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Inhalable Particulate Matter Measurements (Pm2.5) In The Metropolitan Area Of Valle De Aburrá. Colombia

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ABSTRACT
This study was conducted in the Metropolitan Area of Valle de Aburrá (Colombia), which is characterized by being a narrow valley with thermal inversion problems, and is located in the Andes mountain range.
The study was conducted by the National University of Colombia in the Air Quality Monitoring Network, in agreement with the environmental authority in the area (Metropolitan Area of Valle de Aburrá).
The aim was to optimize the monitoring of air quality in the urban areas of Valle de Aburrá for inhalable particulate matter less than 2.5 micrometers (PM2.5) during the period January- December 2013, as it is the critical pollutant monitored in the area.
Values of annual average concentrations and maximum daily concentrations obtained in each month are presented in this study, also the daily and weekly cycles for each monitoring station. These concentrations were compared to the Colombian daily and annual standard for PM2.5, equal to 50.0 g/m^3 and 25 g/m^3 respectively.
It is worth highlighting the behavior of the decrease during evening times of the diurnal cycle of PM2.5, it can be explained partly because the atmosphere in the evening is generally unstable favoring greater dilution of pollution.
Keywords **–**. Air pollution, Colombian Environmental standard, Inhalable particulate material (PM2.5)

I. INTRODUCTION

Since about 14 years ago, the Air Quality Network of the Metropolitan Area of Valle de Aburrá (Colombia) has been monitoring air quality, with 22 permanent measurement stations, which are distributed in the different municipalities of Valle de Aburrá , see table 1.1.

These stations have an acid rain gauge, a total suspended particles meter (TSP), 17 metering equipment for particles less than 10 micrometers (PM10), 5 meters for particles less than 2.5 micrometers (PM2.5), a meter for particles less than one micron (PM1), 4 automatic carbon monoxide (CO) monitors, 9 automatic Ozone (O3) monitors, 6 automatic nitrogen oxides (NOx) meters, an automatic sulfur dioxide (SO2) meter and 13 weather stations. Figure 1.1 shows the geographical location of the stations operating for the period January-December 2013 in the Air Quality Network of the Valle de Aburrá. Given that the critical pollutant monitored in the Metropolitan Area of the Aburrá Valley is the inhalable particulate matter (PM2.5), in the present study only the results of measurements of this pollutant will be addressed for the period January- December 2013. This pollutant is reported in only 5 of the 22 monitoring stations [1]. Additionally, the values of annual average concentrations and maximum daily concentrations obtained in each month of the year are presented, also the daily and weekly cycle for each monitoring station; these concentrations were compared to the Colombian daily and annual standard for PM2.5 equal to 50.0 g/m^3 and 25 $\mu g/m^3$ respectively

II. INHALABLE PARTICULATE MATERIAL (PM2.5)

Sampling and laboratory analysis to determine the concentration of particles smaller than 2.5 micrometers (PM2.5) in ambient air is done by the EPA 0308-170 EQPM method (BAM -1020 Particle Monitor). The operating range of the equipment is 0-1000 $\mu g/m^3$, the state of the pollutant is particulate and the matrix is air (atmosphere) [2][3][4][5][6].

The Colombian standard that establishes the maximum permissible limits in air quality is the Resolution 610 of 24 March 2010, then issued by the Ministry of Environment, Housing and Territorial Development (MAVDT). Daily and annual Colombian standards for PM2.5 are 50 and 25 $\mu g/m^3$ respectively at reference conditions (atmospheric pressure of 760 mm Hg and ambient temperature of 25°C) [7].

III. INHALABLE PARTICULATE MATERIAL MEASUREMENTS (PM 2.5)

3.1. Municipality of Medellín. Estación Universidad Nacional station – El Volador campus (MED-UNNV)

The results associated with measurements of inhalable particulate matter PM2.5 at this station for the period January- December 2013 are reported in Figure1 and Table 1

Additionally, the values of the average and maximum concentration levels obtained each month for this station are shown in Table 1.

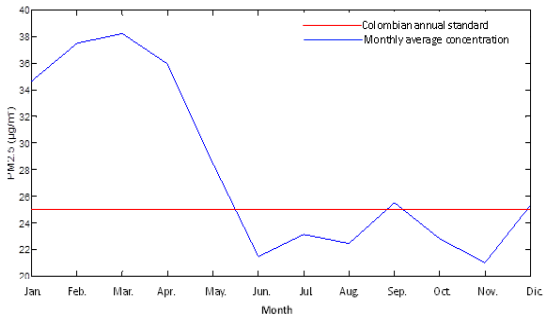

Figure 1. Monthly concentrations of PM2.5 in the MED- UNNV station for the period January- December 2013.

Month	Month Avg Conc (µg/m3)	Max Conc .D. (µg/m3)	NEND
January	34,6	42,0	0
February	37,5	49,9	0
March	38,2	53,5	3
April	35,9	47,7	0
May	28,4	40,1	0
June	21,5	27,8	0
July	23,1	32,2	0
August	22,4	29,2	0
September	25,5	44,3	0
October	22,8	38,3	0
November	21,0	33,7	0
December	25,3	41,1	0

Note: Avg. Conc (µg/m^3): monthly average concentration. **Max Conc. D. (µg/m^3):** Maximum daily concentration. **NEND:** Number of exceedances of the daily standard (*Número de excedencias de la norma diaria* in Spanish).

Table 1. Monthly average concentration, as well as the maximum monthly concentration of PM2.5 in the MED- UNNV station for the period January- December 2013.

The average concentration of PM2.5 for the period January to December 2013 in this station was 28.0 µg/m^3, whereby this station exceeds the Colombian annual standard for particulate matter PM2.5 (25 µg/m^3). November 2013 was the month with the lowest average PM2.5 concentration equal to 21.0 µg/m^3, while in March the highest monthly average concentration was obtained, equal to 38,2 µg/m^3.

Moreover, the maximum daily concentration recorded in the MED- UNNV station for the period January- December 2013 , equal to 53.5 ug/m^3, allows to conclude that exceedances of the daily Colombian standard for PM2.5 (50 µg/m^3) were presented at this station for the recording period. Now, in Figure 2 the diurnal cycle of PM2.5 in MED- UNNV station is presented. This diurnal cycle shows a bimodal behavior with a first maximum between 07:00 and 9:00, and a weaker second maximum in the evening hours, between 19:00 and 21:00.

Weekly figure 3 shows that usually, for the period January- December 2013, Thursday and Friday were the days with the highest concentration of particulate matter PM2.

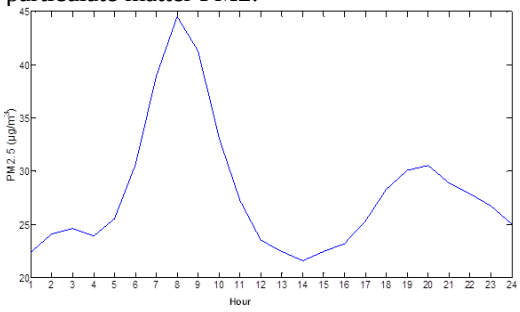

Figure 2. Diurnal cycle of PM2.5 in the MED- UNNV station for the period January- December 2013.

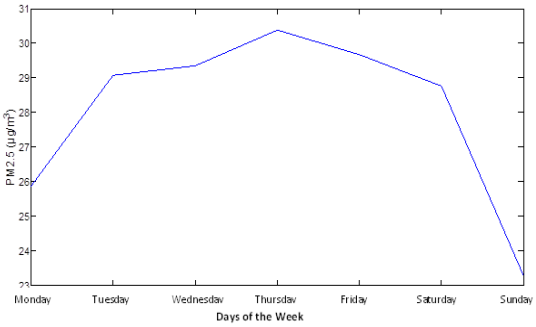

Figure 3. Weekly cycle of PM2.5 in the MED- UNNV station for the period January- December 2013.

3.2. Municipality of Medellín - Museum of Antioquia station (MED- MANT)

The results associated with measurements of inhalable particulate matter PM2.5 in the MED- MANT station are reported in Figure 4 and Table 2 for the period January- December 2013. Additionally, the values of average concentrations, as well as the maximum concentration levels obtained in each month for this station are presented in Table 2.

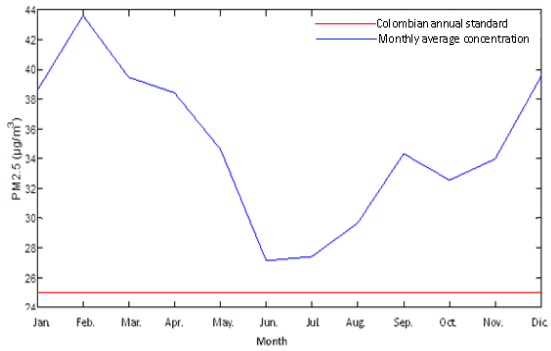

Figure 4. Monthly concentrations of PM2.5 in the MED-MANT station for the period January- December 2013.

Month	Month Avg Conc (µg/m3)	Max Conc .D. (µg/m3)	NEND
January	38,6	51,0	1
February	43,6	54,6	6
March	39,4	50,6	1
April	38,4	51,1	1
May	34,6	52,1	1
June	27,1	38,9	0
July	27,4	41,1	0
August	29,7	36,5	0
September	34,3	49,8	0
October	32,5	46,0	0
November	34,0	44,3	0
December	39,5	50,0	0

Note: Avg. Conc (µg/m3): monthly average concentration. **Max Conc. D. (µg/m3):** Maximum daily concentration. **NEND:** Number of exceedances of the daily standard (*Número de excedencias de la norma diaria* in Spanish).

Table 2. Monthly average concentration and maximum monthly concentration of PM2.5 in the MED-MANT station for the period January- December 2013.

The average concentration of PM2.5 for the period January to December 2013 in this station was 34.9 µg/m^3, whereby this season surpassed the Colombian annual standard for particulate matter PM2.5 (25 µg/m^3). June 2013 was the month with the lowest average PM2.5 concentration equal to 27.1 µg/m^3, while in February, the highest average monthly concentration was obtained, equal to 43.6 µg/m^3.

Moreover, the maximum daily concentration recorded in the MED-MANT station for the period January- December 2013, equal to 54.6 ug/m^3, leads to conclude that exceedances of the Colombian daily standard (50 µg/m^3) were presented for PM2.5 at this station for the recording period. The diurnal cycle of PM2.5 in MED- MANT station is presented in Figure 5.

This diurnal cycle has a bimodal behavior with a first maximum between 07:00 and 10:00, and a second weaker peak between 19:00 and 22:00. The weekly cycle of PM2.5 in MED-UNNV station is presented in Figure 6. This weekly cycle shows that, in general, for the period January- December 2013, Fridays were the days with the highest concentration of particulate matter PM2.5.

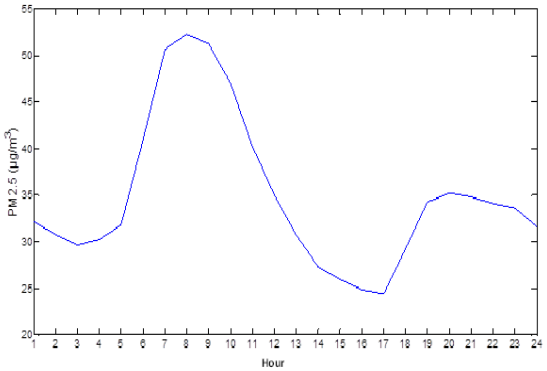

Figure 5. Diurnal cycle of PM2.5 in the MED-MANT station for the period January- December 2013.

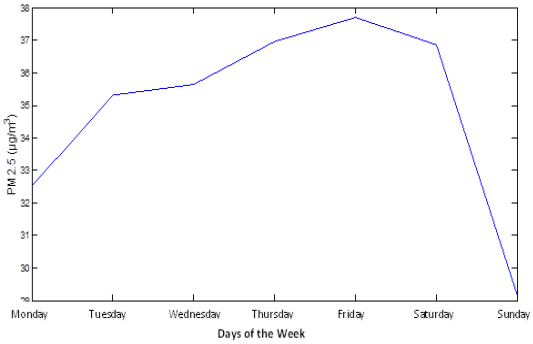

Figure 6. Weekly cycle of PM2.5 in the MED-MANT station for the period January- December 2013.

3.3. Municipality of Medellín. Une-casa Yalte station (MED-UNEP)

The results associated with measurements of inhalable particulate matter PM2.5 in the MED - UNEP station for the period January- December 2013 are reported in Figure 7. and Table 3, where the values of average concentrations are presented, as well as the maximum concentrations obtained in each month for each station.

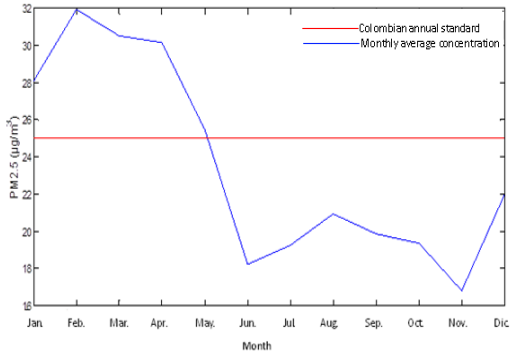

Figure 7. Monthly concentrations of PM2.5 in the MED -UNEP station for the period January- December 2013.

Month	Month Avg Conc (µg/m3)	Max Conc .D. (µg/m3)	NEND
January	28,1	40,8	0
February	31,9	44,5	0
March	30,5	44,5	0
April	30,2	44,7	0
May	25,4	43,8	0
June	18,2	27,1	0
July	19,3	30,1	0
August	20,9	32,3	0
September	19,9	31,2	0
October	19,3	26,8	0
November	16,8	25,0	0
December	22,0	32,0	0

Note: Avg. Conc (µg/m^3): monthly average concentration. **Max Conc. D. (µg/m^3):** Maximum daily concentration. **NEND:** Number of exceedances of the daily standard (*Número de excedencias de la norma diaria* in Spanish).

Table 3. Monthly average concentration and maximum monthly concentration of PM2.5 in the MED -UNEP station for the period January- December 2013.

The average concentration of PM2.5 obtained in the MED -UNEP station for the period January- December 2013 was 23.4 µg/m3, allowing to conclude that the Colombian anual standard for PM2.5 particulate matter (25.0 µg/m^3) was not exceedeed.

Moreover, the maximum daily concentrations recorded at this station 44.5 ug/m^3 u, to conclude that no exceedances of the Colombian daily norm (50.0 ug/m^3) for PM2.5 were presented at this station.

The diurnal cycle of PM2.5 for this station is shown in Figure 8. This diurnal cycle shows a bimodal behavior with a first maximum between 08:00 and 10:00, and a weaker second peak in the evening hours between 22:00 and 23:00.

The weekly cycle of PM2.5 in MED-UNEP station is presented in Figure 9.

This weekly cycle shows that in general, for the period January- December 2013, Friday was the day with the highest concentration of particulate matter PM2.5 in this station.

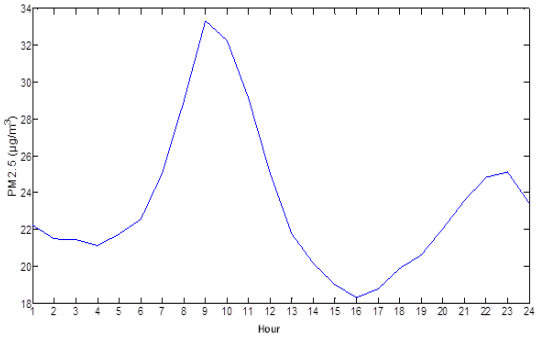

Figure 8. Diurnal cycle of PM2.5 in the suburban stations of Medellín for the period January- December 2013. MED –UNEP.

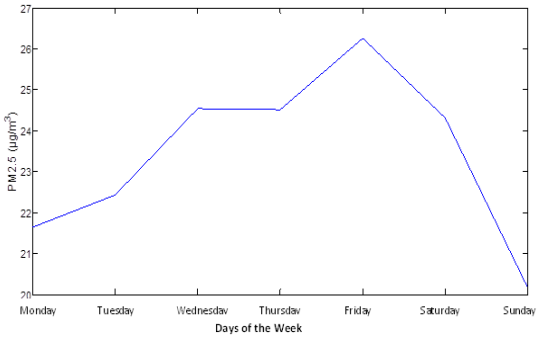

Figure 9. Weekly cycle of PM2.5 in suburban stations in the municipality of Medellín for the period January- December 2013. MED-UNEP.

3.4. Municipality of Itagui. Casa de Justicia station (ITA-CJUS)

The monthly behavior of the concentrations of inhalable particulate matter PM2.5 obtained for the period January- December 2013 in the ITA- CJUS station is presented in Figure 10. Additionally, in Table 4 of the mean values and the maximum concentration levels obtained at each station for each month are shown.

In the ITA- CJUS station, April 2013 was the month with the highest average concentration of PM2.5, equal to 32.5 µg/m^3 respectively.

The average concentration of PM2.5 at this station for the period January- December 2013 is 27.1 µg/m^3, allowing to conclude that this station surpassed the Colombian annual standard for PM2.5 particulated matter (25.0 µg/m^3) during the recording period.

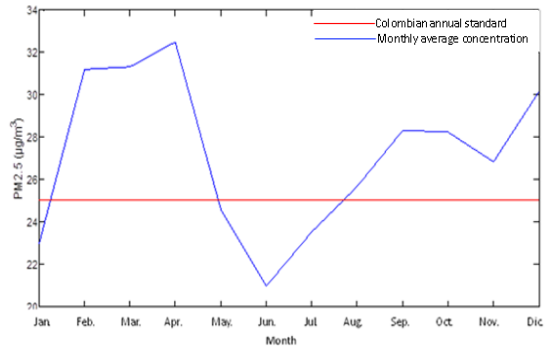

Figure 10. Monthly concentrations of PM2.5 in the ITA- CJUS station for the period January- December 2013.

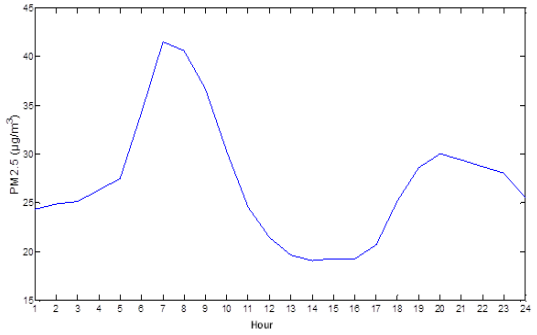

Figure 11. Diurnal cycle of PM2.5 in the ITA-CJUS station for the period January- December 2013.

Month	Month Avg Conc (µg/m3)	Max Conc .D. (µg/m3)	NEND
January	23,0	31,7	0
February	31,2	43,1	0
March	31,3	43,6	0
April	32,5	50,5	1
May	24,6	41,0	0
June	21,0	34,7	0
July	23,5	39,7	0
August	25,7	37,3	0
September	28,3	48,5	0
October	28,2	38,9	0
November	26,8	38,0	0
December	30,2	41,6	0

Note: Avg. Conc (µg/m3): monthly average concentration. **Max Conc. D. (µg/m3):** Maximum daily concentration. **NEND:** Number of exceedances of the daily standard (*Número de excedencias de la norma diaria* in Spanish).

Table 4. Monthly average concentration and maximum monthly concentration of PM2.5 in the ITA- CJUS station for the period January- December 2013.

Moreover, the maximum daily concentration recorded in the ITA- CJUS station, equal to 50.5 µg/m3 obtained in April 2013, allows to conclude that exceedances of the Colombian daily PM2.5 standard (50.0 µg/m^3) are presented at that station during the recording period.

The diurnal cycle of PM2.5 in ITA- CJUS station is presented in Figure 11. This diurnal cycle shows a bimodal behavior in that station. The maximum values during diurnal cycle in the ITA-CJUS station occur between 07:00 and 08:00, and in the evening hours, between 19:00 and 20:00.

The weekly cycle of PM2.5 in the ITA-CJUS station for the period January- December 2013 is presented in Figure 12. In the ITA- CJUS station, Friday was, on average, the day with the highest concentration of PM2.5.

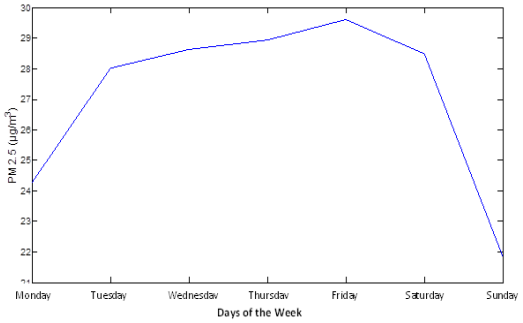

Figure 12. Weekly cycle of PM10 in the ITA-CJUS station in the municipality of Itagui for the period January- December 2013.

3.5. Municipality of Itagui. Concejo station (ITA-CONC)

The results associated with measurements of inhalable particulate matter PM2.5 in the ITA-CONC station for the period January- December 2013 are reported in Figure 13 and Table 5.

The average concentration of particulate matter PM2.5 during the period January- December 2013, equal to 27.5 µg/m^3, allows to conclude that this station exceeded the annual standard for particulate matter PM2.5, defined in the Resolution 610 of 2010 of the Ministry of Environment, equal to 25.0 µg/m^3.

The maximum daily concentration obtained during the period from January to December, equal to 64.8 µg/m^3 and obtained in December, exceeds the daily PM2.5 standard as defined in Resolution 610 of the Ministry of Environment, equal to 50 µg/m^3. Eight exceedances of the daily PM2.5 standard were presented in the recording period.

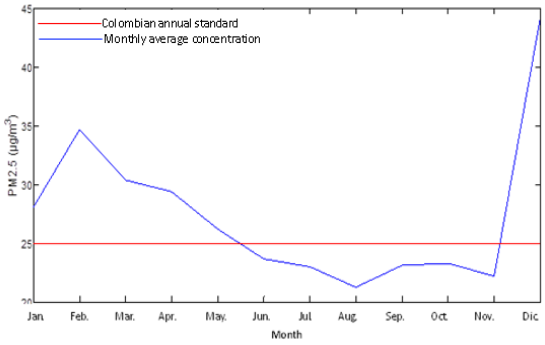

Figure 13. Monthly PM2.5 concentrations in the ITA- CONC station for the period January- December 2013.

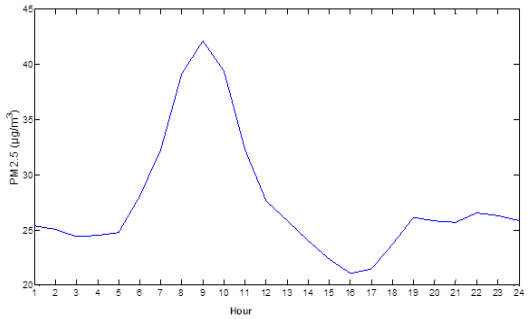

Figure 14. Diurnal cycle of PM2.5 in the ITA-CONC station for the period January- December 2013.

Month	Month Avg Conc (µg/m3)	Max Conc .D. (µg/m3)	NEND
January	28,1	38,2	0
February	34,7	47,2	0
March	30,4	45,0	0
April	29,4	43,7	0
May	26,2	42,8	0
June	23,6	30,2	0
July	23,0	36,4	0
August	21,2	29,5	0
September	23,1	40,4	0
October	23,3	30,2	0
November	22,2	29,7	0
December	44,3	64,8	8

Note: Avg. Conc (µg/m^3): monthly average concentration. **Max Conc. D. (µg/m^3):** Maximum daily concentration. **NEND:** Number of exceedances of the daily standard (*Número de excedencias de la norma diaria* in Spanish).

Table 5. Monthly average concentration and monthly minimum and maximum concentration of PM2.5 in the ITA- CONC station for the period January- December 2013.

The diurnal cycle of PM2.5 in ITA- CONC station for the period January- December 2013 is presented in Figure 14. This diurnal cycle has a unimodal behavior, with maximum values between 08:00 and 10:00.

The weekly cycle of PM2.5 in BEL- USBV station is presented in Figure 15. Taking into account this evidence, Wednesdays, Fridays and Saturdays during the period January- December 2013 were the days with the highest average concentration.

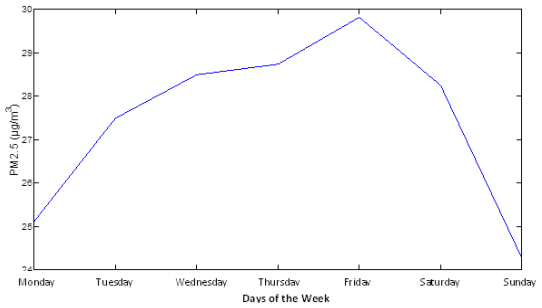

Figure 15. Weekly cycle of PM2.5 in the ITA-CONC station for the period January- December 2013.

IV. CONCLUSIONS

The behavior of the decrease of PM2.5 in the afternoon during diurnal cycle presented in all monitoring stations can be explained partly, because the atmosphere in the evening is generally unstable, favoring greater dilution of pollution.

It is worth highlighting the, generally, cumulative behavior of the weekly cycle with a minimum on Sunday and a gradual increase until Thursday or Friday in some of the stations.

The highest annual average concentration of PM2.5 for the period January- December 2013 was presented in the MED-MANT station with a value of 34.9 µg/m3, followed by the MED- UNNV station with a value of 28.0 µg/m^3, the ITA- CONC station with a value of 27.5 µg/m^3, the ITA- CJUS station with a value of 27.1 µg/m^3, with which these stations exceed the annual Colombian standard for particulate matter PM2.5 (25 µg/m^3).

In the MED -UNEP station, the annual average concentration of PM2.5 was 23.4 ug/m^3, this value does not exceed the annual Colombian standard for PM2.5.

This is due to the fact that the MED-MANT station is located in the center of the city, where a high traffic flow is presented, unlike the MED -UNEP station which is located on the outskirts of the city, and therefore there is not much vehicular flow.

The maximum daily concentration recorded in the MED- UNNV station during the period January- December 2013, equal to 53.5 ug/m^3, in the MED- MANT station equal to 54.6 ug/m^3, in the ITA- CJUS station equal to 50.5 ug/m^3, and in the ITA-CONC station equal to 64.8 ug/m^3, allow us to conclude that exceedances of the Colombian daily standard (50 μg/m^3) for PM2.5 were presented at the aforementioned stations unlike the MED -UNEP r station where the highest recorded concentration was equal to 44.5 μg/m^3. It also leads to the conclusion that no exceedances of the Colombian daily norm (50,0 μg/m^3) for PM2.5 were presented at this station.

V. ACKNOWLEDGEMENTS.

To the Air Quality Laboratory of the National University of Colombia School of Mines.

To the Environmental Authority of Valle de Aburrá (Metropolitan Area of Valle de Aburrá).

To the National University of Colombia School of Mines.

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