controlled by the hydroxyl (OH) radical. Even at low levels (~9 ppm for 8 hours of respiration) CO is toxic and detrimental particularly to human beings and in general, to all life forms that respire [www.epa.gov/air/criteria]. Thus CO levels in the ambient air play a role in determining the air quality of a region.

In this paper, we discuss the ambient levels of CO; its diurnal variation and its response to traffic exhaust emissions at four environmentally differing sites. At one of the sites, viz., Thiruvananthapuram, the seasonal variation is also studied, as data for more than a year is available here. The locations of the sites are given in a map of India in Fig 1. For evaluating the air quality of these locations the National Ambient Air Quality Standards (NAAQS) for atmospheric CO were taken as the reference standard. From the pollution point of view, the CO levels are examined at 1-hour intervals and compared with NAAQ Standards.

MEASUREMENT TECHNIQUE

For monitoring CO, an analyzer using non-dispersive infrared photometer technique (Monitor Europe Model 9830B) is used. The analyser measures CO by spectroscopic absorption at the IR wavelength 4.6 μm, from 0-200 ppm in four ranges, with 0-50 ppm as the default range. It has an auto-ranging facility. CO as low as 10 ppb can be measured and the accuracy of measurement is 1% of measured value in the lowest range. Here a data interval of 5 min. was selected considering the response of ambient air to changes in wind speed and direction, location of the instrument, storable duration in the analyser memory module and the data length. The instrument displays Time in IST, instantaneous CO and its average value over 5 samples. The event log describes 20 events of instrument operation such as power failure, restoration etc. Also, there is an instrument status menu with regard to the components behaviour such as the heater, scrubber gas, CO2, valves operation, electronic status, etc. Analog and digital outputs are available for data monitoring. Data is stored in the memory module and can be transferred to a computer using a communication software package.

RESULTS AND DISCUSSION

a. Thiruvananthapuram

CO was monitored continuously since July 2003 at Thiruvananthapuram, a tropical coastal site (8o 29' 30" N, 77o 24'E). The diurnal variation averaged for a month (January 2004) is shown in Fig. 2. Hourly averages are derived for the month and the standard deviations are shown as error bars. It can be seen that

Figure 1. Map of India showing the four locations where ambient CO was measured.

the CO remains at a low value throughout the day except for two peaks; one in the morning and the other near midnight. The peaks occur as a result of accumulation of CO near the surface at these two periods. A close examination of the lower atmosphere will reveal that these periods coincide with the movement of the boundary layer as well as land and sea breeze conditions. As the boundary layer moves up, it reduces the ambient CO and when it comes down the reverse happens. This is due to the initiation of circulation and inhibition respectively. The ambient CO showing high values during the morning hours and close to midnight, is similar to the one reported (Environmental Health Criteria 1999)

The hourly mean of the CO measured at Thiruvananthapuram for a winter month (January 2004) is evaluated and shown as bar diagram in Fig. 3. As the CO encountered in a year is the highest in winter, this will give the maximum pollution seen. The hourly CO values are in the range 0.044 - 0.624 ppm. CO pollution level stipulated for rural and residential areas by the NAAQS for India is at 3.2 ppm for 1-hr average and 1.74 ppm for 8-hr average [www.geociies.com/envis_ism/standard2]. The CO exposure levels stipulated by the Central Pollution Control Board of India (CPCB) are 2.4 ppm (personal), 3.4 ppm (occupational) and 2 ppm (residential). At Thiruvananthapuram the measured CO values are well below all these limits shown in Figure 3, indicating that pollution due to CO is very less and below the permissible limits.

b. Palode

CO was measured at a midland station for two weeks from 1st to 14th June 2004. The location of the site is at Palode (8o 43' N, 77o 02' E), at an altitude of 140 m ASL, about 30 km off the west coast. The average diurnal variation for the period of measurement is shown in Fig. 4. Here, the CO diurnal pattern exhibited a narrow, abruptly rising morning peak, while there was no distinct evening peak. At this site the average CO level during the measurement period was low (26 ppb), suggesting that Palode is a pristine, clean environment. Hourly CO levels here are far too low compared to the pollution levels stipulated by NAAQS and CPCB for India.

c. New Delhi

CO was measured at two continental locations, one at New Delhi and the other at Jaduguda in Jharkhand state, as part of a campaign to measure trace gases and aerosols in the atmosphere. Before the campaign, as an inter-comparison of different techniques, CO was measured at New Delhi (28o 38' N, 77o 05' E). The site was at an altitude of about 220m ASL in the National Physical Laboratory campus in the metropolis. The nearest highway was about 400 m away from this site. This measurement was carried out during Dec 28th and 29th, 2004. The average variation of CO at New Delhi for these days is shown in Fig. 5. The diurnal pattern at Delhi is similar to

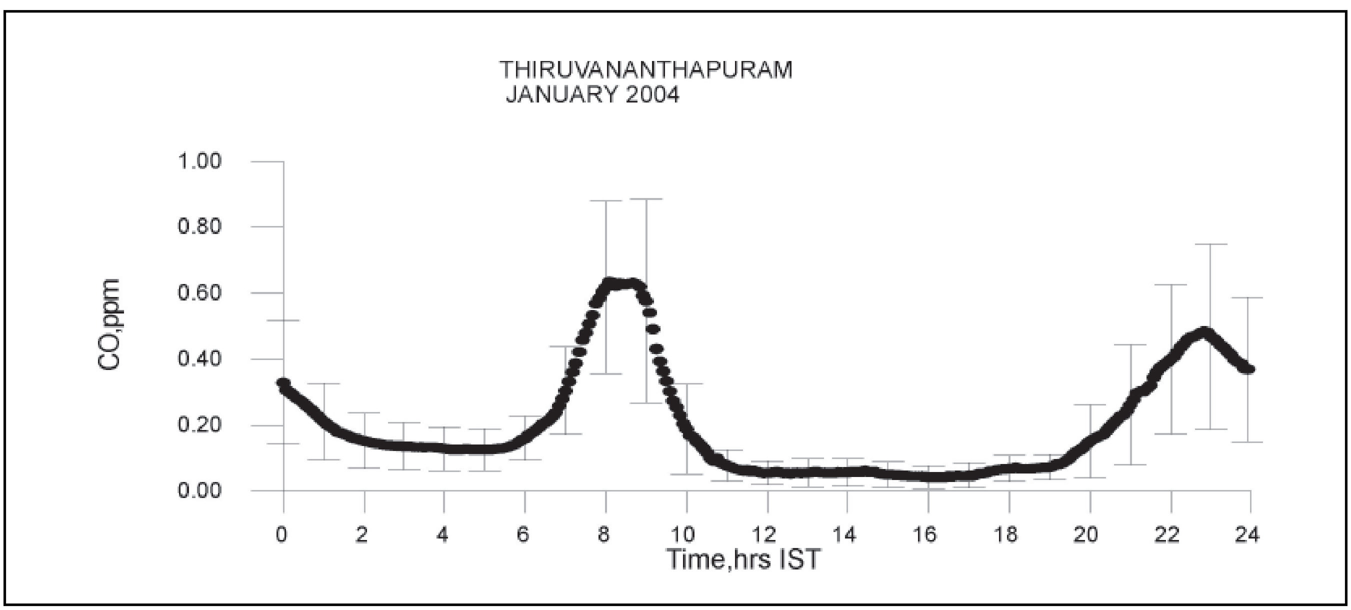

Figure 2. Diurnal variation in CO at Thiruvananthapuram averaged for a winter month (January 2004) plotted with hourly standard deviation posted as error bars.

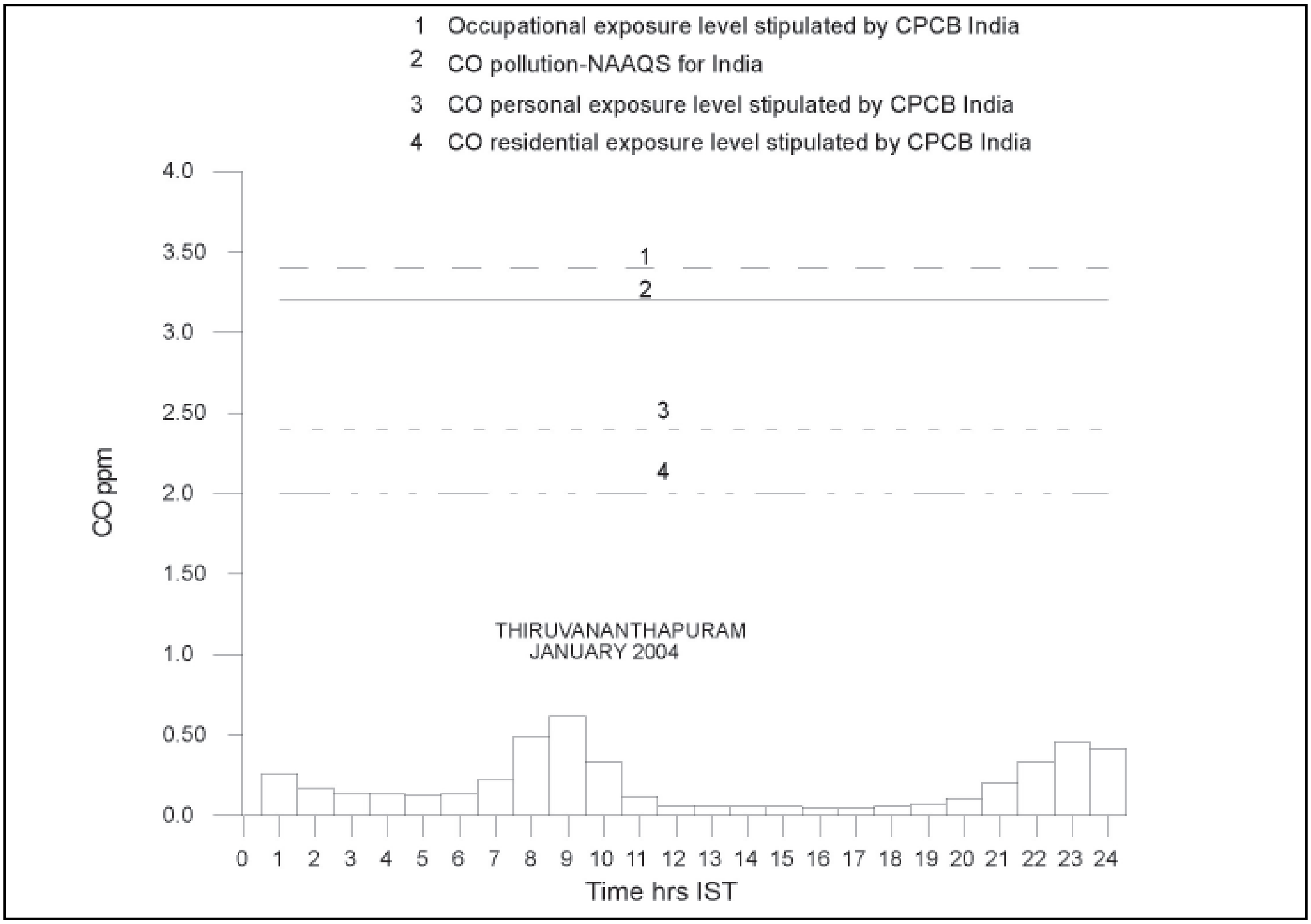

Figure 3. Bar diagram of the diurnal hourly averaged CO for January 2004. CO pollution stipulated as NAAQS and by the CPCB, India too is shown.

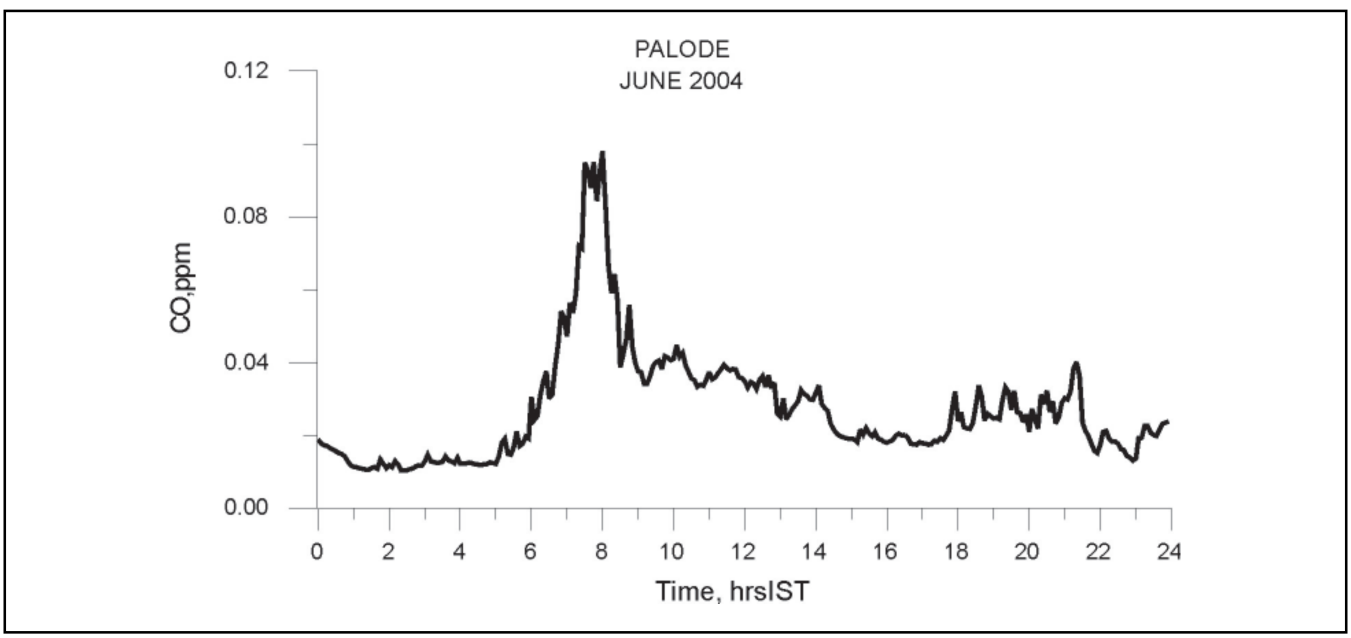

Figure 4. Average diurnal CO at a midland station, Palode. The AN peaks are less pronounced here.

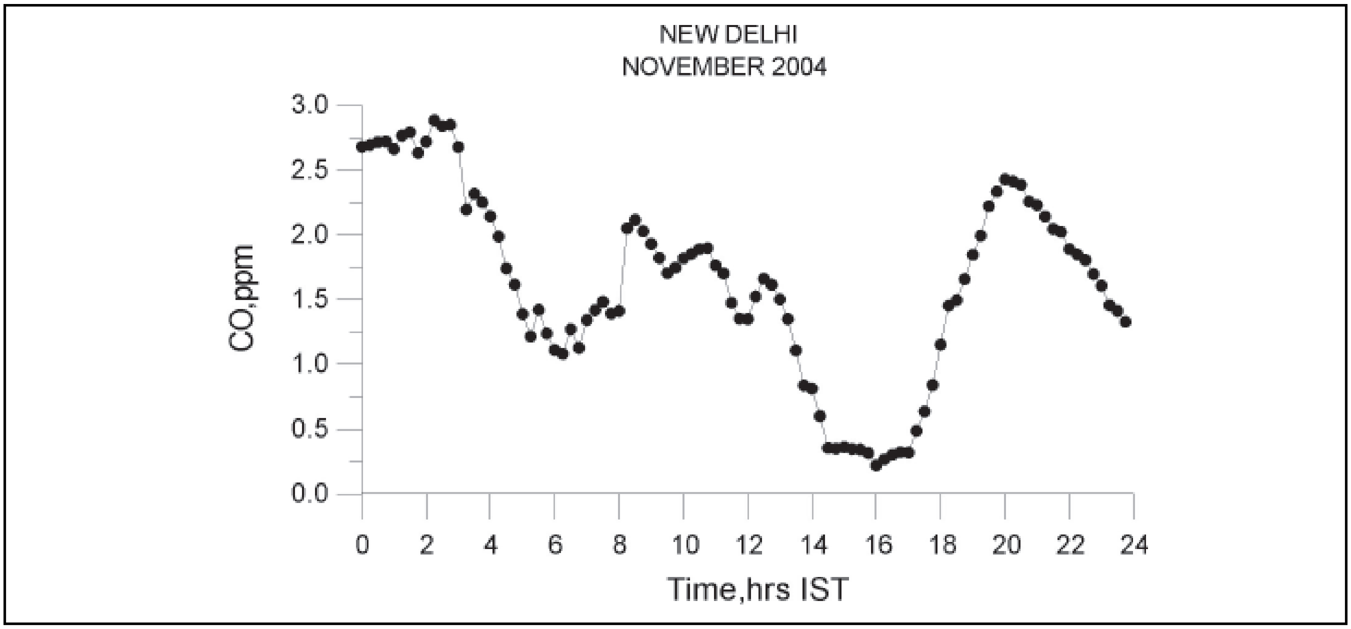

Figure 5. Measurements of CO at New Delhi on Nov. 29th & 30th, 2004. Diurnal pattern shows a high ambient CO.

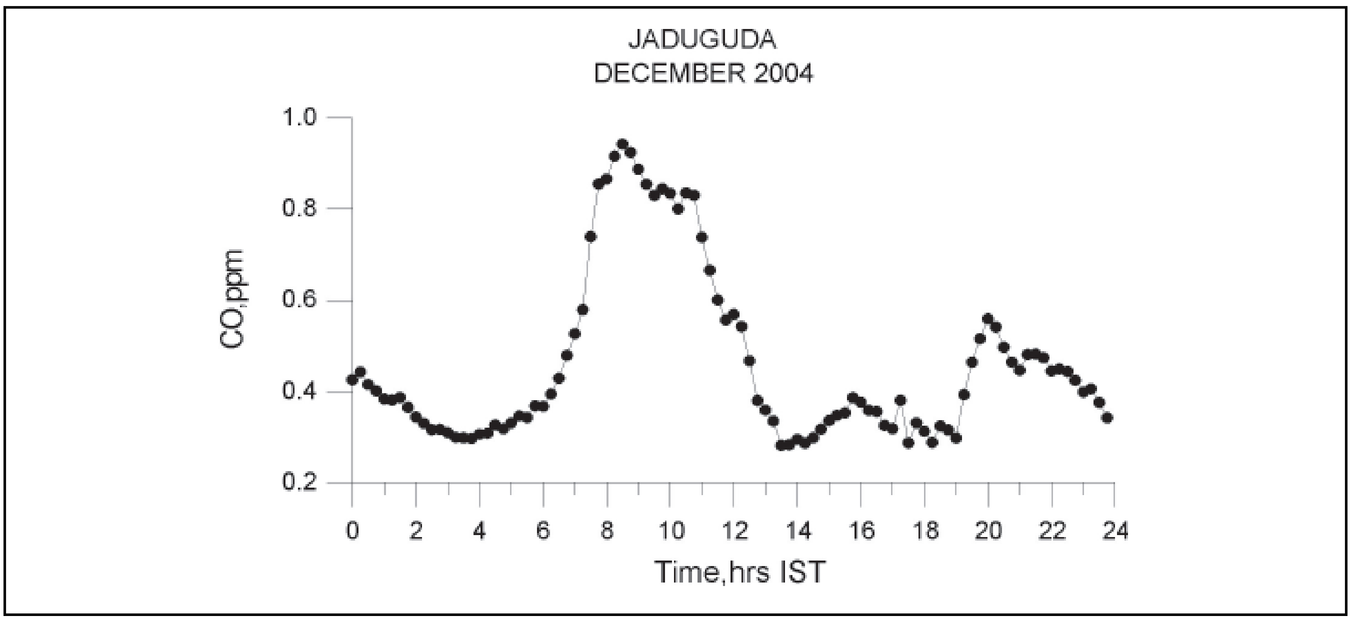

Figure 6. The mean diurnal CO measured at Jaduguda in Dec 2004 too has two peaks in a day and the overall CO level is high.

that seen at Thiruvananthapuram and Palode, except for the large amplitude. The hourly average values vary between 0.21 ppm and 2.83 ppm. These values are lower compared to the earlier study (Nagendra & Khare 2003). This difference could be due to the fact that the present site of measurement is away from traffic. It may be noted that the value of 2.83 ppm is above the CO personal exposure levels at 2.4 ppm and residential exposure at 2 ppm.

d. Jaduguda

The CO analyser was deployed for a month at Jaduguda. The measurement site was at Uranium Corporation of India (UCIL) campus in Jaduguda (22o 38' N, 86o 21' E, 122m ASL), a small town. The nearest city is Jamshedpur about 25 km away from the site. The average diurnal CO profile for the measurement period is shown in Fig. 6. This also

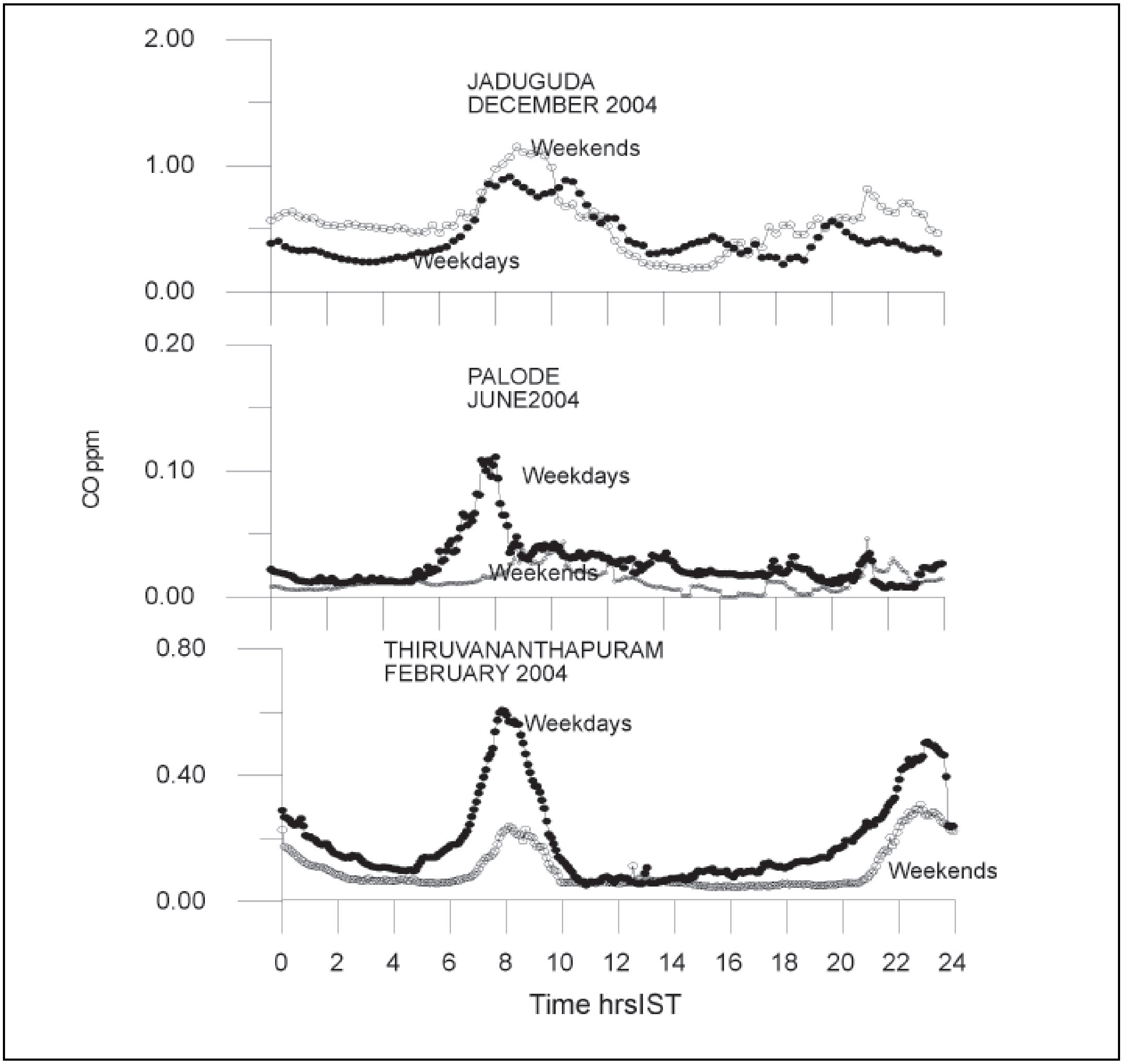

Figure 7. Diurnal patterns of CO at Thiruvananthapuram (Feb. 2004), Palode (Jun 2004) and Jaduguda (Dec 2004). The average diurnal CO on weekdays and weekends are distinct at Thiruvananthapuram and Palode, but there is no effect of traffic seen in the diurnal pattern at Jaduguda.

shows the two distinct peaks during the day. The hourly average values (0.281 ppm and 0.942 ppm) when compared to the NAAQS are low. Mean CO over a day for all days of measurement in December 2004 at Jaduguda were high compared to Thiruvananthapuram or Palode. A possible cause for the high CO values could be due to the operations of mines. Studies in tunnels, bridges and mines conducted by the National Institute for Occupational Safety and Health, USA (report in 1991) indicates about high CO values (National Institute for Occupational Safety and Health 1991). The use of high power diesel vehicles for mining and transport of raw minerals and personnel adds to the CO in the stagnant air in the mining environs. Such high levels of CO are reported in from Utah, USA with abandoned mines, since the open mines can function as storage for stagnant air trapping CO from the mines. Hence, the high background CO in the ambient air Jaduguda could be due to the operation of the mines. The measurements of ambient CO at the 4 sites reveal the level of pollution in the order from Palode, Thiruvananthapuram, Jaduguda and New Delhi.

EFFECT OF TRAFFIC ON CO VARIATION

Traffic affects the concentration of CO in the ambient air (Environmental Health Criteria 1999). If traffic data is available for a location, then a direct correlation between the change in the ambient CO and the traffic flow could be derived. As the traffic flow data is not available for comparison at present, a method to study the effect of traffic has to be devised. To study the effect due to traffic, the monthly mean diurnal CO during weekdays and weekends is studied because the traffic flow is known to be less during weekends compared to weekdays in major cities as most of the offices do not work on weekends. The diurnal pattern of CO is similar during weekdays and weekends, except for the magnitude. During the weekends and holidays, as stated earlier, there is a considerable reduction in traffic that causes a discernible reduction in CO.

The weekday - weekend variations are shown in figs 7 for all the stations. Modulation of CO due to traffic is clearly seen at Thiruvananthapuram since the measurement site is well inside the city. The weekday-weekend effect is observed in the diurnal pattern at Palode also. From earlier studies (Nagendra,S. and Khare,M. 2003), a clear weekday weekend effect was observed in New Delhi also.

From the figure, it is obvious that the weekday-weekend CO change is absent at Jaduguda. Further, weekends show a slightly higher value than the weekdays. Traffic was observed to be constant in the highway from Jamshedpur to Kolkatta and the weekday-weekend change in traffic flow is marginal. The site of CO measurement is about 300 m from the highway. Therefore, change in the high background CO modulated by traffic could have got masked.

SEASONAL VARIATION OF CO

The movement of the boundary layer mostly controls the concentration of CO in air. Therefore, the variation of CO during an annual cycle would also follow the yearly variation of boundary layer altitude. In winter, the surface temperature is low and so is the boundary layer altitude. Consequently, the ambient CO does not get dispersed to higher altitudes, remains close to the surface and a high ambient CO result. During other months, excluding the wet months (June-Sept), the surface temperature is high and so is

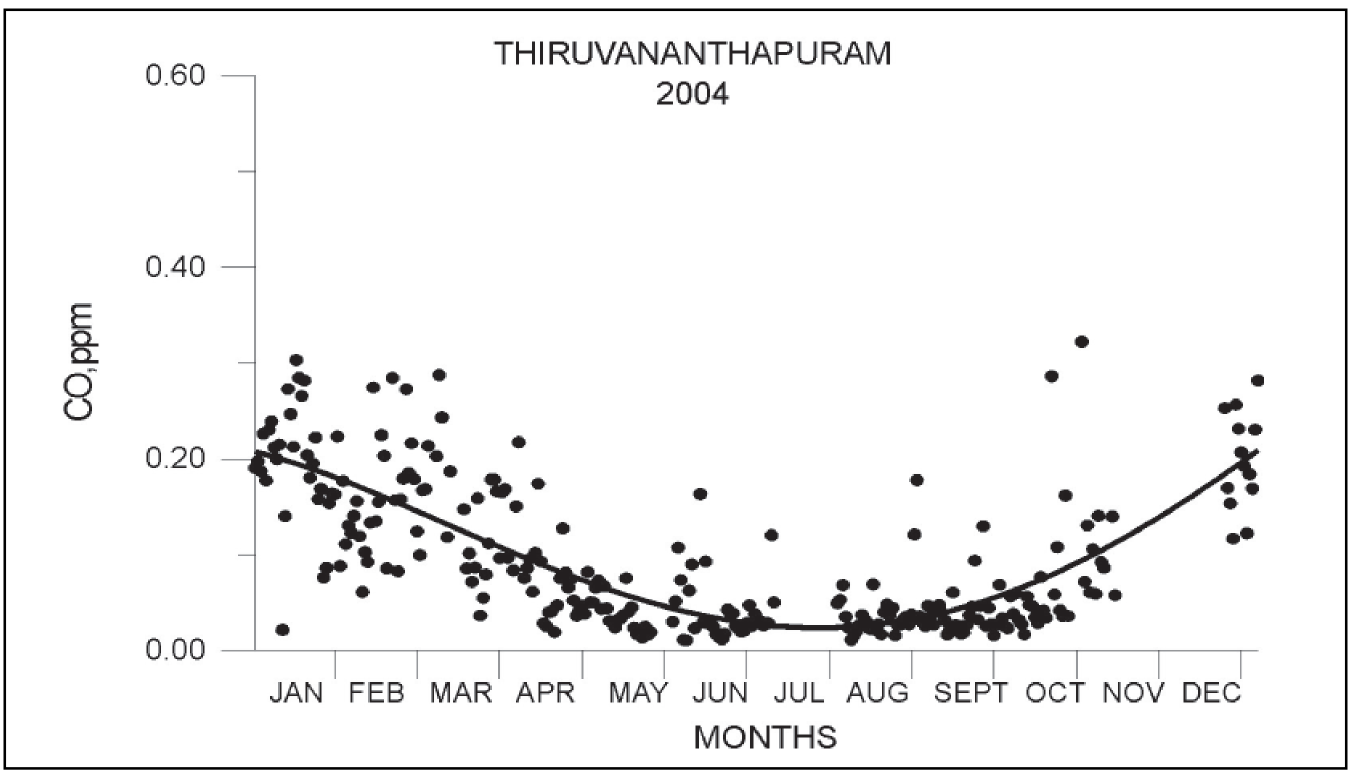

Figure 8: Annual variation in CO from continuous measurements at a tropical coastal site (Thiruvananthapuram) with the daily means to indicate CO deviations. The polynomial fit shows the gross annual pattern.

the boundary layer altitude. This will cause transport of CO to higher altitudes reducing the ambient CO. The annual variation of CO is shown in Figure 8. Low CO during monsoon could be associated with the transport of air mass due to monsoon systems. Measurements of CO in tropical or sub-tropical Asia show similar results (Pochanart, P et al 1999). The ambient CO is dependant on local production and circulation due to boundary layer and sea -land breeze effects.

CONCLUSIONS

The results of the study can be summarized as follows: The ambient CO levels at all the four sites with differing environments show them to be well below the NAAQS levels. The CO levels are the least at Palode (0.026 ppm), followed by Thiruvananthapuram (winter 0.352 ppm, summer 0.108 ppm and wet months 0.032 ppm), New Delhi (1.38 ppm) and Jaduguda (0.462 ppm).

- CO concentrations during weekdays were found to be higher than that during weekends at the three sites except at Jaduguda, establishing clearly the effect of traffic on the ambient air. At Jaduguda, the background CO values are high and the site of measurement is away from the highway, so that the effect of traffic exhaust gases modulating the ambient CO appear to have got masked.
- Diurnal pattern of CO obtained at Thiruvananthapuram, Palode, New Delhi and Jaduguda are similar, with only the daily mean of CO or in other words the amplitude of the diurnal pattern differing from site to site.
- Seasonal variation in CO is obtained for Thiruvananthapuram as the observations exceed an year. The seasonal high in CO is observed in winter, followed by a moderate value in summer and low in the wet season. This seasonal pattern in CO is similar to the results of the studies on regional scale pollution with respect CO reported for the tropics.

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