Concentrations of $PM_{2.5}$ in the northwest of Mexico City: 2004–2006 and 2008–2012

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Abstract

The Metropolitan Zone of Mexico City with an approximate surface area of 7854 square kilometers, is located in the Valley of Mexico whose boundaries are marked by four mountainous masses that form a basin with hollows and plains. There are more than 29 million people and an approximate of 9 million registered automobiles in the Metropolitan Area. Furthermore, Mexico City is the principal industrial center in the Country with more than 46,000 industries, among them we find cement, metal processing and chemical plants. Sampling of respirable particles $PM_{2.5}$ was done using an Airmetrics Minivol Portable Sampler and the mass of particles was determined gravimetrically. Particles samples were collected during 24 hours from Monday to Tuesday and from Thursday to Friday. The data of particles concentrations were correlated with the wind velocity and relative humidity. The particles were collected during the years 2004 to 2006 and 2008 to 2012 excepting the year 2007, obtaining a total of 323 samples. Sampling showed that $PM_{2.5}$ concentration has been increasing through the years of monitoring. Since 2011, $PM_{2.5}$ concentration has registered a considerable rise when compared with previous years, possibly due to the increase in the vehicle fleet in the Metropolitan Zone of Mexico City, according to data obtained by INEGI. The relative humidity remained at a range from 40 to 80%, during all the years of the sampling campaign, by comparing relative humidity against $PM_{2.5}$ concentration, it was observed that the higher the relative humidity, the lower the $PM_{2.5}$ concentration.
Keywords: air pollution, respirable particles.

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1 Introduction

The Metropolitan Zone of Mexico City (ZMCM), with an approximate surface area of 7854 square kilometers, is located in the Valley of Mexico whose boundaries are marked by four mountainous masses that form a basin with hollows and plains. The main entrance of tropospheric wind to the ZMCM is located in the North where the terrain is flat, except for the small Sierra de Guadalupe.

There are more than 29 million people [1] and approximate 9 million registered automobiles in the Metropolitan Area [2]. Furthermore, Mexico City is the principal industrial center in the Country with more than 46,000 industries [3], among them we find cement, metal processing and chemical plants.

According to the Atmospheric Monitoring System (SIMAT), the main problems in air quality in the Metropolitan Zone of Mexico City are related to high concentrations of ozone, PM_{10} and $PM_{2.5}$. Motor vehicles stand out as the main polluting source [1].

Particulate Matter (PM) is a complex mixture of dry, solid particles, solid cores whit liquid coatings, and small liquid droplets. $PM_{2.5}$ is mainly originated on combustion process and in coal, gasoline and wood burning [4]. These particles vary greatly in their physicals and chemicals properties, which are shape, size, solubility, residence time, reactivation, toxicity and chemical composition and structure. In addition to the definition of these properties, determination of pollution reduction strategies also depends on the definition of their pollution sources.

The local and regional meteorology, wind speed, wind direction, atmospheric stability, long-range transport, and pollution dispersion are all factors that play an important role in PM concentration reduction strategies. Analysis of local and regional meteorology is important to fully understand the process responsible for the spatial and temporal distribution of PM [5].

Reducing pollutants concentrations in the atmosphere involve a nationwide decrease in the emission of these pollutants and its precursors, not only from the transport industry, but also from the electric and petrochemical industries, since a concentration threshold has not been identified for some of the effects on health evaluated by epidemiologic studies in many cities around the world.

To achieve a decrease in the concentration of atmospheric pollutants it is necessary to design measures that make a systemic approach that include the joined instrumentation of strategies to improve the environmental quality of fuels (particularly the reduction of sulfur in gasoline and diesel) along with the vehicular performance, with the review of vehicular emission rules (NOM-044-SEMARNAT-2006 and NOM-042-SEMARNAT-2003), that have become gradually stricter [3].

2 Methodology

Sampling of respirable particles $PM_{2.5}$ was done using an Airmetrics Minivol Portable Sampler and the mass of particles was determined gravimetrically.

Particles samples were collected during 24 hours from Monday to Tuesday and from Thursday to Friday. The data of particles concentrations were correlated with the wind velocity and relative humidity. The particles were collected during the years 2004 to 2006 and 2008 to 2012 excepting the year 2007, obtaining a total of 323 samples.

The sampling site was located at the facilities of the Metropolitan University Campus Azcapotzalco. This site is located Northwest of Mexico City, and it is a zone with urban and industrial developments.

3 Results and discussion

Meteorological conditions play an important role in $PM_{2.5}$ dispersion, therefore meteorological parameters such as wind speed and relative humidity corresponding to the monitoring campaign, were taken from the data base of the Atmospheric Monitoring System (SIMAT). Generally, the higher the wind speed is, the less particle concentration since it favors dispersion; and, the higher the relative humidity is, the less particle concentration since particles tend to form clusters whose mass favors its sedimentation.

A statistical analysis was performed using the StatAdvisor package. For multiple linear regression analysis, the meteorological parameters considered initially were: wind speed, relative humidity and temperature. The model determined to discard the temperature because it is not a determining factor in the particles concentration. In a second analysis, only the relative humidity and wind speed were considered [$PM_{2.5}$ = 72.0648 – 0.297735*relative humidity – 3.33691*wind speed], noting that the relative humidity has a higher incidence than the wind speed in the concentration of $PM_{2.5}$.

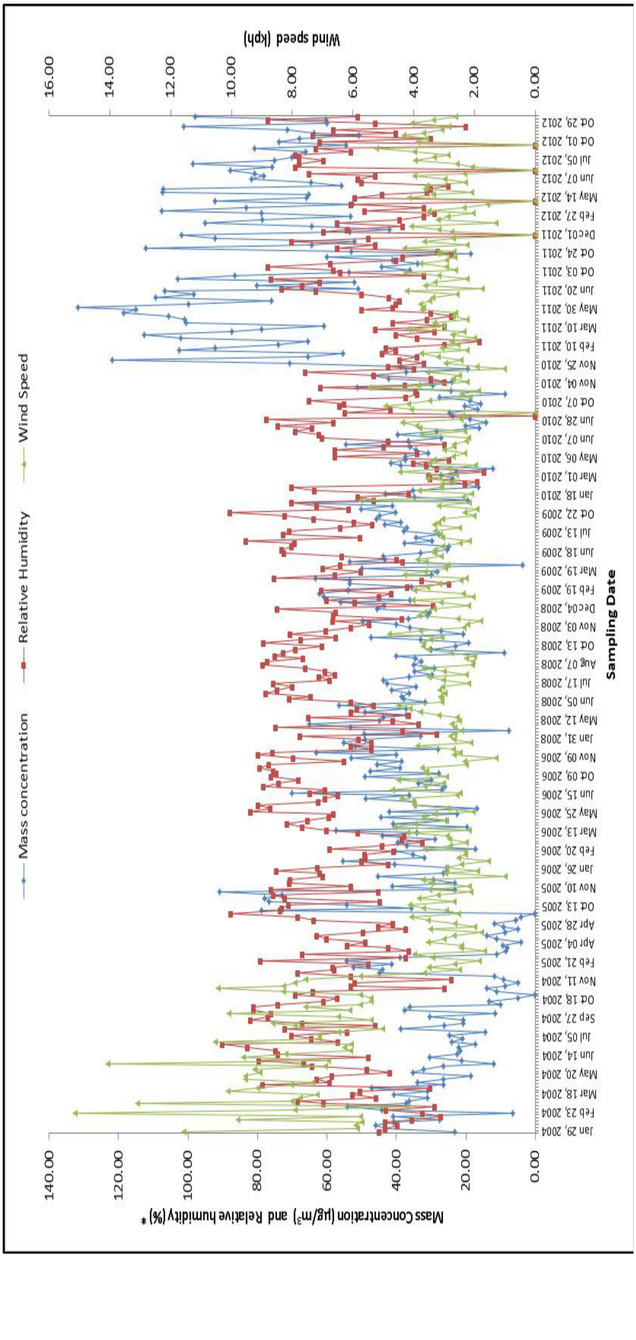
On the other hand, wind direction was not considered because in the sampling point, the predominant direction is from north to south according to the wind rose reported by the Ministry of Environment [6].

In Figure 1 we can observe that the values of $PM_{2.5}$ concentration have been increasing over time; it should be noted that for 2004 and 2009, none of the samples exceeded the Maximum Allowable Limit (LMP) reported by the Official Mexican Rule NOM-025-SSA1-1993. The rule for $PM_{2.5}$ is of 65 $\mu g/m^3$ (24hrs, average) [7].

The relative humidity remained at a range from 40 to 80%, during all the years of the sampling campaign, by comparing relative humidity against $PM_{2.5}$ concentration, it was observed that the higher the relative humidity, the lower the $PM_{2.5}$ concentration.

In Table 1 it can be observed: the number of samples that were collected, the percentage of samples that exceeded the LMP, and corresponding dates and year. In the reported data for 2011 and 2012, an important increase in the days that the LMP from the rule was exceeded, is observed, representing 65% and 63% of the samples collected for the respective years.

As it is observed in Figure 2, vehicle fleet has risen in approximately 100,000 units from 2004 to 2012. According to the modification on the NOM-045-



* *Relative humidity scale is represented from 1 to 100%.*

Figure 1: $PM_{2.5}$ concentration vs. relative humidity and wind speed.

Table 1: Sample percentage that exceeded the LMP during the monitoring campaign.

Year	Total samples	% of samples that exceed the LMP	Date
2004	50	–	–
2005	31	16	Oct 10, 20, 24, 27 Nov 3
2006	40	2.5	Jun 19
2008	46	2	May 8
2009	33	–	–
2010	45	2	Jan 11
2011	40	65	Jan 24, 31 Feb 7,10, 14, 17, 21, 24 Mar 7, 10, 16 May 16, 19, 23, 26, 30 Jun 6, 9, 13, 16, 27 Jul 7 Sep 26 Nov 3, 14 Dec 1
2012	38	63	Feb 20, 23 Mar 1, 5, 8, 15 May 17, 24, 28 Jun 7, 11, 21, 25, 28 Jul 2, 5, 23 Sep 20, 24 Oct 1, 4, 22, 25 Nov 8
Total	**323**		

SEMARNAT-2006, diesel vehicles contribute with 47% of the respirable particles. In urban areas, diesel vehicle emissions may have a more significant impact. For example, in the Metropolitan Zone of Mexico City (ZMCM), trucks and buses with diesel engines generate 78% of the $PM_{2.5}$ [8].

Figure 3 presents the average concentration of $PM_{2.5}$ in dry and rainy seasons. In 2012, the difference between both seasons was significant, reporting a yearly average in dry season of 91.18 $\mu g/m^3$, and in rainy season a value of 105.57$\mu g/m^3$ is reported. This behavior is atypical to that expected, due to weather conditions. The highest $PM_{2.5}$ concentration is expected in dry season, since during rainy season the particles agglomerate and precipitate.

The results are likely due to the weather system known as jet stream which occurs during the dry season and affects the central area of the country. The system can lose altitude and its strong winds are projected with a certain speed to

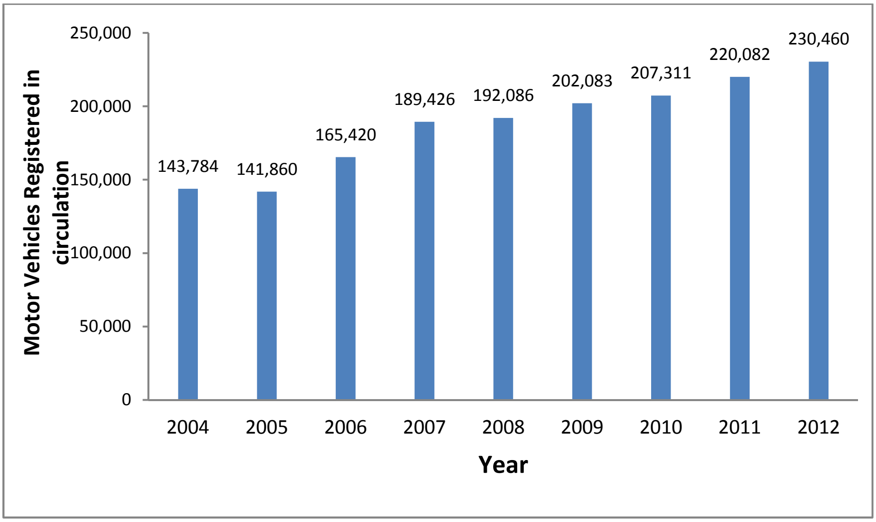


Figure 2: Motor vehicles registered in circulation northwest of the ZMCM yearly total.

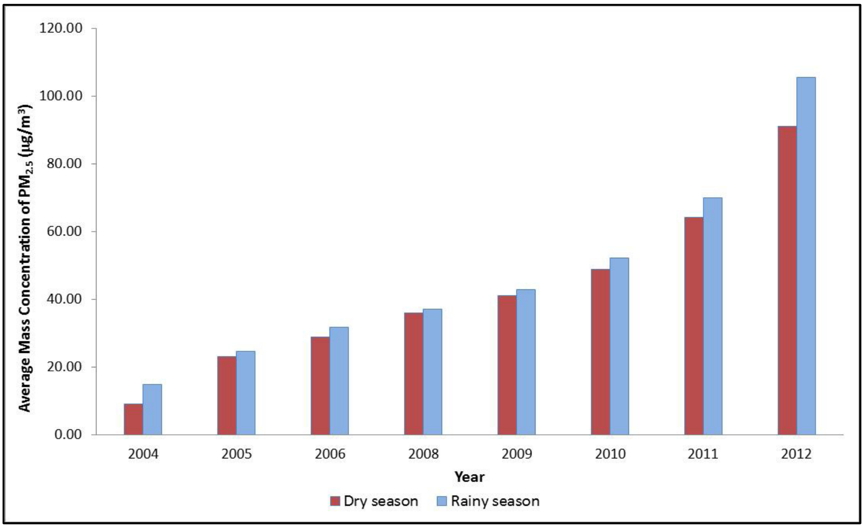


Figure 3: $PM_{2.5}$ concentration during dry and rainy seasons.

the surface of the ZMCM [9], so it is assumed that there is greater dispersion of particles at this season.

$PM_{2.5}$ average concentration is slightly lower during dry season (November through May), compared with the average concentration during rainy season (June through October). It can also be observed that the yearly average of $PM_{2.5}$

rose from 9.08 μg/m^3 in 2004 to 91.18 μg/m^3 in 2012 during dry season. In rainy season, the $PM_{2.5}$ yearly average concentration is 14.93 μg/m^3 in 2004 and a yearly average of 105.57 μg/m^3 in 2012. In both cases, the increase means about eight times its magnitude compared to 2004.

4 Conclusions

Sampling showed that $PM_{2.5}$ concentration has been increasing through the years of monitoring. Since 2011, $PM_{2.5}$ concentration has registered a considerable rise when compared with previous years, possibly due to the increase in the vehicle fleet in the Metropolitan Zone of Mexico City, according to data obtained by INEGI.

According to the Report on Air Quality in Mexico City, North of ZMCM registers the maximum values of pollutants concentrations. Our zone of study is included in this area [10].

A tendency is observed between $PM_{2.5}$ concentration and wind speed; days that registered high values of wind speed coincide with a decrease in the concentration of $PM_{2.5}$ particles, and days with a decrease on wind speed report an increase in the concentration of particles.

This study revealed that in the northwest of the ZMCM there is a larger concentration of $PM_{2.5}$ during rainy season than in dry season. At this time the ZMCM is affected by a weather system called jet stream that facilitates the dispersion of pollutants, which might explain this unusual behavior.

Year after year, the average concentration of $PM_{2.5}$ had an increase in both dry season and rainy season, though slightly more noticeable during rainy season.

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