Study of Tropospheric Ozone in São Paulo Metropolitan Region

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ABSTRACT

Ozone is the most serious air pollutant in São Paulo Metropolitan Region (SPMR), Brazil, a region with more than 17 million inhabitants and about 6 million registered vehicles. In 2001, the State of São Paulo ozone standard (82 ppb for 1 hour) exceeded 22% of the days, and for several times exceeded the attention level of 102 ppb. The maximum hourly ozone concentrations observed in this year was180 ppb.

The aim of this paper is to present an investigative study about the tropospheric ozone in SPMR. Ozone concentrations data were gathered by the Air Quality Monitoring Stations Network operated by the State of São Paulo Environmental Agency (CETESB), from 1997 to 2001.

The temporal distributions show that ozone exceedances last from August to March. The typical duration of high ozone concentrations is short, most of them never lasting more than one or two hours per day, usually between 1300 and 1600 and there is no day-of-week dependence. The ozone exceedances occur in warm days and with relative humidity less than 60%.

INTRODUCTION

The increasing levels of the surface ozone in metropolitan areas have been the subject of concern for many environmental institutions all over the world[1-4].

Ozone, although beneficial in the stratosphere, where it forms a protective layer against the harmful effects of the sun's ultraviolet radiation, has toxic effects to human health and plant life near the earth's surface [1, 3,5].

In São Paulo Metropolitan Region (SPMR) ozone is the most serious air pollutant. According to the recent report of the State of São Paulo Environmental Agency (CETESB)[6], in 2001 the State of São Paulo standard (82 ppb for 1 hour) was exceeded 78 days, and for several times exceeded the value of 102 ppb (attention level).

SPMR is Brazil's main economic center and one of the world's biggest human conglomerates with more than 17.8 million inhabitants (about 10% of the nation's population). Nearly 70% of this population lives in São Paulo City. The remaining population is distributed among other cities in the region. Presently the SPMR is the largest industrial zone in Brazil.

The main sources of air pollution in the SPMR are vehicles, followed by industrial processes, waste burnings and fuel storage.

Nowadays the fleet in the SPMR is composed of 6 million registered vehicles. It is estimated that 90% of the anthropogenic emissions elapse from this enormous fleet. Brazil is the only country that has a significant fleet of light duty vehicles using alcohol (ethanol) as fuel. Furthermore ethanol is added to gasoline with the present blends being 22% ethanol and 78% gasoline.

The SPMR is located on the Atlantic plateau on the Tropic of Capricorn, 80 km from the seaboard, an area of about 8,000 km^2, in the southeastern region of the country. The urban area of the region is 5,000 km^2 and is 700m to 900m above sea level with ridges towering up to 1200m. The general topography is rather complex and the air flow is strongly influenced by local conditions.

Ozone concentrations, as well as further atmospheric pollutants, are highly influenced by meteorological conditions, which determine the ozone concentrations for one particular episode, such as for the medium concentrations associated with the climatological conditions. Thus, identification of the main factors that affect weather and climate in the SPMR is essential to understand ozone behavior.

In terms of climate, SPMR can be divided in two predominant seasons: the wet one, that normally comprehends the period from October to April, and another one, dryer, that goes from May to September. The wet season is centralized in summer, when rising of medium temperatures and large ventilation occur. At this time, the continental heating in association with the tropical convection, extra tropical systems (cold front) and continental instability area, promote the increasing of cloudiness and precipitation.

During the dry season, the climate is determined by the presence of high pressure systems and by the quick passage of cold fronts coming from the south of the continent, being characterized not only by the precipitation decrease, but also by the fall of temperatures, calm occurrences and periods of large atmospheric stability, promoting unfavorable conditions to the dispersion of pollutants present in the atmosphere. Another characteristic during the dry period is the low relative humidity in some days, achieving values of 15%.

The purpose of this report is to provide an investigative study about the tropospheric ozone in the São Paulo Metropolitan Region to understand the formation and dispersion processes, giving support to regulatory and forecast programs.

DATA SOURCES

The data used in this work originates from 8 AQMS stations in the SPMR that have ozone monitors. The locations of the monitoring stations considered in this work are shown in a simplified map in Figure 1. All the data used refer to the period from 1997 to 2001.

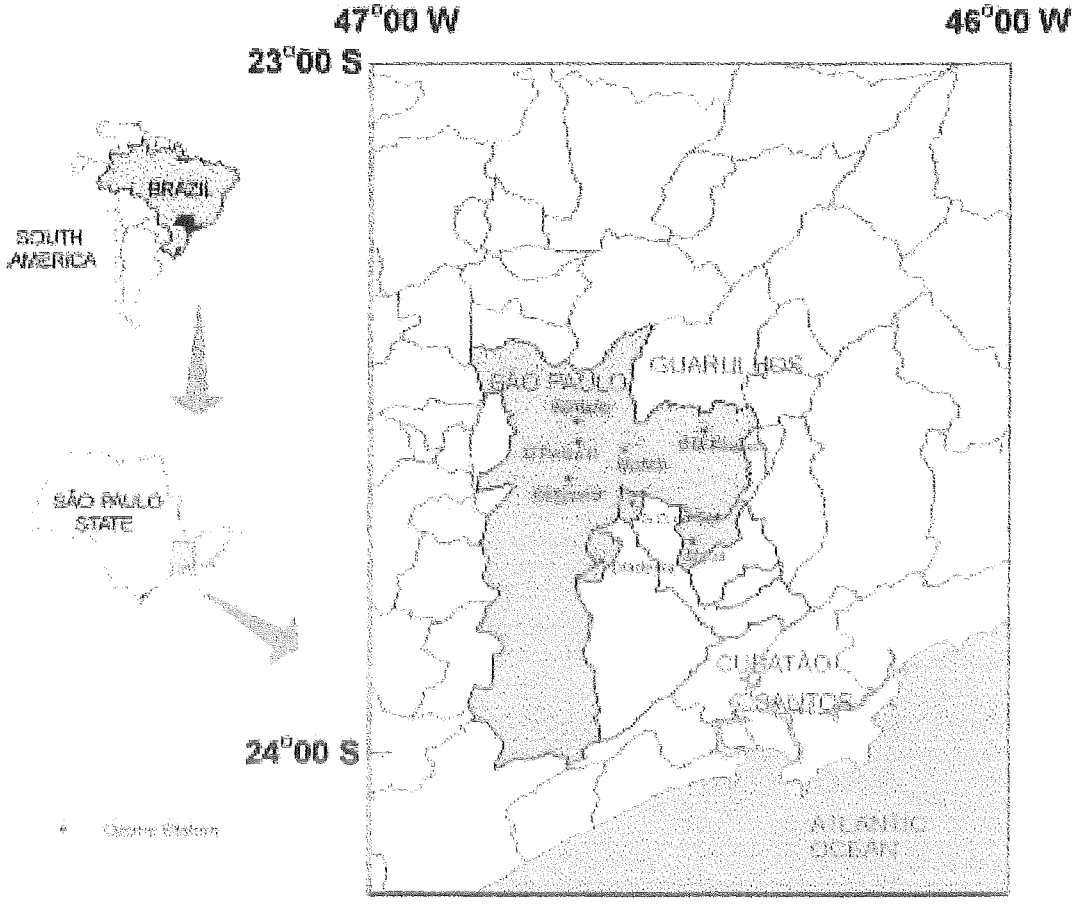


Figure 1 – Location of Ozone Stations in the SPMR.

The spatial scale of representativeness and the measured parameters of the stations used in this work are present in Table 1.

Table 1. Spatial scale of representativeness and monitors of SPMR stations used in this study.

STATION	**O_3**	**NO_x**	**NMHC**	**Meteorological Parameters**	**Scale of representativeness**
P. D. Pedro II	X	X	X	X	Micro
Moóca	X			X	Neighborhood
Ibirapuera	X	X		X	Urban
S.Caetano S.	X	X	X	X	Middle
Diadema	X				Neighborhood
Santana	X			X	Neighborhood
S. Miguel P.	X	X		X	Neighborhood
Mauá	X	X			Neighborhood

Levels of pollutants concentration measured in a determined monitoring station, occurred due to several factors related to the location of this station, and the emission sources that influence it.

Among the factors that may influence the monitoring results, it is possible to remark the proximity of roadways, the use and occupation of the soil in near areas, etc. All these factors determine the representative scale of the station that should be considered concerning the monitoring objectives.

In the case of the O_3 monitoring stations, these must not be located too close to roadways and trees because these tend to reduce the measured concentration.

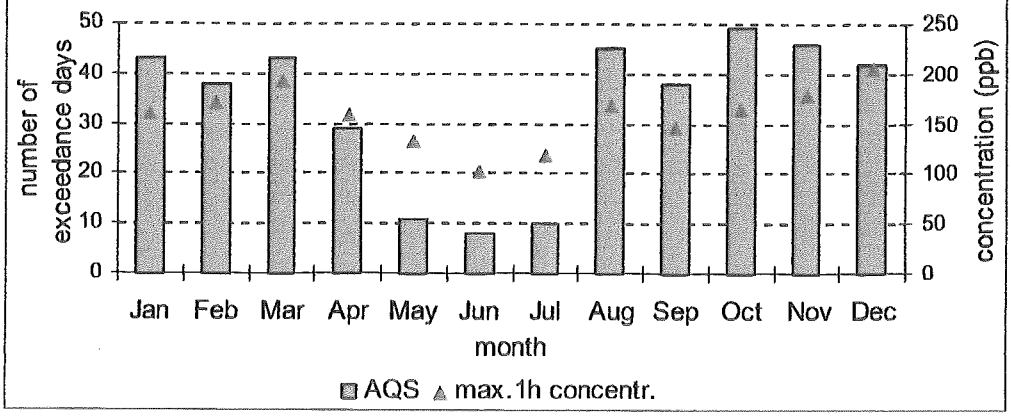
Among the O_3 monitoring stations in SPMR, the Ibirapuera station located in the Ibirapuera Park, situated in the central region of the urban area, is the station with the highest number of O_3 exceedance, followed by Mauá Station, located in the southwest of the SPMR.

TEMPORAL DISTRIBUTION OF OZONE

The number of ozone exceedance days by month for the Primary Air Quality Standard (PAQS) at the SPMR, from 1997 to 2001, is presented in Figure 2. Most of the episodes occur between the end of the winter and the beginning of summer.

High temperature and the intensity of solar radiation lead to the ozone formation in the atmosphere. That explains the reduction in the number of episodes during the winter observed in Figure 2.

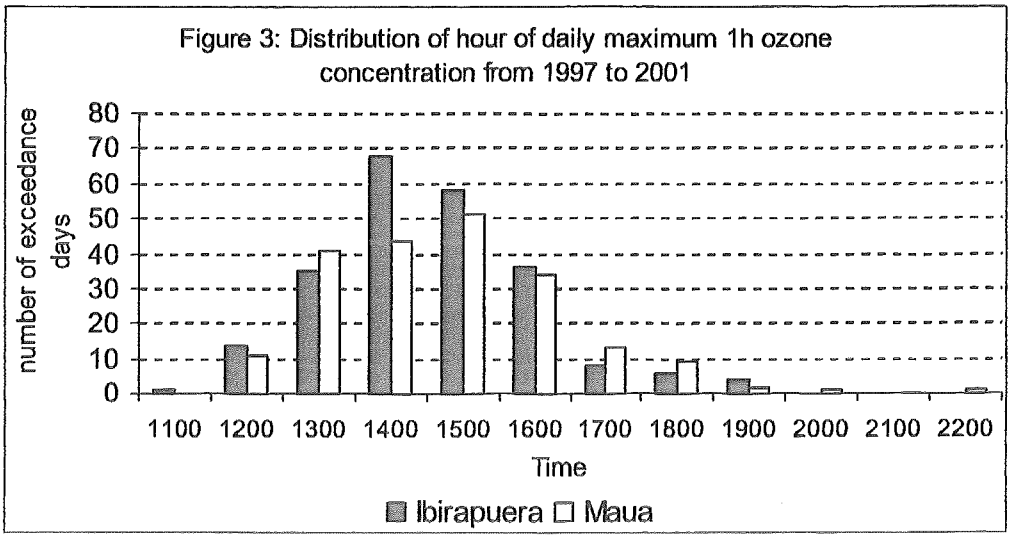
Figure 2: Number of exceedance days of the ozone AQS by month for SPMR from 1997 to 2001



Nevertheless, comparing the number of ozone episodes by month of the year, according to Figure 2, it is observed that the higher frequency does not happen necessarily in the summer months with maximum UV intensity as observed in the northern hemisphere. Probably this phenomenon is related to the increasing of cloudiness that occurs in SPMR during the summer, decreasing the sunlight intensity and consequently decreasing the surface ozone formation.

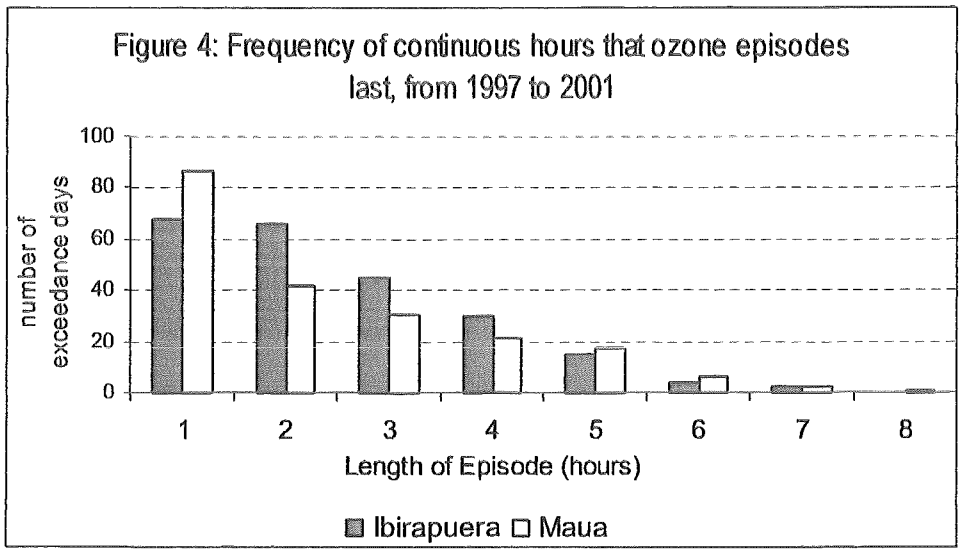
It should be pointed out that even in days of ozone exceedance during the summer, it was observed large amounts of convective rains soon after the occurrence of maximum ozone concentration.

Figure 3 shows the distribution of hour of daily maximum 1-hr O_3 concentrations at Mauá and Ibirapuera stations for O_3 standard exceedance days. It is observed on this figure that most of the episodes occur between 1300 and 1600 local time, with higher incidence of maximum concentrations at 1400 in Ibirapuera and 1500 in Mauá. This different time occurrence could be caused due to differences in emissions and transport conditions across the region.

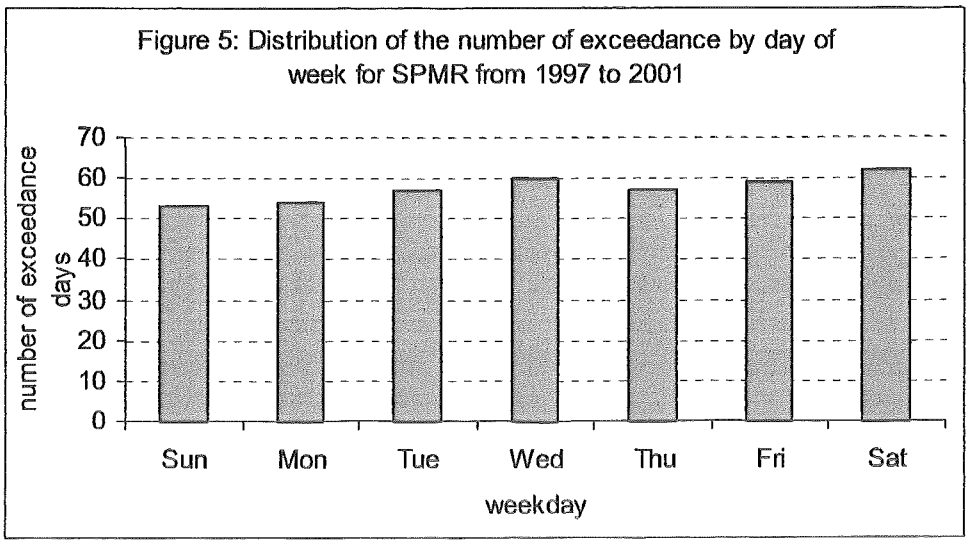


The number of continuous hours with high ozone concentration at Mauá and Ibirapuera stations are presented in Figure 4. The typical duration of high ozone episodes is short, most of the ozone episodes never lasting more than one or two hours, on both sites. Episodes have been observed, though, with seven or eight hours of consecutive standard exceedance.

However, high variations in maximum ozone concentrations are observed for one day to another and the occurrence of ozone exceedance in consecutive days is not frequent.



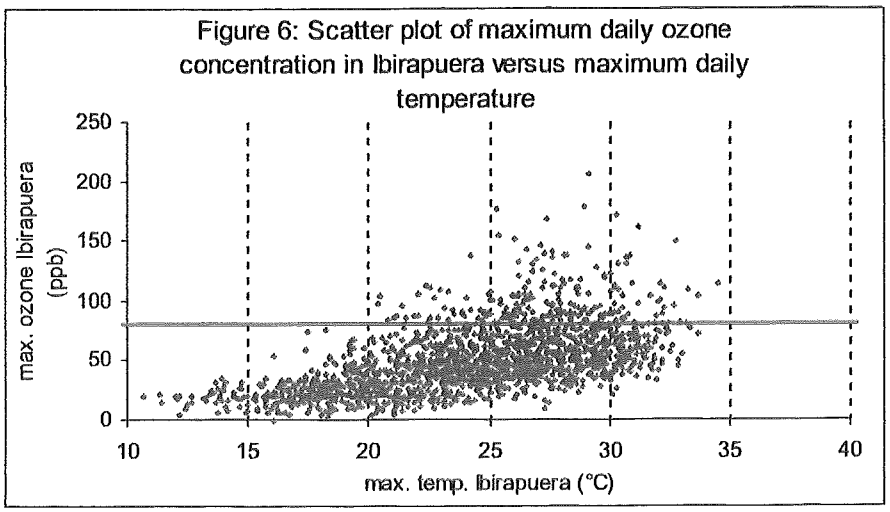
The distribution of the number of ozone exceedances by day of the week is shown in Figure 5. It is observed that the occurrence of episodes does not depend on day of the week because, even on weekends, when there is a reduction of precursors emission due to a decrease in the traffic, ozone exceedance takes place.

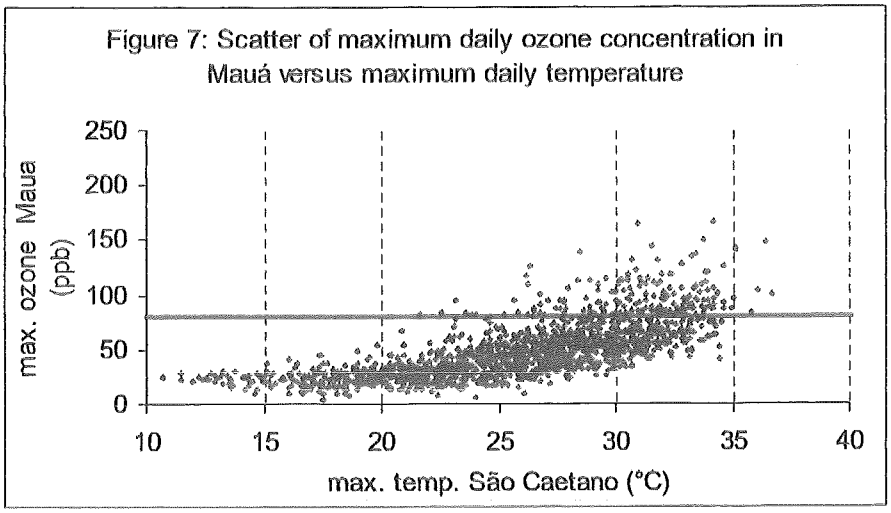


The high number of episodes on days with less traffic is not a phenomenon of easy interpretation because several variables are involved. Although important factors must be considered, the presence of precursors, even on weekends, could be enough for the ozone formation, and its formation is being determined mainly by the present meteorological conditions.

METEOROLOGICAL PARAMETERS

Ambient air temperature is a factor that influences the photochemical reaction of the ozone formation in the troposphere. Figures 6 and 7 show a scatter plot of maximum ozone concentration as a function of maximum daily temperature[1,7] from 1997 to 2001, at Ibirapuera and Mauá stations, respectively. The red line means the value of Air Quality Standard – AQS to the ozone (82ppb).





Notice that at Mauá station there are no temperature and relative humidity data, so it was used dataset from São Caetano do Sul station, the nearest meteorological station.

It is observed in Figure 6 that in Ibirapuera most of the ozone high concentrations occur when the temperature is higher than 25°C, and in Mauá most of them occur when the temperature is higher than 28°C. Notice that most of the episodes occur on warm days. However, particularly in Ibirapuera, it happens also when temperature is lower than 25°C.

Although there are days with high temperatures, the occurrence of high ozone concentrations is not necessarily observed, once other meteorological factors also influence the process of photochemical reactions.

Figures 8 and 9 present scatter plot of daily maximum ozone concentration versus the minimum daily relative humidity in Ibirapuera and Mauá, respectively, from 1997 to 2001.

Figure 8: Scatter plot of maximum daily ozone concentration in Ibirapuera versus minimum relative humidity

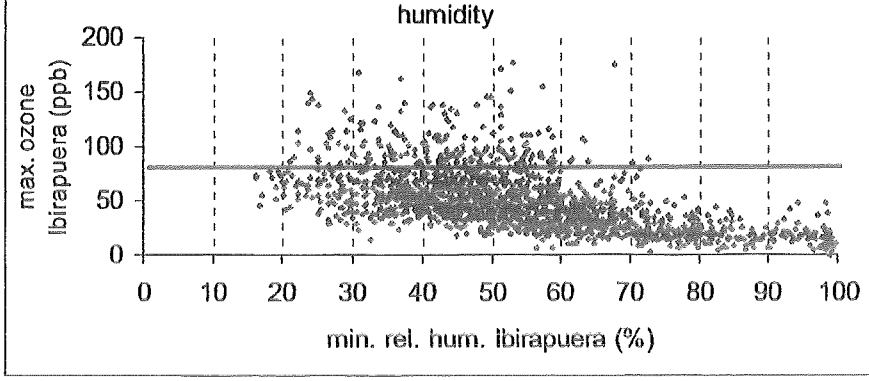
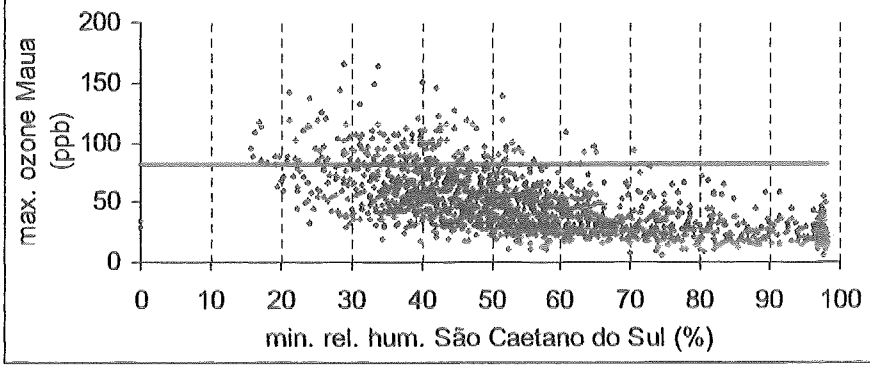


Figure 9: Scatter plot of maximum daily ozone concentration in Mauá versus minimum relative humidity



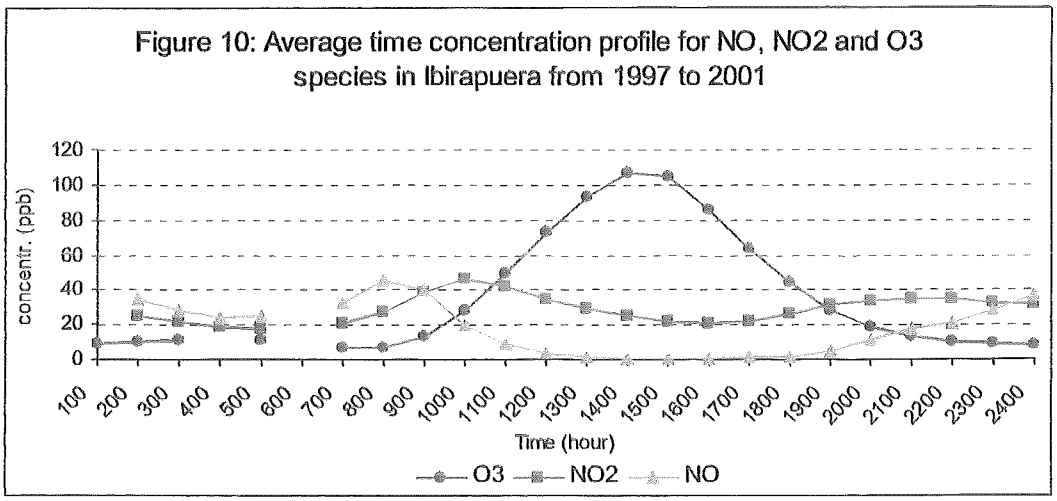
It is observed that most of the ozone standard exceedance occurs with relative humidity less than 60% on both sites, although in Mauá exceedances are centralized on dryer days.

In Mauá, higher temperatures and lower relative humidity than Ibirapuera, observed on ozone exceedance days, usually occur due to the predominance of warm and dry winds coming from the northwest.

In terms of daily solar global radiation[7], it is observed that ozone exceedance normally occurred on days with solar global radiation values above 600 W/m^2.

OZONE PRECURSOR EMISSIONS

Figure 10 shows the average time concentration profile for NO, NO_2 and O_3 species in Ibirapuera. It is observed that the maximum NO value typically occurs around 0800, coinciding with the rush hour. In the morning the NO concentration decreases, being followed by the NO_2 increase, which maximum concentration occurring around 1000 local time.



Ozone concentration, in general, has a very similar pattern at Ibirapuera and Mauá stations. However, considering the total number of exceedance days on these sites, only 20% of the exceedance days occurred on both sites on the same day. This may also occur due to spatial variation in emissions and meteorological conditions.

Mauá has the predominance of the wind from the north, changing between the NE and NW, with high wind speeds occurring from the NW during the ozone exceedance days. On exceedance days in Ibirapuera, it is noticed a convergent circulation with weak winds to the central region of urban area, where this site is located.

CONCLUSIONS

In terms of temporal distribution of ozone in the SPMR, high ozone episodes last from August to March. The highest frequency does not happen in the summer probably by the increase of nebulosity that occurs on these months. The typical duration of high

ozone concentrations is short, most of them never lasting more than one or two hours per day, usually between 1300 and 1600 local time and there is no day-of-week dependence.

In Ibirapuera, most ozone exceedance has occurred with maximum temperatures between 25 and 30°C and relative humidity less than 60%. In Mauá, higher temperatures (>28°C) and lower relative humidity occur due to the predominance of warm and dry winds from the northwest. Regarding the global solar radiation, it was observed that the standard exceedances occur generally on days with values above 600 W/m^2.

Ozone concentrations at the Ibirapuera and Mauá stations from 1997 to 2001, in general, were similar, with no occurrence of ozone exceedances on consecutive days. Nevertheless, from the total days of episodes that occurred on those stations, only 20% of the exceedance days occurred on both sites on the same day. That probably happens due to the different geographic location of those stations in the SPMR, being influenced by different transport conditions.

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