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Air Pollution in Medium-Sized Mexican Cities

Hermes Ulises Ramírez-Sánchez [a*] and Aida Lucia Fajardo-Montiel [a]

[a] University Center of Tonalá, University of Guadalajara, Av. Nuevo Periférico No. 555 Ejido San José Tateposco, C.P. 45425, Tonalá, Jalisco, México.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Medium-sized cities are in the population range of between 500,000 and one million inhabitants. Despite the importance of large cities, the greatest urban growth occurs in medium and small cities. During the last century these cities enjoyed acceptable air quality, however from the last years of the last century and the two decades of this century the atmospheric health has deteriorated, generating problems. The dynamics of population growth faced by these cities represent a serious threat to the environment, as well as to the health and quality of life of its inhabitants, since it generates new economic processes, accompanied by an increase in industrial activities, motorization rates, greater fuel consumption and higher emissions of air pollutants.
Objective: To carry out an analysis of the air quality condition and to show the trends of the criteria pollutants for 10 medium-sized Mexican cities with the highest population growth.
Materials and Methods: The data for the analysis of air quality of medium-sized cities were downloaded from the consultation system of Air Quality Indicators-SCICA through the http://scica.inecc.gob.mx/exec/addl website. The downloaded data are hourly concentrations of the six criteria pollutants PM_{10}, $PM_{2.5}$, O_3, SO_2, NO_2 and CO for the monitoring stations of the cities of

**Corresponding author: E-mail: ramirez@astro.iam.udg.mx, hermes.ramirez@academicos.udg.mx;*

Aguascalientes (863 893 h), Mexicali (854 186 h), Ciudad Juárez (1 501 551 h), Chihuahua (925 762 h), León (1 579 803 h), Morelia (743 275 h), Puebla (1 542 232 h), Querétaro (794 789 h)), San Luis Potosí (854 186 h) and Torreón (690 193 h), indicators were calculated of the daily, monthly and annual trend, averages, percentages of days with concentrations above the norm and number of days per year in which any of the norms is exceeded during the period 2000-2020. Compliance with environmental health NOMs (at one hour, 8 h, 24 h and annually) was evaluated depending on the pollutant criterion.

Results and Discussion: Medium-sized cities have grown between 21 and 55% in the last 20 years, some surpassing the category of medium cities. The concentrations of PM_{10}, $PM_{2.5}$ and O_3 in all medium-sized cities are almost always above the normativity which represents a risk to the health of the population. The concentrations of CO, NO_2 and SO_2 are below the limits of the regulations, so these pollutants currently do not represent a risk to the population of medium-sized cities. Most cities present less than a third of the year with days out of the norm, only Torreón, Puebla and León present values of one third to two thirds of the year above the norm.

Conclusions: The pollutants PM_{10}, $PM_{2.5}$ and O_3 represent a risk to the health of the population of medium cities in Mexico, while the concentrations of CO, NO_2 and SO_2 currently do not represent a risk for the population of medium cities.

Keywords: Medium-sized cities; air pollutants; Monterrey Metropolitan Area; environmental and health risks.

1. INTRODUCTION

Cities are humanity's most durable and stable mode of social organization. They bring together the dominant demographic and economic groups of the world [1] and concentrate on industrial, knowledge generation, investment and innovation activities, among others.

By the mid-twentieth century, three out of ten people in the world lived in urban areas. Currently, it is estimated that more than half of the world's population lives in cities and according to the projections of the United Nations (UN) most of the population growth over the next 30 years will be concentrated in urban centers [2]. This process of urbanization occurs most rapidly in countries located in regions classified as developing economies. Particularly in Latin America where it is estimated that 75% of the population lives in cities [3].

Medium-sized cities are those in a population range of between 500,000 and one million inhabitants, and emerge with the greatest potential to lead an inclusive and sustainable economic future that reduces the gap between urban and rural [4]. Despite the importance of large cities, the greatest urban growth occurs in medium and small cities [5]. During the last century these cities enjoyed acceptable air quality, however from the last years of the last century and the two decades of this century the atmospheric health has deteriorated and is causing health problems among the population.

Clark and Clark [6], argue that cities generate displacements of population, resources and goods and services are deployed, so there are complementarities and competitions between cities, which are the basis of the economic system. In these systems, large population centers operate on a national and international scale, while medium-sized cities occupy a binding place between large and small agglomerations – urban and rural.

The dynamics of population growth faced by cities represent a serious threat to the environment, as well as to the health and quality of life of their inhabitants. This growth generates new economic processes and is generally accompanied by an increase in industrial activities, higher motorization rates, large fuel consumption and therefore the generation of higher emissions of air pollutants. The activities that generate the dynamics of activities in medium-sized cities have caused a greater emission of pollutants into the atmosphere, deteriorating air quality and decreasing the quality of life of the population and ecosystems.

As a result, air pollution in urban centers in developing countries is a constantly growing phenomenon [7]. Therefore, governors and decision-makers of these cities have recognized air pollution as one of the greatest environmental challenges that cities must face today [8].

The study and control of air pollution is supported by evidence of its negative impact on respiratory, cardiovascular, skin and eye health, as well as the deterioration of people's quality of life [9-10]. This situation is a priority in medium-sized Mexican cities that have shown accelerated growth in recent decades, where it has been documented that respiratory diseases are the main cause of morbidity and mortality in children under five years of age [11], older adults and people with diseases susceptible to air pollutants [12].

The control of air pollution represents high costs due to its negative effects, significantly affecting the competitiveness of cities. Studies conducted by institutions such as the World Bank indicate that the cost of air pollution is in the order of billions of dollars per year in developing countries [13]. A situation that worsens when simultaneously the investment in the control of air pollution, the city must diversify its spending in the solution of other problems of the growing urbanization associated with the deterioration of air quality, such as health, road infrastructure, mobility, security, basic sanitation, among others).

Thus, the objective of this study is to perform an analysis of air quality conditions and evidence of the trends of criteria pollutants for 10 medium-sized Mexican cities with the highest population growth. In this analysis, urbanization processes are related to the levels of air pollution present in the city.

1.1 Background

Air pollution poses a major threat to global society by having deleterious effects on people [14], medical systems [15], ecosystem health [16] and economies [17] in both developing and developed countries [18-21]. About 90% of the world's citizens lived in areas that exceeded the safe level of the World Health Organization (WHO) air quality guidelines [22]. Among all types of ecosystems, urban ecosystems produce approximately 78% of the carbon emissions and substantial air pollutants that negatively affect more than 50% of the world's population living in them [18,23]. While air pollution affects all regions, there is substantial regional variation in air pollution levels [24]. For example, the average annual concentration of fine particulate matter with an aerodynamic diameter of less than 2.5 μm ($PM_{2.5}$) in the most polluted cities is almost 20 times higher than in the cleanest city according to a survey of 499 global cities [25]. Many factors can influence regional air quality, including emissions, meteorology, physicochemical transformations, among others. Another important driver is urbanization, a process that alters the size, structure, and growth of cities in response to population explosion and leads to lasting air quality challenges [26-28].

It is estimated that in Latin American countries the percentage of people living in cities is close to 80%. Also, in 2009 three important Latin cities were on the list of the ten most populated urban areas in the world (Sao Paulo, Mexico City and Buenos Aires). It is estimated that by 2050, there will be 29 cities in the world with more than ten million inhabitants [3].

The fact that more and more people live in cities has important economic, social and environmental implications. The phenomenon of urbanization demands better conditions in basic sanitation, public transport, health and urban infrastructure services aimed at offering a better quality of life for citizens. Particularly in medium-sized Mexican cities, population growth has been accompanied by a better economy. Thanks to the dynamism of sectors such as industry, construction, commerce, tourism among others, during the last years the economy in these cities has grown at a rate close to 5% [29].

The economic growth of medium-sized Mexican cities has led to the generation of new consumption and behavior trends that have important repercussions on the conditions of environmental sustainability and the quality of life of the population. For example, the dynamics of mobility two decades ago were based on public transport and in the last two decades it is increasingly common to make use of particular means of mobilization [29].

The importance of medium-sized Mexican cities can be judged if one considers their role within the network of cities. In 2000 and 2010, population and gross domestic product (GDP) growth in these cities was, in relative terms, higher than that of any other type of urban agglomeration. Medium-sized cities have grown between 21 and 55% in the last 20 years, with some surpassing the category of medium cities (Table 1).

Table 1. Population, % growth between 2000 and 2020 in 10 medium-sized Mexican cities

State	Municipality	City	Position (2000)	Position(2020)	Population City (2000)	Population City (2020)	% Growth
Guanajuato	León	León	3	1	1 020 818	1 579 803	55%
Puebla	Puebla	Puebla	1	2	1 271 673	1 542 232	21%
Chihuahua	Ciudad Juarez	Ciudad Juarez	2	3	1 187 275	1 501 551	26%
Chihuahua	Chihuahua	Chihuahua	4	4	657 876	925 762	41%
Aguascalientes	Aguascalientes	Aguascalientes	6	5	594 042	863 893	45%
Baja California	Mexicali	Mexicali	8	6	549 873	854 186	55%
San Luis Potosi	San Luis Potosi	San Luis Potosi	5	7	629 208	845 941	34%
Queretaro	Queretaro	Queretaro	9	8	536 463	794 789	48%
Michoacán	Morelia	Morelia	7	9	549 996	743 275	35%
Coahuila	Torreón	Torreón	10	10	502 964	690 193	37 %

Source: Own elaboration INEGI (2000, 2020) [30-31]

This group of cities brought together, in 2010, 16.3 million people, equivalent to 18% of the urban population, and represented 23.3% of GDP, in both cases similar to that of large cities, which suggests a relatively proportional weight between large and medium-sized cities. In environmental matters, something similar is happening where the concentrations of air pollutants have been gradually increasing in these cities, where in some of them they are already beginning to represent risks to both environmental and human health as occurs in large cities.

2. MATERIALS AND METHODS

The air quality analysis was based on information from 9 Air Quality Monitoring Systems (SMCA) of 10 medium-sized cities in Mexico [City (year of start of operations)] were: Aguascalientes (2018), Mexicali (2018), Ciudad Juárez (2019), Chihuahua (2007), León (2006), Morelia (2008), Puebla (2000), Querétaro (2011), San Luis Potosí (2018) and Torreón (2013) in 9 states (Fig. 1). However, the time series of air quality data is not the same for all SMCAs since they entered into operation in different years. The analysis was performed in SMCAs that have information on some of the following criteria pollutants: Particulate matter both less than 10 µm (PM_{10}), and those less than 2.5 µm ($PM_{2.5}$), Ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO) from the year of commencement of operations until 2020. Data were obtained from hourly concentration databases and processed once the data were cleaned, reviewed and verified. Likewise, the sufficiency criterion of at least 75% of valid data was taken into account to determine the indicators.

The data were downloaded from the Air Quality Indicators consultation system-SCICA through the website http://scica.inecc.gob.mx/exec/addl [32]. The data were downloaded by pollutant, monitoring system and year for each of the stations that recorded hourly concentrations in CSV format and converted into .xlsx format in the Microsoft Office Excel program. The diagnosis and trends of air quality of the six criteria pollutants PM_{10}, $PM_{2.5}$, O_3, SO_2, NO_2 and CO in the cities of Aguascalientes (863 893 h), Mexicali (854 186 h), Ciudad Juárez (1 501 551 h), Chihuahua (925 762 h), León (1 579 803 h), Morelia (743 275 h), Puebla (1 542 232 h), Querétaro (794 789 h), San Luis Potosí (854 186 h) and Torreón (690 193 h), were generated by calculating indicators of the monthly and annual trend of the minimum, maximum, average, percentage of days with concentrations above the norm for each pollutant and the number of days per year in which any of the norms is exceeded during the period 2000-2020. Compliance with environmental health NOMs was evaluated about the average concentration (at one hour, 8 h, 24 h and yearly). Table 2 presents the limit values of the environmental health NOMs of the criteria pollutants.

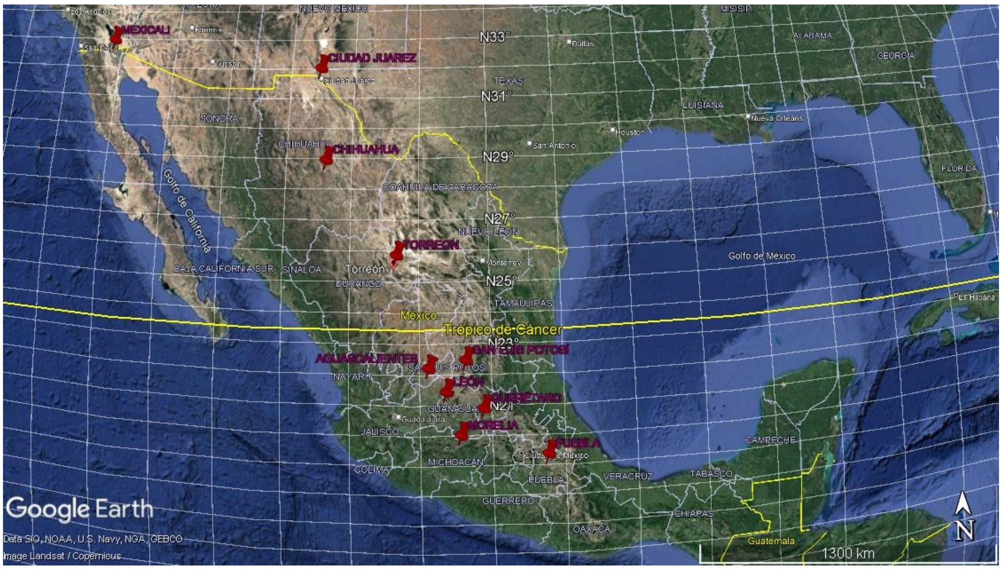

Fig. 1. Medium-sized cities in Mexico where the analysis of the concentration of air pollutants was carried out. Courtesy of Google Maps

Table 2. Criteria pollutants, indicator, limit values and NOMs for each pollutant

Pollutant	Base data used	Exposition	Tolerated Frequency	Limit value and indicator	Annual sufficiency criterion	Official Mexican Standard
PM_{10} particles	Average 24 hours	Acute	Not allowed	75 µg/m^3 Maximum	At least three quarters with at least 75% of 24-hour averages valid (DOF, 2014)	NOM-025-SSA1-2014 (DOF, 2014a) [33]
		Chronicle	-------	40 µg/m^3 Annual average		
$PM_{2.5}$ particles	Average 24 hours	Acute	Not allowed	45 µg/m^3 Maximum		
		Chronicle	-------	12 µg/m^3 Annual average		
Ozone (O_3)	Timetable data	Acute	Not allowed	0.095 ppm Max	At least 75% of hourly data	NOM-020-SSA1-2014 (DOF, 2014b) [34]
	8-h moving average		Not allowed	0.070 ppm Max	At least 75% of 8-h moving averages	
Sulphur dioxide (SO_2)	Daily maximum of historical data	Acute	1% times a year	0.075 ppm Simple average of 3 consecutive years in the 99th percentiles	At least 75% of daily data for each quarter of three consecutive years (DOF,2019)	NOM-022-SSA1-2019 (DOF, 2019) [35]
	Average 24 hours	Acute	Not allowed	0.04 ppm Maximum of three consecutive years	At least 75% of 24-h averages for each quarter or months with high concentrations for three consecutive years (DOF,2019)	
Nitrogen dioxide (NO_2)	Timetable data	Acute	1 time a year	0.210 ppm Second maximum	At least 75% of hourly data	NOM-023-SSA1-1993 (DOF, 1994a) [36]
Carbon monoxide (CO)	8-h moving average	Acute	1 time a year	11 ppm Second maximum	At least 75% of 8-h moving averages	NOM-021-SSA1-1993 (DOF, 1994b) [37]

The information was then plotted and the main trends for each pollutant in each average city were determined. Likewise, the results were compared between cities and in this way to show the behavior of air quality in the last two decades and evaluate which cities present risks concerning air pollutants criterion.

3. RESULTS AND DISCUSSION

The analysis of the criteria pollutants in the medium-sized Mexican cities shows a great heterogeneity because the monitoring systems in each of the different cities were implemented in different years and the amount of information is very different from one city to another. This shows us how the concern for monitoring air quality has been increasing in cities that in previous years did not worry, no longer were events with high levels of air pollution not noticed. However, with population growth and industrial, commercial and service development, it has been necessary to incorporate air quality measurement systems in these cities. Thus, we can see those cities such as Puebla (2000), León (2006), Chihuahua (2007) and Morelia (2008) implemented their air quality monitoring system in the first decade of this century, while Querétaro (2011), Torreón (2013), San Luis Potosí (2018) Aguascalientes (2018), Mexicali (2018) and Ciudad Juárez (2019) implemented it in the second decade of this century. Thus, with the pertinent clarification about the start of operations of each of the SMCAs, the results found in this analysis are as follows:

3.1 PM_{10}

The criterion pollutant Particles Smaller than 10 µm (PM_{10}) was the one that was presented in all the medium cities analyzed, it is also the one that presented the highest concentrations in the daily, monthly and annual averages and those that presented the greatest number of days outside the norm. According to the normativity NOM-025-SSA1-2014 (DOF, 2014a) [33] the values that most affect the population are the maximums (75 $\mu g/m^3$) and the annual averages (40 $\mu g/m^3$) and all the medium cities presented maximum values that ranged between 75-375 $\mu g/m^3$ during the entire period analyzed (Fig. 2a). On the other hand, the annual averages showed a range of 30-95 (75 $\mu g/m^3$) also in all cities and during practically the entire period analyzed (Fig. 2b). The percentage of days out of the norm for PM_{10} ranged from 2 to 55% (Fig. 3). Thus, practically in all cities, PM_{10} is almost always above normativity, which represents a risk to the health of the population. At times the maximums reach values equal to or higher than those of megacities.

3.2 $PM_{2.5}$

Particulate matter smaller than 2.5 µm ($PM_{2.5}$) was also present in all medium cities analyzed, and concentrations are the second highest in daily, monthly, annual and non-normative averages. According to NOM-025-SSA1-2014 (DOF, 2014a) [33] the maximum permissible values were exceeded in practically all cities and throughout the period analyzed, except San Luis Potosí, Torreón and Cd. Juárez in which there was not enough data to evaluate the trends. The regulations establish daily maximum limits of 45 $\mu g/m^3$ and annual averages of 12 $\mu g/m^3$ and all medium-sized cities presented higher values. Maximum values ranged from 30-120 $\mu g/m^3$ throughout the period analyzed (Fig. 4a). On the other hand, the annual averages showed a range of 12-30 $\mu g/m^3$ also in all cities and during practically the entire period analyzed (Fig. 4b). The percentage of days out of the norm for $PM_{2.5}$ ranged from 1 to 12% (Fig. 5). Thus, in practically all cities, $PM_{2.5}$ is almost always above the normativity, which represents a risk to the health of the population, since these particles can enter the deepest part of the respiratory system. At times the maximums reach values equal to or higher than those of megacities.

The values found here are below the average Chinese cities in which they were reported during the period from 2000 to 2014, the average annual concentration in all Chinese cities increased from 27.78 to 42.34 $\mu g/m^3$ [38], however in all Mexican cities the annual average values exceed the average annual standard recommended by the World Health Organization (10 $\mu g/m^3$). Spatially, changes in $PM_{2.5}$ levels exhibit heterogeneous patterns between cities in both medium-sized Chinese and Mexican cities. Finally, cities in terms of different population levels have significant differences in the changes in the concentration of $PM_{2.5}$, the greater the population, the greater the concentration of $PM_{2.5}$, with the increases in risks to the health of the population.

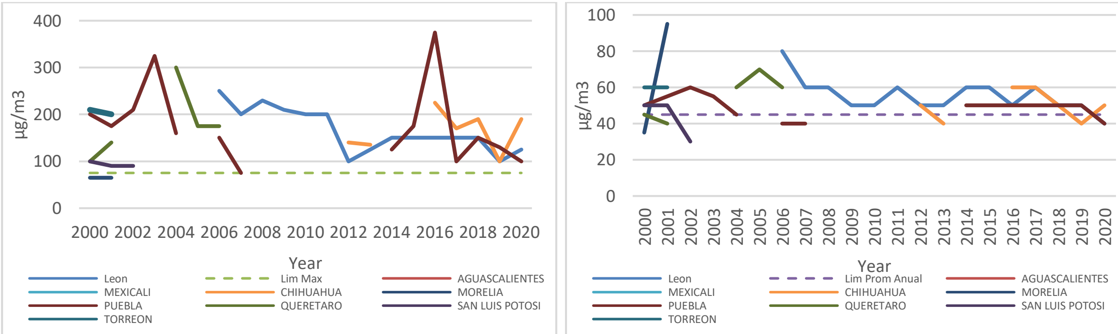

Fig. 2. a) Maximum values of PM_{10} in medium-sized Mexican cities b) Annual maximum values of PM_{10} in medium-sized Mexican cities

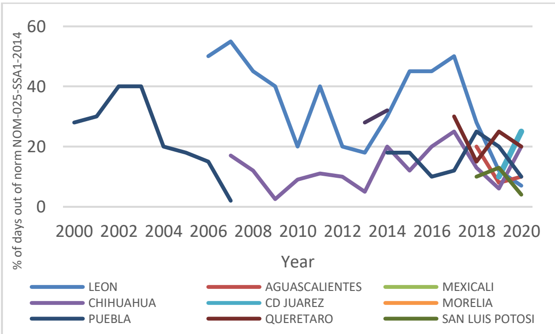

Fig. 3. Percentage of days out of standard NOM-025-SSA1-2014 for PM_{10}

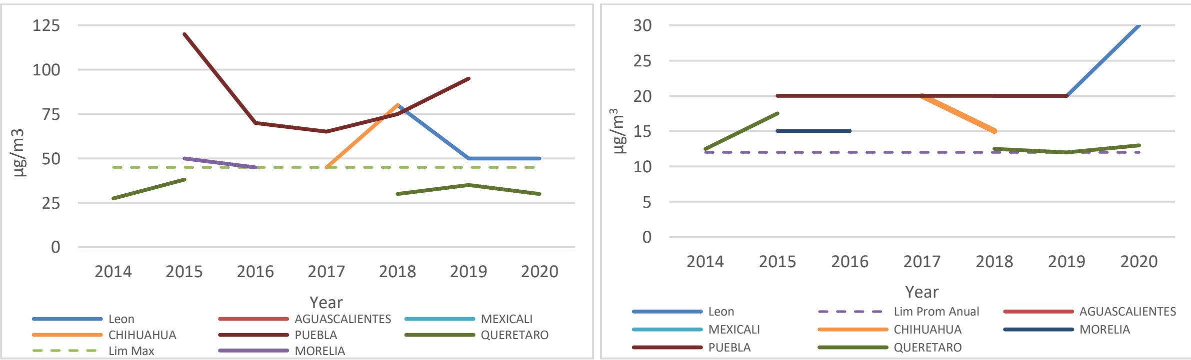

Fig. 4. a) Maximum values of $PM_{2.5}$ in medium Mexican cities b) Annual maximum values of $PM_{2.5}$ in medium Mexican cities

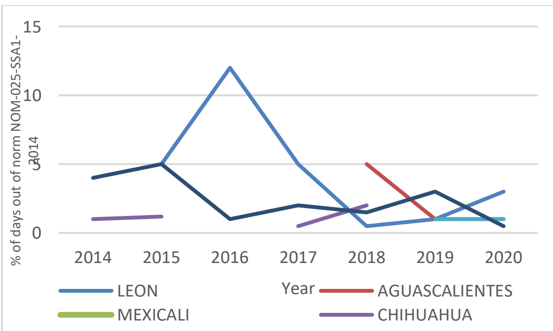

Fig. 5. Percentage of days out of standard NOM-025-SSA1-2014 for $PM_{2.5}$

3.3 O_3

The behavior of ozone (O_3) is another of the criteria pollutants that were also presented in all the medium cities analyzed, and the concentrations are high both in the daily, monthly and annual averages and days out of standard. According to NOM-020-SSA1-2014 (DOF, 2014) [34] the maximum permissible values were exceeded in practically all cities and throughout the period analyzed, with the exception of Aguascalientes and San Luis Potosí. The regulations establish limits of daily maximums of 0.095 ppm and annual averages of 0.070 ppm maximum in averages of 8h. The maximum values ranged between 0.06-0.3 ppm during the entire period analyzed (Fig. 6a), most of them above the norm, with few values below the norm in Querétaro and Chihuahua. On the other hand, the annual averages presented a range of 0.025-0.060 also in all cities and during practically the entire period analyzed (Fig. 6b); all values are below the norm of 0.07 ppm. The percentage of days out of the norm for O_3 ranged from 0.2 to 39% (Fig. 7). Thus, practically in all cities the maximums of O_3 are almost always above the normativity, while the maximums of the 8h averages are always below the norm. This may begin to represent a risk for the population, it would be necessary to avoid high concentrations of primary pollutants such as NO_x and precursor VOCs of O_3, to try to keep concentrations below the norm.

3.4 CO

The carbon monoxide standard NOM-021-SSA1-1993 (DOF, 1994b) [35] sets a limit of 11 ppm as the second maximum. The values of daily maximums reported in the 10 Mexican cities ranged from 2-12 ppm: the value of 12 ppm was only presented once in 2014 in the city of Querétaro (Fig. 8a). All other values were below the 11 ppm limit. As for the averages, the values were between 0.4 and 5 ppm well below the norm of 11 ppm (Fig. 8b). As for the days outside the norm, these were not registered. Based on the results obtained, CO concentrations are well below the limits of the regulations, so practically this pollutant currently does not represent a risk to the population of medium-sized cities.

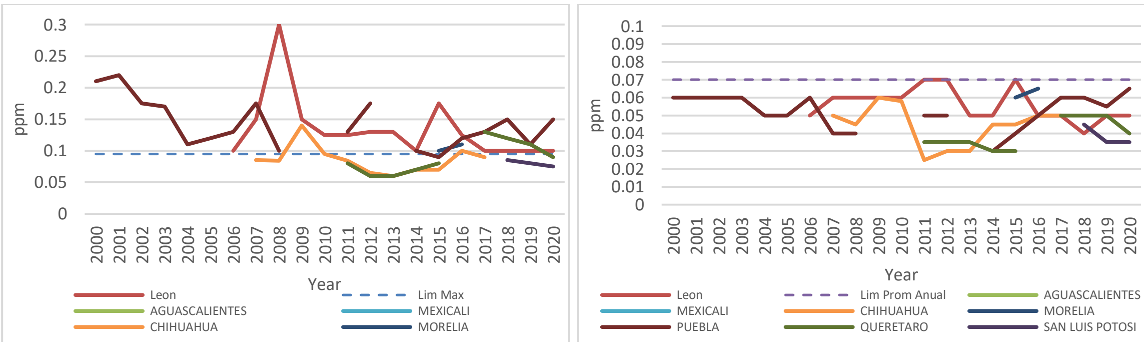

Fig. 6. a) Maximum values of O_3 in medium Mexican cities b Annual maximum values of O_3 in medium Mexican cities

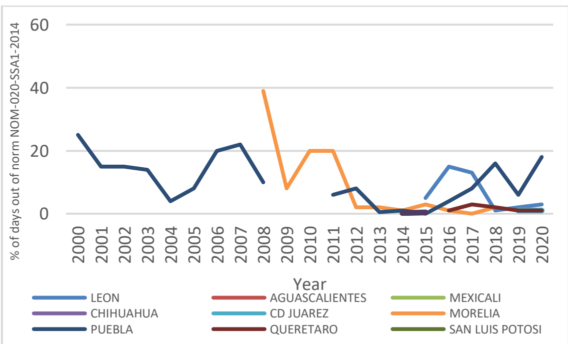

Fig. 7. Percentage of days out of standard NOM-020-SSA1-2014 for O_3

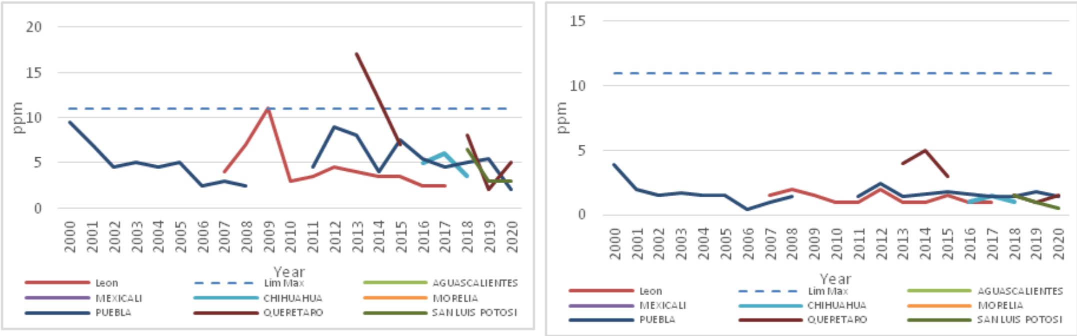

Fig. 8. a) Maximum CO values in medium-sized Mexican cities b Annual maximum CO values in medium-sized Mexican cities

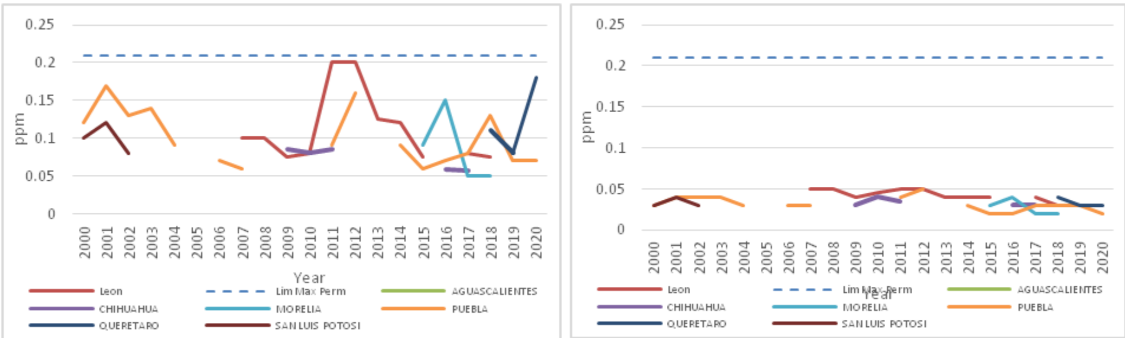

Fig. 9. a) Maximum values of NO_2 in medium Mexican cities b. Annual maximum values of NO_2 in medium Mexican cities

3.5 NO_2

The regulations for dioxide NOM-023-SSA1-1993 (DOF, 1994a) [36] mark as limit 0.21 ppm as second maximum. The values of daily maximums reported in the 10 Mexican cities ranged from 0.04-0.2 ppm (Fig. 9a). As for the averages, the values were between 0.03 and 0.05 (Fig. 9b) well below the norm of 21 ppm. As for the days outside the norm, these were not registered. Based on the results obtained, the concentrations of NO_2 are well below the limits of the regulations, so practically this pollutant currently does not represent a risk to the population of medium-sized cities.

3.6 SO_2

The standard NOM-022-SSA1-2019 (DOF, 2019) [37] is the one that specifies the maximum permissible limits for sulfur dioxide and where it marks that the 24-hour average is 0.04 ppm maximum of three consecutive years, while the daily maximum of 1 h of the historical data is 0.075 ppm. In the case of medium-sized Mexican cities, the average values of 24 h ranged from 0.001 to 0.1 ppm (Fig. 10a): the values are above the norm in 6 of the cities analyzed with the exception of Cd. Juárez, Mexicali, León and Aguascalientes. If we take the annual averages of the daily averages, the values are between 0.002 and 0.02 ppm (Fig. 10b) so practically all the values are within the norm which conceals what happens on some days when the maximums exceed the norm. When we analyze the information of the daily maximums to one hour, the values registered in the Mexican cities oscillate between 0.01 and 0.3 ppm (Fig. 11a), the cities that present values above the norm are Morelia, Puebla, Querétaro and León, the remaining 6 cities are under norm for SO_2 maximum daily to 1 h. The annual average values of daily maximums of 1 h are between 0.0005 and 0.025 ppm (Fig. 11b) practically like the annual average at 24 h all cities are under standard for SO_2, so there are no risks with respect to this pollutant except for maximums that occur on some days in the cities of León, Puebla and Queretaro. As for the days outside the norm, the maximum daily values at 1 h presented values between 1 and 20% mainly in Mexico, Puebla and Querétaro (Fig. 12).

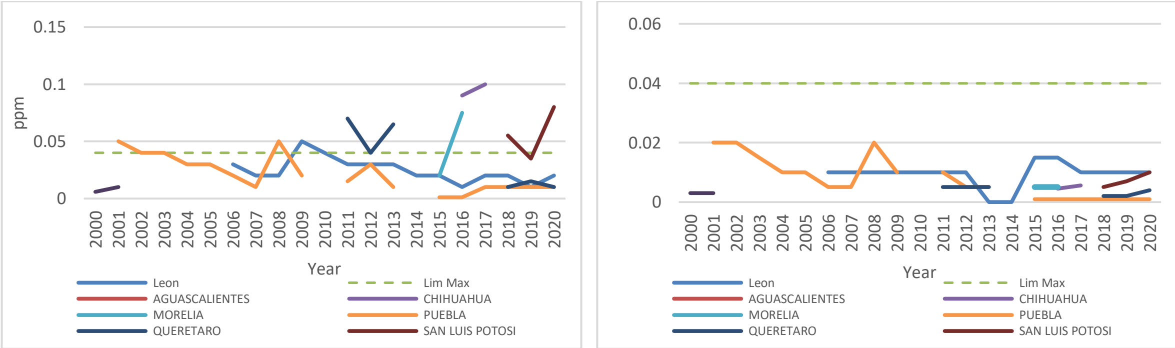

Fig. 10. a) Maximum values of SO_2 in 24 h in Mexican medium cities b) Annual maximum values of SO_2 in 24 h in medium Mexican cities

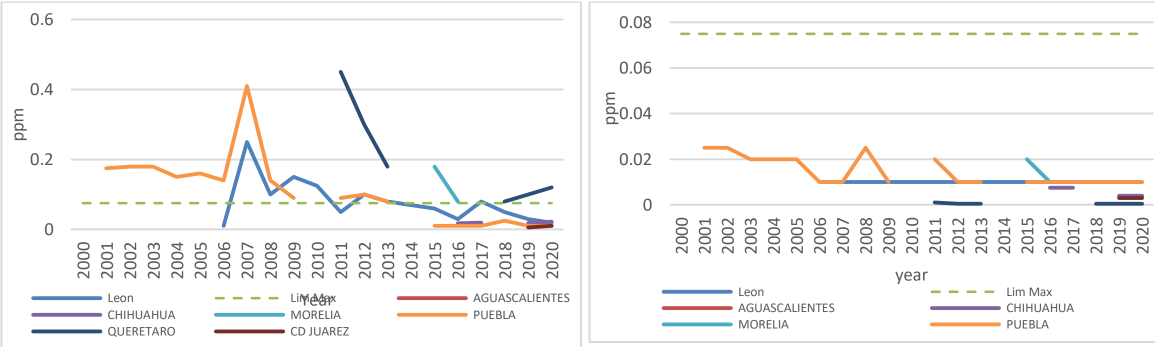

Fig. 11. a) Maximum values of SO_2 in 1 h in Mexican medium-sized cities b) Annual maximum values of SO_2 in 1 h in medium-sized Mexican cities

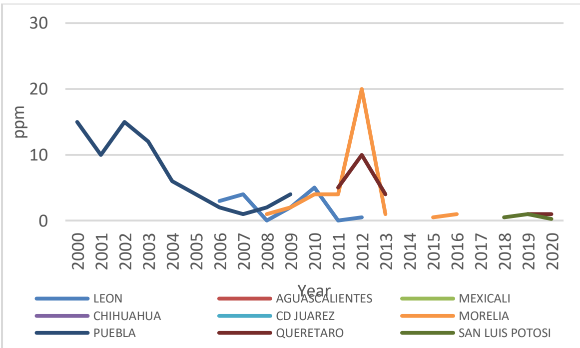

Fig. 12. Percentage days out of standard NOM-022-SSA1-2019 for daily maximums of SO_2 to 1h

If we analyze the days outside the norm we can see that practically all cities present to a greater or lesser degree days out of norm the values range between 1 and 28 days out of norm. Most cities present less than a third of the year with days out of the norm, only Torreón, Puebla and León present values above a third of the year (Fig. 13). An interesting fact is that in almost all cities during the last two years of the last decade, the concentrations of all pollutants and days out of the norm decreased, which is probably due to the decrease in activities resulting from the COVID-19 pandemic, so it would be necessary to analyze how pollutants would behave post-pandemic.

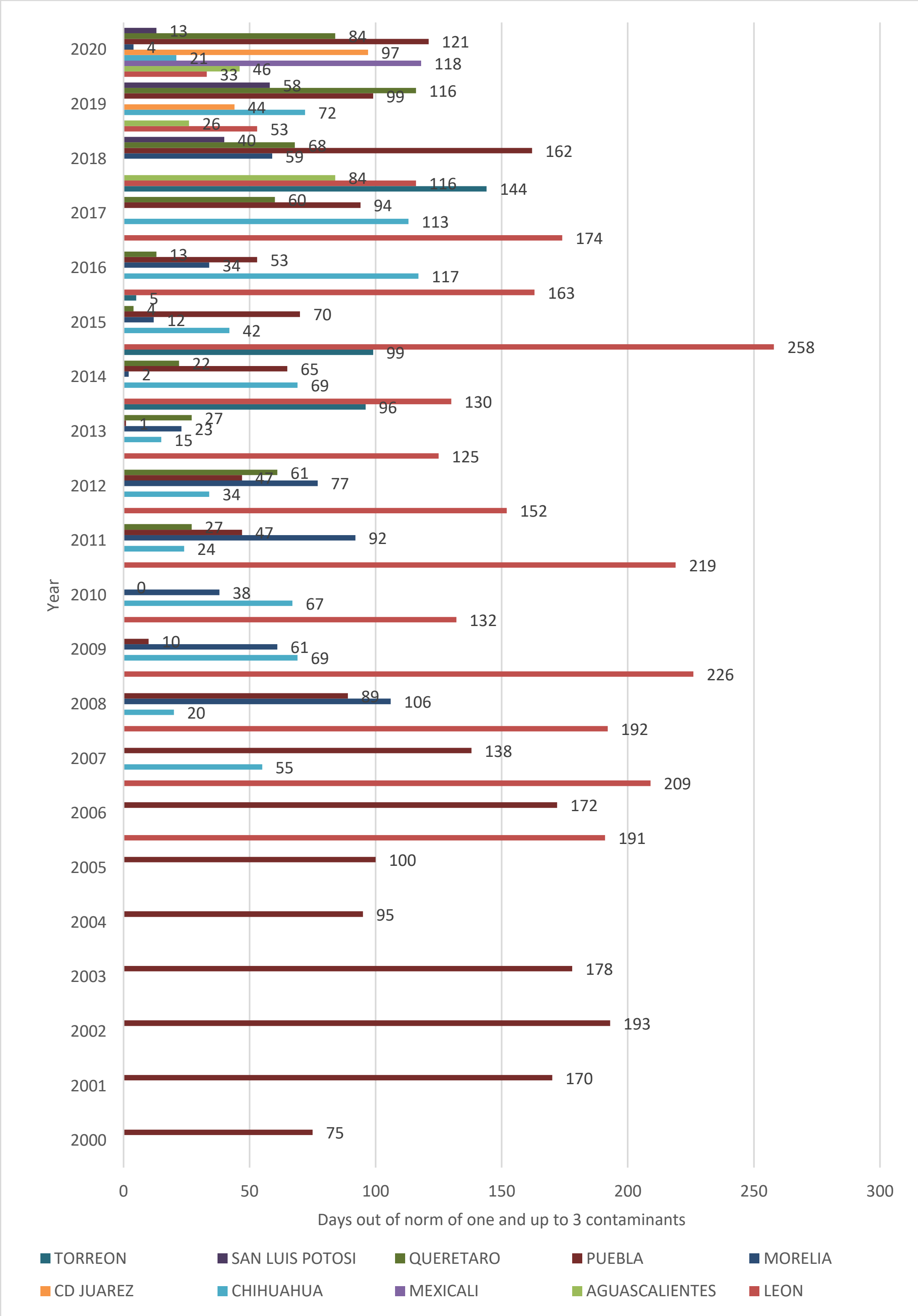

Fig. 13. Days out of norm of one and up to 3 atmospheric pollutants in medium-sized cities of Mexico

4. CONCLUSION

The analysis of criteria pollutants in the medium-sized cities of Mexico during the period 2000-2020 gave us as conclusions:

1. Medium-sized cities have grown between 21 and 55% in the last 20 years, some surpassing the category of medium city. In environmental matters, something similar is happening where the concentrations of air pollutants have been gradually increasing in these cities, and in some of them they are already beginning to represent risks to both environmental and human health as it occurs in large cities.
2. PM_{10} concentrations in all cities are almost always above the normativity, which represents a risk to the health of the population. At times the maximums reach values equal to or higher than those of megacities.
3. Practically in all cities the concentrations of $PM_{2.5}$ are above the normativity which represents a risk to the health of the population, since these particles can enter to the depths of the respiratory system. At times the maximums reach values equal to or higher than those of megacities.
4. The maximums of O_3 are almost always above the normativity in all the medium-sized cities analyzed, while the maximums of the 8-h averages are always below the norm. This may begin to represent a risk for the population, so it is necessary to control emissions of primary pollutants (NOx and VOCs) precursors of O_3, to try to keep concentrations below standard.
5. Based on the results obtained, the concentrations of CO and NO_2 are well below the limits of the regulations, so these pollutants currently do not represent a risk to the population of medium-sized cities.
6. For SO_2 the annual average values of daily maximums of 1 h as well as the annual average at 24 h in all the medium cities analyzed are under the norm, so there are no risks concerning this pollutant except for maximums that occur on some days in the cities of León, Puebla and Queretaro.
7. Most cities present less than a third of the year with days out of the norm, only Torreón, Puebla and León present values above a third of the year.
8. During the last two years of the last decade, the concentrations of all pollutants and the days out of the norm decreased, which was probably a result of the COVID-19 pandemic, so their post-pandemic behavior would have to be analyzed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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