This paper is part of the Proceedings of the 24th International Conference on Modelling, Monitoring and Management of Air Pollution (AIR 2016)
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$PM_{2.5}/PM_{10}$ relationship in the Metropolitan Area of Valle de Aburrá, Colombia

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Abstract

Valle de Aburrá is a valley located in the Andes mountain range, and it is characterized for being a geographically narrow valley with thermal inversion problems. The environmental authority (*Área Metropolitana del Valle de Aburrá*), has established an Air Quality Monitoring network with stations in nine of the ten municipalities forming the valley. The network is operated by the National University of Colombia.

Although the air quality network monitors particulate material (PST, PM_{10}, $PM_{2.5}$ and PM_1), nitrogen dioxide, sulphur dioxide, carbon monoxide and ozone, apart from meteorological variables, the problematics concerning air quality in Valle de Aburrá has historically been associated with the breathable particulate matter PM_{10} and the inhalable particulate matter $PM_{2.5}$.

Results obtained from the monitoring of PM_{10} and $PM_{2.5}$ for the period July–December 2013 are presented in this study, for the stations measuring both of the pollutants. Additionally, the $PM_{2.5}/PM_{10}$, relationship is reported, which can be used as a parameter for decision-making concerning health protection of the inhabitants of Valle de Aburrá, as well as the correlation coefficients for each station. According to the results, the $PM_{2.5}/PM_{10}$ relationship in the MED-UNFM station was 0.501, in the MED_PJIC station this relationship was of 0.380, and in the ITA_CONC station, it was 0.496.
Keywords: atmospheric pollutants, inhalable particulate matter ($PM_{2.5}$), breathable particulate matter (PM_{10}), $PM_{2.5}/PM_{10}$, relationship, emission, Colombian environmental standard.

1 Introduction

The Valle de Aburrá, which is characterized by being a narrow valley with thermal inversion problems, is located in the Andean Colombian mountains. The valley is between 1,300 and 1,580 meters above sea level. The mountains around the valley are up to 2,100 meters above sea level, creating a complex wind pattern and low dispersion of air pollutants. The valley extends for 60 kms in length and has a variable width. It is formed by ten municipalities, nine of which are under the jurisdiction of the environmental authority of Valle de Aburrá (AMVA) (its geographical position is shown in Figure 1).

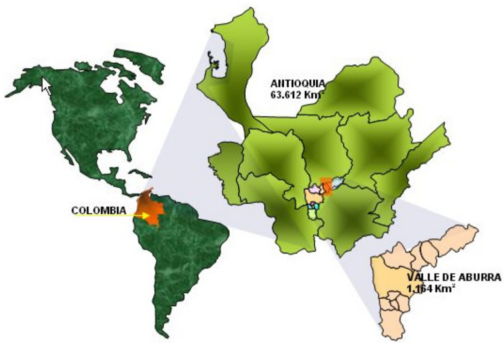


Figure 1: Geography of Valle de Aburrá.

Since approximately 14 years ago, the Air Quality Network of Valle de Aburrá (Colombia) has been monitoring air quality. Currently this monitoring is conducted in 22 (fijos) measurement sites, apart from a mobile station, spread through the municipalities that are under the jurisdiction of the environmental authority (AMVA). Among the quality variables that are monitored, there are: acid rain, total suspended particulates (TSP), particles less than 10 micrometers, particles less than 2.5 micrometers, particles less than a micrometer, carbon monoxide, (CO), ozone, (O_3), nitrogen oxides, (NO_x), and sulphur dioxide, (SO_2). The monitored meteorological variables are: wind speed and direction, relative humidity, rainfall, global radiation and atmospheric pressure [1].

Since the critical pollutant that is monitored in the Metropolitan Area of Valle de Aburrá is the inhalable particulate material smaller than 2.5 ($PM_{2.5}$), and the particulates smaller than 10 micrometers (PM_{10}), in the present study only measurements of these two pollutants and the $PM_{2.5}/PM_{10}$ correlation for the period July–December 2013 are addressed. These two pollutants are simultaneously reported in only 3 out of the 22 monitoring stations [1]. Furthermore, the values of average concentrations for the period July–December 2013 are presented, as well as the maximum daily concentrations obtained in each month for the period July–December 2013. Such concentrations were compared to the daily standard (Resolution 610 of 24 March 2010, then issued by the Ministry of Environment, Housing and Territorial Development

(MAVDT)) for $PM_{2.5}$ equal to 50.0 μg/m^3 and for PM_{10} equal to 100 μg/m^3 respectively, under reference conditions (atmospheric pressure 760 mm Hg and room temperature of 25°C) [2].

The measurement of PM_{10} is justified by its association with mortality and morbidity data in the population, the epidemiologic evidence indicates that an increase of 10 g/m^3 in PM_{10} is associated to an increase of around 1% in all-cause mortality [3]. With regard to the measurements of $PM_{2.5}$, in the last years, evidence has been found about stronger associations between $PM_{2.5}$ and the morbidity and mortality data, which made some states in the US set a standard for $PM_{2.5}$, aiming at reducing the health risks associated to this pollutant [4]. Such evidence is supported on the fact that $PM_{2.5}$ particulates are breathable. However, toxicological studies have shown that are the particulates smaller than 0.1 micrometers the ones causing toxic responses such as irritation and alveolar inflammation, which has led to suggest that the measurement of $PM_{2.5}$ will not effectively substitute the measurement of PM_{10} [5].

2 Methodology

As was previously mentioned, the following methodology is applied to only 3 of the 22 monitoring stations that are under the jurisdiction of the Environmental Authority of Valle de Aburrá (AMVA), this is because those 3 stations were monitoring simultaneously PM_{10} and $PM_{2.5}$, during the period July–December 2013; being that correlation the object of study. It should be noted that filters are weighed in a conditioning environment, with a controlled temperature between 20° and 23°C and with a controlled relative humidity between 30 percent and 40 percent, according to EPA regulations.

The sampled stations were: Municipality of Medellín-Universidad Nacional Facultad de Minas (MED-UNFM), Municipality of Medellín-Politécnico Jaime Isaza Cadavid (MED-PJIC), Municipality of Itagüí-Colegio Concejo de Itagui (ITA-CONC) (as is shown in Figure 2).

3 Sampling

In the case of semi-automatic equipment (that monitoring equipment that is manual, i.e. PM_{10} Hi-Vol and $PM_{2.5}$ Low-Vol), in the MED-UNFM and MED-PJIC stations sampling for determining the concentrations of particulate matter PM_{10} is carried out according to the method EPA, 40 CFR, Part 50, Appendix J: PM_{10}. Sampling for determining concentrations of $PM_{2.5}$ particulate material in the MED-UNFM is carried out according to the manual reference method EPA RFPS-0498-116, and the MED-PJIC station is carried out according to the manual reference method EPA RFPS-0498-118 [6–10].

Sampling of the semi-automatic equipment that monitors PM_{10} and $PM_{2.5}$, in the MED-UNFM station, is conducted every three days. In the case of the MED-PJIC station, although it is semi-automatic equipment, sampling is done every day.

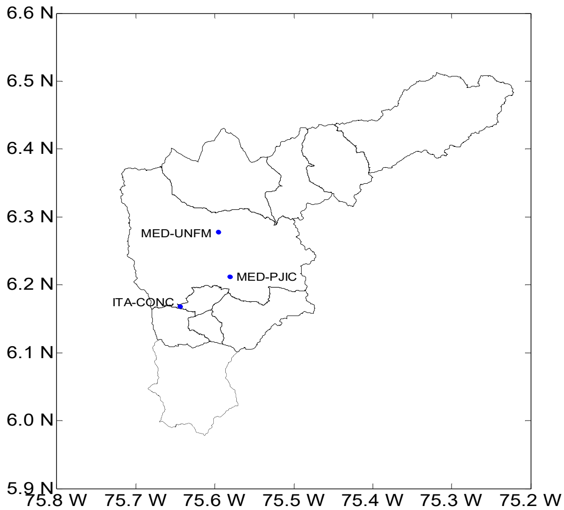


Figure 2: Sampled stations in Valle de Aburrá.

Now then, in the case of automatic equipment, ITA-CONC station, sampling for determining the concentration of particulates smaller than 10 µm (PM_{10}) in ambient air is carried out by the equivalent method EPA EQPM-0798-122. Sampling for determining the concentration of particulates smaller than 2.5 µm ($PM_{2.5}$) in ambient air is carried out according to the EPA EQPM-0308-170 method. Data obtained in this station have hourly resolution [6–9].

4 Results

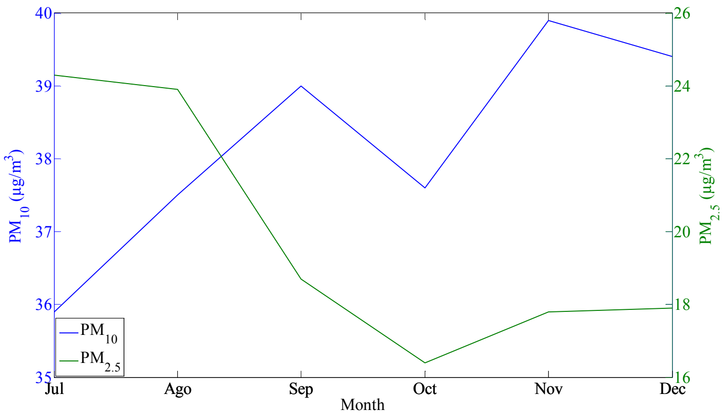
Figure 3 presents the variation of the monthly average concentration of PM_{10} and $PM_{2.5}$ for the period July–December 2013 for the stations aim of this study. Additionally, Tables 1 and 2 present the values of monthly average concentrations and also daily maximum concentrations obtained each month in each of the stations.

For the period July–December 2013, the ITA-CONC station had the highest average concentration of both PM_{10} and $PM_{2.5}$, being these equal to 44.4 µg/m^3 and 22.7 µg/m^3 respectively. MED-UNFM station was the one with the lowest average concentration of PM_{10}, equal to 38.2 µg/m^3 and the MED-PJIC station was the one with the lowest average concentration of $PM_{2.5}$, equal to 17.2 µg/m^3.

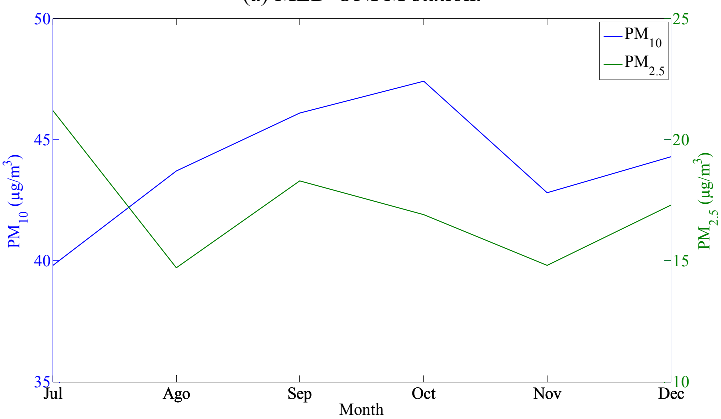
Variability of data has a relation with the type of source of air pollution to which station is subjected to, apart from the possible micro-climates typical of the climate zones where the stations are located [11, 12].

Moreover, in the ITA-CONC station the highest daily concentration of PM_{10}, equal to 74.6 µg/m^3 was obtained in September. The highest daily concentration of $PM_{2.5}$, equal to 60.8 µg/m^3 was obtained in October in the MED-PJIC station.

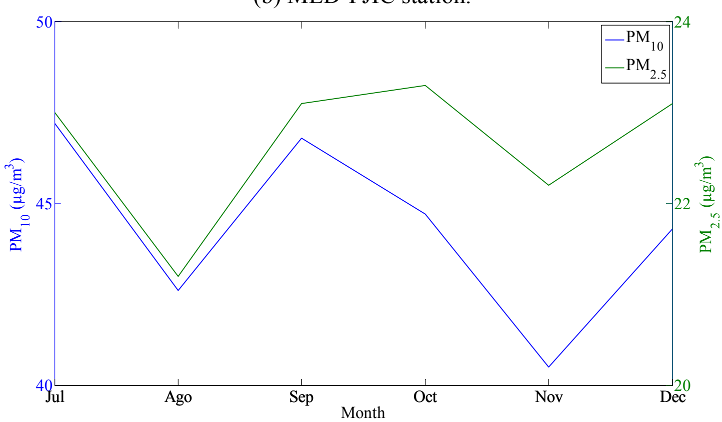
Concerning maximum permitted levels for 24-hour periods, established in Resolution 610 for the particulate matter PM_{10}, the permitted levels were not



(a) MED-UNFM station.



(b) MED-PJIC station.



(c) ITA-CONC station.

Figure 3: Monthly concentrations of PM_{10} and $PM_{2.5}$ in the MED-UNFM, MED-PJIC and ITA-CONC stations during the period July–December 2013.

exceeded in any station. Although the maximum permitted level for $PM_{2.5}$ was exceeded once in the MED-PJIC station, and eight times in the ITA-CONC station. It is worth mentioning that these exceedances were calculated according to the average concentrations for a calendar day.

Table 1: Monthly average concentration of PM_{10} and $PM_{2.5}$, in the MED-UNFM, MED-PJIC and ITA-CONC stations during the period July–December 2013.

	MED-UNFM		**MED-PJIC**		**ITA-CONC**	
Mes	**C. P. PM_{10} (μg/m^3) ***	**C. P. $PM_{2.5}$ (μg/m^3) ****	**C. P. PM_{10} (μg/m^3) ***	**C. P. $PM_{2.5}$ (μg/m^3) ****	**C. P. PM_{10} (μg/m^3) ***	**C. P. $PM_{2.5}$ (μg/m^3) ****
Jul.	35.9	24.3	39.8	21.2	47.2	23.0
Aug.	37.5	23.9	43.7	14.7	42.6	21.2
Sep.	39.0	18.7	46.1	18.3	46.8	23.1
Oct.	37.6	16.4	47.4	16.9	44.7	23.3
Nov.	39.9	17.8	42.8	14.8	40.5	22.2
Dec.	39.4	17.9	44.3	17.3	44.3	23.1

*C. P. PM_{10} (μg/m^3): Monthly average concentration for particulate matter PM_{10} for each month. **C. P. $PM_{2.5}$ (μg/m^3): Monthly average concentration for particulate matter $PM_{2.5}$ for each month.

Table 2: Maximum daily concentration of PM_{10} and $PM_{2.5}$ for each month of the period July–December 2013 in the MED-UNFM, MED-PJIC and ITA-CONC stations.

	MED-UNFM		**MED-PJIC**		**ITA-CONC**	
Mes	**C. M. D. PM_{10} (μg/m^3) ***	**C. M. D. $PM_{2.5}$ (μg/m^3) ****	**C. M. D. PM_{10} (μg/m^3) ***	**C. M. D. $PM_{2.5}$ (μg/m^3) ****	**C. M. D. PM_{10} (μg/m^3) ***	**C. M. D. $PM_{2.5}$ (μg/m^3) ****
Jul.	58.0	28.8	51.3	32.4	67.7	36.4
Aug.	48.1	31.6	50.6	22.1	54.4	29.5
Sep.	51.3	27.3	63.3	30.4	74.6	40.4
Oct.	53.0	20.7	66.5	60.8	58.5	30.2
Nov.	54.7	23.0	58.0	19.0	47.3	29.7
Dec.	60.0	27.2	56.0	26.6	64.8	33.4

*C. M. D. PM_{10} (μg/m^3): Maximum daily concentration of particulate matter PM_{10} for each month. **C. M. D. $PM_{2.5}$ (μg/m^3): Maximum daily concentration of particulate matter $PM_{2.5}$ for each month.

4.1 $PM_{2.5}/PM_{10}$ relationship

Table 3 shows the results corresponding to the $PM_{2.5}/PM_{10}$ relationship, coefficient of determination, and the correlation coefficient obtained in the stations aim of this study.

Table 3: $PM_{10}/PM_{2.5}$ relationship, coefficient of determination and correlation coefficient for the stations MED-UNFM, MED-PJIC and ITA-CONC.

Station	$PM_{2.5}/PM_{10}$ Relationship	Coefficient of determination R^2	Correlation coefficient
MED-UNFM	0.501	0.346	0.588
MED-PJIC	0.380	0.246	0.496
ITA-CONC	0.495	0.663	0.814

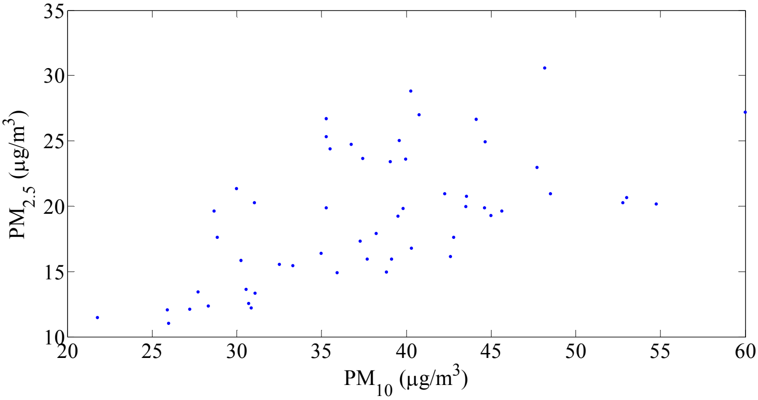
According to the results, the $PM_{2.5}/PM_{10}$ relationship in the MED-UNFM station was equal to 0.501, in the MED-PJIC station this relationship was equal to 0.380, and in the ITA-CONC station it was equal to 0.495. Historical data show that the $PM_{2.5}/PM_{10}$ relationship until 2008 was approximately equal to 0.7 [13]. This is evidence of the fact that contingency measures concerning the development of mobility projects, infrastructure, and cleaner production campaigns addressed by the Environmental Authority of Valle de Aburrá have allowed the decrease of breathable particulate matter, improving quality of life and impact on the inhabitants' health.

Furthermore, from the correlation and determination coefficients obtained in the MED-UNFM and MED-PJIC stations, it can be concluded that there is no significant linear correlation between the PM_{10} and $PM_{2.5}$ concentrations in these stations, so it would not be prudent to predict data of $PM_{2.5}$ from PM_{10} data.

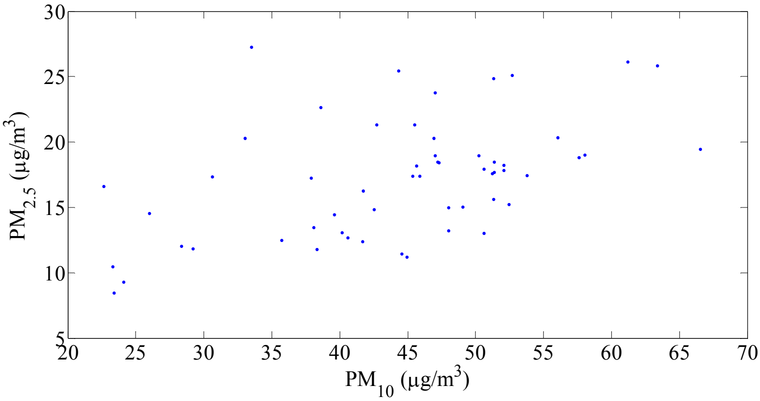
Now, the ITA-CONC station represents the one with the highest coefficient of determination, equal to 0.663, which implies that 66.3% of the variability of $PM_{2.5}$ can be explained from the variability of the PM_{10} concentrations. However, and according to what was stated by Echeverri and Maya [13], since the correlation coefficient is lower than 0.90, in this station it would not be possible to predict $PM_{2.5}$ concentrations from PM_{10} concentrations, unless additional variables were included, so that linear regression is multivariate and not simple, as it was taken in this study.

5 Conclusions

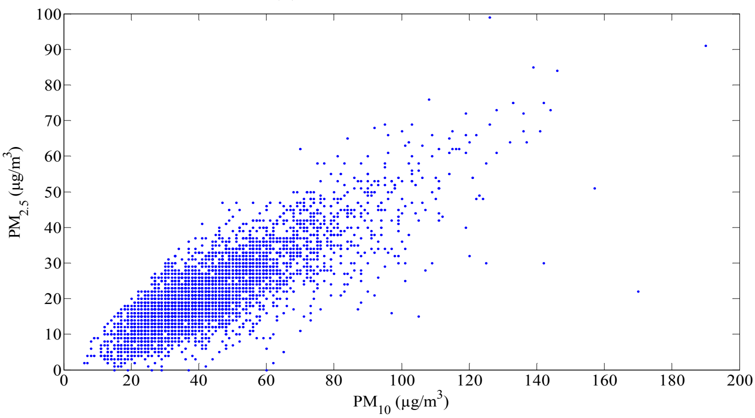
- Regarding the maximum permitted levels established for Colombia in the Resolution 610, in respect to the particulate matter PM_{10}, the daily permitted levels were not exceeded in any station. However, the maximum level permitted for $PM_{2.5}$ was once exceeded in the MED-PJIC station, and 8 times in the ITA-CONC station.



(a) MED-UNFM station



(b) MED-PJIC station



(c) ITA-CONC station

Figure 4: Scatterplots of the PM_{10} and $PM_{2.5}$ data in the MED-UNFM, MED-PJIC and ITA-CONC stations for the period July–December 2013.

- During the period July–December 2013 excedances to the daily standard only occurred in 3 of the 22 monitoring stations, which allows concluding that fine particulates ($PM_{2.5}$) are present as the major problem of contamination in Valle de Aburrá.
- The differences in the $PM_{2.5}/PM_{10}$ relationship among the stations MED-UNFM, MED-PJIC and ITA-CONC with values equal to 0.501, 0.380 and 0.495 are probably caused by the difference among air pollutant sources in the monitored zones.
- Since the correlation coefficient obtained for the MED-UNFM, MED-PJIC and ITA-CONC stations is lower than 0.90, it is not possible to predict $PM_{2.5}$ concentrations from PM_{10} concentrations, unless additional variables are included; so that the linear regression is multivariate and not simple as it was taken in this study.

Acknowledgements

- To the Working Group of the Air Quality Laboratory of the National University of Colombia, Faculty of Mines.
- To the Environmental Authority of Valle de Aburrá (*Autoridad Ambiental del Valle de Aburrá - Área Metropolitana del Valle de Aburrá*).
- To the Faculty of Mines, National University of Colombia.

References

[1] AMVA – UNAL, operar la red de monitoreo de la calidad del aire, meteorología y ruido, en el valle de aburrá. Informe Técnico, January 2014.
[2] Colombia. Ministerio de Ambiente, Vivienda y Desarrollo Territorial. Resolución Número (610) del 24 de marzo de 2010. Norma de calidad del aire o nivel de inmisión (March 2010).
[3] WHO, 2000, Air quality Guidelines, World Health Organization.
[4] Harrison R, Deacon A. "Sources and Processes affecting Concentrations of PM10 and PM2.5 Particulate Matter in Birmingham (UK)". Atmospheric Environment 31, pp. 4103–4117, 1997.
[5] U.S. Environmental Protection Agency, "Air Quality Criteria for Particulate Matter". National Center for Environmental Assessment – RTP Office, Office of Research and Development. Vol 1, 2003.
[6] IDEAM. "Protocolo para la Vigilancia y Seguimiento de Módulo Aire del Sistema de Información Ambiental", Bogotá, September 2005.
[7] Instituto Colombiano DE Normas Técnicas y Certificación. Sistemas de Gestión de la Calidad. Fundamentos y vocabulario. NTC-ISO 9000. Bogotá D.C. El Instituto, 2005. 29 pp.
[8] Instituto Colombiano de Normas Tecnicas y Certificación, Requisitos generales para la competencia de los laboratorios de ensayo y calibración. NTC-ISO/IEC 17025:2005.

[9] Instituto Colombiano De Normas Tecnicas y Certificación. Sistemas de Gestión de la Calidad. Requisitos. NTC-ISO 9001. Bogotá D.C.: El Instituto, 2008. 35 p.
[10] EPA, United States Environmental Protection Agency. 1990. Code of Federal Regulations, CFR. Book 40. Protection of Environment, Parts 50, Appendix A. Washington, www.epa.gov.
[11] AMVA – UPB, Clasificación estaciones de monitoreo de calidad del aire. Informe Técnico, December 2012
[12] Palacio, Carlos Alberto and Jiménez Mejía, José Fernando, Climatología urbana y de montañas. Dyna, 79. pp. 61–69. ISSN 0012-7353, 2012.
[13] C. Echeverri, and G. Maya, “Relación entre las partículas finas (PM2.5) y respirables (PM10) en la ciudad de Medellín”, Revista Ingenierías Universidad de Medellín, vol. 7, no. 12, pp. 23–42, 2008.