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Local levels of carbon monoxide in the urban air of San Miguel de Tucumán, Argentina

Niveles de monóxido de carbono en el aire urbano de San Miguel de Tucumán, Argentina

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ABSTRACT

Carbon monoxide, a highly toxic gas, is one of the most common and widely distributed air pollutants; in San Miguel de Tucumán, Argentina, the main sources of emission are the vehicle engines and the fire produced by the burning of cane fields. The objective was to evaluate the local levels of carbon monoxide (CO) concentration in the urban air of San Miguel de Tucumán during a period of 13 years. Four monitoring stations with high population concentration were selected. Testo 625 measuring instruments with specific probe for CO were used. The measurements were made during the months of September, October and November during the period 2003-2015. The concentrations of CO were compared using Variance analysis of Kruskal & Wallis and Conover post-test at 5 % significance. Minimum, maximum and Percentiles values (P25, P50 and P75) were considered. Results: No significant differences were observed in annual CO concentrations (p = 0.7177), with min = 24ppm, P25 = 28 ppm, P50 =28.9 ppm, P75 = 32 ppm and maximum = 38 ppm. With significant differences in CO concentrations (p <0.001) according to month and sampling season, higher values were detected in the month of November in Station 4 with min=27.0ppm, P25=30.7 ppm, P50=31.0 ppm, P75=33.2 ppm and maximum=38.0 ppm. Conclusion: The City of San Miguel de Tucumán is located in a mountainous area with little air movement, which means it has a notable accumulation of atmospheric pollutants, with high concentrations of CO in the microcenter of this city.

KEYWORDS: *Pollution, Microcenter*, *CO Concentration*, *Environmental health*.

RESUMEN

El monóxido de carbono (CO), gas altamente tóxico, es uno de los contaminantes atmosféricos más comunes y ampliamente distribuidos. En San Miguel de Tucumán, Argentina, las principales fuentes de emisión son los motores de vehículos y los incendios producidos por la quema de cañaverales. El objetivo de la presente investigación fue evaluar los niveles locales de concentración de CO en el aire urbano de San Miguel de Tucumán durante un período de trece años. Se seleccionaron cuatro estaciones de monitoreo con alta concentración poblacional. Se emplearon instrumentos de medición Testo 625, con sonda específica para CO. Las mediciones se realizaron en los meses de septiembre, octubre y noviembre durante el período 2003-2015. Las concentraciones de CO se compararon empleando análisis de la varianza de Kruskal-Wallis y postest de Conover al 5 % de significación. Se consideraron valores mínimos, máximos y percentiles P25, P50 y P75. Resultados: No se observaron diferencias significativas en las concentraciones anuales de CO ($p = 0{,}7177$), con min = 24 ppm, P25 = 28 ppm, P50 = 28,9 ppm, P75 = 32 ppm y máximo = 38 ppm. Con diferencias significativas en las concentraciones de CO ($p < 0{,}001$), según mes y estación de muestreo. Los mayores valores fueron detectados en el mes de noviembre en Estación 4, con min = 27,0 ppm, P25 = 30,7 ppm, P50 = 31,0 ppm, P75 = 33,2 ppm y máximo = 38,0 ppm. La ciudad de San Miguel de Tucumán se encuentra en zona montañosa, con escaso movimiento de aire, lo que determina una marcada acumulación de contaminantes atmosféricos, con concentraciones de CO elevadas en el microcentro de esta ciudad.

PALABRAS CLAVE: *contaminación*, *microcentro*, *concentración de CO*, *salud ambiental*.

INTRODUCTION

Carbon monoxide, a highly toxic gas, is one of the most common and widely distributed air pollutants. An important emission source is the vehicle engines due to incomplete combustion of hydrocarbons and carbon-containing substances, such as gasoline, diesel, etc. Other important sources of carbon monoxide formation are the fires produced by the burning of cane fields.

The province of Tucumán is considered the nucleus of communications of the Northwest region of Argentina and is located between latitudes of S26º 05’ and S28º 01’ and longitudes of W64º 28’ and W66º 13’. It has a population of approximately 2 million, with a population density of 64.2 inhabitants/km^2, and in particular 6,102 inhabitants/km^2 in San Miguel de Tucumán [1], which accumulates 81 % of the automotive fleet of the whole province [2] with an important annual increase [Image 1]. The second economic activity is the production of sugar from sugarcane, producing 64.3 % of the national total [3]. The harvest period is concentrated between the months of April and November. Even though there is a prohibition on burning cane plantations as an alternative method of harvesting (provincial law 6253), to date it was not possible to eradicate it, affecting the health of the population of San Miguel de Tucumán [Image 2].

Different investigations warn about the effect of different pollutants on the health of the population such as that published by Barnett et al. [4] where associations between atmospheric pollution and hospital admission for cardiovascular problems were estimated in patients older than 65 years. The study included several cities in Australia (Brisbane, Canberra, Melbourne, Perth and Sydney) and New Zealand (Auckland and Christchurch). Based on these results, of the pollutants considered: NO_2, CO, suspended particles and O_3, the most consistent pollutant/disease association corresponded to CO. When their air level differed by 0.9 ppm, they determined significant increases in cardiovascular diseases in general. The heterogeneity between cities with similar pollution was attributed to the different humidity conditions and to the proportion of adults considered in the study.

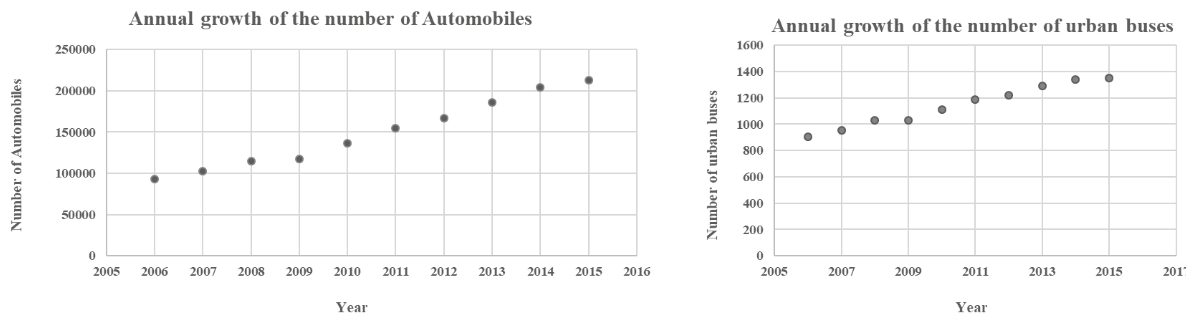

Image 1. Annual growth of the automotive fleet.
Source: National Observatory of Transport Data. Technological Center of Transportation, Traffic and Road Safety-Universidad Tecnológica Nacional de Avellaneda - Province of Buenos Aires. Upgrade. February 2017.

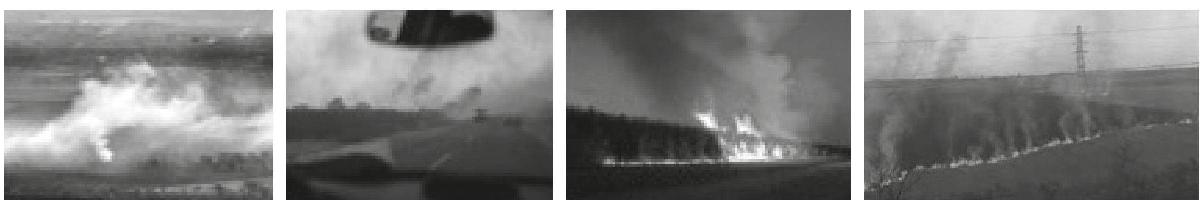

Image 2. Burning of sugar cane in Tucumán in the harvest period and its incidence on environmental pollution in September 2015.
Source: http://www.lagaceta.com.ar/nota/584190/sociedad/por-polucion-aerea-tucumanos-somos-esclavos-antialergicos.html.

In Argentina, the main cause of mortality is cardio-vascular diseases, and the fifth cause is chronic respiratory diseases [5]. To date, there are no studies that investigate the possible associations between CO and causes of mortality in Tucumán.

The allowed limit values of CO concentration in Argentina are presented in Table 1.

Table 1. Limit values of CO concentration in Argentina*

Pollutant (unity)	Quality standard of air	Alert	Alarm	Emergency
CO (ppm)	10 ppm – 8h 50 ppm – 1 h	15 ppm – 8h 100 ppm – 1h	30 ppm – 8h 120 ppm – 1h	50 ppm – 8h 150 ppm – 1h

* Law No. 20,284, Plan for the Prevention of Critical Air Pollution Situations, Buenos Aires, April 16, 1973
Source: http://servicios.infoleg.gob.ar/infolegInternet/anexos/40000-4999/40167/norma.htm.

Identifying the levels of maximum tolerable concentration provide the opportunity to take actions to protect the health of the general population. The aim of the present work was to evaluate the levels of carbon monoxide concentration (CO) in 4 stations of San Miguel de Tucumán during the period 2003-2015.

METHODS

Experimental, analytical, comparative and prospective design. Calibrated measuring instruments were used (Testo 625, with specific probe for CO), with a measurement range below 0 ppm and above 500 ppm. In addition, humidity and air temperature, direction and wind speed and solar radiation were considered.

The concentrations of CO were measured every 8 hours and expressed in parts per million (ppm). Four sampling points were selected from the microcenter of San Miguel de Tucumán, identified as E1 (corner of Córdoba and Muñecas), E2 (corner of September 24 and Salta), E3 (corner of Maipú and San Martín) and E4 (corner of May 25 and San Martín) [Image 3].

Image 3. CO sampling points, microcenter of San Miguel de Tucuman.
Source: https://www.maps.google.com.ar.

For the comparative study of CO concentrations by Month, week and sampling Point, the coding presented in the following Table was used.

Table 2. Coding by month, week and sampling point

Month and week*	Sampling point**	Month, week and sampling Point
S1	E1	1
S2	E2	2
S3	E3	3
S4	E4	4
O1	E1	5
O2	E2	6
O3	E3	7
O4	E4	8
N1	E1	9
N2	E2	10
N3	E3	11
N4	E4	12

* S: September; O: October; N: November. ** E1 (corner of Córdoba and Muñecas), E2 (corner of September 24 and Salta), E3 (corner of Maipú and San Martín) and E4 (corner of May 25 and San Martín).

Statistical analysis

Exploratory Data Analysis (EDA) techniques were used. For the comparison of the CO values Kruskal & Wallis nonparametric Variance analysis and Conover's Post-test at 5% significance were used.

RESULTS

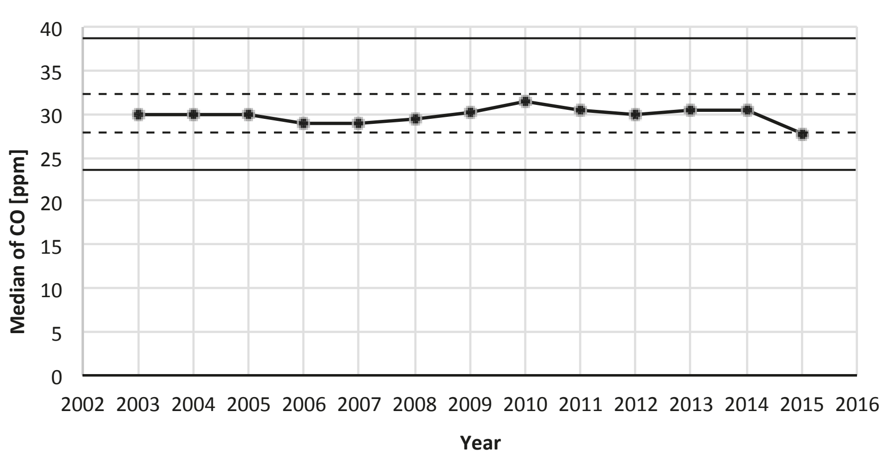

Figure 1. Annual evolution of CO, with bands of 50% of central data and extreme values, period studied 2003-2015. No significant differences between the Median annual CO concentrations were detected (Kruskal& Wallis, p=0,7177). With values in the alarm zone according to Table 1. Min. = 24 and Max. = 38. P25 = 28 and P75 = 32.

Table 3. Statistical measures of CO [ppm] concentration discriminated by year

Year	Average	Standard Deviation	Minimum	Maximum	P25	P50	P75
2003	30.6	5.1	21.5	4.0	27.0	29.6	33.2
2004	30.8	5.7	23.5	42.1	26.5	28.9	32.6
2005	30.6	5.1	21.5	40.0	27.0	29.6	33.2
2006	29.4	4.9	22.4	38.2	24.5	28.9	30.7
2007	29.4	4.9	22.3	38.2	24.5	28.9	30.7
2008	30.3	4.2	25.2	39.0	26.5	28.3	33.1
2009	31.1	5.5	25.6	41.4	27.0	29.8	32.1
2010	32.0	4.0	26.1	38.3	28.7	30.4	33.4
2011	29.5	4.2	23.5	36.1	25.0	30.1	31.2
2012	30.4	4.1	23.5	39.3	27.0	28.9	32.1
2013	29.6	2.6	23.5	32.3	27.5	30.3	31.0
2014	30.2	1.9	26.3	32.7	29.3	30.5	31.1
2015	27.9	1.9	24.5	30.5	26.3	27.6	28.9

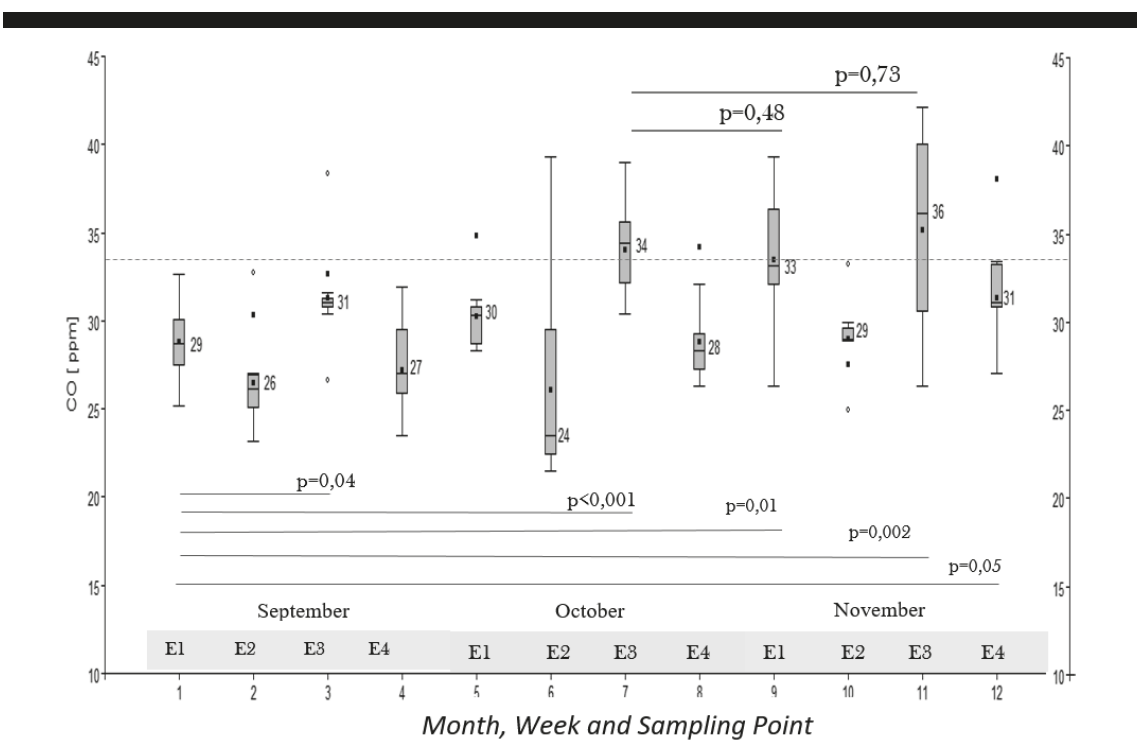

Figure 2. Distribution of CO concentration, according to month, week and sampling Point. Significant differences were observed in the medians of CO (Kruskal & Wallis non-parametric ANOVA and Conover’s Postest); highest concentrations observed in the month of November with values in the alarm zone according to Table 1.

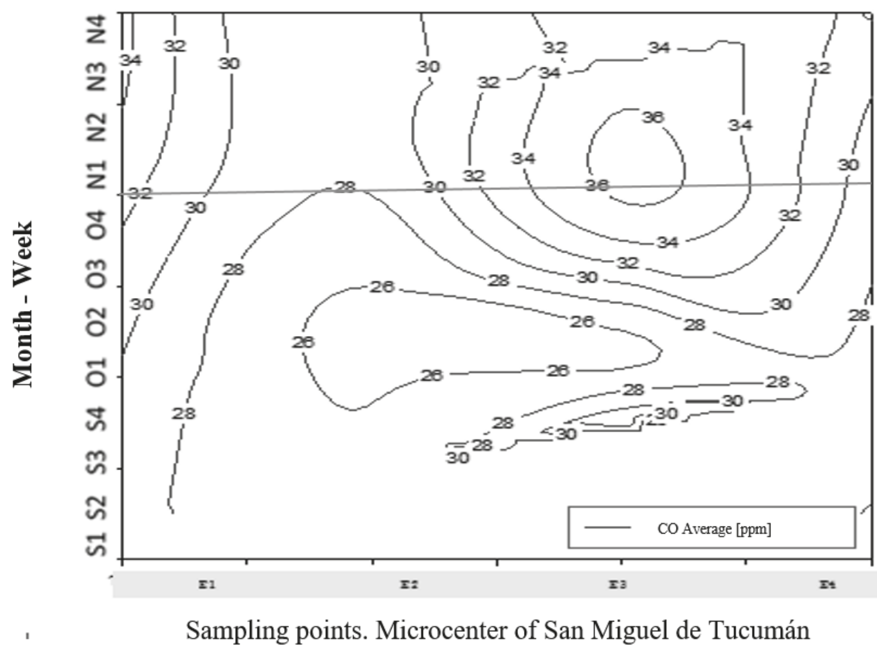

Figure 3. Distribution of CO concentration, according to month, week and sampling point. Highest concentrations observed in the month of November with values in the alarm zone according to Table 1.

Table 4. Statistical measures of CO [ppm] concentration discriminated by month, week and sampling point

Month, week and sampling point*	Average	Standard Deviation	Minimum	Maximum	P25	P50	P75
1	28.8	2.2	25.2	32.6	27.4	28.7	30.1
2	26.4	2.6	23.2	32.7	25.0	26.1	26.9
3	31.3	2.5	26.6	28.3	30.7	31.0	31.3
4	27.2	2.5	23.5	31.9	25.8	27.0	29.5
5	30.3	1.7	28.3	34.8	28.6	30.3	30.8
6	26.0	5.1	21.5	39.3	22.4	23.5	29.5
7	34.0	2.6	30.4	39.0	32.1	34.4	35.6
8	28.8	2.3	26.3	34.2	27.2	28.3	29.3
9	33.4	3.9	26.3	39.3	32.0	33.1	36.3
10	29.0	1.9	24.9	33.2	28.9	28.9	29.6
11	35.2	5.3	26.3	42.1	30.5	36.1	40.0
12	31.3	2.9	27.0	38.0	30.7	31.0	33.2

* Table 2. Month, Week and Sampling Point=9, 10, 11 and 12 correspond to the month of November.

DISCUSSION

International agreements such as the Paris Protocol, among others, contemplate the care of the environment including water and air. In compliance with these agreements, different countries implemented actions to protect the environment. It is possible to mention that for several years in Paris' district 15, a hot air balloon was placed to measure the air quality of this city and its surroundings, in real time changing color according to the level of contamination. Airparif, the organization in charge of weighting air quality in France, has permanent and semi-permanent stations distributed in the French capital and peripheral neighborhoods (https://www.veoverde.com/2014/08/globo-aerostatico-mide-la-calidad-del-aire-en-paris/). Nottingham is another city that also has a real-time air quality-monitoring center (http://aqicn.org/map/united-kingdom/nottingham-centre/).

In different studies, the levels of CO concentration are associated with vehicle emissions according to the type of fuel used. The use of better quality fuels usually leads to substantially low emissions of pollutants harmful to health and the amount of vehicle in the cities [6].

Fernández-Bremauntz et al. [7] studied the concentrations of CO in Mexico DF to determine the risk of street vendors. The reported values ranged between 2.0 and 70.0 ppm, with an average concentration of 26 ppm.

Another subsequent study by Fernández-Bremauntz and Ashmore [8] concluded that all CO dosages performed inside cars, minivans and minibuses had TWA (time-weighted average) of 35 ppm or more; The median values for the subway were the only ones that never exceeded the value of 35 ppm, which is the standard of air quality during 1 hour of exposure to CO. These results were consistent with data from few studies published in this regard. Cortese and Spengler [9] determined, in Boston, that the type of transport affected the levels of personal exposure to CO; car passengers were exposed to twice as much CO as public transport.

Chan and col. [10] studied the exposure to CO, in public transport, of the inhabitants of the urban area of Guangzhou (China) and determined similar levels (28.7 ppm) to those observed in San Miguel de Tucumán until 2009.

Previous studies denote a lower CO concentration in past decades. A study [1] conducted in Paris in the period 1991-1992 reported an average of 12 ppm of CO in the interior of cars in the center. In addition, the air quality was much better in the subways since they obtained averages of between 2-5 ppm. In the general urban environment, away from automobile traffic, the quantities are lower by a factor of 2 to 3. During the same day, the climatic conditions and the traffic density that affects the amount of gases emanating from vehicle leaks can explain the variations in the concentration of pollutants. The air quality-monitoring network in the region consists of 55 permanent stations located in the general environment or close to the traffic: intersections, sidewalks of narrow streets or avenues. According to this study, the concentrations registered in certain stations exposed to car exhaust pipes represented the exposure suffered by a city inhabitant. In this regard, they consider that the contribution of CO is such that its impact on health should be recorded by biomarkers, for example, CO level in air exhaled by specially exposed persons.

Dhakal [12] published a study on the increase of energy use in 4 relevant cities of China: Beijing Shanghai, Tianjin and Chongqing. The analysis showed that, in 2006, they were responsible for 84% of the total energy consumption of that country. He estimates that their growth will continue and therefore the consumption of energy will also increase. However, there are no published studies related to the air quality of these cities evaluated with atmospheric CO levels.

The air quality in Nottingham, like that reported for Paris [11] is significantly better than the one determined for San Miguel de Tucumán. However, it should be noted that the studies in Nottingham and Paris date back 20 years and, given the global environmental problems, the current values could be very different.

Georgoulis et al. [13] reported the geometric mean of CO concentrations in different urban areas of Europe and determined values between 0.53 and 2.43 mg/m^3 (0.43 and 1.97 ppm) for Helsinki (Finland), Basel (Switzerland), Prague (Czech Republic), Athens (Greece) and Milan (Italy), in ascending order; values significantly lower than those detected in San Miguel de Tucumán.

CONCLUSION

The City of San Miguel de Tucumán is located in a mountainous area, with little movement of air, which means it has a notable accumulation of atmospheric pollutants.

Comparing the initial and final values, obtained in the period studied (2003-2015), for the same time of the year, there was a statistically significant increase of CO in the microcenter of San Miguel de Tucumán.

The explanation of this increase could respond to the growth of the vehicle fleet as well as to the higher height of the recent building structures.

As palliative measures to such an increase and prevention in the future, it would be healthy to establish policies and strategies for control and application of air quality standards, in compliance with the regulations in force for the emission sources.

Special attention must be paid to public and private means of transport to achieve a clean atmosphere and a better quality of life.

The results of this research will serve as a regional and national reference, given the few bibliography on the subject under study and will provide the opportunity to initiate new lines of research, in which other pollutants that threaten environmental health can be considered.

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