CARBON MONOXIDE CONCENTRATION IN A STREET CANYON OF BUENOS AIRES CITY (ARGENTINA)

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Abstract. The analysis of three years of 8-h CO concentration values registered in a deep street canyon downtown shows high frequency of values that exceed WHO health protection guidelines. An inverse relationship between opposing percentiles of the distributions of CO concentrations and mean wind speed could be found. Data also showed a variation of mean CO values with prevailing wind direction. The averaged concentration value obtained when the sampler probe is on the leeward side is lower than the obtained when it is on the windward wall. A preliminary explanation of this feature may be related to the advection of polluted air from a high traffic density area nearby.

Keywords. Street canyon; Air quality monitoring; Urban air pollution; Carbon monoxide

1. Introduction

Buenos Aires City is situated on a flat terrain, it has an extension of 200 km² and a population of three millions inhabitants. In Buenos Aires there are usually three millions vehicles, one of them comes to the city from the surroundings during working hours. Carbon monoxide (CO) is a product of incomplete combustion of carbon and its compounds. Gasoline powered motor vehicles are the major sources of carbon monoxide (CO) in urban atmosphere (Onursal and Gautam., 1997). This pollutant is a colourless, odourless and tasteless gas slightly lighter than air. It is considered a dangerous asphyxiant because it combines strongly with haemoglobin and reduces blood's ability to carry oxygen to cell tissues. Carbon monoxide air concentrations are measured in a highly populated area of Buenos Aires City with intense activity during working hours. Measurements are done by an automated continuous nondisperse infrared monitoring system. The available CO data include three years (1994-1996) of 8-h average concentration from 8a.m. to 4p.m. Hourly wind speed and wind direction are measured at a meteorological station of the National Weather Service located in the city. In this paper, we study the variation of 8-h CO concentrations with mean wind speed and prevailing wind direction considering the characteristics of the street canyon and of the monitoring site neighbourhood.

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2. Sampling site

The sampling point of CO concentrations is located on the West side of a North-South street (see Figure 1). The street canyon is straight, 9 m width and 100 m length approximately. The sampler is situated outside a building near midblock and at 6m height above the ground. The building where the sampler is located is 13m high. The buildings on the West side of the street are of about 18-20 m high. In front of the sampler location there is a building of 6m high but the height of other buildings on the East side is 16-18 m. The buildings in the area situated West and Northwest from the sampler are taller than the buildings of the East and Southeast area. Crossing the Northern intersection there is a wide square of approximately 30000m² (Lavalle Square).

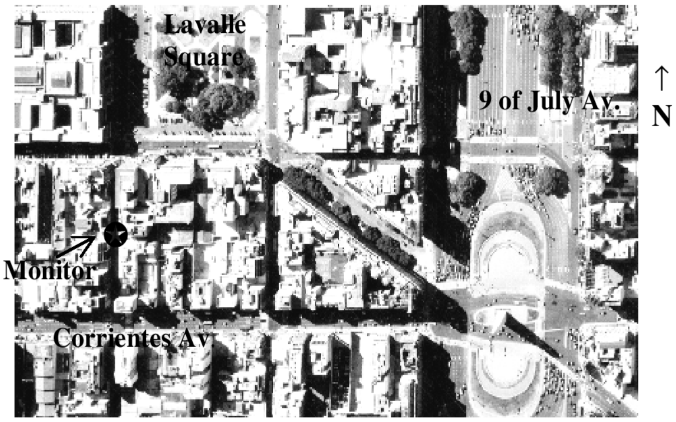

Figure 1. Sampling site and its surroundings

3. Data analysis

3.1. INTRODUCTION

In a recent study, Mazzeo and Venegas (1998) obtained that 8-h average concentration of CO observed at downtown during 1994-1996 could reach 19.2 ppm and the mean value of these data was 9.3 ppm. The cumulative percent curve on Figure 2 shows that 57% of the 8-h CO values were greater than 9 ppm (Air Quality Standard for CO, for an 8-h averaging period, according to the World Health Organisation and the United States Environmental Protection Agency, Murley, 1991).

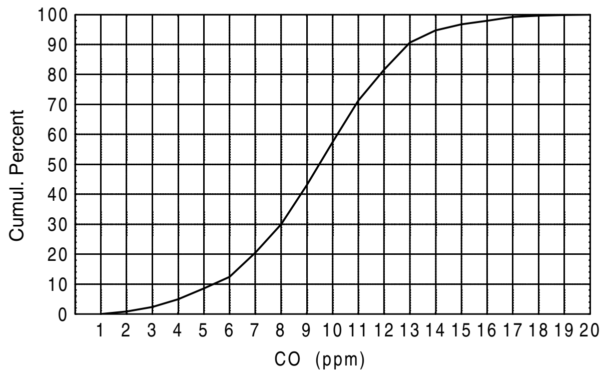

Figure 2. Cumulative percent frequency of 8-h CO

Figure 3 illustrates the relative frequency of 8-h average concentrations that exceeded 9 ppm during each month. The highest frequency (92.3%) of concentrations greater than 9 ppm was observed during October. In January (during summer vacations) 7.6% of the cases exceeded the limit of 9 ppm.

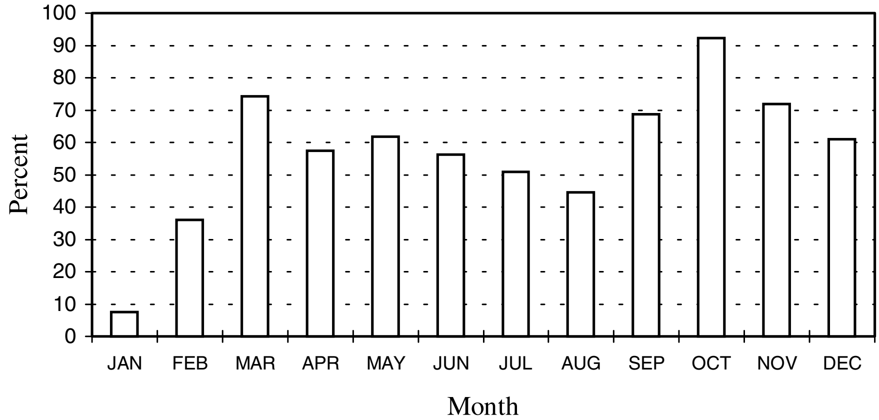

Figure 3. Relative frequency of 8-h CO greater than 9 ppm.

In order to consider no variation in emission rate, in this paper we analysed the 8-h average CO concentration values observed during working days only. Little variation of the mean 8-h CO value from Monday to Friday was found. Total traffic flow from 8a.m. to 4p.m. can be considered the same during working days. January and February data were not included in the analysis because some people were on summer holidays during these months. The data were grouped in the following way: autumn (March, April, May); winter (June, July , August) and spring (September, October, November). December was also excluded. Finally, 555 values were included in the analysis. The mean value of this data set was 10.2 ppm.

3.2. CO CONCENTRATION AND MEAN WIND SPEED

The dependence of observed 8-h concentrations on corresponding mean wind speed was not clear, as can be seen in Figure 4.

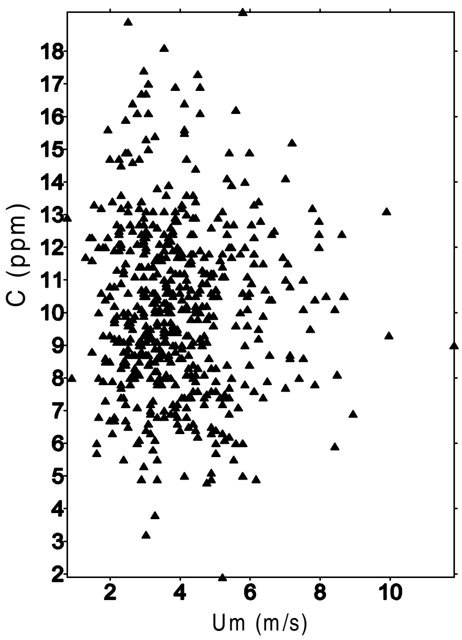

Figure 4. Variation of 8-h CO concentration with mean wind speed (Um)

Following Simpson et al. (1985) we studied the relationship between opposing percentiles of the distributions of 8-h CO concentration and mean wind speed. Previous studies (Daly and Steele, 1975, 1976; Simpson at al., 1983) have found that a simple relationship of the form $C = K\ (Um)^{-1}$ would appear to exist because of the high correlation between percentiles of mean wind speed (Um) and air pollution concentrations (C) at several sites. Simpson et al. (1983) have shown that C value corresponding to p-percentile (C_p) and mean wind speed value corresponding to (100 - p)-percentile ($Um_{(100-p)}$) are related by: $K=[C_p.Um_{(100-p)}]$. The values of K calculated from the cumulative distributions for 8-h CO data and mean wind speed data are shown in Figure 5. The mean value of K is Km= 6.76ppm.m.$s^{-1}$and its standard deviation is σ =3.73ppm.m.s^{-1}.

Figure 5 shows that for 15% ≤ p ≤ 80% the values of K are within the interval (Km ± σ). These results show that the expression $C_p = K (Um_{(100-p)})^{-1}$ is a good representation of the relationship between opposing percentile-values in the statistical distributions for 8-h CO monitored in the canyon and mean wind speed, for the 15- to 80- percentile range. The linear regression fitting in Figure 5 is given by the expression K = 43.56 - 0.13 p (K is expressed in [ppm m s^{-1}] and p is expressed in [%]), with a coefficient of determination (r^2) of 0.964.

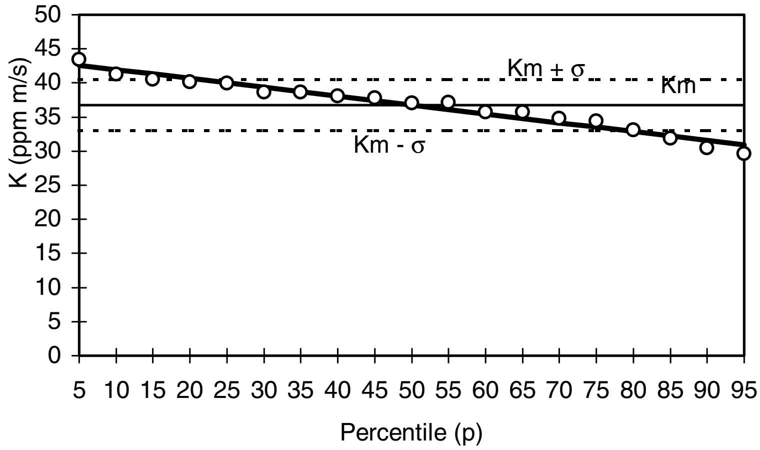

Figure 5. Values of $K = C_p.Um_{(100-p)}$. Thin solid line indicates mean value (Km); dashed lines (Km ± σ); thick solid line is the calculated regression line.

3.3. CO CONCENTRATION AND PREVAILING WIND DIRECTION

The frequency of 8-h CO concentrations that exceeded 9 ppm was: 65.1% in autumn, 54.3% in winter and 77% in spring. The mean value for each season was: 10.0ppm (autumn), 9.8 ppm (winter) and 10.7 ppm (spring). Wind roses of the same period showed that during autumn and spring winds from NE, E and SE were very frequent. During winter the frequency of SW, W and NW winds increased. To study the variation of mean 8-h CO concentration with wind direction, we considered the cases with more than four hours of wind blowing from a given sector. Only these cases had a corresponding prevailing wind direction. Figure 6 shows the mean CO concentration calculated for prevailing wind directions grouped every 30° degrees. It can be seen a variation of mean 8-h CO concentrations with wind direction. Lower mean concentration values occurred when prevailing wind direction was from West sector. In these cases, the building where the sampler is located may affect the observations. Higher mean concentration values were observed when prevailing wind direction was from sector between E and S. The frequency of 8-h CO concentrations greater than 9 ppm was more than 80% with prevailing wind direction from this sector.

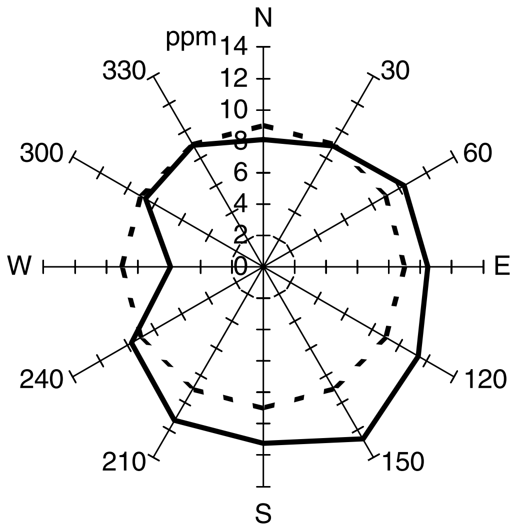

Figure 6. Variation of mean 8-h CO concentrations (ppm) with prevailing wind direction for working days (solid line). Dashed line indicates 9 ppm.

This deep and narrow street canyon has two lanes of one-way traffic. Assuming a classic vortex recirculation inside the canyon, under westerly winds it can be expected that the vehicle emissions are transported to the leeward canyon wall, towards the sampler. Only the effect of a classic recirculation pattern would not be able to explain the distribution of averaged concentration with wind direction showed in Figure 6. The averaged value obtained when the sampler probe is on the leeward side is lower than the obtained when it is on the windward wall. Simultaneous measurements of CO concentrations on both sides of the street canyon are needed to determine whether this pattern occur and how often.

Two major avenues are located S and E from the sampler. The first one is Corrientes Avenue with 6 lanes (24 m wide) and the second is 9 of July Avenue (the widest avenue of the City) with 20 lanes (133 m wide) at two blocks E from the sampling point (see Figure 1). There is a high traffic density in both avenues during working hours. The high mean values of 8-h CO obtained for prevailing wind direction within E→ S sector, may show that these cases can be affected by a greater advection of polluted air than the cases with prevailing wind from the opposite sector. There is a low building opposite the sampler site. Through this narrow passage the polluted air from SE, E can easily penetrate and be caught by the sampler probe and thus influence substantially measurement. The advection of polluted air from the West towards the sampling point could be hindered because of the presence of tall buildings and narrow streets at W and NW. On the other hand, Northern winds advect less polluted air from Lavalle Square to the sampler.

In addition, sometimes small-scale circulations inside the street-canyon might also be responsible of the high concentration values observed on the windward side. According to some studies (Theodoridis and Moussiopoulos, 1999; Scaperdas and Colvile, 1999) the flow patterns inside a deep street canyon (street width/ building height = 0.5) may lead to high concentration values on the windward side building. In a deep canyon two counterrotating vortices can be formed. A primary vortex covering the top 2/3 of the canyon region and a counter rotating vortex in the bottom. The opposite rotation of the two vortices leads to a wind direction at street level being the same as the wind at roof top level.

In the canyon considered in this paper, dense traffic may induce strong momentum and turbulence in the carriageway so small-scale vortex may have very little chance to form. Additional field measurements of CO concentrations and air flow parameters are needed to study the presence of a small-scale vortex at the bottom of this canyon and its effect on concentration distributions at windward and leeward canyon walls.

4. Summary

In this paper we analysed three years of 8-h (8 a.m. to 4 p.m.) CO values registered at a sampler point located at 6m height in a deep street canyon. Only working days observations were considered. These cases had a mean value of 10.2 ppm. and showed high frequency of 8-h CO values greater than 9ppm. Dependence of 8-h CO on mean wind speed was not clear but data showed an inverse relationship between opposing percentiles of the distributions of concentration and mean wind speed. Also a variation with prevailing wind direction could be observed. Considering the two main avenues located upwind in these cases, the advection of polluted air from an area with high traffic density seems to be important. Further studies on local recirculations inside this canyon are needed to evaluate the relative contribution of different scale motions to high concentration values.

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