PM_{10} Chemical Characteristics in a Background Site at the Universidad Libre Bogotá

Laura X. Martinez, Andrés F. Rodríguez, Ruth A. Catacoli

***Abstract*—**One of the most important factors for air pollution is that the concentrations of PM_{10} maintain a constant trend, with the exception of some places where that frequently surpasses the allowed ranges established by Colombian legislation. The community that surrounds the Universidad Libre Bogotá is inhabited by a considerable number of students and workers, all of whom are possibly being exposed to PM_{10} for long periods of time while on campus. Thus, the chemical characterization of PM_{10} found in the ambient air at the Universidad Libre Bogotá was identified as a problem. A Hi-Vol sampler and EPA Test Method 5 were used to determine if the quality of air is adequate for the human respiratory system. Additionally, quartz fiber filters were utilized during sampling. Samples were taken three days a week during a dry period throughout the months of November and December 2015. The gravimetric analysis method was used to determine PM_{10} concentrations. The chemical characterization includes non-conventional carcinogenic pollutants. Atomic absorption spectrophotometry (AAS) was used for the determination of metals and VOCs were analyzed using the FTIR (Fourier transform infrared spectroscopy) method. In this way, concentrations of PM_{10}, ranging from values of 13 $\mu g/m^3$ to 66 $\mu g/m^3$, were obtained; these values were below standard conditions. This evidence concludes that the PM_{10} concentrations during an exposure period of 24 hours are lower than the values established by Colombian law, Resolution 610 of 2010; however, when comparing these with the limits set by the World Health Organization (WHO), these concentrations could possibly exceed permissible levels.

***Keywords*—**Air quality, atomic absorption spectrophotometry, Fourier transform infrared spectroscopy, particulate matter.

I. Introduction

AIR pollution is defined as the existence of high concentrations of substances in the air over a period of time, due to anthropic activities or natural processes, which could cause harmful effects to the environment and the health of people and living beings [1]. Found within the relevant atmospheric pollutants are total suspended particulates (PST), particulate matter (PM_{10} and $PM_{2.5}$), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), tropospheric ozone (O_3), carbon monoxide, Lead and its Compounds, mercury, benzene, cadmium, toluene and vanadium [2]. Thus, the particulate matter is found within the main pollutants. These particles are bodies of matter that exist in liquid or gas phases and accumulate in different shapes and sizes (0 - 100 µm). Furthermore, it has an aerodynamic diameter, equal to or less than 10 µm, being of great importance in urban pollution, due to its negative influence on the pulmonary alveoli, affecting society's quality of life [3].

Specifically, air quality refers to the state in which air pollution is found, namely, it is estimated as an air pollution indicator to define how suitable the air is to be respired [4]. From this view point, Bogotá has relatively acceptable pollution levels with respect to CO, NOx and SOx, however, the problem is directly related to photochemical smog and particulate matter [5].

In the case of Universidad Libre Bogotá, there is a community of students and workers who could be exposed to the risks generated by PM_{10} levels present on the campus for long periods of time. In this way, the characterization of particulate matter has been identified as a problem in a background site at the Universidad Libre, using a high-volume sampler, which allowed the daily pollutant concentration to be determined, taking into consideration the importance of the community's wellbeing and quality of life regarding the contact with this material.

II. Materials and Methods

Initially, a TSP and PM_{10} high volume sampler were used, which are approved by EPA method 5 for total PM mass. Secondly, the TSP and PM_{10} HI-VOL were installed in a background site close to the Engineering Faculty air labs. In addition, 10" x 8" quartz fiber filters were used.

The sampling process was carried out between November and December 2015, collecting a total of 11 samples. Each filter remained on site for 24 hours +/- 1 hour in the sampling process which took place on Mondays, Wednesdays and Fridays.

Based on the samples collected by the filters, the concentrations of PM_{10} were then determined using the gravimetric analysis method. With respect to chemical characterization, the parameters were the nonconventional pollutants with carcinogenic effects, such as Benzene, Lead and its compounds, Cadmium, Inorganic Mercury, Toluene and Vanadium, established by the Colombian Resolution 610 of 2010, considering it was necessary to implement the filter's extraction process for its reading. The procedure was performed using an extractive solution composed of 63% nitric acid (HNO_3) and 37% hydrochloric acid (HCl), to which an 8" x 1" filter fragment was added. Subsequently, the obtained sample was introduced to a heating process using the

A. Rodriguez is with Universidad Libre, Engineering Faculty, Department of Environmental Engineering, Bogotá, Colombia (phone: (+57) 321 265 5324; e-mail: andresf.rodriguez@unilibrebog.edu.co).
L. Martinez is with Universidad Libre, Engineering Faculty, Department of Environmental Engineering, Bogotá, Colombia (phone: (+57) 311 281 8214; e-mail: laurax.martinezr@unilibrebog.edu.co).
R. Catacoli is with Universidad Libre, Engineering Faculty, Department of Environmental Engineering, Bogotá, Colombia (phone: (+57) 300 410 9052; e-mail: rutha.catacolij@unilibrebog.edu.co).

ultrasound technique, maintaining the water temperature at 60°C for six cycles of 30 minutes each [6].

Apart from that, an analytical study was carried out using the AAS method, determining the elements Vanadium (V), Lead (Pb), Inorganic Mercury (Hg) and Cadmium (Cd) that were individually present in the sample. The FTIR method was used to identify the volatile organic compounds.

Additionally, a comparative analysis was carried out using IDW maps that showed the distributions of PM_{10} concentration in the city. Information obtained from the Bogotá Air Quality Monitoring Network (RMCAB) was also used, demonstrating the similarities between the sampled concentrations and those consulted theoretically.

Lastly, using particulate matter and unconventional pollutant concentrations, the harmful effects on the health of the community surrounding the university were identified, marking a comparison with the levels set in the guidelines for air quality according to the exposure degree established by the WHO.

III. Results and Discussion

A. PM10 Concentrations

Table I presents the results obtained during the sampling in November and December 2015, displaying the respective flow rate and concentration calculations in actual conditions (Qa and Ca) and standard conditions (Qstd and Cstd), taking into consideration the permissible limits established by Resolution 610 of 2010 and the WHO, in order to make a comparison, and determine their fulfillment in both cases.

TABLE I
Flow Rates and Concentrations (Actual and Standard)

No. Sample	Qa (m^3/min)	Qstd (m^3/min)	Ca (μg/m^3)	Cstd (μg/m^3)	Res. 610/2010 (μg/m^3)	WHO (μg/m^3)
1	1.187	1.4002	21	18	100	50
2	1.187	1.4558	18	15	100	50
3	1.187	1.3826	15	13	100	50
4	1.187	1.4488	20	16	100	50
5	1.187	1.4906	20	16	100	50
6	1.187	1.6046	42	31	100	50
7	1.187	1.5084	20	15	100	50
8	1.187	1.5400	26	20	100	50
9	1.187	1.4954	36	28	100	50
10	1.187	1.4368	80	66	100	50
11	1.187	1.4853	22	17	100	50

Fig. 1 shows the behavior of particulate matter (PM_{10}) concentration during the respective sampling, where the analyses of 11 samples were performed, suppressing sample number 10 present in Table I, since this one has an outstanding value with respect to the rest, being considered an atypical data due to a burning process carried out the same day in an area near the sampling point. In this context, the maximum concentration value is 31 g/m^3 and the minimum value is 13 g/m^3, corresponding to sample 6 and sample 3, respectively.

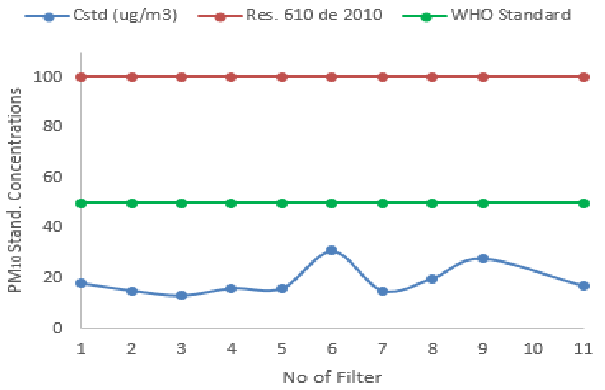

Fig. 1 Standard Concentrations vs. Res. 610 / 2010 – WHO

Table II presents the descriptive statistics performed on the calculated concentrations, where it is observed that the average is below the permissible limit established by Resolution 610 of 2010. In addition, the variance and standard deviation have low values, concluding that the concentrations varied a little and that their behavior remained close to average during the sampling period.

TABLE II
PM_{10} Statistical Analysis

PM_{10} statistical analysis	
Average	18.9
Standard deviation	5.933895104
Variance	35.21111111
Minimum	13
Maximum	31

In this context, the concentrations found in the sampling period are within the permissible limits established by Colombian legislation in resolution 610 of 2010 and the WHO, which both exhibit a maximum PM_{10} concentration level of 100 g/m^3 and 50 g/m^3 in a 24 hour exposure period [7], [8]. Table III shows the maximum permissible PM_{10} levels.

TABLE III
Maximum Permissible Levels

Pollutant	Maximum permissible level Res. 610/2010 (μg/m^3)	Maximum permissible level WHO (μg/m^3)	Exposure time
PM_{10}	50	20	Annual
	100	50	24 Hours
Lead	0.5	-	Annual
Cadmium	$5x10^{-3}$	-	Annual
Inorganic Mercury	1	-	Annual
Vanadium	1	-	24 Hours

Fig. 2 presents the concentration data taken during sampling and those obtained through records from the RMCAB and the IDRD station. It is observed that the concentrations consulted in the station, as well as those obtained in the sampling, do not exceed the maximum permissible limits indicated in the resolution. Likewise, the station and sampling point concentrations follow a similar tendency; however, IDRD concentrations are higher than those known from the sampling. On the other hand, it is important to emphasize that station selection was made with comparative purposes in mind, considering that the sampling point is in a background area that had similar characteristics to the Universisdad Libre. Likewise, Fig. 3 shows the correlation between the concentrations of the sampling point and the IDRD station, making it evident that the values present a significant difference since their R^2 is 0.3186, with 1 being the optimal value in the analysis.

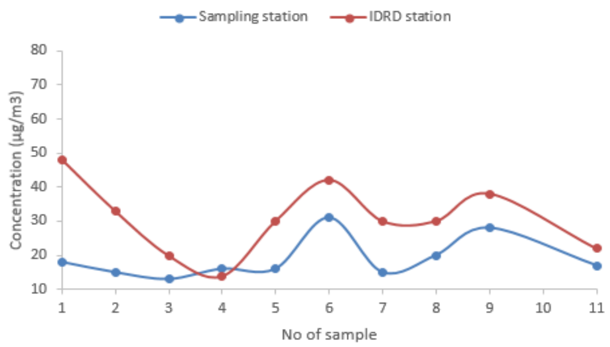

Fig. 2 Comparison between IDRD and Universidad Libre station

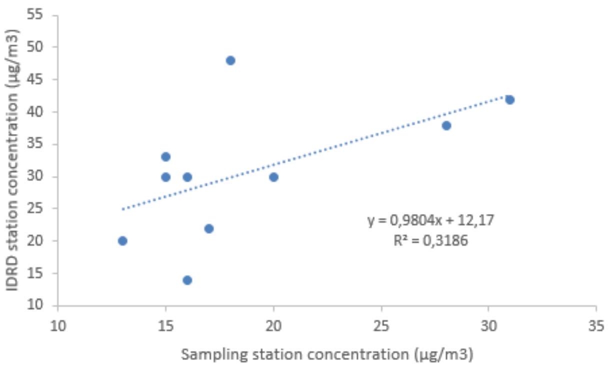

Fig. 3 Correlation between sampling point and IDRD station

B. IDW Method

The IDW (Inverse Distance Weighting) method is an interpolation process used to predict an unknown contaminant concentration value using a known value in neighboring locations which may be regularly or irregularly spaced. Values derived in this way are not necessarily a true value; they are a mathematical "best approximation" based on known values. In general, interpolation methods use the weighted average of the nearby data to calculate the pollutant estimates, obtaining maps of their concentration in the study area, in order to compare the sampled concentration with the theoretical value generated on the map [9].

The IDW maps contain a total of five concentration ranges, each having a specific color assigned. Fig. 4 corresponds to sample 3 and sample 4, verifying that the concentration calculated for these days coincides with the IDW map ranges. This also takes into account the fact that the same case is presented for the rest of the concentrations found in the sampling process. This confirms that the IDW methodology is an efficient tool that can be used to identify the approximate concentration of a specific zone, allowing the ability to compare other studies.

C. Presence of Heavy Metals

In order to identify the presence of heavy metals in the samples, the respective extraction process was implemented using hot acids. The analyses were performed using the atomic absorption spectrophotometer (EAA), where concentrations were found to be below the value established by Colombian air quality legislation (Res. 610 / 2010), displayed in Table IV.

TABLE IV
HEAVY METAL CONCENTRATIONS (µG/M³)

Sample	Cst (µg/m³)	Heavy metal concentrations (µg/m³)			
		Pb	Hg	V	Cd
1	18	<0.45	< 4.2	<1.9	<0.028
2	15	<0.45	< 4. 2	<1.9	<0.028
3	13	<0.45	< 4.2	<1.9	<0.028
4	16	<0.45	< 4.2	<1.9	<0.028
5	16	<0.45	< 4.2	<1.9	<0.028
6	31	<0.45	< 4.2	<1.9	<0.028
7	15	<0.45	< 4.2	<1.9	<0.028
8	20	<0.45	< 4.2	<1.9	<0.028
9	28	<0.45	< 4.2	<1.9	<0.028
10	66	<0.45	< 4.2	<1.9	<0.028
11	17	<0.45	< 4.2	<1.9	<0.028

D. FTIR Analysis

In order to conduct the FTIR analysis, an infrared spectrum was used, as well as a white filter, and pure forms of benzene and toluene. This comparative process helped identify and conclude if the PM_{10} samples showed traces of benzene and toluene.

Fig. 4 shows the sample 1 spectrum and the white filter spectrum. The graph allows to determine that the peaks located between the 993 cm^{-1} - 1246 cm^{-1} and 412 cm^{-1} - 514 cm^{-1}, demonstrate the possible existence of filter (without sample) components, which explains the reason why they are not taken into account when performing the Spectrum analysis. It is important to notice that these peaks are present in all samples.

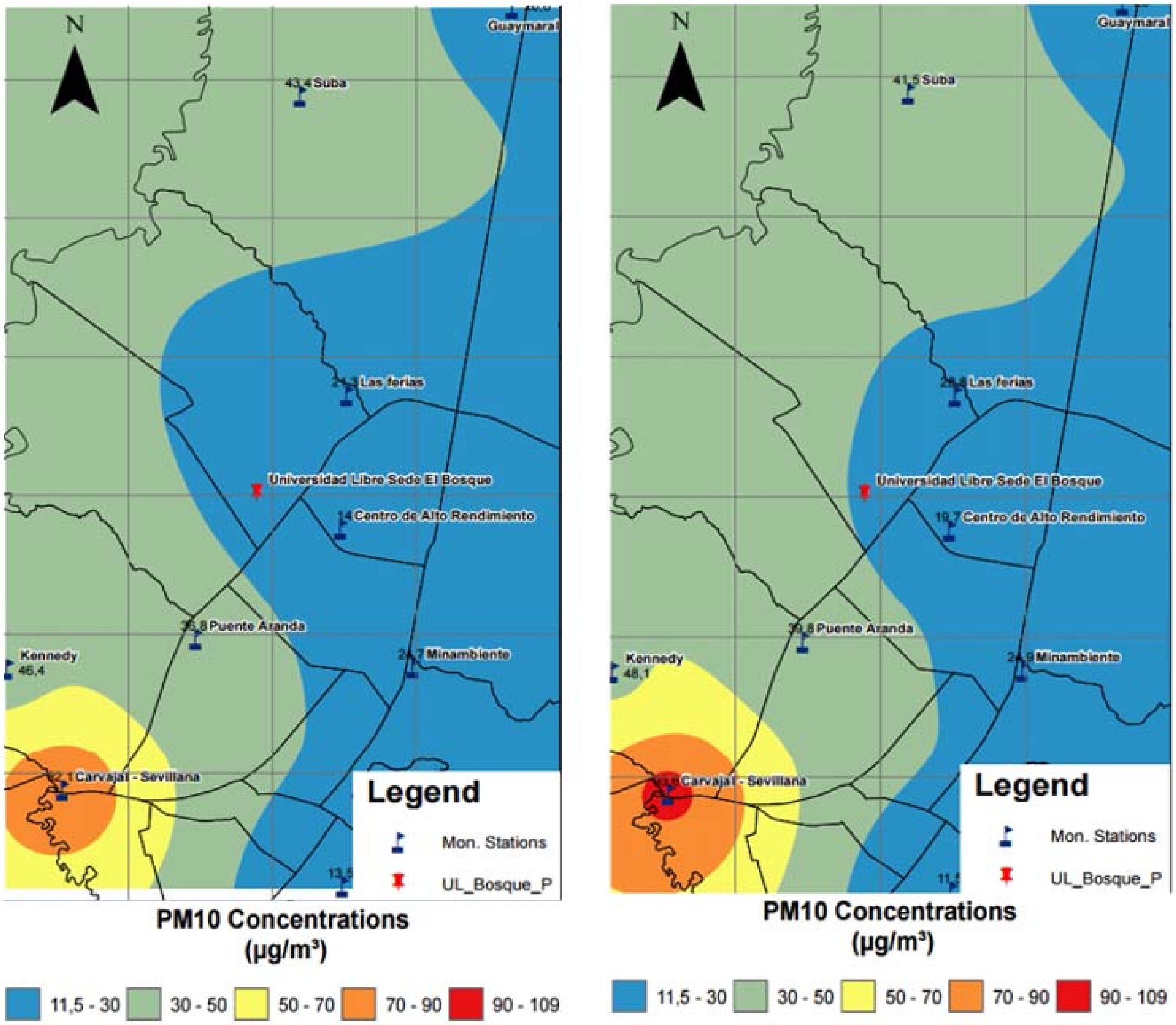

Fig. 4 IDW Maps - Samples 3 and 4

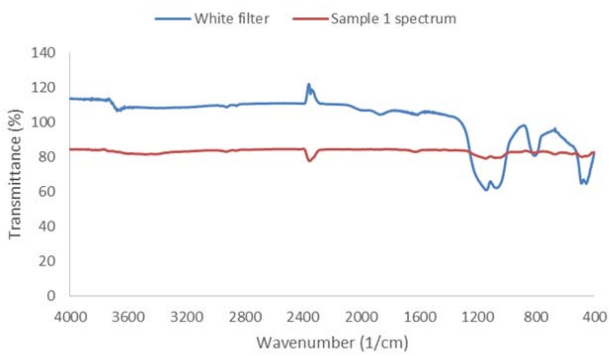

Fig. 5 White filter and Sample 1 spectrum

Figs. 6-13 allow to infer that the samples obtained do not contain toluene traces, due to the absence of stress peaks in the ranges of 1496 cm^{-1} - 1605 cm^{-1} and 3000 cm^{-1} - 3100 cm^{-1}, in addition to a bending strip between 696 cm^{-1} and 729 cm^{-1} [10]. Therefore, it was established that the samples taken from the background site did not include any traces of toluene.

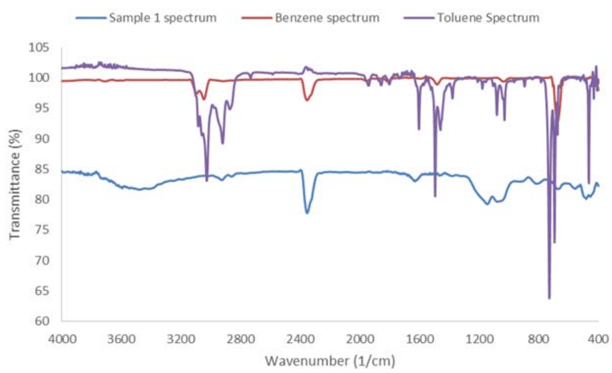

Fig. 6 Sample 1 spectrum

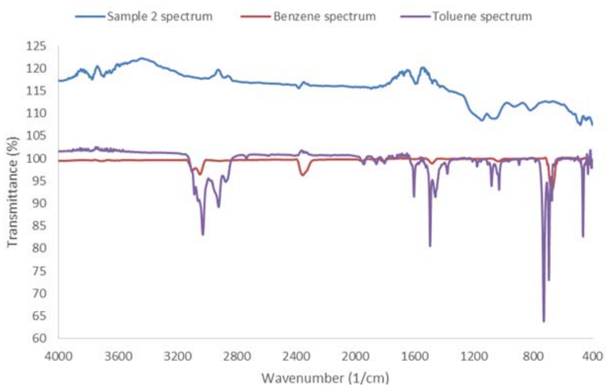

Fig. 7 Sample 2 spectrum

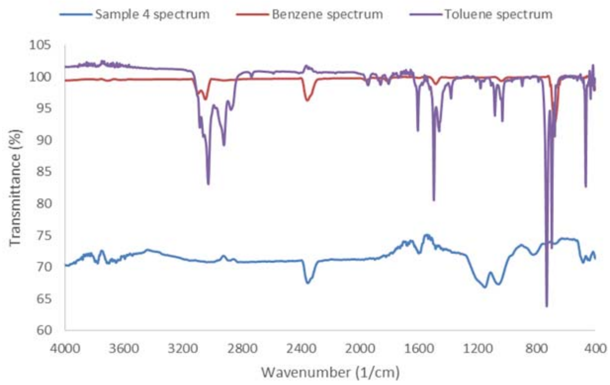

Fig. 8 Sample 4 spectrum

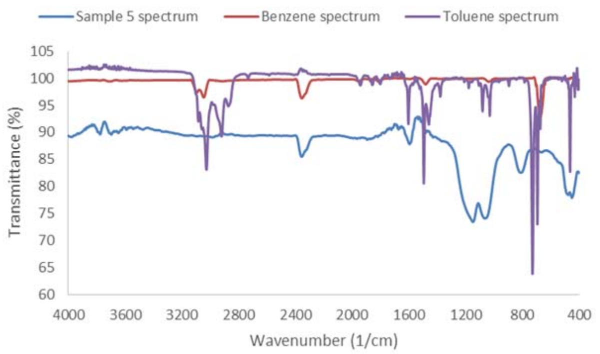

Fig. 9 Sample 5 spectrum

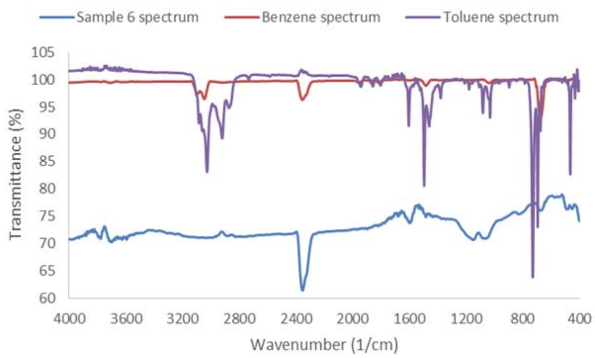

Fig. 10 Sample 6 spectrum

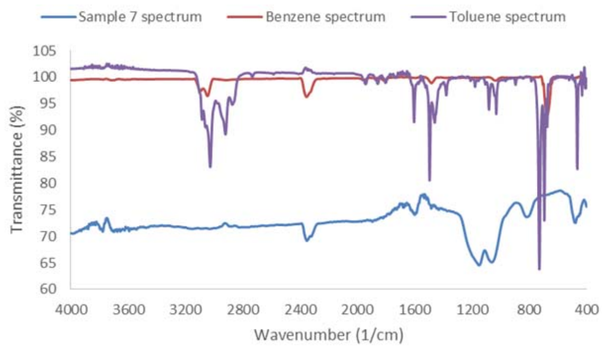

Fig. 11 Sample 7 spectrum

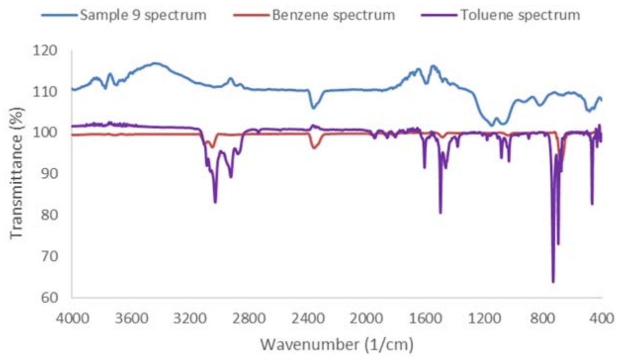

Fig. 12 Sample 9 spectrum

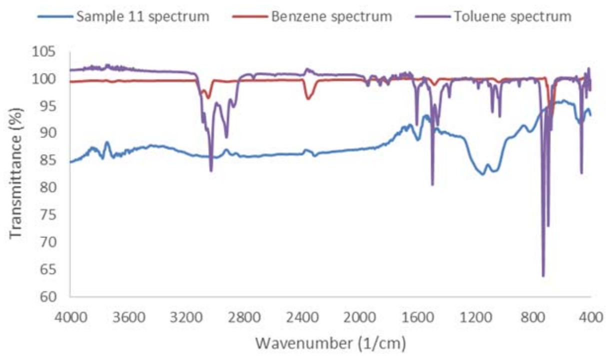

Fig. 13 Sample 11 spectrum

On the other hand, all samples, with the exception of sample 2 and sample 11, show a peak characterized by benzene in the 2280 cm^{-1} - 2380 cm^{-1} range, which allows to affirm that during the sampling period there were benzene traces which may have been generated by the combustion caused by vehicles used by the community surrounding the university.

IV. Conclusion

In conclusion, particulate matter (PM_{10}) concentrations, during an exposure period of 24 hours, are lower than the values established in Resolution 610 of 2010; however, the comparison of these values with the limits determined by WHO allows to infer that the concentrations could exceed the levels stipulated by this organization.

It can also be shown that the limits established by Colombian legislation are double the amounts of those established by the WHO, which shows that air quality management could be improved if international standards were followed, allowing to establish strict limits on the same exposure times, creating a necessary change in the country's stationary sources.

From analyzing PM_{10} to analyzing heavy metal concentrations, it is concluded that the air quality present at Universidad Libre Bogotá does not present a risk to the population's well-being, since the values do not exceed the maximum permissible limits of Resolution 610 of 2010 and those established by WHO. Likewise, the spectrums obtained from the FTIR exhibit an absence of toluene in the analyzed samples. On the other hand, the spectrum showed that there is a possibility of finding traces of benzene, which may have possibly been a product of the vehicles used around the university. The majority of these vehicles use fossil fuels; therefore, a gas chromatographic analysis would determine the amount of pollutant that is present, allowing for a comparison to be made with the current Colombian legislation.

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