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# VOC dispersion modeling in five points of vehicular flow of the city of Bucaramanga

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--------------------------------------------------------***ABSTRACT***--------------------------------------------------------
*This research work is about the characterization that was carried out in 5 strategic points, one of them is career 33 with calle 52 Barrio Cabecera of the city of Bucaramanga, where one of the quality control stations is located. air by the Regional Autonomous Corporation for the Defense of the Plateau de Bucaramanga CDMB. Eight continuous hours were available in 12 days of measurements for the month of November of the year 2018, in order to obtain data on the concentrations of VOC volatile organic compounds present in this site, which has been passed by motorcycles, cars and public service buses. This was done, thanks to a sensor developed in the GAIA Research Group, also a count was made of the vehicles named above and subsequently the data obtained was treated statistically in order to get a conclusion regarding resolution 610 of 2010 for the quality of air. The development of this is presented in the following report. Then this data was corroborated with the AERMOD model to determine points of maximum impact in the determined area*

***KEYWORDS;-****Aermod, VOC, vehicular Flow air quality*
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## I. INTRODUCTION

The growth of the vehicle fleet is also a major factor when analyzing air pollution. Figures presented by the Traffic Directorate of Bucaramanga (DTB) show that the municipality had 76,576 automobiles and 24,503 motorcycles registered as of December 31, 2011. Figures as of December 2016 show an automotive fleet 646,848 vehicles of which 378,677 motorcycles (59%), 146,591 vehicles (23%) and the rest between trucks and other heavy vehicles (18%). The conflicts generated by the increase in vehicles in the area have to do with the frequent traffic jams in which drivers are forced to stop and start consecutively, this being an action that generates more pollution than that produced by a vehicle. car that goes at 60 kilometers per hour without stopping. So far no VOC data in the air of Bucaramanga, therefore this work aims to cover this lack of information to know the real impact on human health of bumangueses and risk areas, for it using in a first phase an electronic device design for VOC registration, and later in another phase a simulation was performed with the Aermod software.

## II. MATERIAL AND METHODS

Conventional pollutants in the environment are routinely measured in air quality monitoring networks and there are very extensive databases and, in general, good quality, but for certain unconventional atmospheric pollutants such as Volatile Organic Compounds (VOCS), the data are often inconsistent and not extensive (in space and time). In accordance with widely accepted criteria, in the term COV are grouped compounds with carbon present in the atmosphere that have a vapour pressure higher than 0.01 kPa at 293.15 K, except for the methane that by its special characteristics is treated separately. VOCS are composed of a complex mixture of low molecular weight compounds, with a number of carbon atoms normally between 2 and 12 [1]

The availability of VOC ambient concentration data is essential for any risk assessment, as ultimately, the assessment of the human health risks derived from air pollution requires information on Levels of exposure of the population to the different pollutants, the number of people exposed (including risk groups) and the knowledge of the quantitative relationships between exposure and health effects[2]

In Urban Atmospheres the main anthropogenic sources of VOC, although not the only ones, are the mobile sources. Of these, the emissions due to the road traffic, mainly emissions by the exhaust pipe and evaporation losses, are highlighted, in addition to the own emissions of the liquid petrol which are present in the ambient air of practically any urban area. [3, 4] These emissions depend not only on the type of engine (explosion, diesel, etc.), but also on the operating system itself, the fuel they use and the age of the vehicle. Even the composition of the gasoline varies depending on the geographical region, the season of the year, octane requirements or the source of crude of which it proceeds. Fugitive emissions from the transport and distribution of fuels (petrol, gas oils and LPG), emissions from natural gas and the use of solvents are Also of particular importance in urban areas. The realization of the measures is not simple task given the large number of compounds and the low levels of concentration in which many of them are in ambient air (PPBV-PPTV). Analytical instrumentation Is required with multicomponent capacity and high sensitivity and resolution The most commonly used techniques for The analysis of VOC's in ambient air, are currently based on gas chromatography, mainly because it is instrumentation Highly specialized analytical, with multicomponent capacity, high sensitivity and resolution. The measures are not simple because of the difficulty of speciation complex VOC mixtures, such as those present in ambient air, which come from various anthropogenic and natural emission sources, and their atmospheric oxidation products. It is Also necessary to take into account the large number of compounds and the low levels of concentration in which many of them are in ambient air [5].

Many VOCS from Anthropogenic and biogenic sources (See Table 1 and 2) participate in atmospheric chemical reactions which, together with nitrogen oxides and the presence of solar radiation, are the main precursors of troposphericic ozone and other photochemical oxidants. It is Necessary to take into account the qualitative composition of the mixture of organic compounds in the atmosphere, since some VOCS react more effectively than others, that is to say that they have among themselves different capacity of generation of photochemical oxidants, as a consequence of its different reactivates and structure. Among them ozone is usually considered the most important because of the high concentrations of the same that can be achieved (up to several hundred ppb) and the important documented effects on human health, plants and materials.

| **PLOT COLUMN** | | **BP1 COLUMN** | |
|---|---|---|---|
| **Peak number** | **Compuesto** | **Peak Number** | **Compound** |
| 1 | Ethane | 28 | n-Hexane |
| 2 | Ethylene | 29 | Methyl Cycle Pentane |
| 3 | Propane | 30 | 2,4-Dymetil Pentane |
| 4 | Propylene | 31 | Benzene |
| 5 | i-Butane | 32 | Cycle Hexane |
| 6 | n-Butane | 33 | 2-Methil Hexane |
| 7 | Acetylene | 34 | 2,3-Dymetil Pentane |
| 8 | trans-2-Butene | 35 | 3-Methyl Pentane |
| 9 | 1-Butene | 36 | Trichloroethylene |
| 10 | i-Butylene | 37 | 1-Heptene |
| 11 | cis-2-Butylene | 38 | 2,2,4-Trimetyl Pentane |
| 12 | Cycle Pentane | 39 | n-Heptane |
| 13 | i-Pentane | 40 | Methyl Cycle Hexane |

**Table 1(List of some of the 62 COV identified and quantified)**

| | | |
|---|---|---|
| 1,3-butadiene | 2,2,4-trimetylpentane | m&p-xylene |
| n-hexane | Toluene | styrene |
| benzene | Tetrachloroethane | o-xylene |
| Trichloroethane | Ethylbenzene | Isopropyl Benzene |

**Table 2 (List of mean of the toxic COV identified)**

## III. RESULT VIEW

Figure 1, 2, 3 and 4 shows an electronic VOC measurement device in air, based on a sensor created by Dean Miller, which was taken to a box with temperature display, $CO_2$ concentration and VOC concentration in ppb.

**Figure 1Diagram of sensor Blocks in the air**

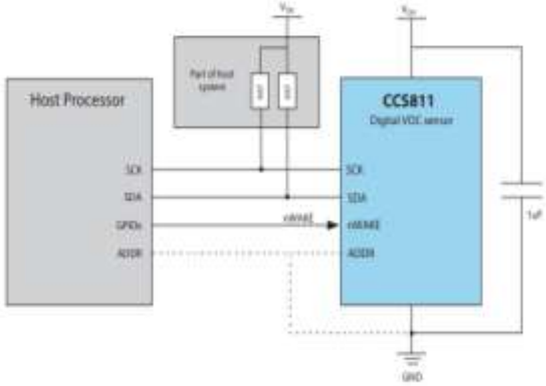



**Figure no 2Connection to the sensor**

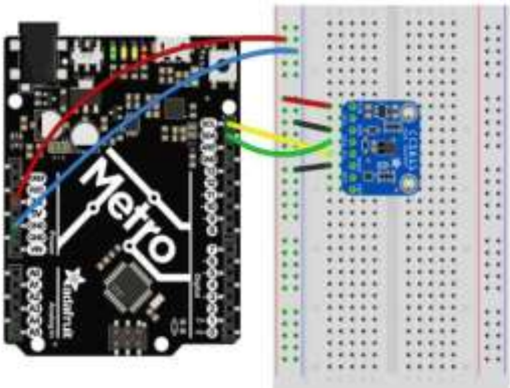



**Figure no 3Box Construction**

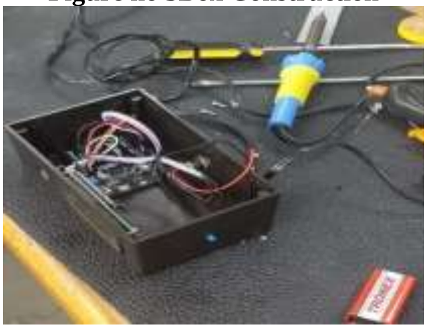
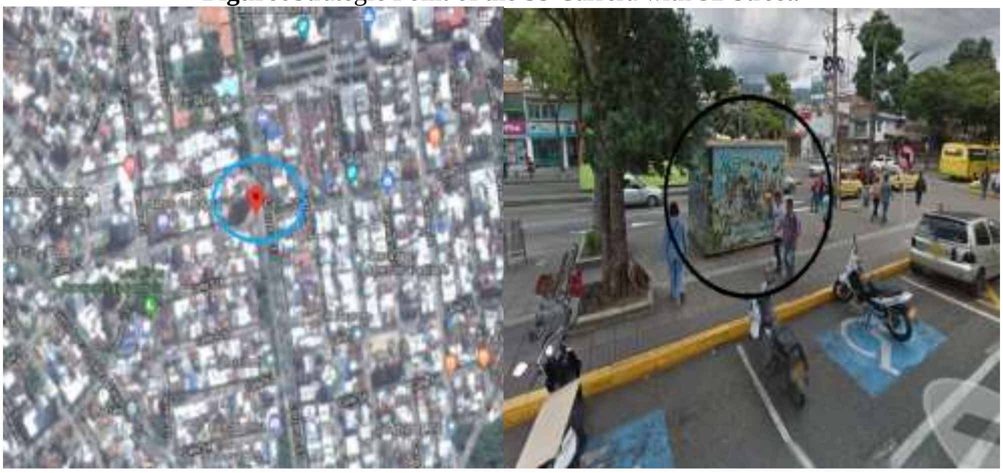


**Figure no 4Box Viewer Device**

Figure 6 shows the field data-taking work based on 8-hour measurements at each point taken into account.These measurements were made every 5 minutes and then the value was averaged every hour, 6 values were recorded for each day of taking.

**Figure 5Data Taking at the strategic points of the city of Bucaramanga AMB**

**Figure**6Strategic Point of the 33 Carrera with 52 Street.



Sampling and data taking were carried out at five strategic points in the metropolitan area of Bucaramanga, which comprises the municipalities of Bucaramanga, Floridablanca, Piedecuesta and Girón, which in total have a population that exceeds one million inhabitants. Figure 6 presents the first point located at the intersection of the Carrera 33 and 52 street in the municipality of Bucaramanga, a place where automotive traffic, commercial area and is the beginning of the western escarpment of the green lung of the city**.**

| Nª | VOC (ppb) | T(ªC) |
|---|---|---|
| **1** | 73 | 25.1 |
| **2** | 86 | 25 |
| **3** | 31 | 24.2 |
| **4** | 288 | 24.1 |
| **5** | 49 | 23.4 |
| **6** | 202 | 23.6 |
| **7** | 133 | 23.6 |
| **8** | 192 | 23.1 |
| **9** | 201 | 22 |
| **10** | 146 | 22.1 |
| **11** | 130 | 23.1 |
| **12** | 148 | 22.1 |
| **13** | 167 | 22.2 |
| **14** | 160 | 22.8 |
| **15** | 194 | 22.9 |
| **16** | 129 | 22.5 |

**Table 3 VOC and temperature Measurements every half hour in a range of 8 hours**

On the 33 Race with 52 Street the measured temperature in an interval of 8 hours present an overage of 23.2375 °C with a Standard Deviation of 0.98718
Figure 7 presents the second strategic point of data-taking of VOC, located at the Aurelio Martínez School in the area of Ciudadela Real de Minas in the municipality of Bucaramanga.

**Figure 7Strategic Point of the Ciudadela de minas**

| Nª | VOC (ppb) | T(ªC) |
|---|---|---|
| **1** | 11 | 24.3 |
| **2** | 21 | 24 |
| **3** | 8 | 24.2 |
| **4** | 81 | 24.1 |
| **5** | 117 | 23.7 |
| **6** | 48 | 23.6 |
| **7** | 206 | 23.7 |
| **8** | 113 | 23.8 |
| **9** | 58 | 22.9 |
| **10** | 19 | 22.8 |
| **11** | 51 | 23.1 |
| **12** | 12 | 22.5 |
| **13** | 61 | 22.1 |
| **14** | 63 | 22.1 |
| **15** | 40 | 21.9 |
| **16** | 86 | 22.1 |

**Table 4 VOC and temperature Measurements every half hour in a range of 8 hours**

On the Ciudadela de Minas the measured temperature in an interval of 8 hours present a media of23,1813°C with a Standard Deviation of 0,8463
The strategic Point Number three, is located in the Hospital of the North, zone close to suburbs and also of industrial zones of the municipality of Bucaramanga. (See Figure 8)
Point four corresponds to the registration station on 34 Street with Carrera 15, the neuralgic point of the municipality of Bucaramanga. (See Figure 10).

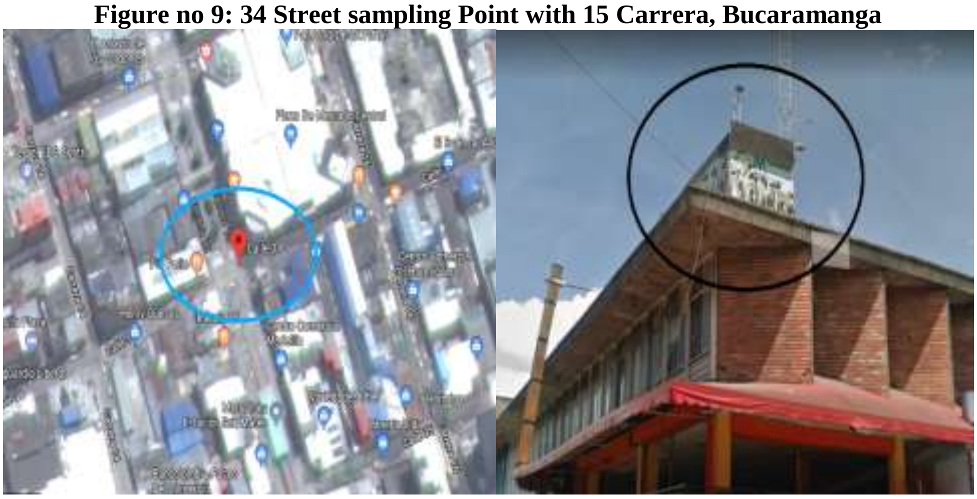
**Figure 8Registration Point of the North Hospital, Bucaramanga**

| Time | VOC (ppb) | T(ºC) |
|---|---|---|
| **1** | 1 | 21.2 |
| **2** | 8 | 22.1 |
| **3** | 15 | 22.2 |
| **4** | 11 | 22.1 |
| **5** | 33 | 23.1 |
| **6** | 54 | 23.4 |
| **7** | 27 | 23.2 |
| **8** | 91 | 23.5 |
| **9** | 135 | 22.1 |
| **10** | 177 | 22.1 |
| **11** | 262 | 21.1 |
| **12** | 75 | 21.5 |
| **13** | 78 | 22.1 |
| **14** | 61 | 22.3 |
| **15** | 84 | 22.1 |
| **16** | 72 | 21.8 |

**Table 5 VOC and temperature Measurements every half hour in a range of 8 hours**

The average value from Temperature in North Hospital was 21,2313 °C whit a Standard Deviation of 0,71528.

**Figure no 9: 34 Street sampling Point with 15 Carrera, Bucaramanga**



| Nª | VOC (ppb) | T(ªC) |
|---|---|---|
| **1** | 98 | 24.5 |
| **2** | 111 | 25.1 |
| **3** | 223 | 25.2 |
| **4** | 85 | 25.1 |
| **5** | 172 | 25.1 |
| **6** | 39 | 25.4 |
| **7** | 88 | 25.2 |
| **8** | 109 | 24.5 |
| **9** | 54 | 24.1 |
| **10** | 99 | 24.4 |
| **11** | 118 | 24.1 |
| **12** | 159 | 23.5 |
| **13** | 112 | 23.1 |
| **14** | 114 | 23.3 |
| **15** | 129 | 23.1 |
| **16** | 103 | 23.8 |

**Table 6 VOC and temperature Measurements every half hour in a range of 8 hours**

On 34 Street sampling Point with 15 Carrera, the overage temperature value was 24,3438 °C , whit a standard deviation from 0,80247.

Figure 10 shows the strategic point five, given in the ring road specifically, place of confluence of the municipalities of Girón, Floridablanca and Piedecuesta.

**Figure 10Anillo vial Registration Point**

| Nª | VOC (ppb) | T(ªC) |
|---|---|---|
| **1** | 90 | 25.6 |
| **2** | 6 | 26.1 |
| **3** | 27 | 26.3 |
| **4** | 92 | 27.1 |
| **5** | 69 | 27 |
| **6** | 112 | 26.8 |
| **7** | 79 | 26.7 |
| **8** | 93 | 27.3 |
| **9** | 207 | 26.4 |

| | | |
|---|---|---|
| **10** | 121 | 26.7 |
| **11** | 112 | 27.1 |
| **12** | 53 | 26.9 |
| **13** | 87 | 26.4 |
| **14** | 90 | 26.7 |
| **15** | 56 | 26.3 |
| **16** | 112 | 25.9 |

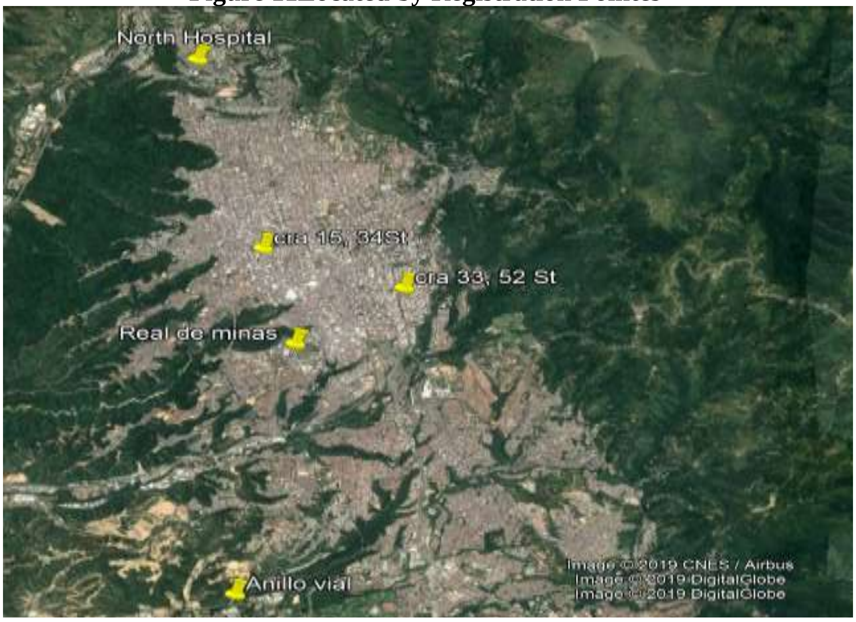
**Table 7 VOC and temperature Measurements every half hour in a range of 8 hours**

On Anillo vial, the overage temperature value was 26,5°C, whit a standard deviation from 0,469.

**Statistical analysis**
Data was analyzed using Statgraphics
In Figure 11, you can observe the Registration pointes location on the city of Bucaramanga to the present study.

## IV. ANALYSIS

**Figure 11Located by Registration Pointes**




Taken from Google Earth

**Figure 12Comparative of VOCs Values from Registration Pointes**

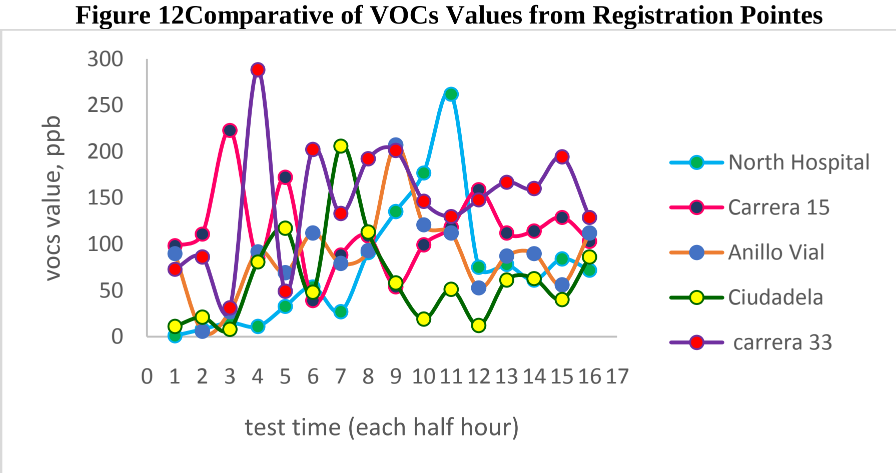
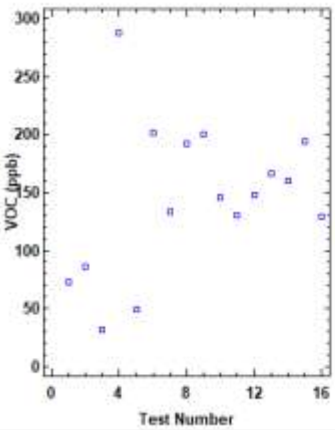
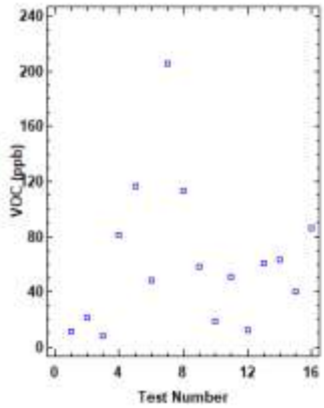


**Figure 13Dispersion of VOCs Values from Registration Pointes**

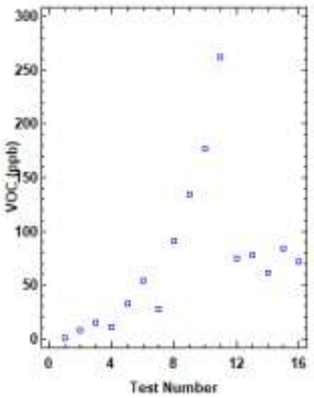
***a. The 33 Race with 52 Street***



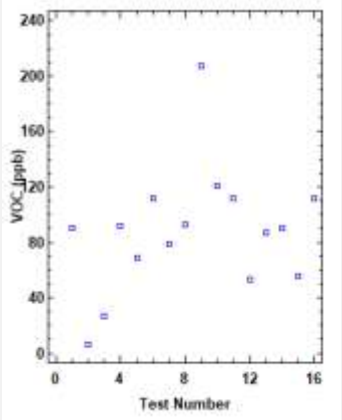

***b. Ciudadela de Minas***



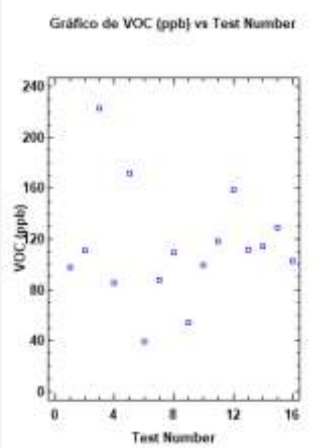

***c. On the North Hospital***




***d. Anillo Vial***




*e. **34 Street with 15 Carrera***




Ministry of environment, housing and territorial development resolution number (601) 04 April 2006 by which the Standard of Air Quality or Level of Inmision is established, for the whole national territory under conditions of reference.

| Contaminants | ppm permissible |
|---|---|
| **Etil mercaptano ($C_2H_5SH$)** | 0.0002 |
| **Etil acrilato ($C_5H_8O_2$)** | 0.00047 |
| **Estireno ($C_8H_8$)** | 0.047 |
| **Monometil amina ($CH_5N$)** | 0.021 |
| **Metil mercaptano ($CH_3SH$)** | 0.002 |
| **Nitrobenceno ($C_6H_5NO_2$)** | 0.0047 |
| **Propil mercaptano ($C_3H_8S$)** | 0.007 |
| **Butil mercaptano ($C4H_{10}S$)** | 0.0007 |
| **Sulfuro de dimetilo ($C_2H_6S$)** | 0.002 |
| **Sulfuro de hidrógeno ($H_2S$)** | 0.005 |

**Table 8 Permissible limits to Colombian lawyer**

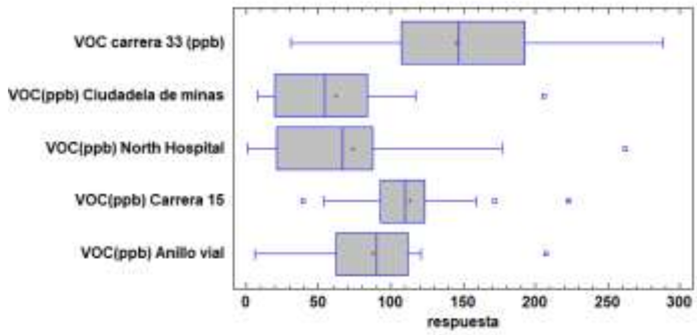
| **Place** | **Range** | **Count** | **VOCs Overage** | **Coefficient of variation** | **Standardized bias** | **Kurtosis** |
|---|---|---|---|---|---|---|
| Carrera 33, 53 Street | 31.0 to 288.0 | 16 | 145,56 | 44,75% | 0,206557 | 0,3198 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ciudadela de minas | 8.0 to 206.0 | 16 | 62,18 | 82,68% | 2,4751 | 2,467 |
| North Hospital | 1.0 to 262.0 | 16 | 74 | 93,41% | 2,5068 | 2,169 |
| Carrera 15 | 39.0 to 223.0 | 16 | 113,31 | 38,72% | 1,4067 | 1,4704 |
| Anillo vial | 6.0 to 207.0 | 16 | 87,87 | 51,03% | 1,259 | 2,3011 |
| Total | | 80 | 96,58 | 64,35% | 2,7359 | 0,8072 |

**Table 7 statically analyze**

Note that standardized bias and kurtosis are outside the range of-2 to + 2 for Anillo vial, North Hospital and Ciudadela de minas values, so the normal distribution from VOCs does not apply in these cases.

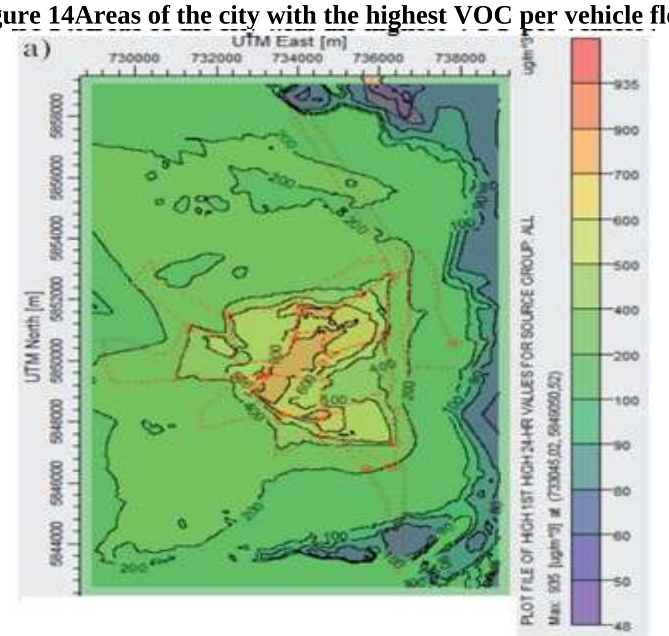
**Figure 14Box chart and Whiskers**




Carrera 33 present the highest values to VOCs particulates, followed by Carrera 15. Observe that these points are located into the city. It cause that the air dispersion to the gases and particulate material was slower because the high building that prevents normal passage of air currents that another points when the environmental conditions makes that COVs will be disperse quickly and and make these not accumulate.

Details of the dispersion of the VOC concentration for 8 hours and for the period studied are shown in Figures 11. These show a general behavior of higher concentrations in the inner neighborhoods of the city where there is greater vehicular flow. See figure 14

**Figure 14Areas of the city with the highest VOC per vehicle flow**

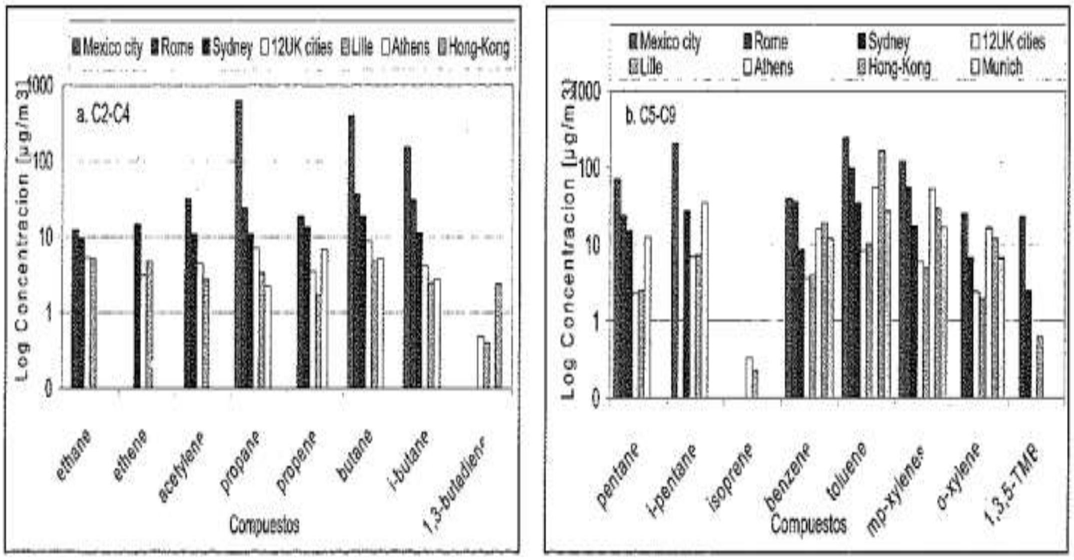


**Comparison of VOCS levels in some important cities of the world**

An atmosphere of the VOCS levels present in the different cities of the world is shown in Figure 12

According to that study Mexico is the city most affected by the VOCs followed by Rome and Hong Kong. The most abundances compounds are ethane, ethene, acetylene and toluene.[12]

**Figure 15Comparison of $VOC_S$ levels in some cities of the world**




## V. CONCLUSION

Using an electronic device that registers total VOC values from several critical points in Bucaramanga was possible to take the overage values to this Concentration, finding an average of 96.85 ppb, and as the area with the highest concentration is the center (Carrera 15 with street 36) with a value of 145.5 ppb, that highest value was associated with the high traffic in the area.

When comparing these values with some other cities, considering that the measuring devices they use measure each component individually: benzene, etane, propane, etc; At the same time we can guarantee that similar studies have not been done in the City, since the city is not so great, therefore the levels of air pollution are not so high when compared with Mexico for example.

However, considering that the portable device that is used is new in the market, it is recommended to carry out other measurements in places close to factories, industrial zone and parks, to collate the information. In A second phase will be sampling of the VOC best

## REFERENCES

[1]. Zuluaga Gómez Carlos Mario. Estudio de la dispersión de contaminantes en la jurisdicción de Cornare. Convenio Cornare-UPB Medellín, Colombia. (2015). Disponible en https:// www.cornare.gov.co/ SIAR/aire/CALIDAD_DE_AIRE/CONTENIDO/ Informe_Modelo_Dispersion_Valles_de_San_Nicolas.pdf

[2]. Torres Jerez Agustín. Aplicación Práctica del Modelo de dispersión de contaminantes en la atmósfera ISC. Escuela de Negocios. Madrid. España. (2008). Disponible en file:///C:/Users/Walter/Downloads/componente45570%20(1).pdf

[3]. Gómez Navazo María del Carmen. Evaluación de COVs en emplazamiento urbano del País Vasco. Environment and Systems. Bilbao. España. (2010). Disponible en http:// www.euskadi.eus/ contenidos/documentacion/ esia_fundiguel/es_doc/adjuntos/ modelo_dispersion_contaminantes.pdf

[4]. Sánchez Montejo. José María. COVs en el medio ambiente. Universidad Complutense de Madrid España. (2008). Disponible en http://ritsq.org/wp-content/uploads/reach-uah/Sanchez-UAH-2008.pdf

[5]. Behera S. Scope of Algae as Third Generation Biofuels. Front Bioeng Biotechnol. (2014); 2: 90. Disponiblehttps: //www.ncbi.nlm.nih.gov/pmc/articles/PMC4324237/

[6]. Chandra A.and Sharma S. Simulation of Air Quality using an ISCST3 Dispersion Model. Clean soil Air Water. Volume 36, Issue 1 January (2008). Disponible en http://onlinelibrary.wiley.com/doi/10.1002/clen.200700036/abstract

[7]. Patiño Mario. Modelos de Dispersión Gausianos Principales Parámetros que Afectan la Dispersión de Contaminantes en el Aire. Escuela Superior Politécnico del Litoral. Guayaquil. Ecuador. (2007). Disponible en http:// www.cdts.espol.edu.ec/ documentos/Presentaci%C3%B3n%20DISPERION%20MP.pdf

[8]. Silva Adrian y Arcos Dagoberto. Aplicación del programa AERMOD para modelar dispersión de PM10 emitido por equipos de calefacción a leña en la ciudad de Constitución. Universidad Católica de la Santisima Concepción. Chile. (2011). Disponible en http://www.scielo.cl/pdf/oyp/n9/art01.pdf

[9]. Prato Sánchez Daniel. Estudio de dispersión de contaminantes en zona minera del César Colombia, usando Fluent. Universidad EAN. (2012). Disponible en http://repository.ean.edu.co/bitstream/handle/10882/4607/PratoDaniel2012.pdf?sequence=3

[10]. HernandezAnel y otros. Aplicaciones del modelo lagriangiano de dispersión atmosférica. Ciencias de la tierra y el espacio. España. (2016). Disponible en http://www.iga.cu/publicaciones/revista/assets/calpuffreview2.pdf

[11]. Méndez Juan Felipe y otros. Estimación de factores de emisión de material particuladoresuspendido antes, durante y después de la pavimentación de una vía en Bogotá. Ciencia e Ingeniería Neogranadina. (2017). Disponible en http:// www.scielo.org.co/ pdf/cein/v27n1/v27n1a03.pdf

[12]. González-Cruz M.B. Sensibilidad del modelo ISCST3 en la emisión de contaminantes conservativo. Caso de estudio. Revista Mexicana de Ingeniería Química. (2012). Disponible en http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1665-27382012000200008

[13]. Ramos Alfredo. Modelamiento de material particulado emitido por coquización. Samacá. Revista Logos, Ciencia y tecnología. (2017) Disponible en http://revistalogos.policia.edu.co/index.php/rlct/article/viewFile/303/pdf

[14]. C Puente, R Ramoroson, Mediciòn y análisis de los compuestos orgánicos volátiles en la atmósfera, resultads a nivel Europeo (2006) Revista ION, Universidad Industrial de Santander, Vol 19, Pag 43-47, Buaramanga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