Influence of precipitation on concentration of PM10 and TSP in a city of the southeast region of Brazil

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1. Introduction

Limeira is an important city of the Brazil southeast region, with industrial and agricultural activities. In southeastern region of Brazil, the dispersion of pollutants can be limited by the large area of mountains. Heavy vehicles and industries affect unfavorably the air quality, with sources of aerosols and gases released into the atmosphere. These sources can influence in the concentrations of air pollutants near the surface, varying depending on the weather (ALLEN et al., 2009).

The particulate matter (PM), one of the pollutants present in the air, has been investigated as a function of its size, the smaller the diameter, the deeper will be found in the respiratory system and, depending on the severity, can lead to death FRIEDLANDER, 2000).

In Brazil, the MP10 value is 150 µg/m³ for primary and secondary standards (BRASIL, 1990). The values for TSP are 240 µg/m³ for primary and 150 µg/m³ for secondary standards. These standards are for a 24-hour sampling. The National Environment Agency (CONAMA) established as well as the criteria of acute states of air pollution attention (250 µg/m³), warning (420 µg/m³) and emergency (500 µg/m³), situations characterized by high concentrations over a given period.

The fraction of MP10 receives great importance due to factors such as its relation to health and the toxic elements that easily associate themselves the smaller particles moving over long distances (GOOSSENS and BUCK, 2011).

The PTS is also classified as MP and it is an aerodynamic diameter less than 50 µm. These inhalable particles have a part that can cause health problems, and another part that affects quality of life, interfering with the aesthetic conditions of the environment (CETESB, 2012).

Some weather conditions influence the dispersion of airborne particles: wind speed, rainfall, temperature, relative humidity and pressure (RIVERA and GUARIN, 2009; DENG et al., 2011). In the summer in Brazil, more specifically in the southeast, the rainfall and consequently the moisture are more constant, contributing to reducing the MP10, however in winter the air is drier.

According CHOI et al. (2008), usually in dry seasons and with low wind, PM10 concentrations tend to be high, it is during this period that are observed more frequent respiratory problems, unlike when it is rainy or windy seasons significant levels tend decreasing.

The study of AKYUS and ÇABUK (2009) made in Turkey revealed that precipitation and atmospheric pressure were the factors that interfere in the least concentration of particulate matter, but the temperature, local temperature and wind conditions were most affected at concentrations .

ZIBERT and PRAZNIKAR (2012) observed in their study in Slovenia, the concentration of PM10 was reduced due to rainfall intensity and wind speed, but also noted that not only meteorological factors can influence air quality. The days that are carried out collections can be variation of concentration: on weekends, holidays or vacation periods.

SFETSOS and VLACHOGIANNIS (2010) used the Pearson correlation to assess the influence of meteorological parameters at concentrations of PM10 in Athens in Greece, where it was possible to verify the correlation between meteorological and pollutant concentration.

The Person linear correlation, represented by "r", assesses the correlation between two continuous variables. The values range from -1.00 to +1.00, which indicates how close the line are the values (perfect correlation or moderate) or are dispersed as (weak correlation or lack of relationship) (STEVENSON, 2001).
The closer the “r” values calculated by Equation 1 are those limits, the greater the degree of correlation. The positive and negative signs indicate that this correlation is positive (when the variable x increases, also increases the variable y) or negative (when the variable x increases and decreases the variable y) if r = 0, there is no linear correlation between variables (PAGANO and GAUVREAU, 2006).

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x}).(y_i-\bar{y})}{\sqrt{\left[\sum_{i=1}^{n}(x_i-\bar{x})^2\right]\left[\sum_{i=1}^{n}(y_i-\bar{y})^2\right]}} \quad (1)$$

In this study we used the Action software that is able to correlate two independent variables, is a statistical package which can be used in conjunction with MS Excel. One of the methods that you can use this software is the Pearson correlation (PORTAL ACTION, 2012).

2. Materials and methods

2.1 Studies site

The city of Limeira located in the State of São Paulo has coordinated 22° South Latitude and 47° West Longitude (Figure 1), with an average elevation of 567 meters, the climate is subtropical, with characteristic dry winter and summer rainfall (EMBRAPA, 2012).

The city has 276,022 inhabitants (IBGE, 2012), covering an area of 581 km², with a population density of 475.08 inhabitants/km². The average annual rainfall is 1,000 mm, with an average temperature above 22°C (295 K).

Limeira stands out in the region because of the existence of more than one thousand industries, mainly electroplating. Some these industries are monitored, but there are still industries that are not regulated. The jewelry production process can emit large amounts of particulate matter, mainly when it does not make an efficient air pollution control.

The weather station, where the study was conducted, is located in the School of Technology - UNICAMP in city of Limeira.

2.2 Sampling

It was used the high-volume samplers for TSP and PM10. These equipments are installed in the weather station. Sampling of PM10 and TSP were performed in cycles of 24 hours, once every 6 days. The glass fiber filters were desiccator at 24 hours before and 24 hours after sampling to prevent humidity, in order not to jeopardize the final result. These filters are underwent gravimetric analysis, i.e., were weighed before and after collection.

The glass fiber filter of dimensions 20x25 cm square was choose for considered as a standard because it has features essential to a proper operation of collection, for example, its efficiency is greater than 99.9%. It has low reaction with the corrosive material, it is resistant to temperatures up to 813K and is also resistant to tensions, apart from not breaking easily with handling (ENERGÉTICA, 2012).

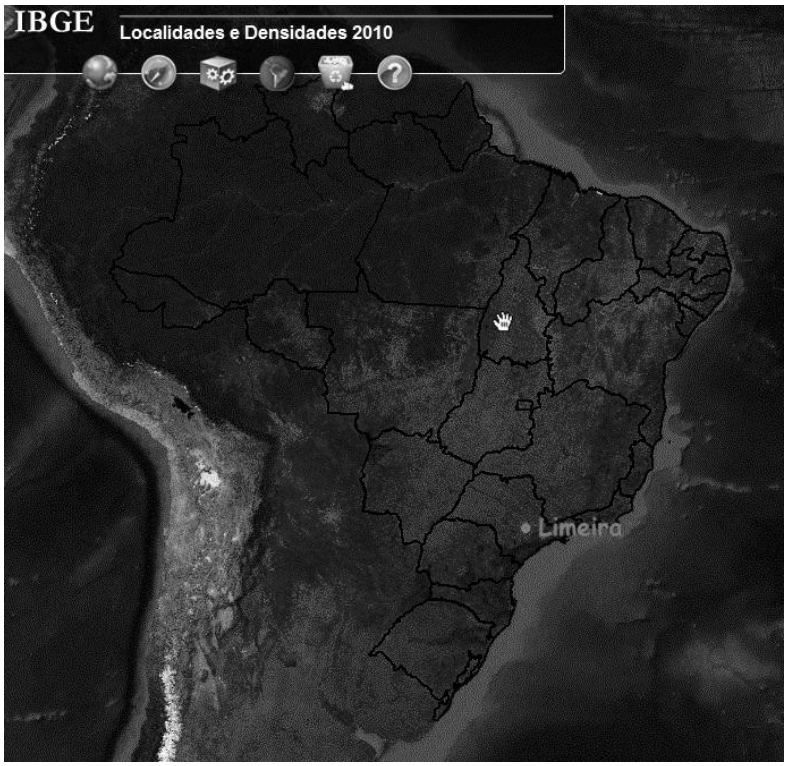

Figure *1*: Localization of city of Limeira in Brazil (Adapted from IBGE, 2012)

3. Results and discussion

Analysis of monthly samples of TSP and PM10, relating them with the rainfall that corresponds to the period from November 2010 to July 2012. Figure 2 shows the concentration data of TSP and PM10 in relation to rainfall, where we can observe that the concentration of TSP influence of rainfall, when there is rain occurrence of TSP concentration is lower, therefore, when it does not rain, the concentration TSP tends to increase.

Concentrations of TSP, mostly were within the established standards (150 $\mu g/m^3$), except for the months of July and August 2011, which can be explained by low rainfall or issues not yet identified.

Seasonality is directly related to the concentrations of pollutants in winter, where the relative humidity is lower the concentrations tend to be higher, unlike what happens in times of rain.

Also in Figure 2 can be argued that the rain contributes to the decreased concentration of PM10, as can be seen clearly in October 2011 and February 2012, where there was heavy rain and visible reduction of the pollutant.

In February 2012, even with the considerable rainfall, the concentration of PM10 is not reduced, this is a factor that must be observed, because this month there were not enough samples due to equipment failure.

In general, rainfall contributed favorably to the reduction of the concentration of PM10 and TSP in the study area, however it is interesting to note, through the statistical methodology used, how strong is this correlation. We first made the processing, we used the box-plot of concentrations in order to remove the outliers, i.e., the outliers that may interfere with Pearson correlation.

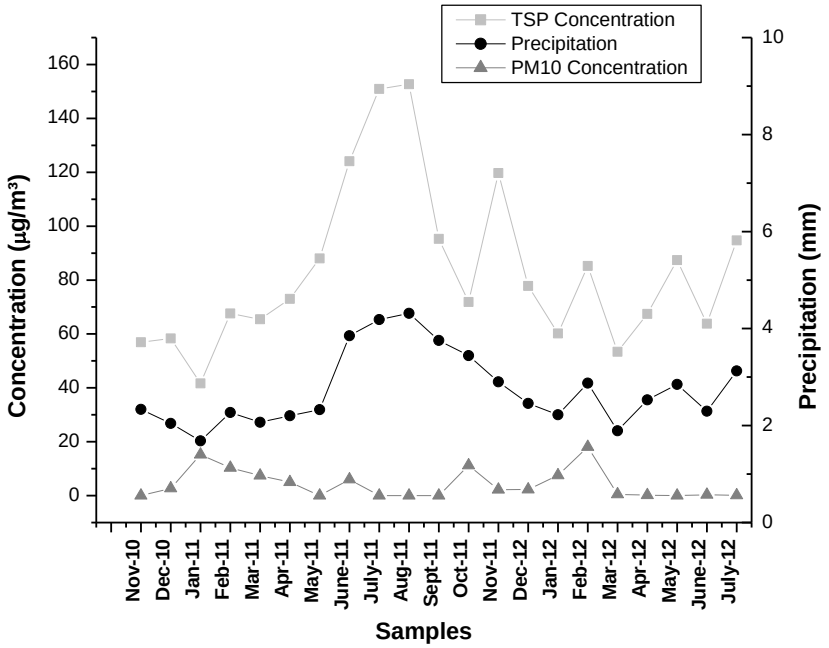

Figure *2*: Monthly averages values of PM10 and TSP concentration and precipitation.

Pearson and could be used to verify that the correlation of rainfall with the TSP and PM10 were weak and negative, as can be seen in Table 1.

Table 1: Pearson correlation of rainfall with TSP and PM10

	TSP	PM10
Rainfall	- 0,30266794	- 0,25463544

3. Results and discussion

The concentrations of TSP and PM10 are within the limits stipulated by current Brazilian law.

The rainfall, in higher incidences, contributes to lower concentrations of both pollutants, verifying that, in the days that do not occur rain the concentrations of pollutants were higher.

Through correlation can confirm that there was an influence of rainfall on PTS and PM10 because the raindrops efficiency have to clean the air and the higher the humidity in the environment, the harder it is for a particle resuspend.

Besides the rain, other factors may contribute to the increased concentration of particles, such as relative humidity, temperature, pressure and wind speed.

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