FINE PARTICULATE MATTER ($MP_{2.5}$) IN THE PARAÍBA VALLEY, 2010 -2011

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Abstract

The Paraíba Valley is a region which presents serious problems of air pollution, with intense industrial activity and surrounded by 4 big federal highways. Furthermore, is located between the two biggest urban polos in Brazil, São Paulo and Rio de Janeiro. Because of this, the Paraíba Valley presents intense traffic of heavy vehicles, mainly trucks that use diesel as fuel. Those character with the topography of this place, contribute for the high particulate matter concentration on this site. The samples were made up of 24 hours with Harvard Impactor, using polycarbonate membranes. Gravimetric analyses were performed with 1μg readability (MX5; Mettler-Toledo) in controlled environment (22 ± 2°C and 45 ± 3% relative humidity) for 24 h prior to weighing. In this study were observed that all these cities presented higher concentrations that exceeded the guidelines values by World Health Organization (WHO) of 10 μg m^{-3} (annual average). The day average was exceeded in 71 days in Cachoeira Paulista, 27 in Guaratinguetá, 92 in São José dos Campos and 60 in Taubaté. According to "Air Quality Guidelines: Global Update 2005" by WHO, the exposure to concentration of $PM_{2.5}$ greater than 25 μg m^{-3} (daily average) causes several effects on human healthy, for example, cardiovascular and respiratory diseases. Comparing dates of each month accumulated precipitation (dates of Taubaté. Source: INMET) with the month average concentrations of $PM_{2.5}$ in the analyzed period were perceived: in months which there were precipitation higher than 100mm (mainly summer months) the $PM_{2.5}$ concentration was less than 19 μg m^{-3}.

Key words: air pollution, fine particle matter, $PM_{2.5}$

Introduction

The particulate matter which aerodynamic size less or equal 2.5 μm ($PM_{2.5}$) is the most aggressive pollutant for human healthy - it is reaching deeper into the respiratory tract. The WHO established daily and annual standards of that pollutant: 25 μg m^{-3} for daily average and 10 μg m^{-3} for annual average (WHO, 2005). Overtaking on daily averages causes several effects on human healthy, for example, cardiovascular and respiratory diseases. Nevertheless, there is not air quality standard of $PM_{2.5}$ on Brazil, only there is of PM_{10} (particulate matter with aerodynamic size less than 10 μm and higher than 2.5 μm). But CETESB (Companhia Ambiental do Estado de São Paulo) monitors $PM_{2.5}$ in some sites in São Paulo state.

This study analyzed the $MP_{2.5}$ concentration variability in 4 cities of Paraíba Valley: Cachoeira Paulista, Guaratinguetá, São José dos Campos and Taubaté. In these cities the sampling periods were from August 2010 to December 2011; from October 2010 to February 2011 and from August to October 2011; from August 2010 to October 2011; from August 2010 to June 2011 and from August to October 2011, respectively.

Sampling site

The Paraíba Valley is a region situated between two megacities and the major economic centers of Brazil: São Paulo e Rio de Janeiro. Furthermore, it has intense industrial activity and is surrounded for 4 big federal highways. Because of all this, it presents intense traffic of heavy vehicles, mainly trucks which use diesel as fuel. Moreover, its topography is unfavorable to dispersion of pollutants. All those characters contribute to this place have high concentrations of particulate matter.

The Paraíba Valley is between Mar and Mantiqueira Saws, with altitude from 0 to 1628 m. To better illustrate the region under study, below are some information about it. The Figure 1 shows a satellite image of Paraíba Valley (Search: Google Maps). The marked in blue is the Dutra Highway and the cities under study are circled in red.

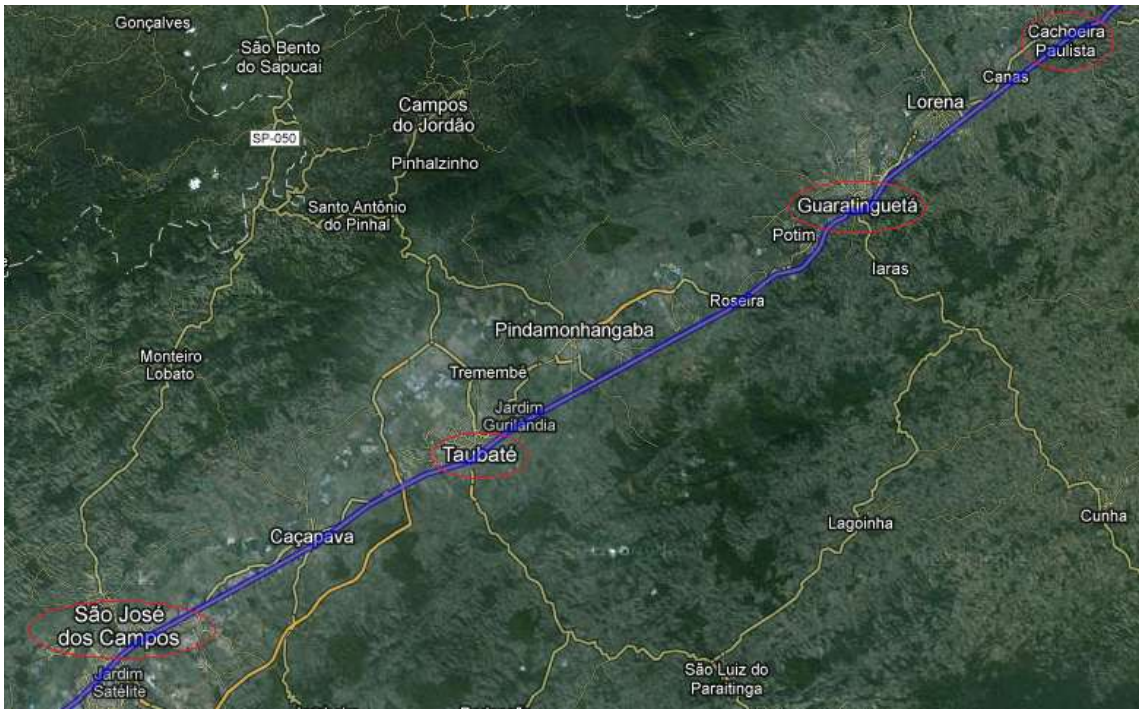

Figure 1: Satellite image of Paraíba Valley with Dutra Highway marked in blue and the cities under study are circled in red.

The main geographic characteristics about the 4 cities in study are presented on Table 1, and economic information on Table 2.

Table 1: Main geographic characteristics about Cachoeira Paulista, Guaratinguetá, São José dos Campos e Taubaté (Source: Explore Brasil: latitude and longitude; Brasil Channel: altitude and average anual temperature; IBGE: area).

City	Latitude	Longitude	Altitude (m)	Area (km²)	Average Annual Temperature (°C)
Cachoeira Paulista	22° 41' 15"S	45° 03' 45"W	521	287.99	27.6
Guaratinguetá	22° 48' 45"S	45° 11' 15"W	539	752.63	22
São J. Campos	23° 11' 15"S	45° 56' 15"W	650	1,099.41	23
Taubaté	23° 03' 45"S	45° 33' 45"W	580	624.88	24

Comparing the figure 1 with the table 1, it is possible see the variation of the coordinates (latitude and longitude) and that the average annual temperature is higher to Cachoeira Paulista (27.6ºC) because this is the city more northerly (latitude 22° 41' 15"S). São José dos Campos is the largest area (1,099.41 km²) and the highest altitude (650 m) of all the cities in this study and Cachoeira Paulista, the smallest area (287.99 km²) and the lowest altitude (521 m).

Table 2: The economic data of Cachoeira Paulista, Guaratinguetá, São José dos Campos and Taubaté, cities of Paraíba Valley (Source: IBGE, population dates from 2007, vehicles and GDP dates from 2010).

City	Population	Light Vehicles	Heavy Vehicles	Agriculture GDP[a]	Industry GDP[a]	Services GDP[a]
Cachoeira Paulista	30,091	8,675	926	11,504	44,768	294,298
Guaratinguetá	112,072	45,116	3,596	19,461	794,032	1,229,826
São J. Campos	629,921	289,303	23,289	40,930	10,652,608	10,128,652
Taubaté	278,686	141,989	11,256	37,553	4,167,929	3,717,308

a- The GDP is on accumulated value.

Observing the table 2, São José dos Campos is the largest population (629,921), the city with the largest number of vehicles - both light (289,303) and heavy (23,289) - and the highest GDP – to all, Agriculture (40,930), Industry (10,652,608) and Services (10,128,625) -, comparing with the other cities in study and Cachoeira Paulista, the smallest population (30,091) , the city with the smallest number of vehicles - both light (8,675) and heavy (926) - and the lowest GDP – to all, Agriculture (11,504), Industry (44,768) and Services (294,298).

Methodology

The samples were made up of 24 hours with Harvard Impactor, using polycarbonate membranes. Gravimetric analyses were performed with 1μg readability (MX5; Mettler-

Toledo, Columbus, OH, USA) in environment (22 ± 2°C and 45 ± 3% relative humidity) for 24 h prior to weighing.

Results and discussions

The Table 3 shows the sampling period, sample number and mass concentration of $PM_{2.5}$ of our study.

Table 3: Paraiba Valley sites and periods of $PM_{2.5}$ sampling and mass concentrations results (sd = standard deviation, N = sample number).

Local	Sampling period	N	Mass concentration $\mu g\ m^{-3}$ (±sd)
Cachoeira Paulista	08/25/2010 – 12/22/2011	358	20.2 (26.1)
Guaratinguetá	10/06/2010 – 02/22/2011 08/15/2011 – 10/27/2012	116	20.0 (8.7)
São J. Campos	08/25/2010 – 12/23/2011	418	18.7 (10.5)
Taubaté	08/23/2010 – 12/23/2011	352	18.4 (9.0)

Analyzing the table 3, the city with more samples is São José dos Campos (418) and the city with less samples is Guaratinguetá (116). Cachoeira Paulista presented the highest mass concentration of $PM_{2.5}$ (20,2 $\mu g\ m^{-3}$) and Taubaté, the smallest (18.4 $\mu g\ m^{-3}$).

The monthly averages of $PM_{2.5}$ concentration to each city in the sampling periods and dates of precipitation (INMET, 2013) is presented on Table 4:

Table 4: Monthly average concentrations of fine particulate matter ($PM_{2.5}$) and precipitation data for Cachoeira Paulista, Guaratinguetá, São José dos Campos and Taubaté.

Year/Month	Cachoeira Paulista	Guara.	S.J. Campos	Taubaté	Rainfall (mm)	Rainy days
	$PM_{2.5}$ μg m^{-3} (±sd)					
2010/Aug.	41.03 (7.88)	-	48.94 (6.28)	43.73 (12.97)	0	0
2010/Sep.	24.56 (9.84)	-	30.00 (17.01)	32.40 (11.77)	60	8
2010/Oct.	22.39 (20.96)	23.14 (12.87)	17.63 (9.01)	18.34 (9.16)	62	8
2010/Nov.	13.64 (6.54)	20.25 (5.56)	14.96 (5.41)	14.44 (13.79)	70	13
2010/Dec.	12.95 (4.38)	12.79 (8.12)	12.01 (2.99)	13.67 (4.51)	115	18
2011/Jan.	17.08 (20.19)	14.92 (4.73)	13.21 (4.09)	13.82 (3.23)	0	1
2011/Feb.	18.77 (14.08)	18.37 (5.25)	16.01 (3.63)	13.59 (2.95)	110	15
2011/Mar.	10.34 (2.61)	-	9.66 (4.43)	11.57 (3.19)	225	21
2011/April	15.40 (12.92)	-	15.12 (4.31)	15.25 (3.76)	125	13
2011/May	20.77 (12.55)	-	19.71 (6.91)	19.25 (5.03)	30	5
2011/June	22.88 (6.24)	-	24.43 (8.47)	28.14 (8.20)	40	3
2011/July	22.51 (7.65)	-	26.70 (9.61)	-	5	2
2011/Aug.	22.76 (8.83)	24.63 (8.56)	21.47 (9.98)	22.11 (8.38)	10	5
2011/Sep.	20.66 (7.22)	24.13 (8.79)	19.19 (6.41)	22.15 (7.64)	20	2
2011/Oct.	19.43 (15.54)	17.70 (9.36)	14.60 (7.00)	15.45 (5.55)	90	9

Observing the table 4, the month with higher mass concentration of $PM_{2.5}$ is August 2010 (41.03 μg m^{-3} to Cachoeira Paulista, 48.94 μg m^{-3} to São José dos Campos and 43.73 μg m^{-3} to Taubaté), this month has 0 mm of rainfall and 0 rainy days. The month with the lowest concentration of $PM_{2.5}$ is March 2011 (10.34 μg m^{-3} to Cachoeira Paulista, 9.66 μg m^{-3} to São José dos Campos and 11.57 μg m^{-3} to Taubaté), this month has 225 mm of rainfall and 21 rainy days.

The results show that more rainy days are most effective than high month accumulated rainfall to disperse pollutants. For example in Cachoeira Paulista, March 2011 was the month that has the lower $PM_{2.5}$ concentration (10.34 μg m^{-3}), with 21 rainy days and

October 2011 has 90 mm of month accumulated precipitation but has 19.43 μg m^{-3} of $PM_{2.5}$ concentration.

To more comparison, below are some graphics which presents dates of $PM_{2.5}$ concentration in rainy months and in dry months:

Cachoeira Paulista

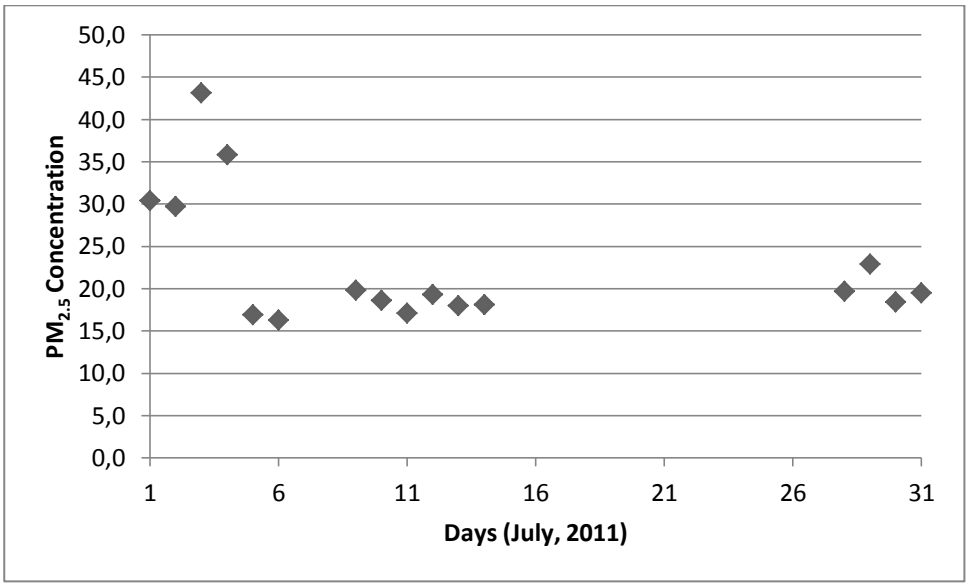

Figure 2: Daily $PM_{2.5}$ concentration on July 2011 (dry month) in Cachoeira Paulista.

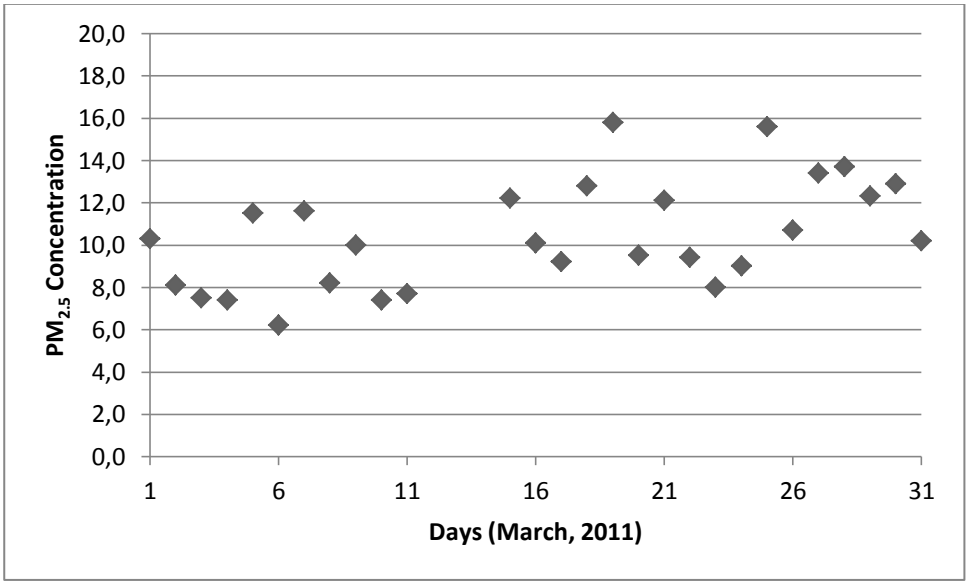

Figure 3: Daily $PM_{2.5}$ concentration on March 2011 (rainy month) in Cachoeira Paulista.

Analyzing the figures 2 and 3, it is observable that on July 2011, the $PM_{2.5}$ concentration was higher than on March 2011. This is because, March 2011 was a rainy month (225 mm), whereas July 2011 was a dry month (5 mm).

Guaratinguetá

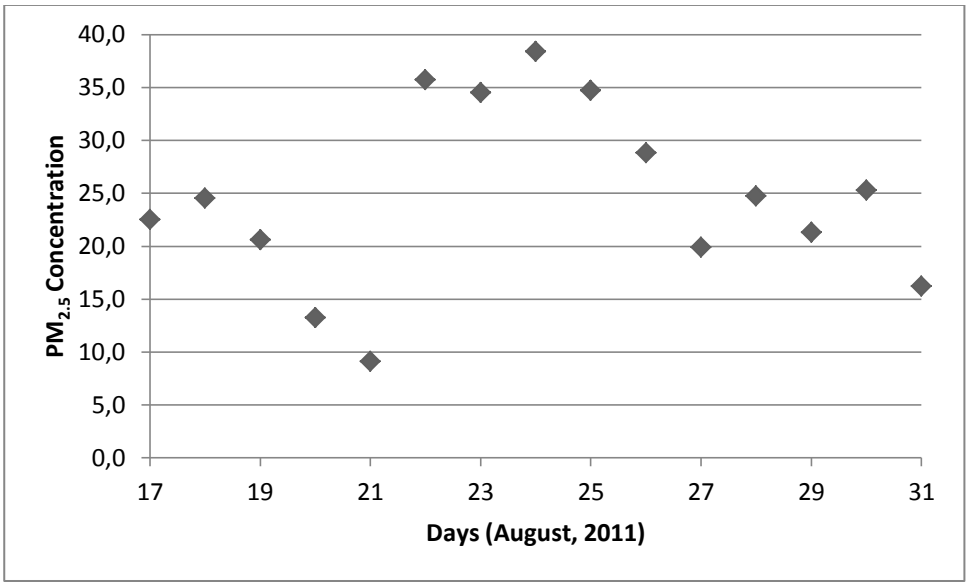

Figure 4: Daily $PM_{2.5}$ concentration on August 2011 (dry month) in Guaratinguetá.

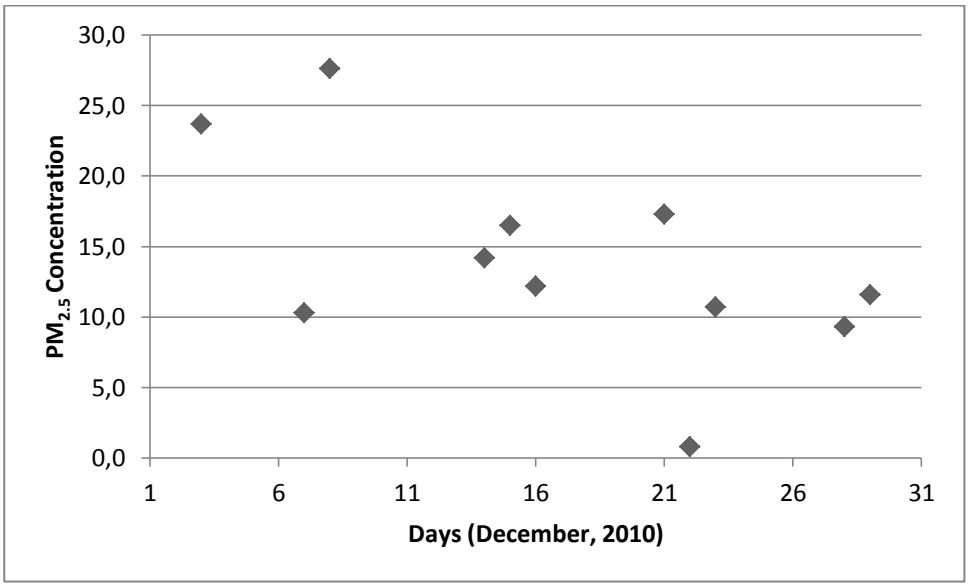

Figure 5: Daily $PM_{2.5}$ concentration on December 2010 (rainy month) in Guaratinguetá.

Analyzing the figures 4 and 5, it is observable that on August 2011, the $PM_{2.5}$ concentration was higher than on December 2010. This is because December 2010 was a rainy month (115 mm), whereas August 2011 was a dry month (10 mm). But there are some fluctuations on $PM_{2.5}$ concentration on graphic of August 2011, this is probably because some rainy days among many dry days.

São José dos Campos

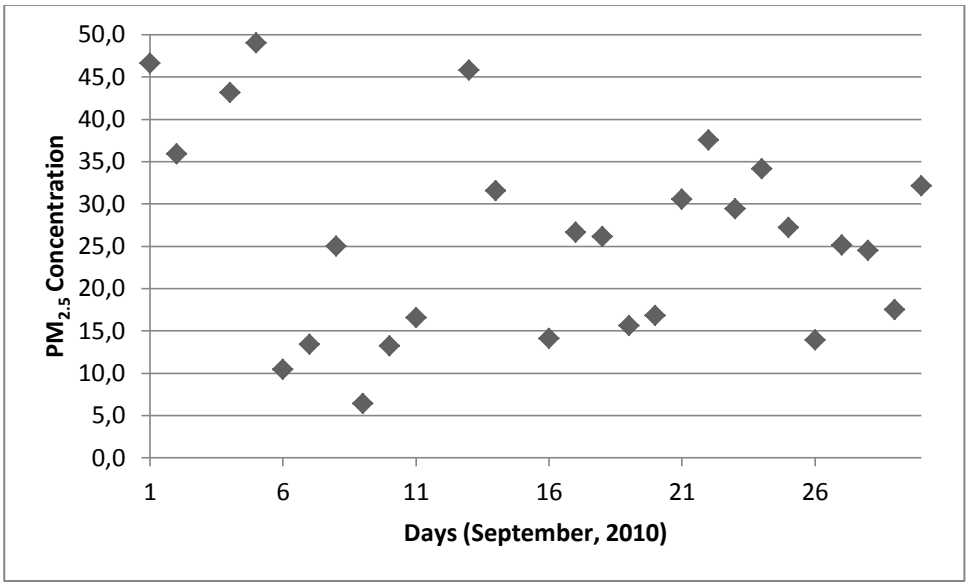

Figure 6: Daily $PM_{2.5}$ Concentration on September 2010 (dry month) in São José dos Campos.

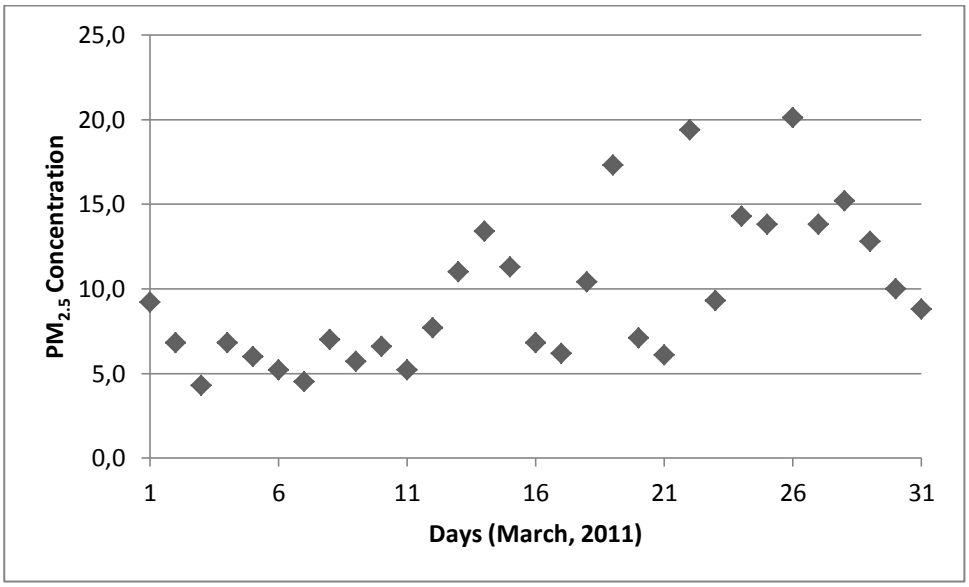

Figure 7: Daily $PM_{2.5}$ Concentration on March 2011 (rainy month) in São José dos Campos.

Analyzing the figures 6 and 7, it is observable that on September 2010, the $PM_{2.5}$ concentration was higher than on March 2011. This is because, March 2011 was a rainy month (225 mm), whereas September 2010 was a dry month (60 mm). The $PM_{2.5}$ concentration is sparse on graphic of September 2010 (probably because some days are rainy and others dry), but is observable that the $PM_{2.5}$ concentration is around to 30 $\mu g.m^{-3}$.

Taubaté

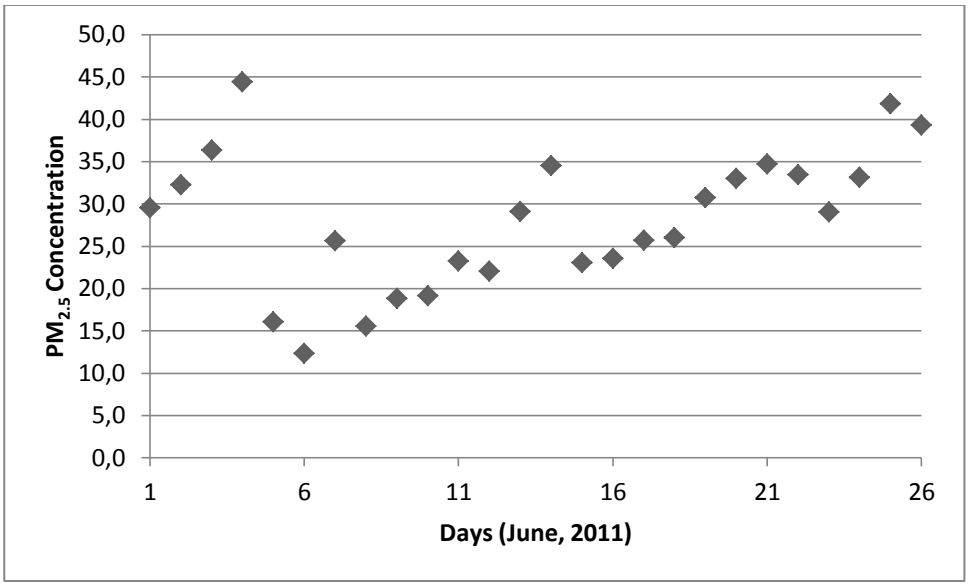

Figure 8: Daily $PM_{2.5}$ Concentration on June 2011 (dry month) in Taubaté.

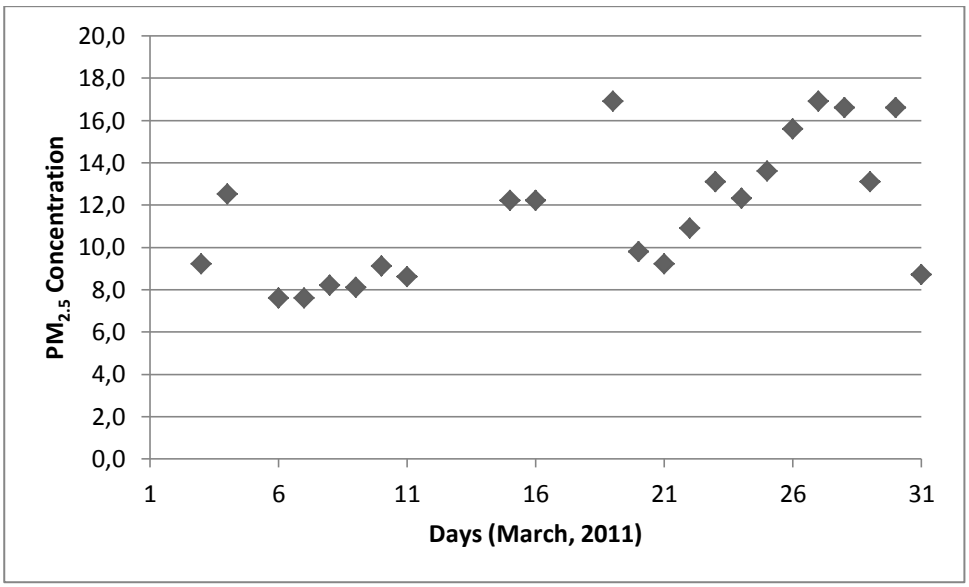

Figure 9: Daily $PM_{2.5}$ Concentration on March 2011 (rainy month) in Taubaté.

Analyzing the figures 8 and 9, it is observable that on June 2011, the $PM_{2.5}$ concentration was higher than on March 2011. This is because, March 2011 was a rainy month (225 mm),whereas June 2011 was a dry month (40 mm). But the some fluctuations on $PM_{2.5}$ concentration were observed on June 2011, this was probably because some rainy days among many dry days.

Observing the figures 2-9, São José dos Campos presented the highest mass concentrations of $PM_{2.5}$ (average: 30.00 µg m^{-3}) in September 2010, even in a month with a rainfall considerable (60 mm). A hypothesis that explain this fact is the low amount of rainy days (8). São José dos Campos presented the lowest mass concentration

of $PM_{2.5}$ (average: 9.66 µg m^{-3}) in March 2011, a month with rainfall of 225 mm and 21 rainy days.

The average concentrations of $PM_{2.5}$ in Beijing were 106.7 µg.m^{-3} in January 2004 and 52.3 µg.m^{-3} in August 2004 (Song et al, 2006). In comparison with the cities in this study, the average concentrations are higher in Beijing.

The $PM_{2.5}$ concentrations to some Brazilian capitals are presented on Table 5 (Miranda et al, 2010):

Table 5: $PM_{2.5}$ concentrations to six Brazilian cities.

City	**Jun-Aug 2008**	**Dec 2007-Feb 2008**
	$PM_{2.5}$ mass concentration (µg m^{-3})	
São Paulo	35.7	19.9
Rio de Janeiro	19.9	12.4
Belo Horizonte	14.8	9.0
Curitiba	16.7	8.3
Porto Alegre	9.5	8.0
Recife	7.2	6.8

In comparison with the cities in this study, Cachoeira Paulista (41.03 µg.m^{-3}), São José dos Campos (48.94 µg.m^{-3}) and Taubaté (43.73 µg.m^{-3}), all in August 2010, had higher concentrations of $PM_{2.5}$ than São Paulo in Jun-Aug 2008 (the city with the highest average $PM_{2.5}$ concentration above - 35.7 µg.m^{-3}). To months with low concentrations of $PM_{2.5}$, São Paulo have the higher concentration of $PM_{2.5}$ (19.9 µg.m^{-3}) in Dec 2007-Feb 2008 that all cities in study, but Cachoeira Paulista (18.77 µg.m^{-3}) and Guaratinguetá (18.37 µg.m^{-3}), both in February 2011, are near to the concentration of São Paulo.

Conclusions

The Paraíba Valley is a region with high concentrations of $PM_{2.5}$ what is very harmful to healthy of population. It is necessary actions and policies to control the pollutant emissions, caused mainly for heavy vehicles that use diesel as fuel and for industries. Furthermore this study shows that more rainy days are more effective to disperse pollutants than high month accumulated precipitation.

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