

# Analysis of Co, Co2 and No2 AirPollutants in the City of Villavicencio - Colombia

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## Abstract

The article summarizes the results of research, whose purpose was to characterize the behavior of gases NO<sub>2</sub>, CO, CO<sub>2</sub> present in the city of Villavicencio Meta Colombia. The methodology used was experimental type whose data were processed using descriptive statistical techniques. The results indicated that the gases under study are in the permissible levels by current legal regulations and recommended continued efforts to mitigate the agentsair pollutants in the city.

**Keywords:** Air Quality, CO, CO<sub>2</sub>, Instrumentation, Descriptive Statistics, Sustainability.

## I. INTRODUCTION

Colombia ranks second among the 12 different mega nations, with an area of 0.7% of the surface of the planet, with 10% of the flora and fauna of the Earth, according to the Research Institute of Biological Resources Alexander von Humboldt likewise alarms are on due to high pollution since it is a problem that is increasing, according to (WHO) Colombia is the second country in Latin America with major environmental problems.

Global warming is a problem that currently increases due to the different sources of contamination, this is produced one of the greatest environmental problems of air pollution, which occurs naturally and / or artificially. Starting from this point, it is important to know in depth each of the variables and factors involved in their development.

The direct consequences that occur in humans due to high levels of air pollution on health are observed. According to official figures, worldwide 3.8 million people die every year from diseases related to pollution of the air, which are pneumonia (27%), stroke (18%), ischemic heart disease (27%), obstructive lung disease occur chronic (20%) and lung cancer (8%) (World Health Organization, 2018).

According to the information above, they are notable attempts to lessen the overall impact of air pollution in Colombia. However, these attempts are premature and insufficient, it is

necessary to implement better technologies in the major generating sources of pollution such as industry and transport, able to consolidate a culture for the care of the air is another important aspect that can lead to lower economic indices and current health of the country.

Likewise, the purpose of the investigation focused enn determine levels of gaseous pollutants CO, NO<sub>2</sub>, CO<sub>2</sub>, and O<sub>3</sub> present in villavicención, Meta Colombia.

## II. BACKGROUND

Among the different models to analyze data sets referring to modeling variables contamination of the air for a case study for the city of Medellin (Colombia), where regression models uses of the soil worked in the estimate is Local monthly concentration of pm<sub>10</sub>, their results were related to indicate the importance of the proper choice of the explanatory variables and access to them for the efficiency of the mathematical model is optimal, likewise, the direct correlation is denoted the closeness between the main roads and traffic density with the concentration of the pollutant PM<sub>10</sub> a measurement point [1],statement is consistent with the one in the city of Cali (Colombia) which states that the dynamics of vehicular traffic is primarily responsible for the pollution of air particulate matter PM<sub>10</sub>, an approach that was developed by using a Spline method modeling the daily behavior of said contaminant [2].

Likewise, in another study conducted in the same city, exactly in the districts 7 and 8, where he worked with a logistic regression model to assess environmental conditions and pollution under which the risk of presence of contamination Total Suspended Particles (PST) is higher. Worked as variables total suspended particles (TSP) and PM<sub>10</sub> particulate material where, from the results of PM<sub>10</sub> is possible to obtain a value for PST that can serve as reference for other studies. Moreover, the influence of the climate variable in the presence of pollution that ultimately supported by the model created, you can obtain a measure of the risk of the presence of contamination by PST in the study area is ratified [ 3].

Similarly, the spatial analysis techniques and methods proximity provide a mechanism with which to define the sampling sites studied variables as main roads and secondary, industrial area and green areas; observe the effect of these variables and their possible application to the normative regulation and surveillance systems [4].

Another model used for the development of control systems of quality of the air is the Kriging method, which functions as a guide in the decision to locate a site sampling and analysis costs of implementing the system, given for some regions (developing countries) costs of equipment for sampling are quite high. The method suggests using criteria recommended by the Environmental Protection Agency (EPA) based on the objective of sampling and the characteristics of the sector, such as the population density, the impacts of contaminants known in the art as well as the location of the sources contamination [5].

Another field of study in the development of statistical and scientific models to the problem of air quality should be your early warning. This has been developed several hybrid models from the combination of individual models, such as those discussed above, which are preferred in contributing to the care of the quality of the air and human health, such as neural network model hybrid, optimized algorithm SALP swarm multiobjetivo characterized by having a module data processing, optimization, forecasting and evaluation for better forecasting and warning, which is currently being tested in three cities in China in order to check their efficacy [6]. As well as, methodology neural network multilayer perceptron with which data can be used pollution air (O<sub>3</sub>, NO, NO<sub>x</sub>, CO, PM<sub>10</sub>, PM<sub>2.5</sub>, NO<sub>2</sub>, bg) and meteorological data (temperature, direction of the wind speed the wind) to predict with great accuracy the gas contaminant, the above related one of the most disturbing sources of pollution, traffic [7]. Moreover, the implications of traffic flow and weather conditions have been integrated into the simulation model of mesoscopic traffic and simplified estimation models air pollutants can project variables such and, therefrom, predicting and displaying various changes environmental, such as those generated by rising air pollution [8]. Besides the above, in the city of town of Puente Aranda (Bogota, Colombia) has worked in an evolutionary fuzzy model for predicting the level of the quality of the air particulate matter PM<sub>10</sub>, with a small number of rules, it is possible to obtain satisfactory results predicting this indicator particulate material [9]. Now it is clear that in many of the developing country, methodologies compression and study of the rapidly changing situations have been limited financially, therefore, have developed models combined with which they can develop emissions inventories that to identify the relative contribution of each source of pollution in the region, as in the case of Bogota-Colombia,

After application of study models a procedure is required to assess the appropriateness and objectivity of these being basic components scientific, statistical and operational, ie, the emphasis on accuracy, efficiency and sensitivity of the data; the predictions of the model compared to the degree of adjustment of the observations to which applicable and finally the operational ease offered by the model evaluated [11]. Such

lack of evaluation methods is of vital importance, since for regulators is imperative to know if their investments have paid off, both in cost efficiency, value and justification for public spending, with the aggravating circumstance that every day costs increase with the quality standards of the strictest air [12]. This need has been felt in the UK, because after a successful implementation of local management systems quality of the air to attack sectorally all normative implications that this brings issue with it, it is inherent in the development of methodologies and research to determine the effectiveness of the measures used at different times; actions that result in guides to other local entities in the process, making good policy decisions and the consolidation of an efficient system to simplify query development times in other sectors [13]. In Poland, where there is no clear regulations governing local emissions of individual consumer units,

However, it is to emphasize the advances that have been obtained regarding the evaluation of interventions short and medium term and long term regulations that are implemented over several years. Supported by the results that the current statistical methods, atmospheric modeling and assessing the exposure of humans are obtained, it has been possible to project long term including variables that can occur during the same time period relationships as what is the demographic and economic factors; projections which are still in process and validation replication [12].

Moreover, global human population and urban development are increasing at an unprecedented rate and creating tremendous stress on the quality of air and water at local, regional and global levels. While there is a growing literature linking urbanization and environmental quality, some regions of the world are better represented than others. Moreover, comparison between the rates of population growth and quality of the air and the water suggests that multiple factors affecting the quality of the environment [15].

Because contamination of the air is a problem that primarily affects the large population centers by the development that has generated indisputably unchecked, different countries have entered worry about polluting gases that create the conditions for which are focused on measuring the amount of polluting gases generated so we can implement technologies that promote the reduction of these and thus improving air quality.

Therefore, various studies seeking to identify the biggest polluters of the environment, if the city of Jaipur where the relationship between spatial variables and the concentration of pollutants in the air is examined, finding observed that the concentration of PM<sub>10</sub> and SPM has the greatest impact on the environment compared with the air gaseous pollutants (SO<sub>2</sub> and NO<sub>x</sub>) [16]. With the same purpose in the region of Malaysia sought to determine and assess levels of BTEX in the air over selected areas. Determining that the vehicle emissions are the main source of generation of this contaminant and the risk of cancer is based on benzene concentrations in urban and suburban areas [17]. These examples show that large population areas developments are the main sources of atmospheric pollutants. Caused by the

implementation of large industries and the effect of mainly mobilization.

To meet the challenges associated with such rapid urbanization, it has become necessary to implement smart strategies for environmental management and planning, addressing the unique demands of urban areas to maintain environmental sustainability and work with minimal interruption. Fernando proposes to "start a new focus area, urban fluid mechanics (UFM, for its acronym in English), designed to investigate these issues. To achieve optimal social impact, the UFM must deepen flow problems fundamental and applied fluid immediately useful for the development of urban public policies and environmental regulations." [18].

At the same time must be integrated information systems that promote interaction of spatial and environmental variables for characterizing the quality of the air inside an urban area. Through a combination of expert systems and tools to support decision making, possessing the ability to receive information from in situ measurements such as environmental telematics posed within a framework for the development of management systems quality of urban air present a comprehensive approach to the implementation and evaluation of relevant scenarios "[19].

As it stated the rapid increase in urbanization is one of the main factors contributing to deterioration of the quality of the air, however, other aspects that are interrelated and promote greater effects of air pollution, such as infrastructure and transport.

Humans spend a considerable amount of time breathing air in closed spaces where, due to various sources, there may be contaminants that deteriorate the quality of the air. This is a major risk factor for the health of the general population. [twenty].

Microorganisms such as fungi, bacteria and biological particles are involved in generating pollution inside buildings, causing deterioration of infrastructure and in some cases, health problems. This paper introduces the general aspects of microbial contamination inside buildings and seeks to provide a perspective on the potential influence of microorganisms as etiologic agents of respiratory diseases and allergies type [21].

In [22] presents the study of concentrations of fine particles (PM10)), culturable bacteria in the air (CAB), Total volatile organic compounds (TVOC), formaldehyde (HCHO), CO<sub>2</sub>, NO<sub>2</sub> and O<sub>3</sub> in 59 station facilities Metro and public parking at a national level in Korea of the South, where possible relationships of pollutants were analyzed indoors with underground environmental factors and characteristics of facilities that evidence lower concentrations to the outdoors in all facilities.

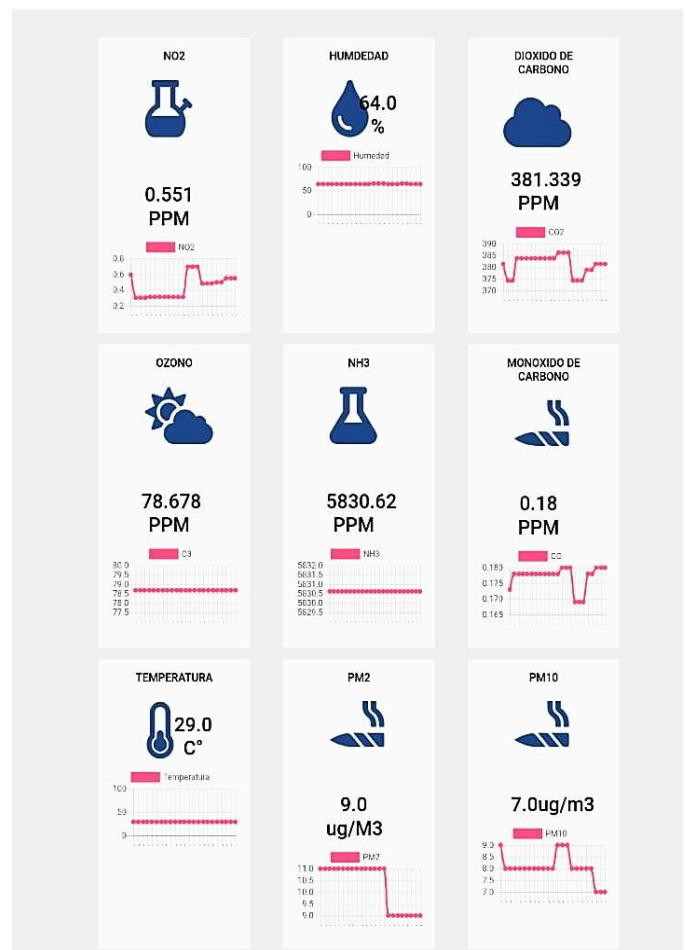
To illustrate another situation we have the case of Portugal, where the influence was assessed a package of resilience solutions based on nature, wind flow and dispersion of air pollutants. Given two pollutants (NO<sub>x</sub> and PM10) and four scenarios: i) a stage basis, ii) an urban green stage, iii) a stage of green roof, and iv) a "gray" stage (without trees). Overall, the results showed that strategic location of vegetation in cities has the potential to make an important contribution to

improving air quality and sustainability of urban environments [23].

### III. METHOD

The study design was based on quantitative research of experimental type, delimited by three phases. Phase 1, Identifying the main sources that contribute to air pollution in the area under study georeferencing. Stage 2, measurement of the gaseous pollutants CO, CO<sub>2</sub> and NO<sub>2</sub>. Phase 3, descriptive statistical analysis to determine the behavior of gases under study in the georeferenced area. Phase 4 presents an analysis of the results against national and international legislation.

For the execution of these phases electronic instrumentation system was used with graphical user interface. The analysis focused on CO, CO<sub>2</sub> and NO<sub>2</sub> gases. In Figure 1, the graphical user interface used is presented.



**Figure 1.** Graphical User Interface instrument measurement of CO and CO<sub>2</sub>

Regarding the current legal regulations it is presented in chronological order resolutions and documentation relevant to the issue of air quality.

**Table 1.** legal regulations in force

regulatory	Year	Observation
<b>resolution 391</b>	2001	stricter standards were established and included pollutants that had not been covered by the national regulation in the capital city - Bogotá
<b>law 631</b>	2001	production, marketing and consumption of ethanol and biodiesel as fuel is driven
<b>resolution 1208</b>	2003	391 resolution repealing and objectives established environmental quality
<b>law 939</b>	2004	production and marketing of biofuels of vegetable or animal origin for use in diesel fuel is promoted.
<b>CONPES 3344</b>	2005	With which it is oriented on the development of intersectoral policies and strategies focused on prevention and control of air pollution in cities and industrial areas of Colombia.
<b>decree 979</b>	2006	Whereby items 7,10, 93, 94 and 108 of Decree 948 1995 modified.
<b>resolution 601</b>	2006	a method of regulating greater detail ranking source of contamination areas-
<b>law 1083</b>	2006	Through which some rules are established on sustainable urban planning and other provisions
<b>resolution 909</b>	2008	With which which they set standards and emission standards for industry, as well as emission measurement procedures and development agreements conversion to cleaner technologies
<b>resolution 910</b>	2008	pollutant emission levels are established by the air vehicles and motorcycles and their regulatory requirements and certification
<b>law 1205</b>	2008	In which the regulation is issued seeking to improve the quality of diesel fuel.
<b>CONPES 3550</b>	2008	With which sought to strengthen the comprehensive management of environmental health-oriented prevention, management and control of adverse health effects resulting from environmental factors
<b>resolution 2604</b>	2009	With which limpios <sup>46</sup> fuels are determined and regulated the maximum allowable emission test dinámica <sup>47</sup> for vehicles associated with the provision of public service inland transport of passengers and motocarros <sup>48</sup> linked to the provision of public ground transportation service with mixed automotive .
<b>resolution 941</b>	2009	the National Register Environmental (RUA) is adopted with which information on the use and exploitation of natural resources is captured by the productive sectors
<b>resolution 6982</b>	2011	With which the resolution 391 and repealing regulations are updated to new demands atmospheric conditions Bogota
<b>resolution 760</b>	2010	A protocol is adopted for the control and monitoring pollution generated by fixed sources
<b>resolution 650</b>	2010	With which the protocol is adopted for monitoring and tracking the quality of the air, which contains an overview of the Surveillance Systems Air Quality (ACLS)
<b>resolution 651</b>	2010	With which the Information Subsystem Air Quality (Sisaire) is created as a primary source of information for the design, evaluation and adjustment of national and regional policies and strategies for prevention and control of pollution of the air

regulatory	Year	Observation
N / A	2010	The Council National Environment adopted the Policy on Prevention and Control of Pollution of the air, in order to encourage management to achieve adequate to protect human health and welfare standards of quality of the air, in the context of sustainable development
decree 98	2011	Decennial Plan Decontamination is adopted in the air of Bogota, as the first plan for prevention, reduction and control of air pollution in the country
decree 1076	2015	Through which the Single Regulatory Decree is issued by the Environment and Sustainable Development Sector and a compilation of all existing regulations is made regarding sustainable environment and development sectors
decree 1077	2015	Through which the Single Regulatory Decree is issued in the housing sector, city and territory, which states that the municipalities and districts must develop mobility plans where prevail mobilization in alternative modes of transport and the use of clean fuels in public transport systems.
decree 1625	2016	In which the decrees 2532 2001 3172 2003 are compiled, with which the only Decree on tax matters with which benefits are granted tax (VAT and income) is defined projects, programs or activities reduced consumption energy or energy efficiency to go towards achieving environmental goals
resolution 1988	2017	In which how the environmental goals of energy efficiency with the introduction of electric vehicles, dedicated to natural gas and hybrid 41286 according to resolution 2016 of the Ministry of Mines and Energy
decree 1116	2017	Whereby reduced tariff for electric and hybrid vehicles approved with 0% and 5% respectively
resolution 2254	2017	By which standards air quality and measures for preventing care episodes, emergency alert and that previous rules were established more restrictive levels. This, in response to the proposed guideline values for air quality by WHO
CONPES 3918	2018	With which they pose strategies for the implementation of Sustainable Development Goals (SDGs) in Colombia
CONPES 3934	2018	It describes a roadmap is established to guide the country to a transition towards a more sustainable economic model, strategies aimed at the efficient and productive use of natural resources and reducing the environmental and social impact from productive activities (National Council Social and Economic Policy, 2018)

#### IV. RESULTS

The results, presented measurements and statistical analysis which describes the behavior of the data for each of the gases, NO<sub>2</sub>, CO and CO<sub>2</sub>. Table 2 shows the statistical data to dioxide Table 3 presents statistical data for carbon monoxide (CO) evaluated in a period of five weeks. Likewise, Figure 3 shows the histogram and the normal distribution curve of the data obtained from the CO during the 5 weeks of monitoring. Nitrogen over a period of five weeks. Also, Figure 2 shows the histogram and the normal distribution curve of the data of NO<sub>2</sub> during 5 weeks of monitoring.

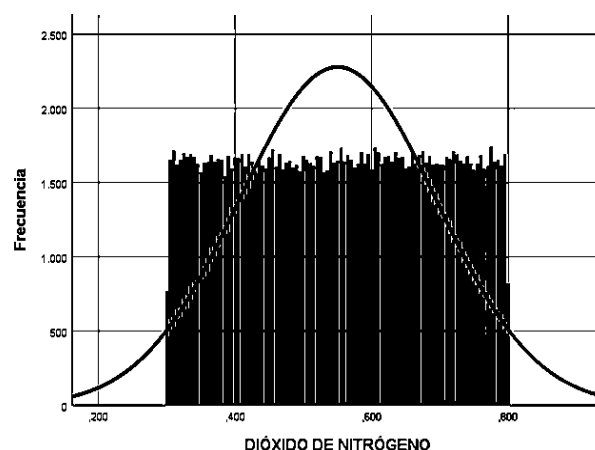
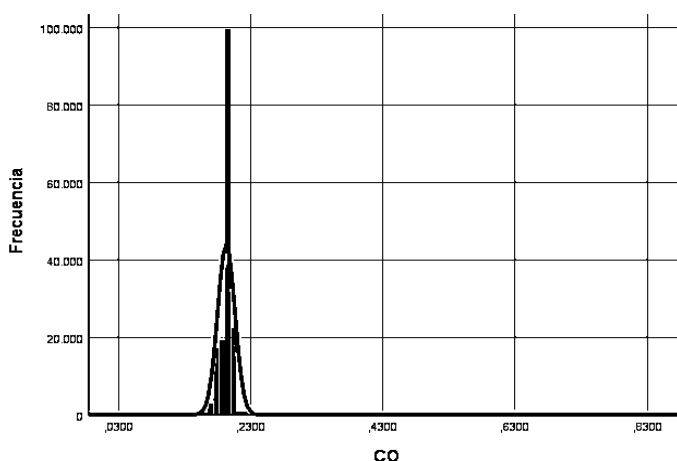


Figure 2. Histogram distribution curve and standard NH<sub>2</sub>

**Table 2.** Statistical data Nitrogen Dioxide NO<sub>2</sub>

NO <sub>2</sub>		WEEK 1	WEEK 2	Week 3	WEEK 4	Week 5	TOTAL
N	Valid	21805	30982	40491	34265	37299	164843
	lost	two	0	one	two	two	one
Half		0.54988	0.55	0.55093	.5497	0.55052	0.55027
Median		0.551	0.551	0.552	0.549	0.552	0.55100
fashion		0,66	0,327	0.633	0.463	0.506	0,660
Desv. Deviation		0.144411	0.144249	0.143878	0.144654	0.144603	0.144363
variance		0,021	0,021	0,021	0,021	0,021	0,021
Asymmetry		-0.005	-0.01	-0.01	0,007	-0.007	-0.005
standard error of skewness		0,017	0,014	0,012	0,013	0,013	0,006
kurtosis		-1.203	-1.208	-1.191	-1.2	-1.199	-1.199
standard error of kurtosis		0,033	0,028	0,024	0,026	0,025	0,012
Rank		0.5	0.5	0.5	0.5	0.5	0,500
Minimum		0.3	0.3	0.3	0.3	0.3	0,300
Maximum		0.8	0.8	0.8	0.8	0.8	0,800
percentiles	25	0.424	0.424	0.427	0.424	0,425	0.42500
	50	0.551	0.551	0.552	0.549	0.552	0.55100
	75	0.675	0.676	0.674	0.674	0.676	0.67500



**Figure 3.** Histogram and standard distribution curve CO

Within the study period shows that the variation does not exceed 0.005 ppm compared to the total global figure of 0.193234 PPM. At the same time data of the standard error of

the mean reflect a high degree of accuracy of the determined average as the values are close to zero and the global data which is 0.0000320.

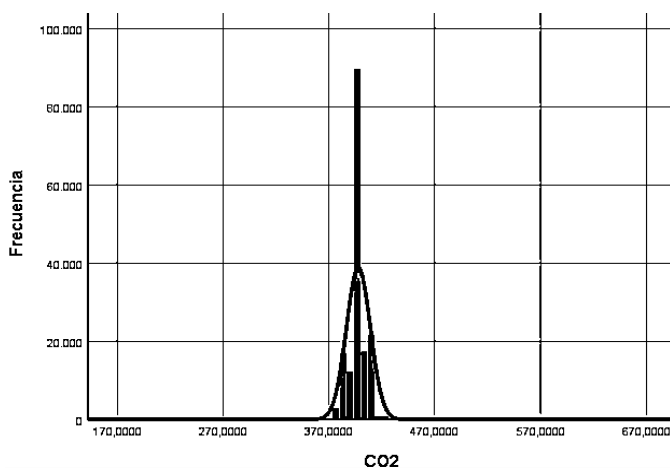
Furthermore, a ratio of median values with the average, especially in the total value of the data is reflected as in both cases corresponds to 0193 PPM. In the case of global fashion can be considered multimodal, because in week 2, 3, 4 and 5 the same value 0193 is present and only consider week one as modal, ie the tendency of variation of the CO in the study period it is the same.

Also, the asymmetry value calculated that is above 0, this value is 9.527 to its reflects time data presented for CO in general are not symmetrical. Similarly it is considered that the precision of the coefficient of asymmetry is quite high since the error of asymmetry (0.006) is close to 0. Moreover, kurtosis 266.443 global data is considered so leptokurtic and indicates that the distribution has heavier tails than the normal distribution, because the value found is significantly above 0; in turn it is considered fairly accurate information because the error kurtosis is 0.012.

**Table 3.** Statistical data Nitrogen Dioxide CO

Statistical data		Week 1	week 2	week 3	week 4	week 5	Total
N	valid	23506	30982	40491	34266	37301	164842
	lost	one	0	one	one	0	two
Half		, 199049	, 191334	, 191860	, 191131	, 194459	, 193234
Error typ. the average		, 000142	, 000033	, 000077	, 000043	, 000064	, 000032
Median		, 203000	, 193000	, 193000	, 193000	, 193000	, 193000
fashion		, 206000	, 193000	, 193000	, 193000	, 193000	, 193000
Desv. typ.		, 021796	, 005833	, 015527	, 007874	, 012326	, 013010
variance		, 000475	, 000034	, 000241	, 000062	, 000152	, 000169
Asymmetry		1.67016	-1.27317	12.15105	- 17979	9.64191	9.52652
Error typ. asymmetry		, 015976	, 013916	, 012173	, 013232	, 012682	, 006033
kurtosis		97.0987	4.6005	252.9021	1.4722	215.3625	266.4432
Error typ. kurtosis		, 031950	, 027830	, 024344	, 026463	, 025364	, 012066
Rank		, 808000	, 077000	, 570000	, 117000	, 458000	, 808000
Minimum		, 030000	, 155000	, 146000	, 146000	, 145000	, 030000
Maximum		, 838000	, 232000	, 716000	, 263000	, 603000	, 838000
percentiles	25	, 193000	, 193000	, 190000	, 185000	, 193000	, 193000
	50	, 203000	, 193000	, 193000	, 193000	, 193000	, 193000
	75	, 206000	, 193000	, 193000	, 193000	, 195000	, 195000

Table 4 shows the statistical data corresponding to the carbon dioxide (CO<sub>2</sub>) evaluated in a period of five weeks. Likewise, Figure 4 shows the histogram and the normal distribution curve of the data of the CO<sub>2</sub> during 5 weeks of monitoring.



**Figure 4.** Histogram and standard distribution curve CO

For the analysis period is 397.946 PPM as an average of the total of the data for variable CO<sub>2</sub>, and comparing this value

with the average score for each week found that the mean difference for each week compared to the ranges overall between 1.1 and 1.8 PPM except week 1 having a greater difference with 4.76 PPM of the global average. Similarly, to the error analysis of the average we found a high degree of accuracy of the calculated means, being the highest error 0.146 in week 1, reflecting data inconsistencies by which it is separated from the overall average.

A median analyzing the data obtained can be seen a relation of symmetry between them, especially in the values as the mean and median values have 397.913 397.946 and respectively. On the other hand, global fashion can be considered multimodal, because in week 2, 3, 4 and 5 the same value 397.913 present and would only be considered the week 1 as modal, ie the trend of variation of CO<sub>2</sub> in the study period it is the same. }

In this statistical analysis we consider the skewness and kurtosis. For total global data graph No. 55, wherein a right skewed distribution, which can be checked with the asymmetry value calculated that is above 0, is evidenced presents this value of 3051 in turn shows that the data presented for CO<sub>2</sub> in general are not symmetrical. Similarly, it is considered that the precision of the asymmetry coefficient is quite high because the asymmetry error (0.006) is very close to 0.

Moreover, kurtosis 143,291 global data is considered so leptokurtic and indicates that the distribution has heavier tails than the normal distribution, because the value found is

significantly above 0; in turn it is considered fairly accurate information because the error kurtosis is 0.012.

**Table 4.** Statistical data Nitrogen Dioxide CO<sub>2</sub>

Statistical data		Week 1	week 2	week 3	week 4	week 5	Total
<b>N</b>	valid	23507	30982	40492	34267	37300	164844
	lost	0	0	0	0	one	0
<b>Half</b>		402.70252	396.37837	396.66348	396.06814	399.08722	397.946323
<b>Error typ. the average</b>		, 146134	, 031033	, 061653	, 039379	, 053645	, 0277846
<b>Median</b>		407.20100	397.9130	397.9130	397.9130	397.9130	397.9130
<b>fashion</b>		409.600	397.913	397.913	397.913	397.913	397.9130
<b>Desv. typ.</b>		22.405321	5.462283	12.40623	7.289594	10.36047	11.28083
<b>variance</b>		501.998	29.837	153.915	53.138	107.339	127.257
<b>Asymmetry</b>		-4.145	-1.410	8,411	-, 292	6,161	3,051
<b>Error typ. asymmetry</b>		016	014	012	013	013	006
<b>kurtosis</b>		58.886	5,189	138.543	1,573	107.449	143.291
<b>Error typ. kurtosis</b>		, 032	, 028	024	, 026	, 025	012
<b>Rank</b>		612.927	75.228	419.179	105.284	320.756	612.9270
<b>Minimum</b>		171.763	357.575	303.499	350.510	348.027	171.7630
<b>Maximum</b>		784.690	432.803	722.678	455.794	668.783	784.6900
<b>percentiles</b>	25	397.91300	397.9130	395.4990	390.7690	397.9130	397.7450
	50	407.20100	397.9130	397.9130	397.9130	397.9130	397.9130
	75	409.60000	397.9130	397.9130	397.9130	400.1900	400.1900

## V. DISCUSSION AND CONCLUSIONS

According to the calculated values and presented in Table 5, it is stated that none of the gases exceeds permissible limits.

**Table 4.** Statistical data Nitrogen Dioxide CO<sub>2</sub>

polluting gas	permissible level	current level		Parameter Verification
		ug / m3 * hour	PPM	
Nitrogen dioxide	200 (1 hour) (g / m3)	69.029		meets
Ozone	100 (8 hours) (g / m3)	71.848		meets
Carbon monoxide	5000 (1 hour) or 35000 (8 hours) (g / m3)	14.758		meets
Ammonia	100 (ppm)		0.846	meets
Carbon dioxide	5000 (ppm)		397.946	meets

Regarding Nitrogen Dioxide (NO<sub>2</sub>) has been shown that for short exposure times may capacity bronchial responsiveness in asthmatics is directly affected when the levels are equal or greater than 200 g / m<sup>3</sup>. lung function also, when these levels reach concentrations exceeding 500 mg / m<sup>3</sup> directly affected causing a reaction even more critical health over a period of one hour. On the other hand, it has also been proven that exposure to NO<sub>2</sub> in periods of annual time increase symptoms

of bronchitis in asthmatic children and lung function in relation to high concentrations of the gas in a span of one year (WHO, 2005)

Similarly, carbon monoxide (CO) reacts to the inhaled reducing oxygen transport in the blood, depending on the concentration and duration of exposure, by a mild poisoning some effects are weakness, fatigue, tendency to sleep, headache, nausea, vomiting, chest pain and rapid pulse. In



cases of increased exposure can manifest seizures, slow heartbeat, respiratory arrest and low blood pressure. Also, as for chronic effects, prolonged exposure increases the risk in heart problems and gradually increasing damage to the nervous system in extreme cases can occur cancer (The LINDE Group, 2012)

Finally, to carbon dioxide (CO<sub>2</sub>) is the most powerful cerebral vasodilator known. Inhaling large concentrations causes rapid circulatory insufficiency leading to coma and death. Low concentrations of carbon dioxide cause increased respiration and headache. The effects can include: rapid breathing, diminished mental alertness, impaired muscular coordination, faulty judgment, depression of all sensations, emotional instability and fatigue. A progressing choking nausea, vomiting, prostration and unconsciousness, eventually leading to convulsions, coma and death can occur.

## ACKNOWLEDGEMENTS

The authors wish to thank the Minuto de Dios Corporation and the Universidad Cooperativa de Colombia for their contribution to the funding of the project under study. Also to the Research Assistants Iván Andrés Acosta Cárdenas, Karen Dayana Diaz Pastrana, Natalia Del Pilar Huiza Fandiño, for their collaboration during the research process.

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