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The Influence of Air Pollutants on the Acute Respiratory Diseases in Children in the Urban Area of Guadalajara

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1. Introduction

Today environmental pollution problems are well known, particularly air pollution, which gives rise to health risks and impacts the well being of the population. Many of the pollutants emitted into the atmosphere generate problems in the short and long term (i.e. global warming, climate change); also at local and regional levels, they generate public health problems such as respiratory and cardiovascular diseases (Ramírez-Sánchez et al., 2006; Romieu, 1991, 1995; Segala, 1999; World Health Organization/United Nations Environmental Programme [WHO/UNEP], 1995; Departamento del Distrito Federal/Gobierno del Estado de México/ Secretaría del Medio Ambiente, Recursos Naturales y Pesca/Secretaría de Salud [DDF/GEM/SEMARNAP/SS], 1990).

Both in the clinical and public health fields, air pollution is a phenomenon known and studied for a long time; however, it gained importance because of a series of episodes that occurred during the first half of the 20th century. The events of Meuse Valley, Belgium in 1930 (Firket, 1936), Donora, Pennsylvania, USA in 1948 (Shrenk, 1949) and London in December 1952 (Ministry of Health, United Kingdom [MHUK], 1954), would perhaps be the most notable and characteristic. These exceptional circumstances resulted in an increase in the mortality and morbidity rate, which left no doubt that high levels of air pollution are causally associated with an increase in early deaths (Schwartz & Marcus, 1990). In the London episode, dense fog covered the city from December 5th through the 8th of 1952, accompanied by an increase in mortality. The number of deaths attributed to this episode was between 3,500 and 4,000. This evidence led to the adoption of air pollution reduction control policies in Western Europe and in the United States.

Children are particularly vulnerable to environmental risks. Over 40% of global morbidity is attributed to environmental conditions affecting children under 5 years of age, a risk about four times greater than in the general population (Smith et al., 1999; Pan American Health Organization [PAHO], 2004b).

According to data from PAHO/WHO, there is little information on incidence and prevalence of respiratory diseases belonging to the group of Acute Respiratory Infections (ARI). However, in Latin American countries, all agree that the ARI represents the main cause of pediatric outpatient cases. Some studies have shown that between 40 and 60

percent of consultations are from ARI. It is common that children receive medical attention four to six times a year, with seasonal variation, which implies a high demand for healthcare. Only a small portion of the large volume of inquiries is for serious cases such as pneumonia or bronchiolitis in young children. In general these are viral infections of the upper respiratory tract and are usually self-limited and resolve spontaneously with home care. According to estimates from the late eighties and early nineties, in the Region of the Americas, ARI accounted for more than 100,000 annual deaths among children less than 1 year of age. About 90% of these deaths are due to pneumonia (PAHO, 1994).

Globally, high child mortality rates from ARI were recorded, with marked differences between developed and developing countries (PAHO, 1980). In some Latin American countries, the risk of dying from this cause in the first year of life can be up to 30 times higher than in the USA (Pio et al., 1984a). It is estimated that in developed countries, 2 percent of children die from pneumonia, while in countries with limited resources, the mortality rate ranges from 10 to 20 percent. In a study conducted by PAHO on the infant mortality rate from influenza and pneumonia in Latin America in children under 5 years, when comparing the deaths in the sixties with those of the seventies (Pio et al., 1984a), a decline in mortality is seen between one decade and another, but persists in 1977 with rates of 1,419 (per 100,000) in Guatemala and 1,718 in Peru. At the same time in Uruguay, the mortality rate for similar cases in children under one year was 241 per 100,000 live births and under 5 years, 67.8. However, the infant mortality rate in some countries is low as a result of relating them to the general population, which dilutes these figures. Analyzing the information reveals special risk groups where infant deaths are concentrated. In Mexico, mortality decreased but remains a risk to the children population as demonstrated in Table 1.

Year	< 1 year		1 - 4 years	
	Deaths	Rate ¹	Deaths	Rate ²
1990	10122	370.0	2785	32.7
1991	8594	311.8	1651	19.4
1992	8127	290.5	1470	17.2
1993	6996	246.4	1614	18.9
1994	7687	264.7	1669	18.8
1995	6955	252.9	1694	19.8
1996	6647	245.5	1498	16.9
1997	6218	281.2	1259	14.2

*Includes pneumonia and influenza
¹Rate per 100 000 live births registered (NVR)
²Rate per 100 000 inhabitants in the age group
Source, Department of Statistics and Informatics. S.S.A.

Table 1. Mortality rates due to ARI* in children by age group under five years (Mexico 1990-1997).

Air pollution has multiple manifestations in communities, with children and older adults being the most vulnerable populations, with a high incidence of morbidity and mortality from acute respiratory and cardiovascular diseases. This forces clinical physicians,

toxicologists, environmentalists and epidemiologists to assess the adverse effects of atmospheric pollutants. Clinical physicians evaluated the health of exposed individuals, toxicologists defined the damage caused by the pollutants, environmentalists quantified the degree of pollution to which society is exposed and epidemiologists studied the effects on exposed groups.

Currently, there are concerns about the social costs of air pollution in terms of morbidity, disability and mortality, which have become a key task of governments and of international agencies responsible for the establishment of environmental policies. Special attention has been placed on the impact of air quality on the health of the most susceptible population: children, without forgetting that all inhabitants of the planet are exposed to different degrees.

The health effects attributable to air pollution exposure include excessive mortality from respiratory causes, such as: exacerbation of asthma, reduced lung function and immunological alterations. The epidemiological evidence comes from clinical, epidemiology, human exposure, clinical exposure and animal toxicology studies. However, some effects observed mechanisms and specific pollutants are not sufficiently well defined. The valuation of the costs of these diseases represents an estimate of the individual, social and institutional cost. However it is necessary to evaluate the consequences that chronic simultaneous exposure to high concentrations of air pollutants may have on health. The synergistic effects of pollutants have not been assessed; however, these can be short, medium or long term causing acute and chronic diseases.

There is epidemiological evidence showing that exposure to atmospheric contaminants, even at levels below the normal limits, is associated with an increase in the incidence and severity of asthma and lung function impairment, as well as with other respiratory diseases in children of less than five years of age.

This chapter aims to demonstrate how air pollutants affect human health, taking as an example a study case, which is intended to establish the influence of air pollutants in acute respiratory diseases in children of less than five years of age in the Urban Area of Guadalajara, Mexico.

2. Study area

The Urban Area of Guadalajara (UAG) is located at the center of the state of Jalisco, Mexico with coordinates limits 20°46'00" and 20°32'08" North latitude and 103°12'30" and 103°29'00" West longitude (Fig. 1), at an altitude of 1,540 meters (above mean sea level). The UAG is situated in the Rio Grande de Santiago Valley, Atemajac Valley and Tonalá plain, between the mountains of the Sierra Madre Occidental and the Transmexican volcanic belt, which constitutes a natural barrier to the circulation of the wind, limiting the release of polluted air outside of the UAG. Typical local meteorological conditions are thermal inversions that cause the deadlock of the pollutants. The frequency of thermal inversions is 283 days per year, and in the periods of January-June and November-December, they are present every day. The thickness of the thermal inversion is typically tens to hundreds of meters, being greater in the dry season and breaking at a layer where the atmospheric temperature is around 13 °C during the colder months of the year (January and February).

The dominant wind comes from the West 15.5% of the time, while winds from the East are present 7.5% of the time. In both cases, the typical speeds are between 5 to 20 km/h and sometimes reach 21 to 35 km/h. Calm conditions (absence of wind and/or very weak winds less than 4 km/h), are present 44.3% of the time, with great potential for accumulation of pollutants due to lack of ventilation in the UAG (Secretaría del medio ambiente, recursos

naturales y pesca - Secretaría de Salud - Gobierno del Estado de Jalisco [SEMARNAP/SS/GE]], 1997).

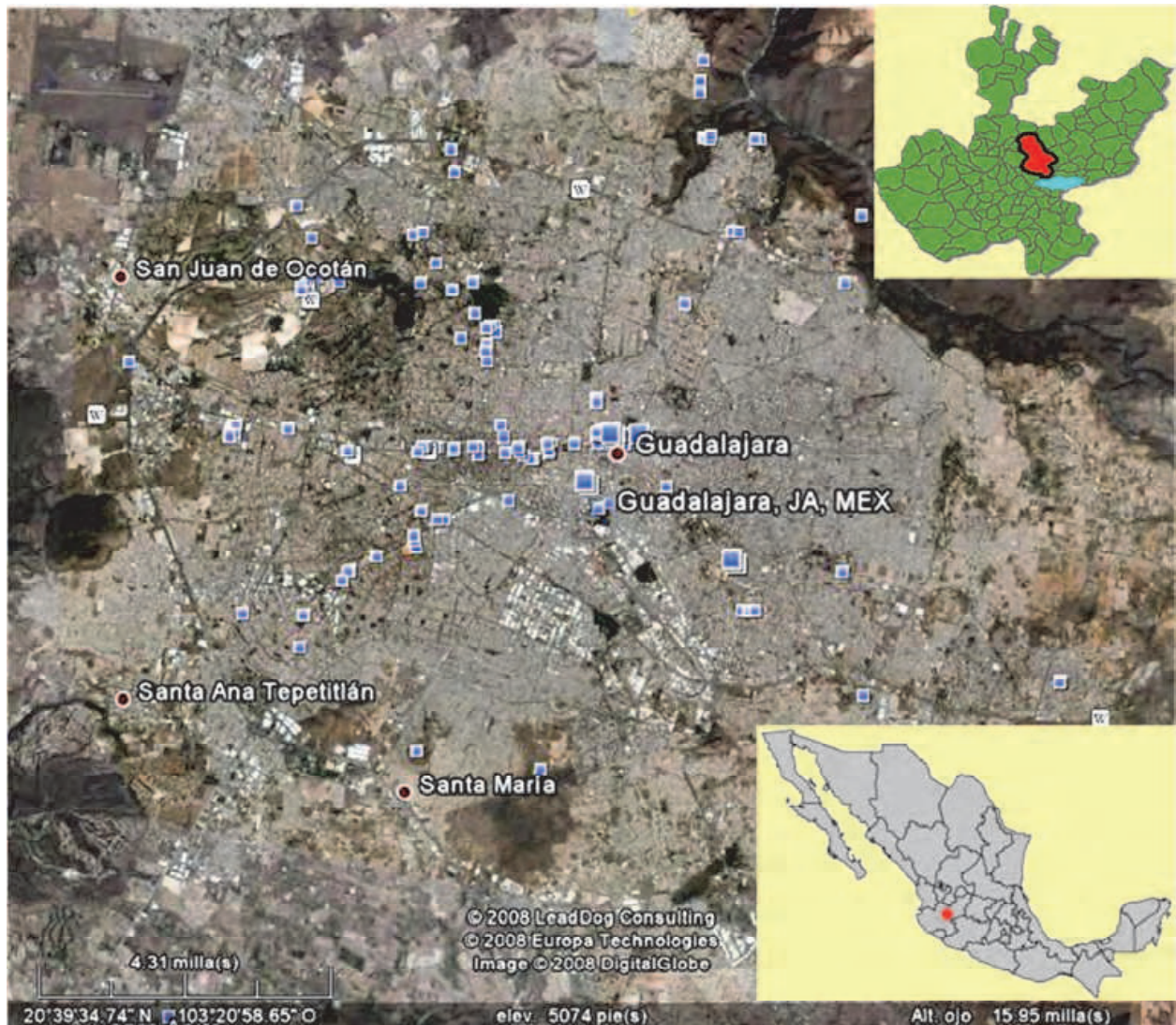


Fig. 1. Geographical location of the UAG. Courtesy of Google Earth.

3. Methods

The measurements of concentrations of air pollutants provided by the Automatic Atmospheric Monitoring Network (RAMA) of the Secretary of Environment for Sustainable Development (SEMADES) of the Jalisco State Government were revised, debugged and validated. From the databases per month and per pollutant from 2000 to 2005, we obtained monthly averages, monthly modes and monthly maximums for concentrations of the atmospheric contaminants: CO, SO₂, NO₂, PM₁₀ and O₃, at the RAMA stations.

The consultations for acute respiratory diseases (ARD) in children of less than five years in health centers, clinics and hospitals of the IMSS (Instituto Mexicano del Seguro Social), ISSSTE (Instituto de Seguridad Social al Servicio de los Trabajadores del Estado) and SSJ (Secretaria de Salud Jalisco), in the study area of the UAG were provided by the Jalisco Health Ministry (SS).

The digital orthophotos and digital topographic maps, F13D65 Guadalajara West, F13D66 Guadalajara East, scale 1: 50,000 were used to perform the cartography of the UAG.

3.1 Information processing

3.1.1 Atmospheric contaminants

The databases with information on monthly averages, monthly modes and monthly maximums for each of the pollutants and for each year were obtained with the aim that concentration information can be entered and processed in the geographic information system (GIS) IDRISI.

3.1.2 Topographic maps and orthophotos, F13D65 and F13D66 scale 1:50,000

The study area was delimited, based on the area of influence of each monitoring station (2 kilometers radius around the station), which was carried out in a digital format on the orthophotos contained in the files of the Guadalajara topographic map. A georeferenced UAG map was built showing the main roads and municipal boundaries, the study area displaying the health centers, clinics and hospitals of the IMSS, ISSSTE and SSJ, and monitoring stations all located in the b, c, e and f F13D65 Guadalajara West orthophotos map and F13D66 Guadalajara East orthophotos map to scale 1:50,000 in the GIS IDRISI. The locations of medical care units and monitoring stations were corroborated in the field by using GPS in coordinates Universal Transverse Mercator (UTM).

3.1.3 Acute respiratory diseases

The ARD information was captured from the health centers, clinics and hospitals of the IMSS, ISSSTE and SSJ. Tables and graphs were prepared to observe trends and establish correlations. Once the information and databases designed for use in IDRISI were prepared, the interpolation technique for the production of concentrations maps of contaminants was applied using the IDRISI software. This process provided the isoconcentration maps and a list of values of the concentrations of the pollutants for each of the health centers, clinics and hospitals of the IMSS, ISSSTE and SSJ. With the databases (listed by month and pollutant), tables and graphs were produced to observe the trends in the pollutants over the years studied. The spatial analysis of pollutants was performed using the maps obtained, in order to observe trends.

3.1.4 Correlation between air pollutants and ARD

With the database of the monthly averages, monthly modes and monthly maximums in the concentrations of air pollutants in the health centers, clinics and hospitals (resulting from interpolation) and with the cases of ARD, we established single correlation, multiple correlation, variance analysis (ANOVA) and the t-student test between the six pollutants and the number of consultations per ARD for the years 2000 to 2005, using Excel and SPSS software. Finally, a spatial analysis of the trends of atmospheric pollutants and ARD consultations was made.

4. Results

4.1 Behavior of the air pollutants (CO, NO₂, O₃, SO₂, PM₁₀) in the UAG, from 2000 to 2005.

The results of the temporal distribution showed that the behavior of air pollutants is highly variable throughout the year and over the years analyzed. However, it was clear that the

more concentrated contaminants are those with particles smaller than 10 microns (PM_{10}), followed by the ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO) and sulfur dioxide (SO_2). The spatial distribution showed that the most affected areas are the south and southeast portions of the UAG, which have the highest levels for maximums, arithmetic means and modes; also they contain the sites with most high events during the period studied. The annual results showed that a significant percentage of days exceeded the Mexican standards of pollutant emission. The analysis of maximums showed that during 21 days in 2000, 5 in 2001, 7 in 2002, 11 in 2003, 8 in 2004 and 3 in 2005, the standard was exceeded for CO (11 ppm). In the case of NO_2 (0.21 ppm), the days above standard were: 18 in 2000, 21 in 2001, 26 in 2002, 5 in 2003, 6 in 2004, and 13 in 2005. For O_3 (0.11 ppm) the days above standard were: 65 days in 2000, 36 in 2001, 75 in 2002, 71 in 2003, 49 in 2004 and 66 in 2005. The PM_{10} (150 mg/m^3) is the pollutant that has the maximum number of days exceeding the standard, 199 days in 2000, 180 in 2001, 183 in 2002, 115 in 2003, 94 in 2004 and 93 in 2005. Finally, the SO_2 (0.13 ppm) is the one with a minimum number of days in which the standard was exceeded with 9 days in the year 2002 (Table 2 y Figure 2). April, May and June presented high concentrations of O_3 and CO while December, January, February and March reflected intense concentrations of PM_{10} , NO_2 , CO and SO_2 , as a result of the presence of low temperatures which prolonged the duration of the thermal inversions and low humidity in the environment, not permitting their dispersion. Table 3 presents the statistical results (averages, modes and monthly maximums).

Air pollutant	Limit values.		2000	2001	2002	2003	2004	2005
		Acute exposure						
Ozone (O_3)	0.11 ppm (1 Hour) ¹	1 time per year	65	36	75	71	49	66
Nitrogen Dioxide (NO_2)	0.21 ppm (1 Hour) ²	1 time per year	18	21	26	5	6	13
Carbon Monoxide (CO)	11 ppm (8 Hours) ³	1 time every 3 years	21	5	7	11	8	3
Sulfur Dioxide (SO_2)	0.13 ppm (24 Hours) ⁴	1 time per year	0	0	9	0	0	0
Particles less than 10 microns (PM_{10})	150 mg/m^3 (24 Hours) ⁵	1 time per year	199	180	183	115	94	93

¹NOM - 020 - SSAI - 1993, ²NOM - 023 - SSAI - 1993, ³NOM - 021 - SSAI - 1993, ⁴NOM - 022 - SSAI - 1993, ⁵NOM - 025 - SSAI - 1993.

Table 2. Number of days exceeding the standard for each of the pollutants found in the UAG.

	Means				Modes				Maximums			
	X	S	Max	Min	X	S	Max	Min	X	S	Max	Min
CO	1.942	0.647	4.883	0.000	1.129	0.502	4.400	0.000	9.166	6.021	53.600	0.000
NO_2	0.034	0.011	0.089	0.000	0.025	0.012	0.136	0.000	0.114	0.071	0.526	0.000
O_3	0.023	0.008	0.053	0.000	0.009	0.006	0.047	0.000	0.110	0.044	0.650	0.000
PM_{10}	50.915	20.218	156.006	0.000	35.488	33.397	499.900	0.000	265.415	108.633	499.900	0.000
SO_2	0.009	0.005	0.068	0.000	0.007	0.003	0.052	0.000	0.049	0.056	0.534	0.000

X= Arithmetic Mean, S= Standard Deviation

Table 3. Statistical results of the means, modes and maximums monthly concentrations of air pollutants CO_2 , NO_2 , SO_2 , PM_{10} and O_3 in the UAG from 2000-2005.

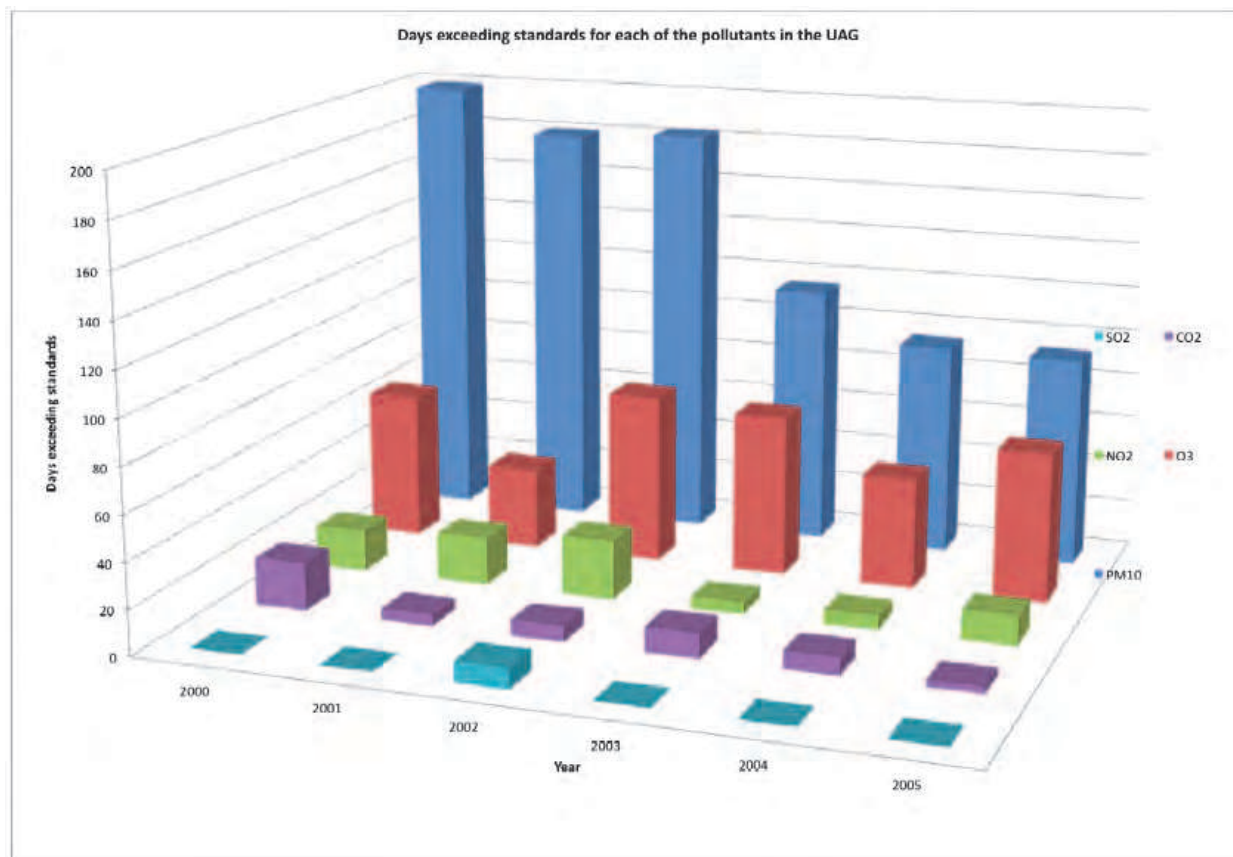


Fig. 2. Days exceeding standards for each of the pollutants in the UAG 2000-2005.

4.1.1 Carbon monoxide (CO)

The behavior of the average monthly concentrations has with seasonal variations, a tendency to maintain constant concentrations during the study period, with values below the norms of the United States Environmental Protection Agency USEPA (9 ppm) and the Mexican Official Norm NOM (11 ppm). The mean of the monthly averages was 1.942 ± 0.647 ppm. The range of the monthly average is between 0.000-4.883 ppm (Fig. 3).

The monthly mode of the concentration presented seasonal variations with a tendency to maintain constant concentrations during the study period, with values lower than EPA and NOM regulations. The average of the monthly modes was 1.129 ± 0.502 ppm. The range of the monthly modes is between 0.000-4.400 ppm (Fig. 4).

In turn, the monthly maximum concentrations showed values above the norm in the majority of the period analyzed (Fig. 5); however, there were major peaks reaching values close to 55.000 ppm, which represents five times the NOM and nine times the EPA regulations, so that these lapses were risk factors for the population. These events are registered in the driest period of the year (March, April, May, June), just before the period of precipitation. The average of the monthly maximums was 9.166 ± 6.021 ppm. The range of monthly maximums is between 0.000-53.600 ppm (Fig. 5).

The spatial distribution showed that the zones most affected were the central and southeast portions of the UAG (Figs. 18-20), however, the pollution generated by the CO in the UAG is considered significant only at times of the peak maximums.

4.1.2 Nitrogen dioxide (NO₂)

Most of the average monthly concentrations present values below the EPA (0.05 ppm) and NOM (0.21 ppm) limits; however, they show irregularities and in some cases values above the EPA limit (0.05-0.10 ppm). The mean of the monthly averages was 0.034 ± 0.011 ppm. The range of the monthly averages varied between 0.000-0.089 ppm (Fig. 6).

The monthly modes presented seasonal variations with a tendency to maintain constant concentrations during the study period, with values below the EPA and NOM limits. The average of the monthly mode was 0.025 ± 0.012 ppm. The range of values of monthly modes is larger than that of averages, with values between 0.000-0.136 ppm (Fig. 7).

In turn, the monthly maximums (Fig. 8) have very important variations with values from 0.000 to 0.526 ppm. The peaks of maximum concentration can occur in the winter or summer, not showing a cyclical behavior. The UAG shows very high maximums of NO₂ in the period of study. The average value of the monthly maximums was 0.114 ± 0.071 ppm. The range of the monthly maximum is between 0.000-0.526 ppm.

In this case, the spatial distribution showed that the zones most affected are the southwest, west and northwest of UAG where the maximum values occur; it is a problem of the whole UAG (Figs. 18-20). The contamination by NO₂ is serious in the UAG.

4.1.3 Ozone (O₃)

The average monthly concentrations showed seasonal variations with tendency to remain constant during the study period, with values below the NOM-020-SSA1-1993 (0.11 ppm). The mean of monthly averages was 0.023 ± 0.008 ppm. The range of the monthly averages oscillated between 0.000-0.053 ppm (Fig. 9).

The monthly modes presented seasonal variations with a tendency to maintain constant concentrations during the study period, with values below the limits. The average monthly mode was 0.009 ± 0.006 ppm. The range of the monthly mode values was between 0.000-0.047 ppm (Fig. 10).

The monthly maximums in most of the reporting period were above the limits and with a slight tendency to rise during recent years. There are very significant variations with values from 0.000 to 0.650 ppm; the highest concentration peaks occur in times of drought and summer when there is more sunshine and transformation of primary pollutants into O₃. The average value of the monthly maximums was 0.110 ± 0.044 ppm (Fig. 11).

The spatial distribution showed that the most affected zones of the UAG are the central, north and southeast (Figs. 18-20); however, the pollution generated by O₃ in the UAG is considered moderate, which represents a risk factor for people's health, especially when maximums occur.

4.1.4 Particles smaller than 10 microns (PM₁₀)

The average monthly concentrations present values between 0 and $156 \mu\text{g}/\text{m}^3$; the majority of the records are located between the limits of EPA ($50 \mu\text{g}/\text{m}^3$) and NOM ($150 \mu\text{g}/\text{m}^3$), and these levels are maintained without showing a reduction, making the PM₁₀ the most important contaminant in the UAG. The mean monthly average was $50.92 \pm 20.22 \mu\text{g}/\text{m}^3$ (Fig. 12).

The monthly modes presented seasonal variations with a tendency to maintain constant concentrations during the dry period from September to May; the majority of the values were below the EPA and NOM limits, with the exception of temporary droughts in

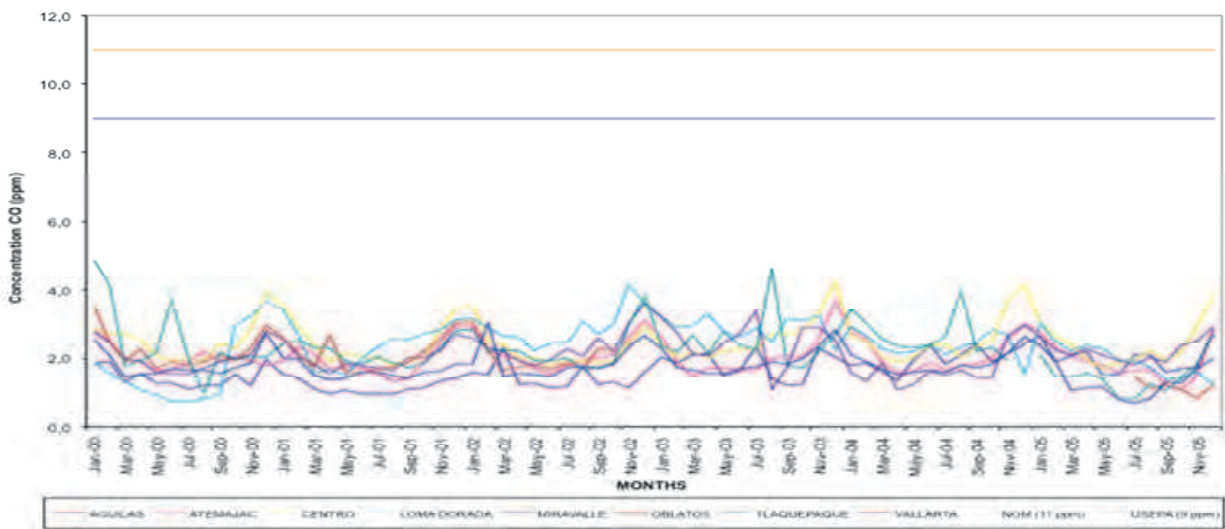


Fig. 3. Time series of monthly averages of CO in the UAG (2000-2005).

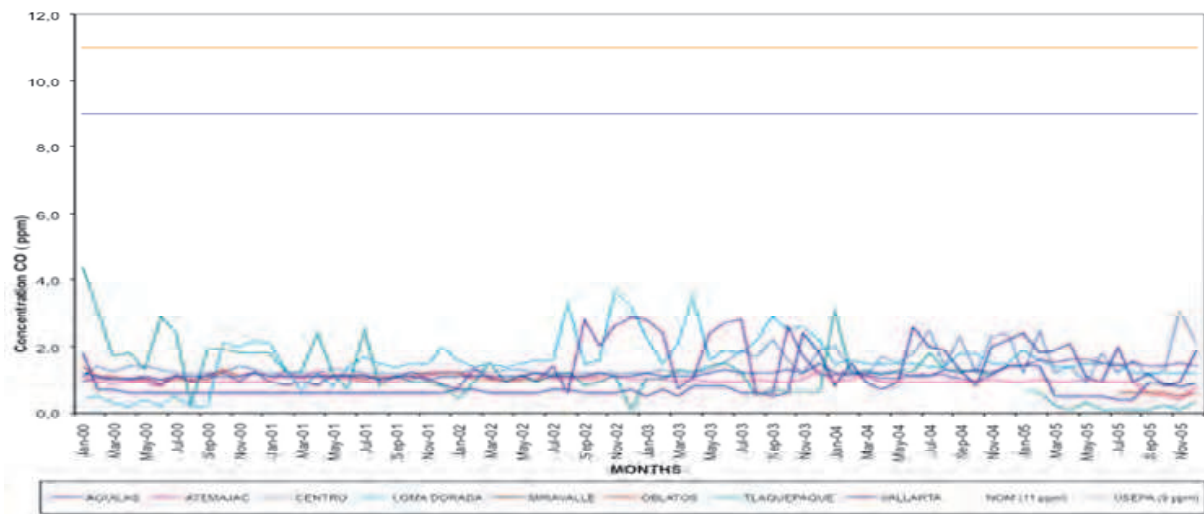


Fig. 4. Time series of monthly modes of CO in the UAG (2000-2005).

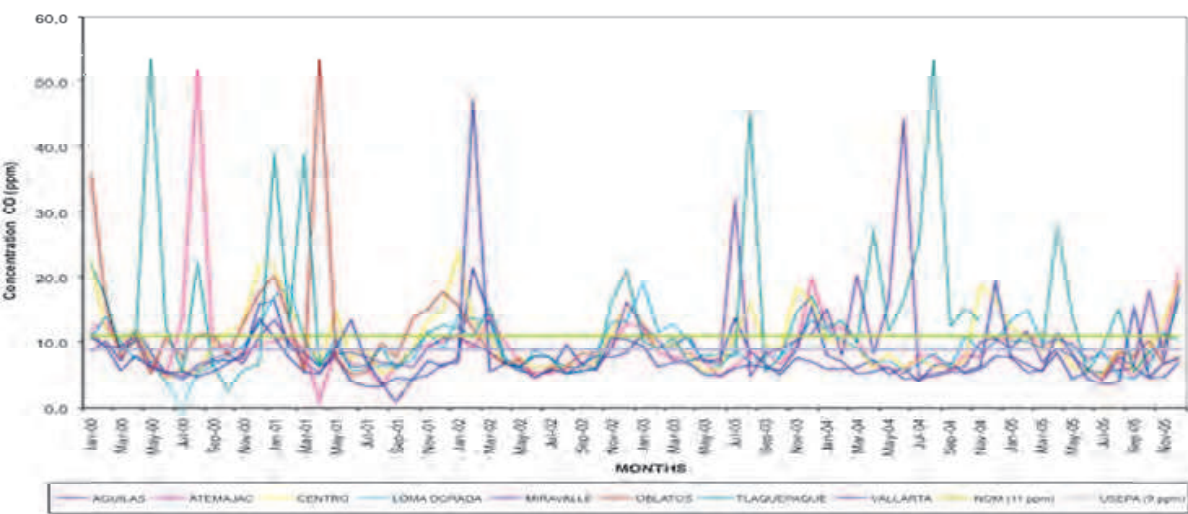


Fig. 5. Time series of monthly maximums of CO in the UAG (2000-2005).

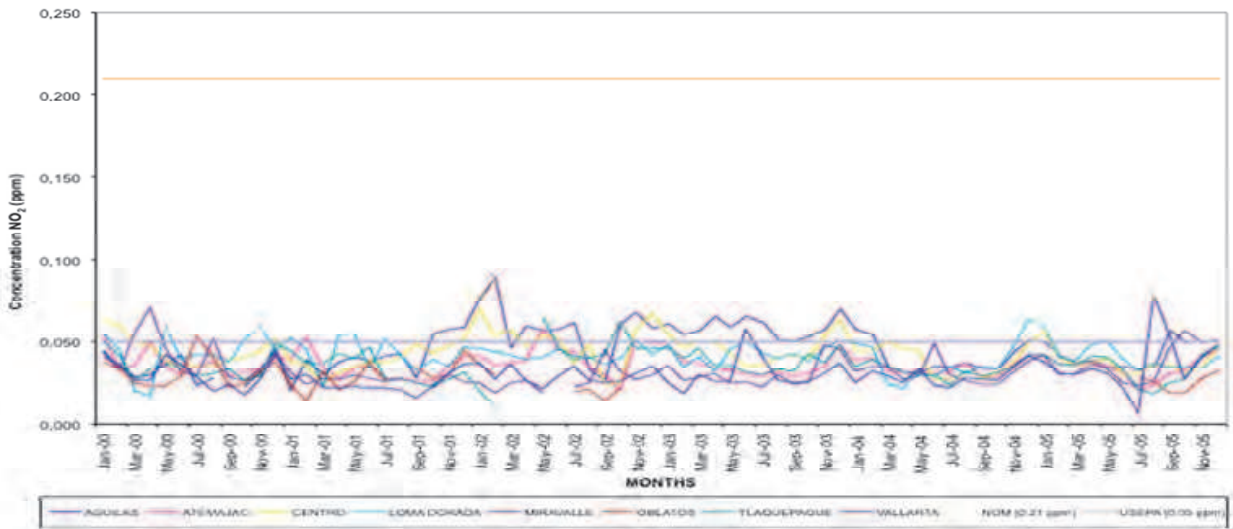


Fig. 6. Time series of monthly averages of NO₂ in the UAG (2000-2005).

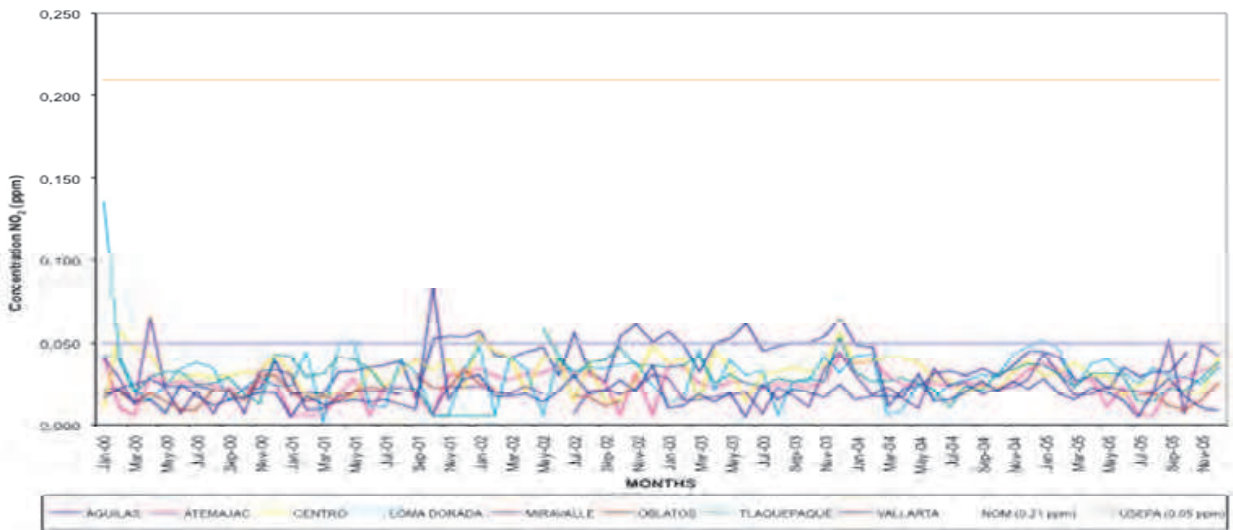


Fig. 7. Time series of monthly modes of NO₂ in the UAG (2000-2005).

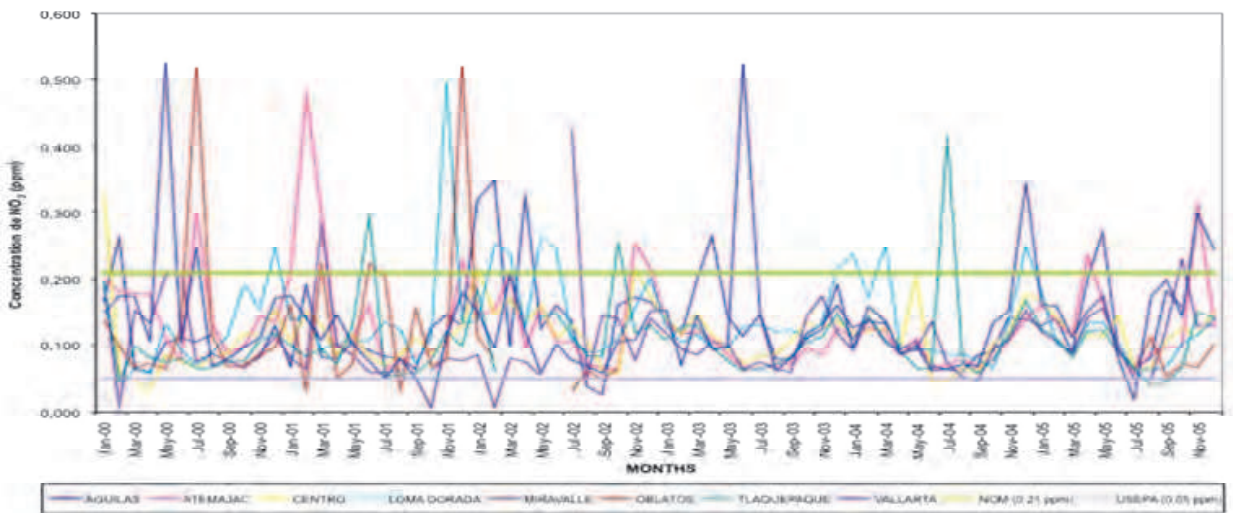


Fig. 8. Time series of monthly maximums of NO₂ in the UAG (2000-2005).

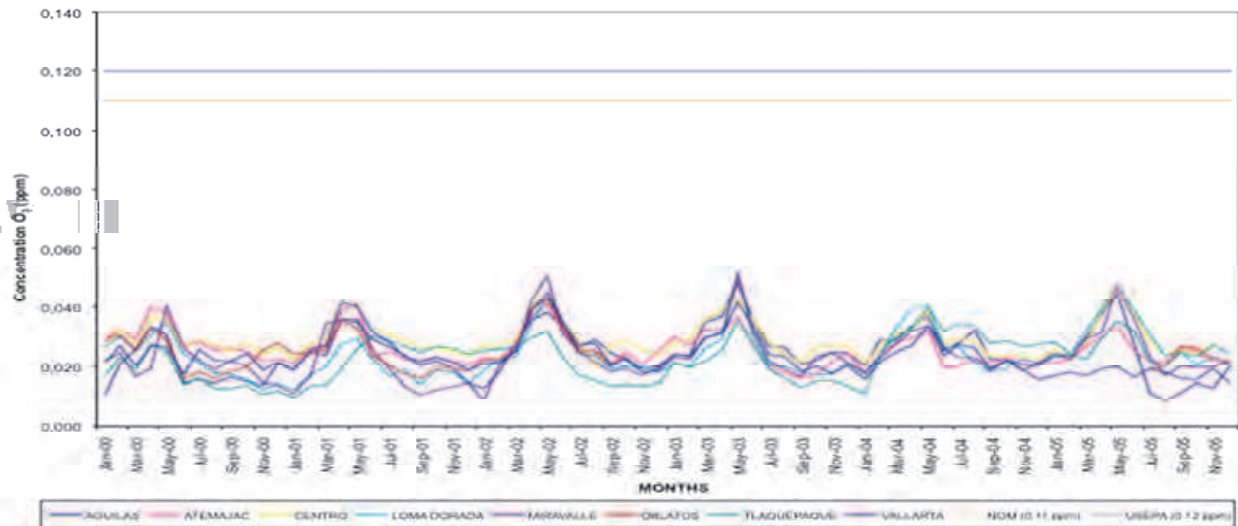


Fig. 9. Time series of monthly averages of O₃ in the UAG (2000-2005).

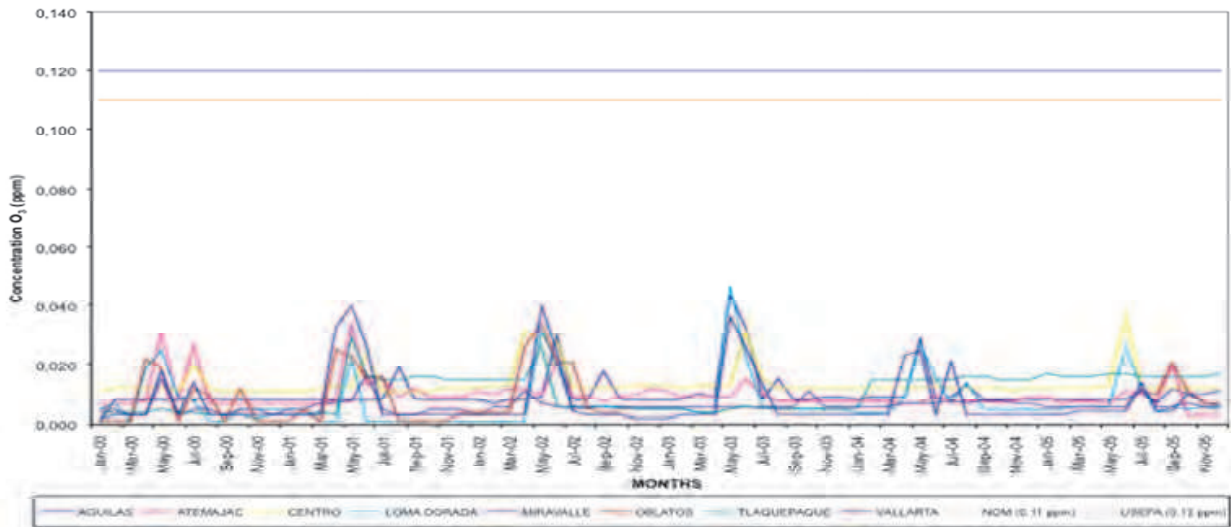


Fig. 10. Time series of monthly modes of O₃ in the UAG (2000-2005).

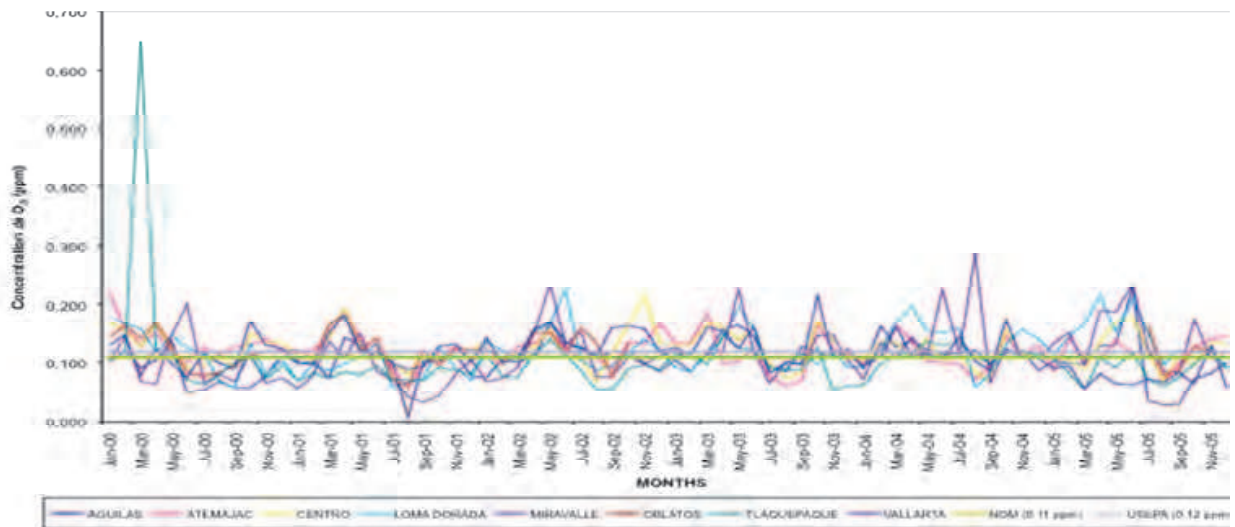


Fig. 11. Time series of monthly maximums of O₃ in the UAG (2000-2005).

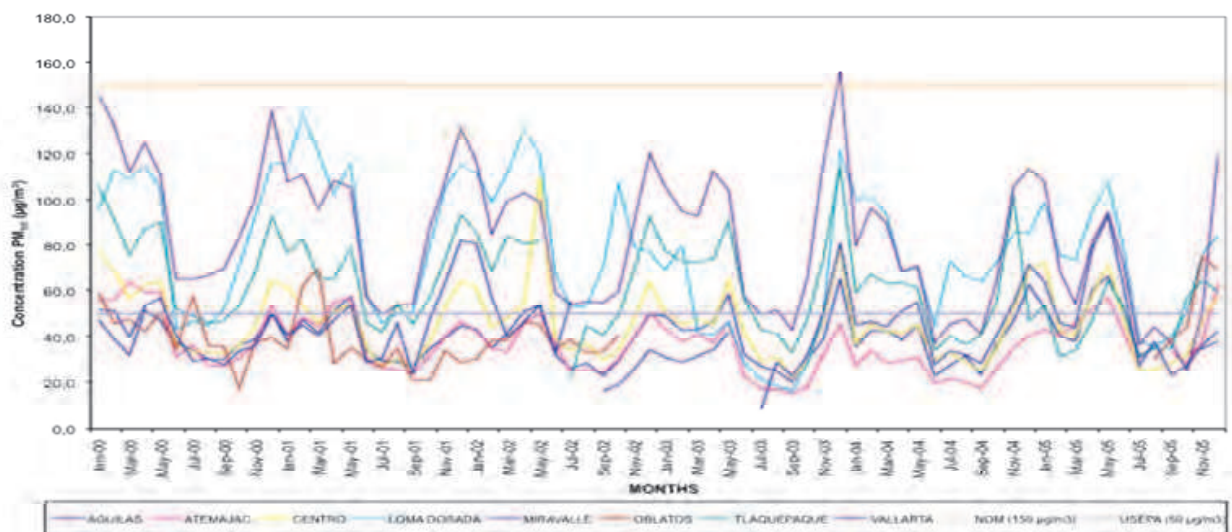


Fig. 12. Time series of monthly averages of PM_{10} in the UAG (2000-2005).

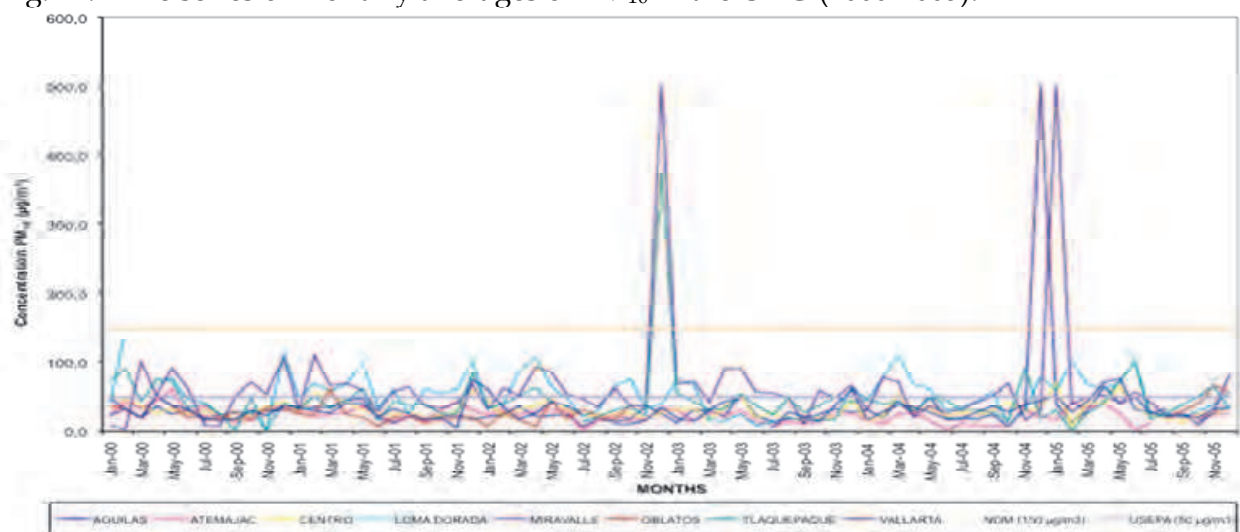


Fig. 13. Time series of monthly modes of PM_{10} in the UAG (2000-2005).

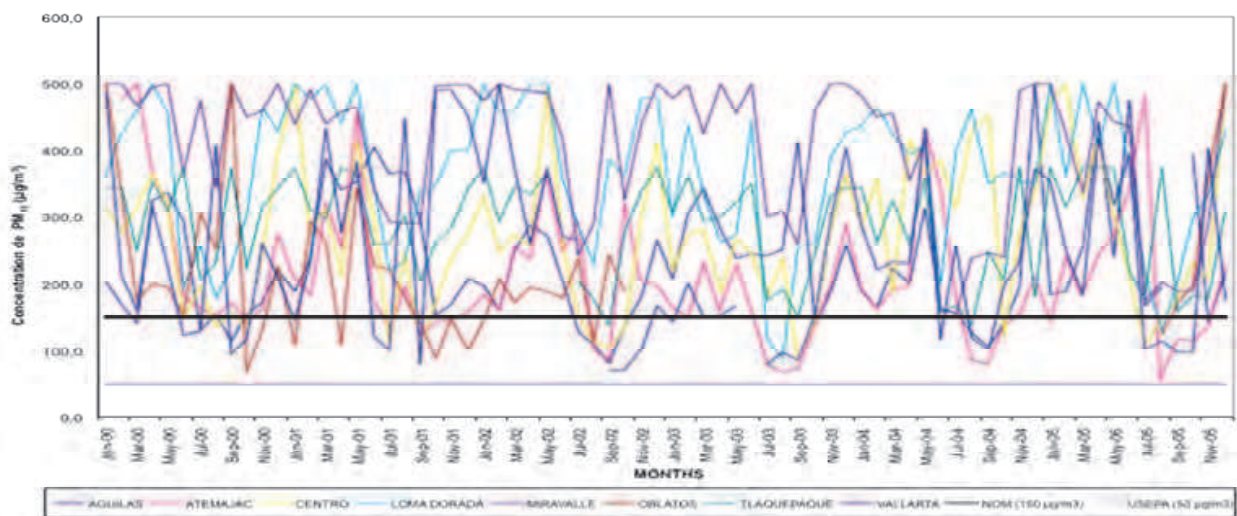


Fig. 14. Time series of monthly maximums of PM_{10} in the UAG (2000-2005).

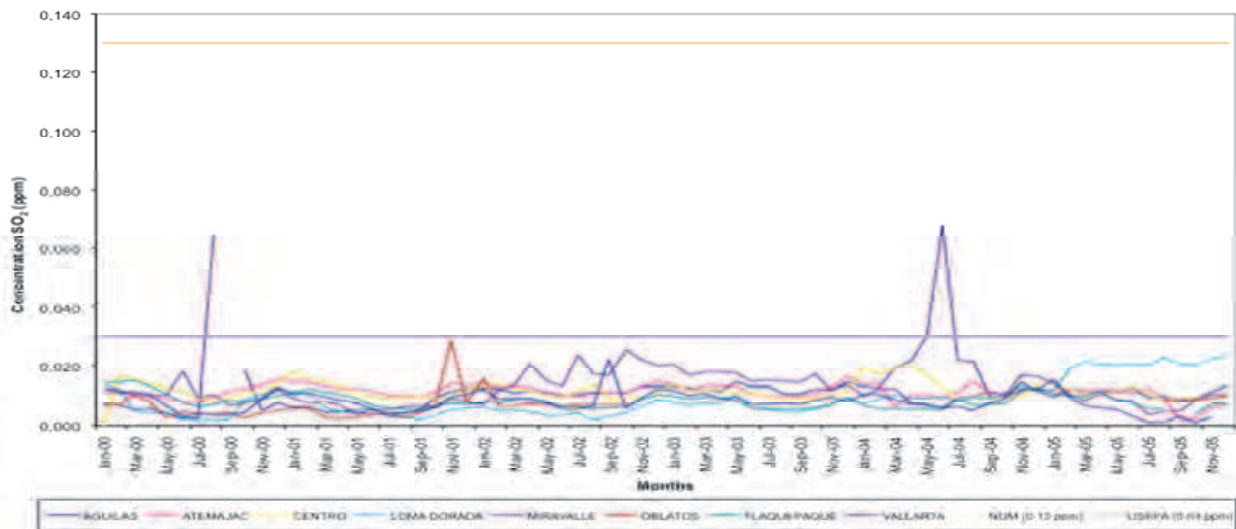


Fig. 15. Time series of monthly averages of SO₂ in the UAG (2000-2005).

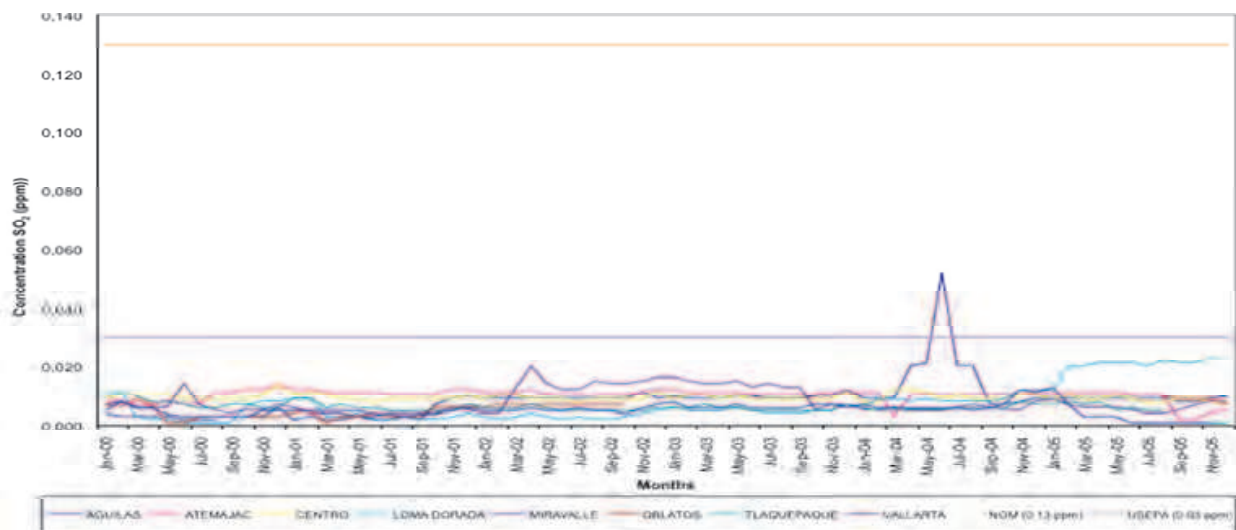


Fig. 16. Time series of monthly modes of SO₂ in the UAG (2000-2005).

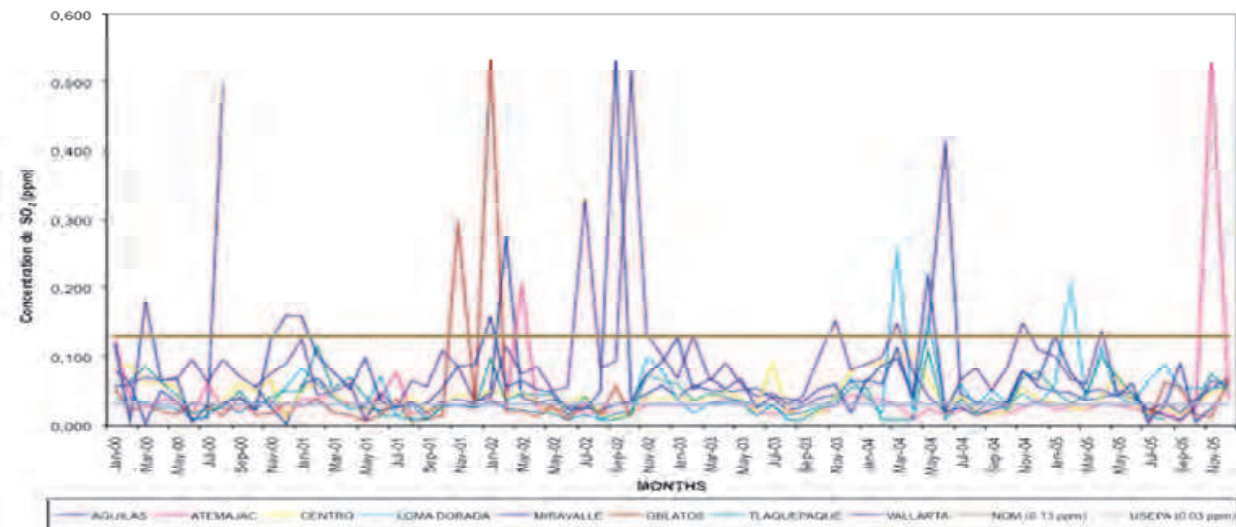


Fig. 17. Time series of monthly maximums of SO₂ in the UAG (2000-2005).

2003-2004 and 2004-2005 in the South and Southeast of the UAG. The mean of the monthly modes was $35.49 \pm 33.40 \mu\text{g}/\text{m}^3$, while the range of values was between 0-499.90 $\mu\text{g}/\text{m}^3$ (Fig. 13).

The monthly maximums are all above limits with a range of 0-500 $\mu\text{g}/\text{m}^3$; the concentrations vary with constant behavior. The measured values are above the limits, so they are the main air pollutants in the UAG. The average of the monthly maximums was $265.12 \pm 108.63 \mu\text{g}/\text{m}^3$ (Fig. 14). The concentrations of PM_{10} represent the main atmospheric contaminant in the UAG, and consequently an environmental contamination problem and risk factor to people's health. However, the spatial distribution showed that the extreme events were located in the south, southeast, east and northeast during the whole year (Figs. 18-20).

4.1.5 Sulfur dioxide (SO_2)

The average monthly concentrations varied between 0.000 and 0.068 ppm. Practically the values never exceeded the EPA (0.03 ppm) and NOM (0.13 ppm) limits. The values remained constant without tendency. The SO_2 is a contaminant of little influence on people's health in the UAG. The mean monthly averages were 0.009 ± 0.005 ppm (Fig. 15).

The monthly modes presented seasonal variations with a tendency to maintain constant concentrations during the period of study, with values below the EPA and NOM limits. The average of the monthly modes was 0.007 ± 0.003 ppm. The range of monthly modes presented values between 0.000-0.052 ppm. Only one extreme event in the summer of 2004 was recorded (Fig. 16).

The majority of the monthly maximums during the period presented values above the EPA limit, but below the NOM limit (Fig. 17). The events that exceeded the NOM limit occurred in the summer of 2000, winter 2001, all of 2002, spring 2004 and winter 2005. Thus, the monthly maximums presented very important variations between 0.000 and 0.534 ppm. The average of monthly maximums was 0.049 ± 0.056 ppm. The spatial distribution showed that the zones most affected were the central, north and southeastern of UAG (Figs. 18-20); however, the concentrations of SO_2 mean that it does not represent a risk to the health of the population in the UAG.

4.2 Results of acute respiratory diseases in children under 5 years from the UAG from 2000 to 2005.

The results obtained during the period from 2000 to 2005 showed that in the six years studied there were 1 664 811 consultations for ARD in children under 5 years in public health institutions distributed as follows: 294 251 in the year 2000, 316 899 in 2001, 336 855 in 2002, 258 068 in 2003, 242 225 in 2004 and 216 513 in 2005 (Table 4 and Figure 21). The annual arithmetic mean was $277 469 \pm 46 254$ consultations per year. The diseases with the highest percentage corresponded to Acute Respiratory Infections: acute rhinopharyngitis, acute sinusitis, acute pharyngitis, acute laryngitis, acute traquitis, acute upper airway multiple or unspecified sites, acute bronchitis and acute bronchiolitis with the 98.0% of consultations, followed by pneumonia and bronchopneumonia with 1.1%, asthma and asthmaticus status with 0.5% and streptococcal pharyngitis and streptococcal tonsillitis with 0.4% (Fig. 22).

The months with the greatest number of consultations by ARD were from October to March, with percentages between 8-12 on the annual total (Fig. 23). The most affected zone is the southeast of the UAG.

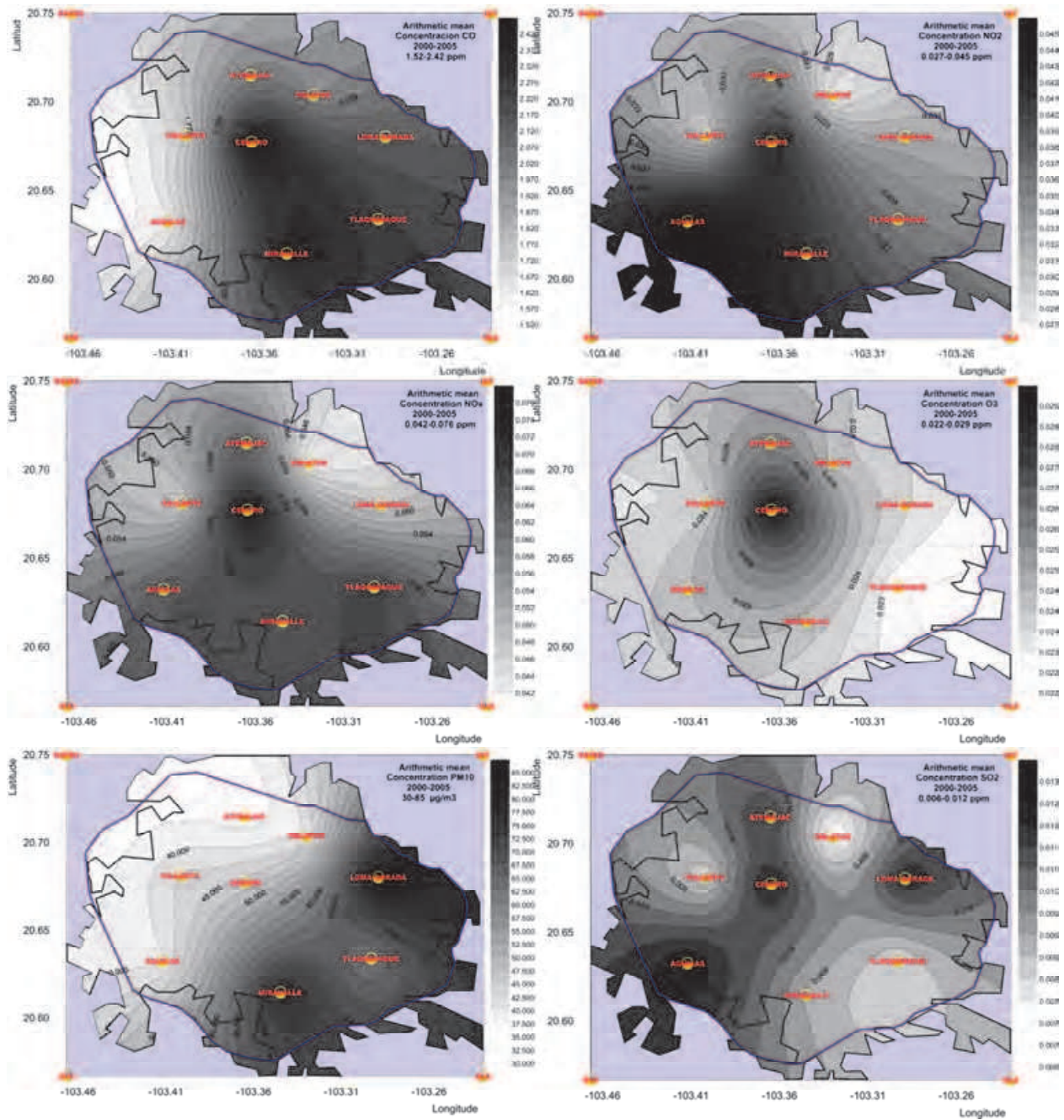


Fig. 18. The spatial-temporal distribution of the atmospheric polluting agents (arithmetic means) in the UAG (2000-2005).

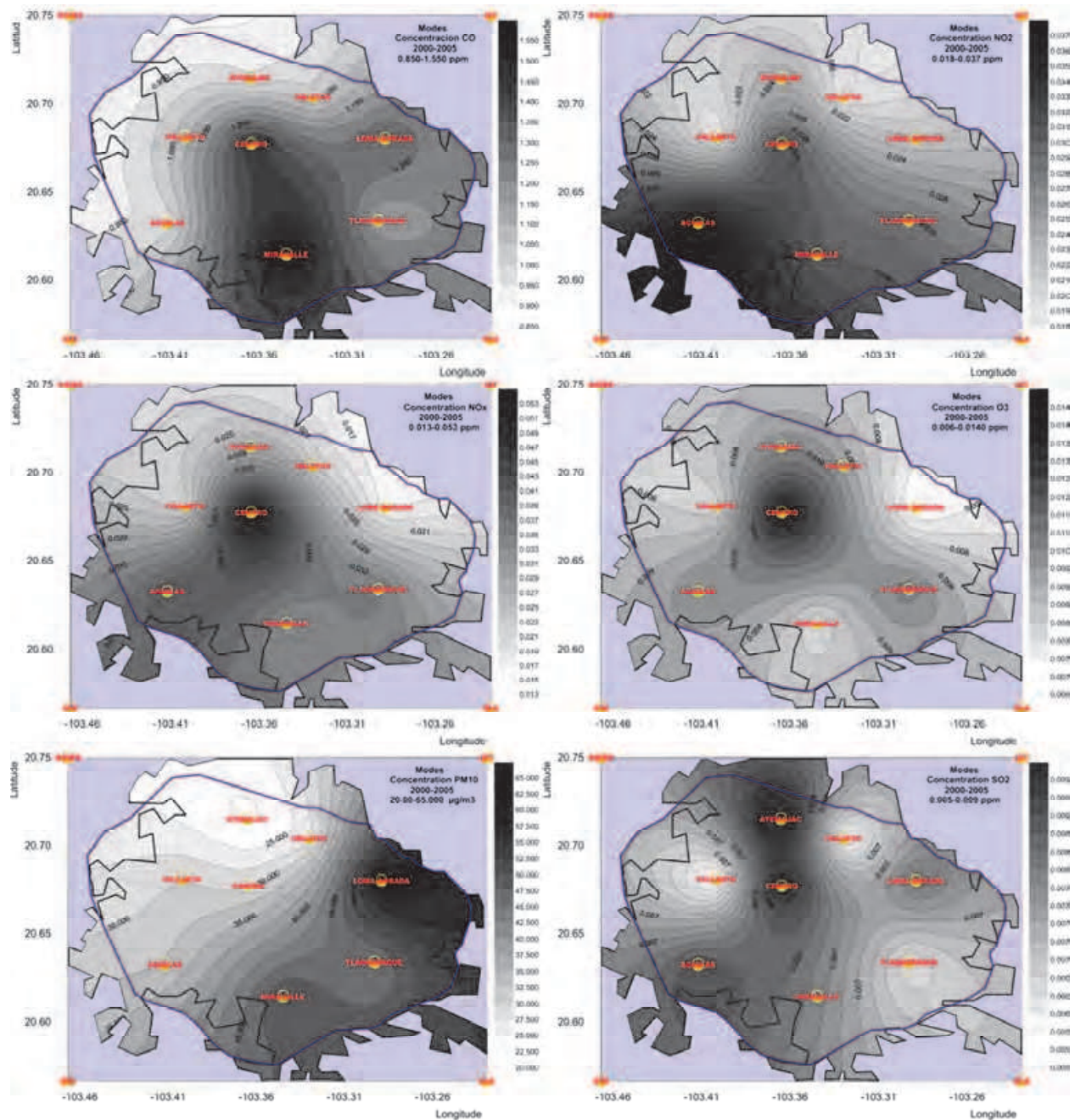


Fig. 19. The spatial-temporal distribution of the atmospheric polluting agents (modes) in the UAG (2000-2005).

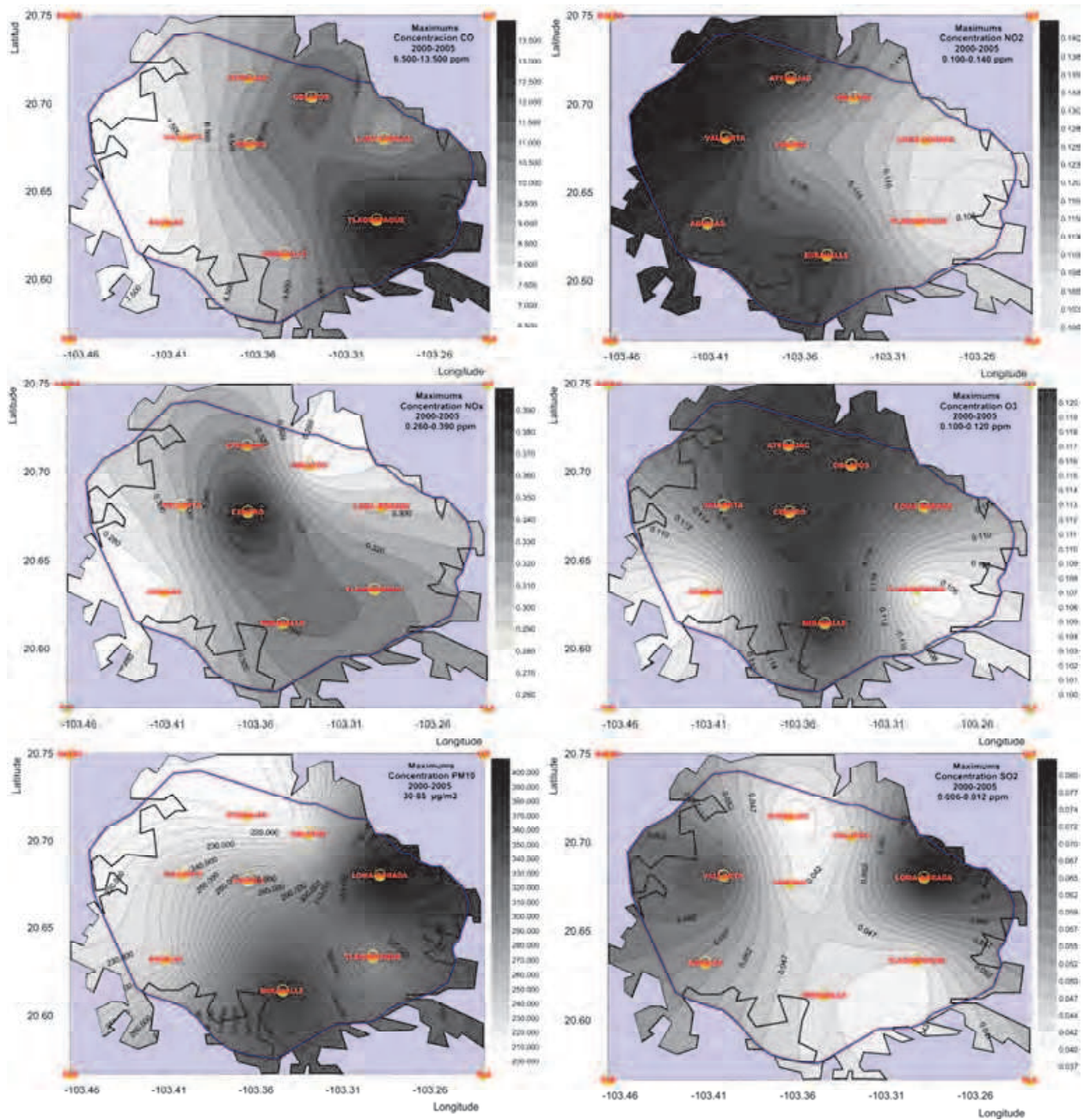


Fig. 20. The spatial-temporal distribution of the atmospheric polluting agents (maximums) in the UAG (2000-2005).

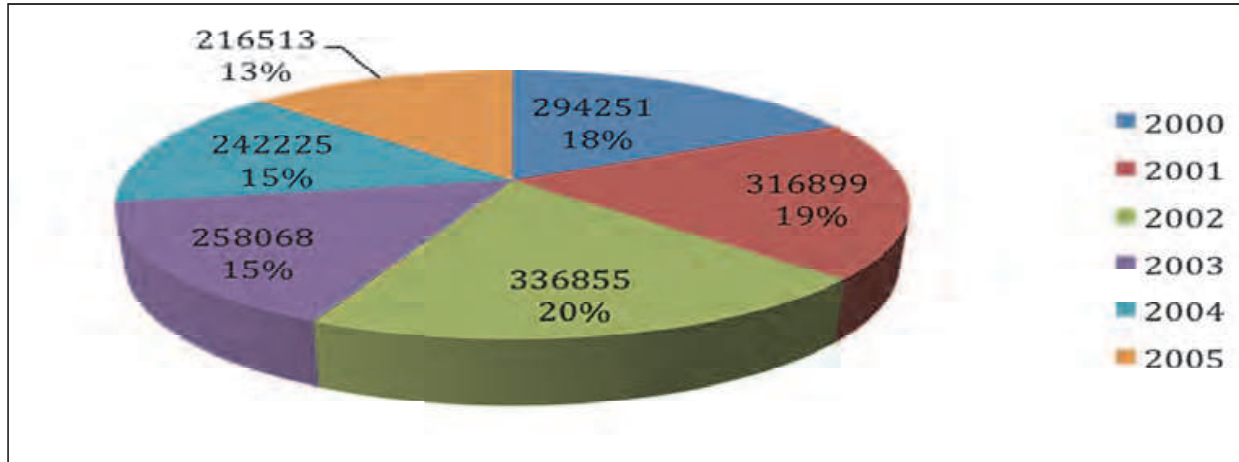


Fig. 21. Number of consultations and percentages of ARD from 2000 to 2005.

Year	Number of consultations
2000	294 251
2001	316 899
2002	336 855
2003	258 068
2004	242 225
2005	216 513
TOTAL	166 4811
Arithmetic mean = 277 469	Standard deviation = 46 254

Table 4. Number of consultations for ARD in children under 5 years of age in the AUG (2000-2005).

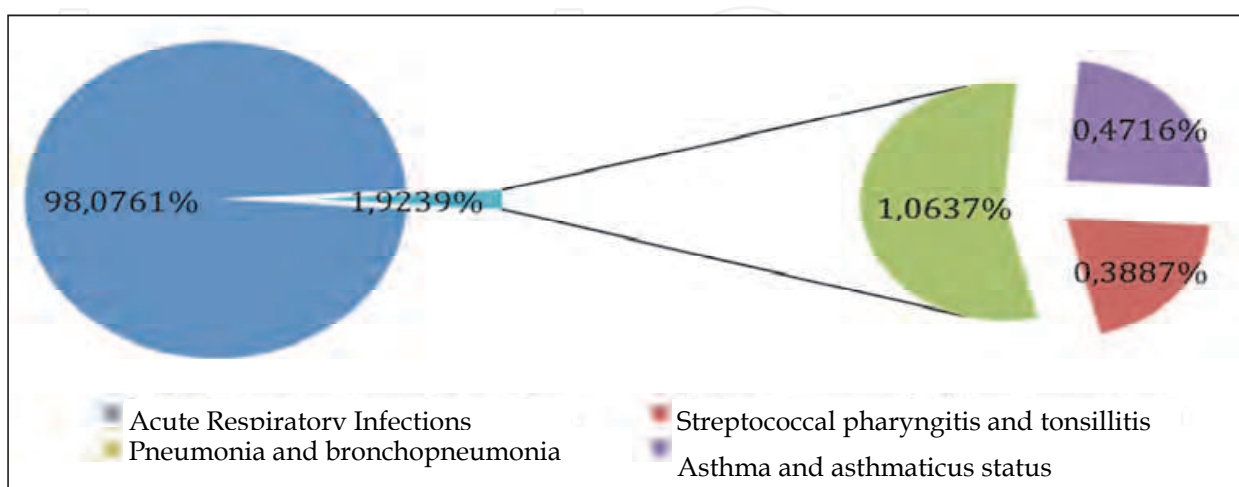


Fig. 22. Distribution of consultations for different ARD in the UAG from 2000 to 2005.

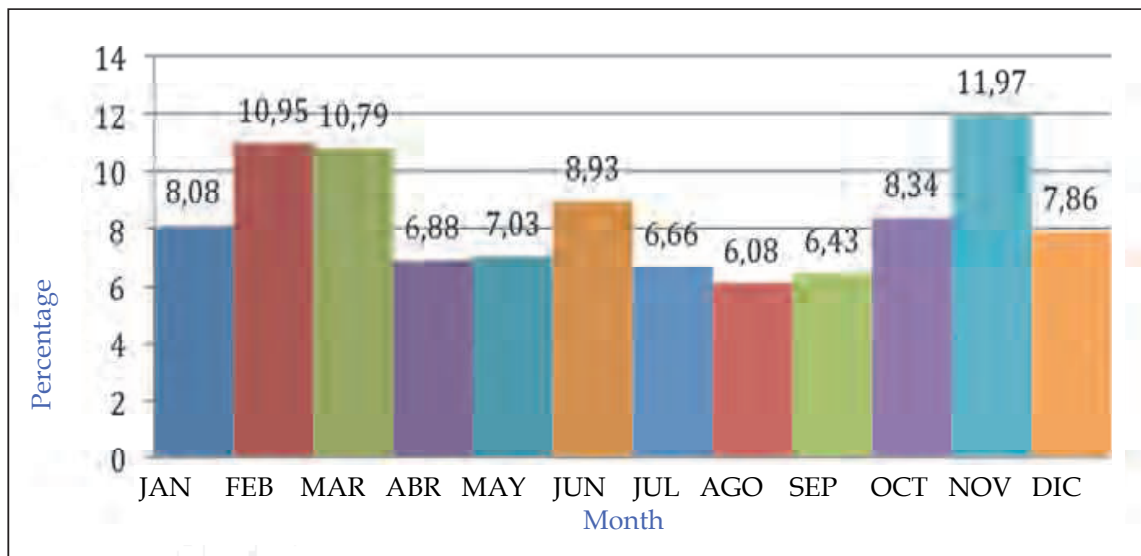


Fig. 23. Distribution of the percentage of consultations per month of ARD in the UAG.

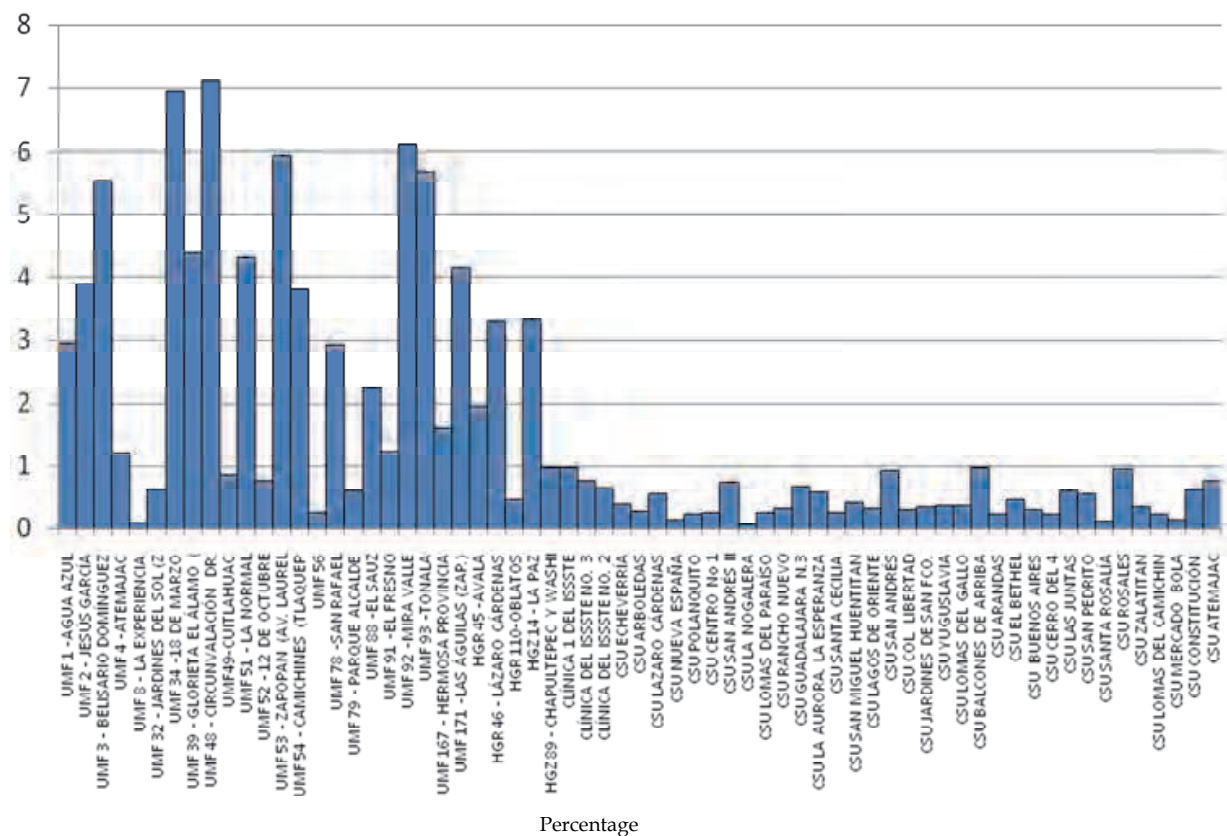


Fig. 24. Consultation distribution of ARD by medical unit in UAG from 2000-2005.

The distribution of diseases by medical units showed that clinics and hospitals in IMSS: Clinic 48 (Circunvalación), Clinic 34 (18 de Marzo), Clinic 92 (Miravalle), Clinic 93 (Tonalá), Clinic 53 (Zapopan) y Clinic 3 (Centro Médico) were those with the highest consultations, the other public health systems (ISSSTE and SSJ) show a great similarity in the number of consultations (Fig. 24).

The percentage of consultations per month shows that November (11.97%), February (10.95%) and March (10.79%) are the months with the highest percentage of respiratory diseases (Fig. 24).

4.3 Correlations between air pollutants and acute respiratory diseases in the UAG.

The results of the correlations between air pollutants and acute respiratory infections in the UAG during the 2000-2005 period, showed the following results:

Analysis of the single and multiple correlations, variance analysis (ANOVA) and t-student test in the Acute Respiratory Diseases with monthly average, monthly modes and monthly maximums of CO, SO₂, NO₂, PM₁₀, and O₃, between 2000-2005 showed the highest significances for monthly averages, followed by maximums and with little significance for modes (Significance was analyzed with a confidence of 95% in all cases).

The analysis of correlations between the monthly average concentrations of air pollutants and ARD showed the following results: for NO₂ significance in 5 years, PM₁₀ significance in 4 years, CO significance in 3 years, SO₂ significance in two years and O₃ showed no correlation with the ARD (Table 5).

	2000							2001						
	ARD	CO	NO ₂	NO _x	O ₃	PM ₁₀	SO ₂	ARD	CO	NO ₂	NO _x	O ₃	PM ₁₀	SO ₂
ARD	1.0000	0.1216	0.0714	0.1211	-0.0281	0.0742	0.0659	1.0000	0.0667	0.0719	0.1019	-0.0350	0.0965	0.0736
CO	0.1216	1.0000	0.5166	0.7776	-0.0101	0.3823	0.2801	0.0667	1.0000	0.3278	0.6587	-0.3979	0.3955	0.4763
NO ₂	0.0714	0.5166	1.0000	0.8202	0.1038	0.5310	0.2453	0.0719	0.3278	1.0000	0.7746	-0.0885	0.1961	0.2872
NO _x	0.1211	0.7776	0.8202	1.0000	0.0044	0.4760	0.3424	0.1019	0.6587	0.7746	1.0000	-0.3736	0.2802	0.4939
O ₃	-0.0281	-0.0101	0.1038	0.0044	1.0000	0.1141	0.0143	-0.0350	-0.3979	-0.0885	-0.3736	1.0000	-0.1297	-0.1120
PM ₁₀	0.0742	0.3823	0.5310	0.4760	0.1141	1.0000	0.2114	0.0965	0.3955	0.1961	0.2802	-0.1297	1.0000	0.1093
SO ₂	0.0659	0.2801	0.2453	0.3424	0.0143	0.2114	1.0000	0.0736	0.4763	0.2872	0.4939	-0.1120	0.1093	1.0000
	2002							2003						
	ARD	CO	NO ₂	NO _x	O ₃	PM ₁₀	SO ₂	ARD	CO	NO ₂	NO _x	O ₃	PM ₁₀	SO ₂
ARD	1.0000	0.0881	0.0498	0.0788	-0.0694	0.0955	0.0113	1.0000	0.0094	0.1010	0.0832	0.0041	0.1013	0.0633
CO	0.0881	1.0000	0.1109	0.6090	-0.4863	0.4533	0.2187	0.0094	1.0000	0.3127	0.5628	-0.2507	0.3547	0.0414
NO ₂	0.0498	0.1109	1.0000	0.7497	0.1363	0.1488	0.0610	0.1010	0.3127	1.0000	0.8117	0.0475	0.3958	0.2276
NO _x	0.0788	0.6090	0.7497	1.0000	-0.1832	0.2714	0.1870	0.0832	0.5628	0.8117	1.0000	-0.2799	0.5014	0.2453
O ₃	-0.0694	-0.4863	0.1363	-0.1832	1.0000	0.1776	-0.1051	0.0041	-0.2507	0.0475	-0.2799	1.0000	0.2159	0.3320
PM ₁₀	0.0955	0.4533	0.1488	0.2714	0.1776	1.0000	0.0425	0.1013	0.3547	0.3958	0.5014	0.2159	1.0000	0.5234
SO ₂	0.0113	0.2187	0.0610	0.1870	-0.1051	0.0425	1.0000	0.0633	0.0414	0.2276	0.2453	0.3320	0.5234	1.0000
	2004							2005						
	ARD	CO	NO ₂	NO _x	O ₃	PM ₁₀	SO ₂	ARD	CO	NO ₂	NO _x	O ₃	PM ₁₀	SO ₂
ARD	1.0000	0.0436	0.0819	0.0951	0.0383	0.0340	0.0973	1.0000	0.1218	0.1130	0.1244	-0.0339	0.0519	0.0345
CO	0.0436	1.0000	0.4343	0.4591	-0.2231	0.1385	-0.0506	0.1218	1.0000	0.7013	0.7842	-0.1248	0.4258	0.3664
NO ₂	0.0819	0.4343	1.0000	0.7285	-0.0970	0.2799	0.1923	0.1130	0.7013	1.0000	0.7454	0.0088	0.4372	0.2256
NO _x	0.0951	0.4591	0.7285	1.0000	-0.0208	0.3277	0.1988	0.1244	0.7842	0.7454	1.0000	-0.2559	0.4232	0.2755
O ₃	0.0383	-0.2231	-0.0970	-0.0208	1.0000	-0.1640	0.1424	-0.0339	-0.1248	0.0088	-0.2559	1.0000	0.5528	0.3044
PM ₁₀	0.0340	0.1385	0.2799	0.3277	-0.1640	1.0000	0.3892	0.0519	0.4258	0.4372	0.4232	0.5528	1.0000	0.5105
SO ₂	0.0973	-0.0506	0.1923	0.1988	0.1424	0.3892	1.0000	0.0345	0.3664	0.2256	0.2755	0.3044	0.5105	1.0000

Correlations significant at p < 0.0500

Table 5. Correlation matrix between ARD cases in children younger than 5 years of age and pollutants from 2000 to 2006.

On the other hand, the presence of a pollutant in the atmosphere is related to the presence of other agents that may increase or counteract their effects (synergy effect); CO shows significant correlation with NO₂, O₃, SO₂ and PM₁₀. NO₂ shows significant correlation with NO_x, O₃, PM₁₀ and SO₂. SO₂ presented significant correlation with NO_x, O₃ and PM₁₀.

5. Discussion

The evolution of contaminants shows that the UAG presents similar environmental risks to Mexico City. During the last years, the UAG has experienced significant environmental contingencies due to the conjunction of factors such as heavy thermal inversions (hundreds of meters) and duration (breaking at 14:00-15:00 hours), atmospheric stability (calm winds) and large quantities of emissions that cannot be dispersed efficiently by climatic factors. Likewise, the vehicular traffic has grown by 20% and a significant portion of the vehicles has been in use for more than 10 years and lacks the proper maintenance. In the case of monthly averages (the most significant indicator of the three evaluated), it was noted that all atmospheric contaminants influenced the health of children under five years in the UAG in the following order: NO_x , NO_2 , PM_{10} , CO and SO_2 . It is paradoxical that O_3 , as one of the main air pollutants in the UAG, does not present correlation with the ARD.

Ruszkiewicz (1997) demonstrated cases of death by CO poisoning within vehicles and inside structures. Also, during the Gulf War, wells and oil refineries were burnt, Kuwait was exposed to this toxic gas and a substantial increase in consultations due to respiratory irritation was noted. Ocaña et al. (1991) noted a relation in the increase of hospital admissions due to respiratory illnesses attributed to CO. Quezada et al. (1997) demonstrated that second hand smoke results in an increase in the concentration of CO. The result of this work ratifies the results of these investigations.

The NO_2 has been linked significantly with asthma attacks and with the number of consultations for respiratory infections. The results of this study corroborate the link between acute respiratory infections and oxides and nitrogen dioxide. Indeed, the oxides of nitrogen (NO_x), have been studied slightly in relation to acute infections of the respiratory tract, the scant literature about the theme does not indicate a significant correlation. However, the results from this research describe a significant correlation between acute respiratory infections and NO_x .

The correlation between contaminants O_3 and SO_2 and acute respiratory infections were significant but not in all the analyzed years. Some other studies corroborate this correlation.

The result of this research raises our awareness that pollutants NO_x , NO_2 , PM_{10} , CO, SO_2 affect the health of the population. With the use of the isoconcentration maps, we can infer the distribution of the highest concentrations of atmospheric contaminants and define areas and populations exposed to risk in the UAG (Central, South and Southeast of the UAG).

It is clear that there is still a lot to do, such as periodical inventories of the major emitting sources of atmospheric pollutants, specifically in areas with high concentrations. Also studies of the population exposed to the highest levels of concentration of pollutants. It is necessary to implement programs and concrete actions that lead us to reduce concentrations of air pollutants and reduce the risk factors for acute respiratory diseases in children and older adults.

The results of the analysis showed that the maximums of all the contaminants exceed the limit and that the average and modal concentrations are maintained below national limits (NOM), but above the international limits (USEPA), which represents potential risk factors for health.

The contamination by CO is considered significant only when the maximum peaks are presented (9.16-53.60 ppm). The parameter proposed by the World Health Organization (WHO) for CO is 10 ppm for 8 hours. The effects of exposure are frequently revealed in the organ systems most sensitive to the absence of oxygen, in particular, the circulatory and central nervous system. High levels of exposure can cause acute poisoning, coma and collapse. The classic symptoms of poisoning for CO are headaches, sickness, severe

headache and cardiovascular symptoms as well as the risk of coma and death (Bascom et al., 1996; Romieu, 1999).

The concentration of NO₂ is important when the maximum peaks are presented (0.11-0.52 ppm). The accumulation of NO₂ in the human body constitutes a risk for the airways, being more frequent in cases of chronic bronchitis. An increased dose results in a sequence of effects: problems with olfactory perception, respiratory inconveniences, acute respiratory pains, pulmonary edema and finally death (SEMARNAP/SS/GEJ, 1997; Romieu, 1999).

The concentration of O₃ is moderate (0.11- 0.65 ppm); however, the exposure to high concentrations during prolonged periods represents a risk to human health. The O₃ provokes injuries in the airways, pulmonary inflammation, depression of the immune system, systemic effects in the liver, decreased aspiratory capacity, bronchi constriction, and decreased pulmonary function, asthma and annoyance of the eyes, nose and gullet (SEMARNAP/SS/GEJ, 1997).

The concentrations of PM₁₀ present the highest maximum averages (265-499 $\mu\text{g}/\text{m}^3$) and is the main atmospheric contaminant in the UAG. This represents a significant problem of environmental pollution and risks to the health of the population. The exhibition to PM₁₀ reduces the pulmonary functions, increases the frequency of respiratory illnesses, cardiovascular and lung cancers, increases asthma attacks, pneumonia, bronchitis and chronic cough (Dockery et al., 1989; Dockery & Pope, 1996).

The concentration of SO₂ (0.05 ppm) remained below the limits (0.13 ppm), which does not represent a risk to human health. The spatial distribution (Figs. 18-20) shows that the most affected zones are the Center, South and Southeast of the UAG and eventually we expect extreme values in the rest of the UAG.

6. Conclusion

The statistical analysis of simple and multiple correlations showed that all air pollutants are influencing the presence and frequency of ARD in children under 5 years of age in the UAG. The results suggest that concentrations of PM₁₀, NO₂, CO, NO_x affect the health of children younger than five years old in the UAG, while concentrations of SO₂ and O₃, although they do influence, are not considered as highly significant.

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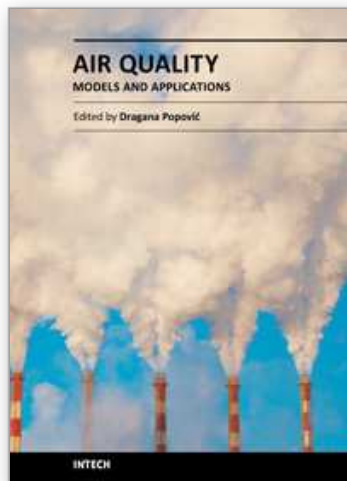
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Air pollution has been a major transboundary problem and a matter of global concern for decades. High concentrations of different air pollutants are particularly harmful to large cities residents, where numerous anthropogenic activities strongly influence the quality of air. Although there are many books on the subject, the one in front of you will hopefully fulfill some of the gaps in the area of air quality monitoring and modeling, and be of help to graduate students, professionals and researchers. The book is divided in five sections, dealing with mathematical models and computing techniques used in air pollution monitoring and forecasting; air pollution models and application; measuring methodologies in air pollution monitoring and control; experimental data on urban air pollution in China, Egypt, Northeastern U.S, Brazil and Romania; and finally, the health effects due to exposure to benzene, and on the influence of air pollutants on the acute respiratory diseases in children in Mexico.

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