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The Program to Improve the Air Quality of Mexicali, Baja California, Mexico 2010-2015

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Abstract

The program to improve the air quality of Mexicali 2010-2015 (PROAIR) represents the joint effort of the society, of the local economic sector and the three levels of government to design and implant a set of actions with the objective of controlling the sources of pollutants that degrade the air quality of the city. Due to its great urban dynamism, industry and entrepreneural activities, as much as its position in the neighborhood with the USA, Mexicali plays an important role in the national economy and makes it one of the most important cities at the USA-Mexican border. The growth of the city brings along social and economic benefits, and also problems related with the urban development and with the availability of infrastructure and services, which at the same time generates problems of environmental type. The analysis of the air quality was based on 11 years (1997-2008) of accumulated data from 6 monitoring stations located in the city, period on which the first PROAIR of Mexicali 2000-2005 was put into practice. The most important findings are described as follows: exceedences by O_3 and NO_2 diminished since 1997. CO is the pollutant with the greater amount of exceedences registered, specially in the winter. SO_2 did not show violations to the norm at any time. PM_{10} showed exceedences for most part of the year as much as $PM_{2.5}$. Based on that Mexicali is classified as non–attainment for CO, PM_{10} and $PM_{2.5}$.

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1. Introduction

1.1. Brief description of the Valley of Mexicali

The Valley of Mexicali, Baja California, with 878,000 inhabitants, is located in a strategic place at the border of Mexico with U.S.A. that emerges as an agricultural land at the start of the twentieth century (Fig. 1). The Valley is

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characterized by a very hot weather during the summer months and an air pollution problem caused primarily by suspended particles arising from the desert environment [1], a large agricultural sector, vehicular activity, and unpaved streets in Mexicali. The location of the Valley of Mexicali and its neighbor Imperial Valley, CA, USA, where the cities of Calexico, El Centro and Brawley are located, cause to consider the region a unique international atmospheric airshed, that, combined with the increasing production activity, makes it more important, not only at the border but at national level.

Fig. 1: The city of Mexicali is located in the northwest of Mexico

Due to the development and evolution of the region, the air quality has deteriorated for the last years. Actually, Imperial Valley does not comply with the North American air quality standards for PM_{10}, and in Mexicali the values exceed the Mexican official norms for PM_{10}, carbon monoxide and ozone [2].

The Program to Improve the Air Quality of Mexicali 2000-2005 (PROAIRE 2000-2005) represents [3] a joint effort of the society, local economic sector and the three levels of government to design and implement a set of actions which has as a final goal to control the sources of pollutants that degrade the air quality of the city.

The proliferation of a great number of industrial, commercial and services activities, as much as an accelerated motorization, have caused a degradation of the air quality of Mexicali, especially due to the poor conditions of the public transport and private automobiles, and in particular due to the importation of preowned vehicles that generally failed to pass the smog check in USA [2]. Additionally, the situation gets exacerbated due to the emissions of particles and dust from the urban and agricultural clandestine burns [4] and emissions from paved and unpaved streets [5].

2. Description of the program to improve the air quality of Mexicali 2000-2005 (PROAIR)

The "PROAIR" had as a general objective to protect the health of the population, reducing the concentration of pollutants in the atmosphere, by the application of coordinated actions that assist to control the emissions generated by industry, commerce, services, transport and soil [3].

2.1. Objectives and general strategies of the program

An analysis of the air quality was performed at the integration of the program. A detailed emissions inventory was prepared and it was divided into the following sectors: industrial, commerce, and services, and in a different category the motor vehicles. An integral diagnosis of the pollution problem was realized, with the actual air pollutants data obtained from known production sources .

2.2 Strategies and actions

The “PROAIR” contains five strategies an each one of them group a different number of specific actions that once applied according to the program, would reduce the emissions of the different pollutants that exceed the acceptable values of the air quality. The strategies are oriented to the following components and areas of work.

- Industry, commerce and services
- Motor vehicles
- Urban and transport management
- Ecological recovery
- Research and international agreements

With a total of 27 actions focused on diverse sectors and with responsibilities well identified and defined for each sector. The number of actions per sector were: Industry, commerce and services (7 actions); motor vehicles (5 actions); urban management and transport (9 actions); ecological recovery (2 actions); research and international agreements (4 actions). The whole description of the actions, responsibles and institutions in charge of its realization are described elsewhere [6]. It is also found what has actually or totally worked and not worked in relation to ProAir 2000-2005.

3. Air quality monitoring stations

Mexicali´s air quality monitoring network began operations in January 1997, rooted in the Border XXI Agreement with funding from U.S. Environmental Protection Agency and the California Air Resources Board (CARB). There are a total of six monitoring stations (see Fig. 2) of which four are automatic, registering ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide, and various meteorological parameters such as temperature, humidity, and wind speed and direction. Manual samplers of PM_{10} also occur at these stations. The only one that measures $PM_{2.5}$ in a continuous basis using the Beta Attenuation Mechanisn (BAM) located at the the Engineering Institute of the Autonomous University of Baja California. The other two stations only sample PM_{10}.

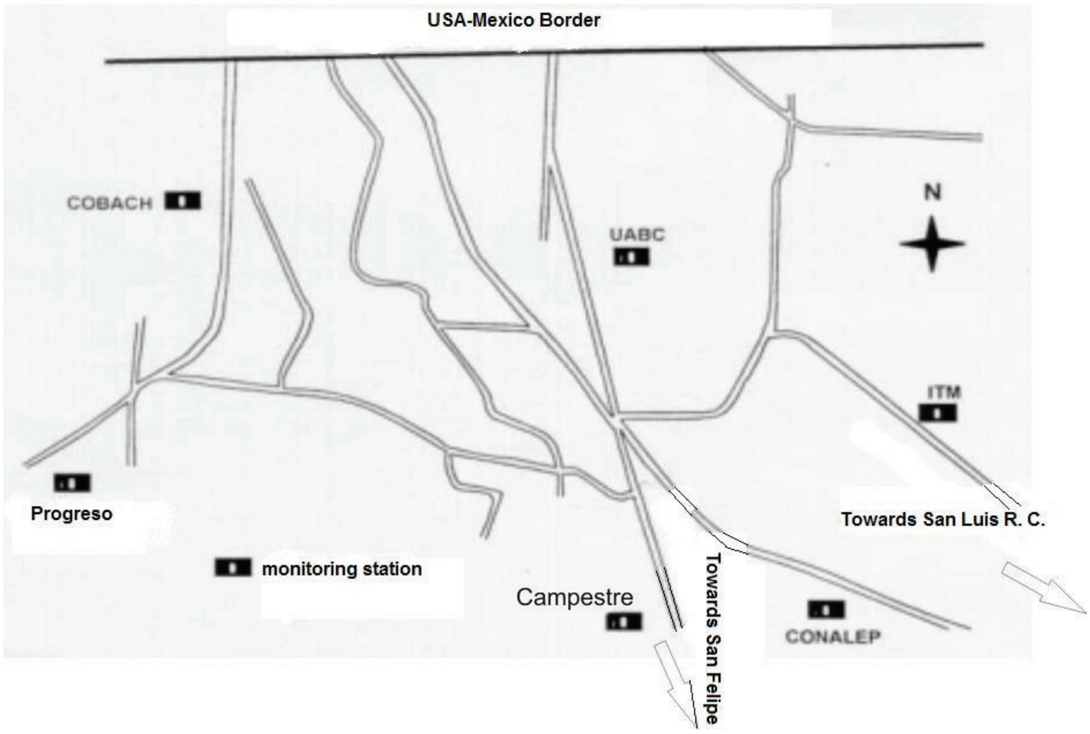

Fig.2 The location of the air quality monitoring net in Mexicali.

The six stations are located at the Vocational Center for Industrial technology and Services (Centro de Bachillerato Tecnologico Industrial y de Servicios-.CBETIS), the Engineering Institute of the Autonomuos University of Baja California (Instituto de Ingenieria de la Universidad Autonoma de Baja California –UABC), The Technological Institute of Mexicali (Instituto Tecnológico de Mexicali-ITM), the Vocational School of Baja California (Colegio de Bachilleres de Baja California), the Health Center in Colonia Progreso (Centro de Salud de la Colonia Progreso), and the National College of Professional Technical Education (Colegio de Educacion Profesional Técnica- CONALEP). The latter was replaced in 2002 by a new monitoring station located at the Campestre, neighbouring the Institute of Research in Veterinary of UABC in the south of Mexicali (see Table 1).

Table 1. Location of the monitoring stations in Mexicali [3]

Monitor	Zone	Predominant use of land	Monitored parameter	Meteorological parameters
Campestre (UABC)	South	Urbane-Rural	O_3, CO, NO_2,PM_{10}	Temperature, wind direction and speed, relative humidity
Institute of Engineering (UABC)	Center	Urbane	O_3, CO, SO_2, NO_2, $PM_{10,}$ PM 2.5	Temperature, wind direction and speed, relative humidity
Technological Institute of Mexicali (ITM)	Southwest	Urbane	O_3, CO, NO_2, PM_{10}	Temperature, wind direction and speed, relative humidity
(Vocational School of Baja California)	West	Urbane	O_3, CO, NO_2, PM_{10}	Temperature, wind direction and speed,

COBACH				relative humidity
Health Center PROGRESO	Southwest	Urbane-Rural	PM_{10}	
(National College of Professional Technical Education) CONALEP	Southwest	Urbane-Rural	PM_{10}	

4. Criteria or "reference" pollutants

Of the myriad of air substances known to be harmful to human health and welfare, some have been identified as being sufficiently hazardous and present in sufficient quantities to merit enforceable standards. Mexico has independently developed and adopted such standards in the form of Normas Oficiales Mexicanas (NOM).

Mexico has set standards for six categories of pollutants: ozone, carbon monoxide, total suspended particulates (more recently, particulate matter specifically), sulfur dioxide, lead, and nitrogen oxide. Because of the particular criteria used to identify these pollutants—principally based on health affects—these are called the criteria pollutants. Over the past 20 years, Mexico has on several occasions increased the strictness of these standards in response to continuing research on the affects of pollutants on public health and on ecosystems. The most recent pollutant criteria of Mexico are shown in Table 2.

Table 2. Ambient Air Quality Standards (AAQS) in, as of February 2010 [7]

Pollutant	Averaging Time	Mexico NOM
Carbon monoxide (CO)	8-hour	11 ppm (12.6 mg/m^3)
	1-hour	
Lead	Rolling 3-Month Average	1.5 µg/m^3
	Quarterly Average	
Nitrogen dioxide (NO_2)	Annual (Arithmetic Mean)	
	1-hour	0.21 ppm (395 µg/m3)
Particulate Matter (PM_{10})	24-hour	120 µg/m^3
	Annual	50 µg/m^3
Particulate Matter ($PM_{2.5}$)	Annual (Arithmetic Mean)	15.0 µg/m^3
	24-hour	65 µg/m^3
Total suspended particulates (TSP)	24-hour	210 µg/m^3
Ozone (O_3)	8-hour	0.08 ppm (1993 std)
	1-hour	0.11 ppm
Sulfur dioxide (SO_2)	Annual	0.03 ppm

	(Arithmetic Mean)	(79 µg/m^3)
	24-hour	0.13 ppm (341 µg/m^3)

Note: Units of measurement for the standards are parts per million (ppm) by volume, milligrams per cubic meter of air (mg/m^3), and micrograms per cubic meter of air (µg/m^3).

Two aspects related to criteria pollutants shown in Table 2, should be explained further. The first is that values for criteria pollutants depicted in Table 2 correspond to primary standards that are set to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly.

The second aspect of the criteria pollutants that merits explanation is the “attainment” concept. When the measured concentrations of a pollutant meet a standard for that pollutant in a geographical area (such as a city or metropolitan area), then that area is considered to be in a status of attainment. When the concentrations measured by any monitor in a geographical area does not meet a standard, then the area is designated to be in non-attainment status for the particular standard. An area may be in attainment status for one pollutant standard and in non-attainment status for another. Cities must design and implement a set of control measures included in the respective Proaire, as described before in order to bring the area back to a status of attainment. Standards in Mexico have become more strict over the past 20 years (the relatively recent development of $PM_{2.5}$ standards has been a prime example).

5. Evaluation of tendencies of gases, PM_{10} and $PM_{2.5}$ in Mexicali (1997-2008)

5.1 Nitrogen dioxide (NO_2)

In 2005 the potencial emissions of nitrogen dioxide were in the order of 28,785 tons, out of which 44.6% come from the electric utilities, 45.6% from the transportation system and 10% from commerces, services, agricultural residuals burning, soil and other industries. It has been observed a relevant change in relation to the contributions of NO_2 to the atmosphere, since the major contributor used to be the vehicular fleet. From the start of the operation of the thermoelectric power plants to the West of Mexicali in 2003, these displaced the latter to second place. From their distance where the plants are located is difficult to detect their contribution to the air quality of Mexicali by using the air quality monitoring equipment. Fig. 3 presents the annual average concentration of nitrogen dioxide for each monitoring stations in Mexicali from 1997 to 2008. It is observed that the main values were obtained at CBATIS 21 in 1999 and in 2007 at Cobach.

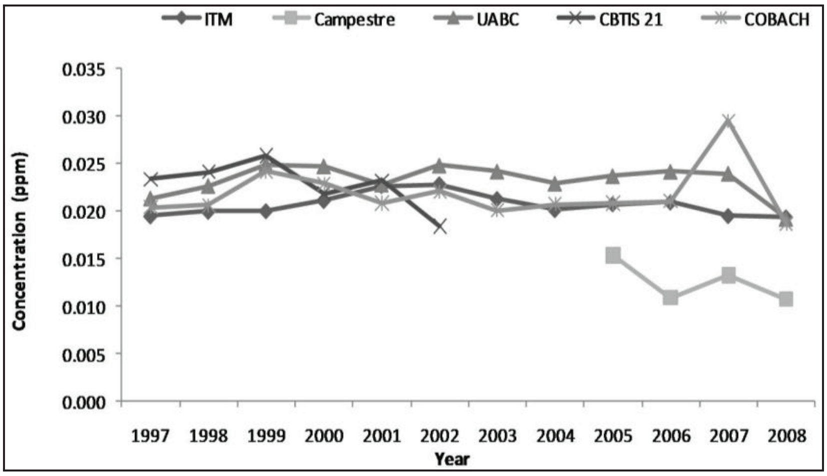

Fig.3. Annual average concentration of NO_2 at five monitoring stations in Mexicali from 1997 to 2008

In figure 4 are shown the days of exceedences for NO_2 in Mexicali from 1997 to 2008. It may be seen that the days of non-atttainment are high from 2001 to 2004. From 2005 to 2008 have not been detected exceedences.

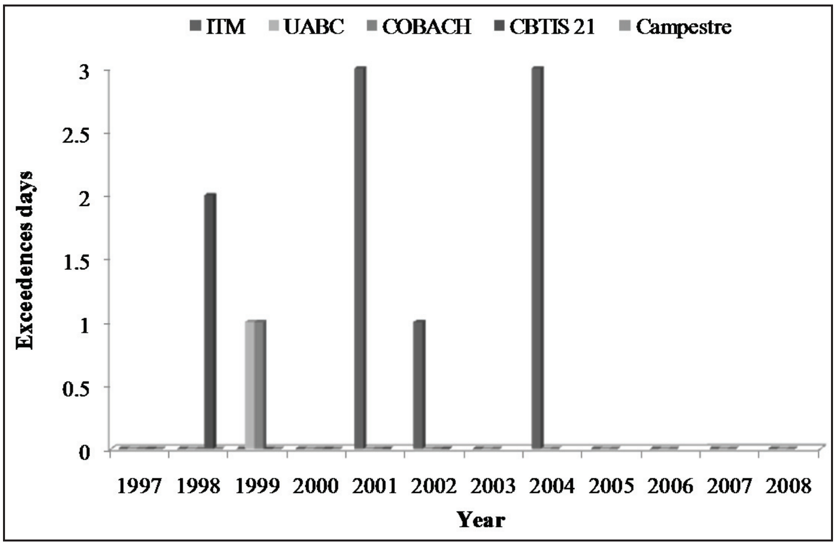

Fig. 4 Days of exceedences of NO2 at the 5 monitoring stations in Mexicali 1997-2008

5.2 *Ozono (O_3)*

Fig. 5 shows the annual average concentration of hourly ozone per monitoring stations in Mexicali from 1997 to 2008. Its observed that main values detected were in 2001 at the COBACH and at the Campestre in 2007.

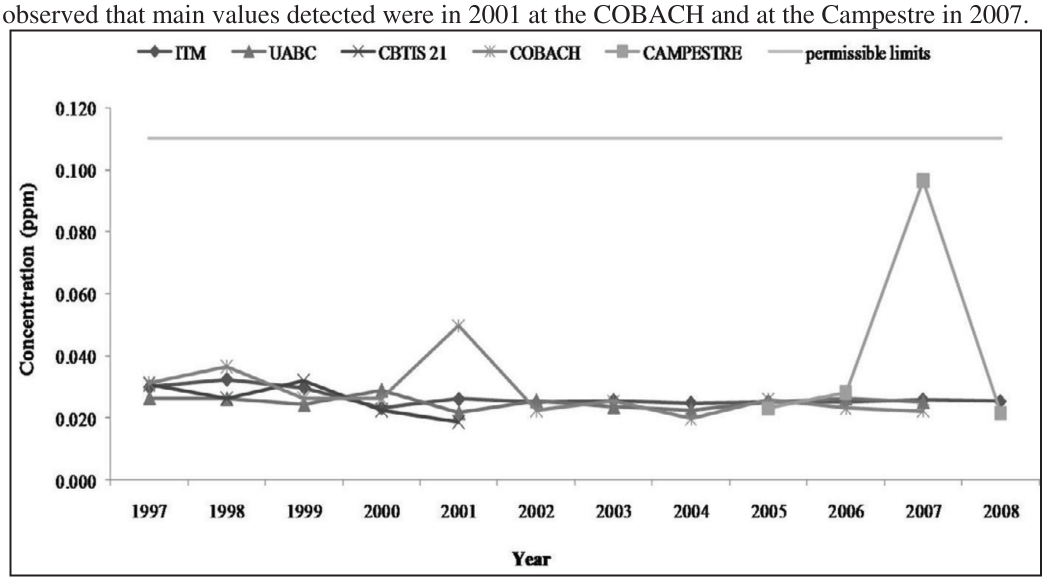

Fig.5 Annual average concentration of hourly ozone at five monitoring stations in Mexicali 1997- 2008

In Fig. 6 are shown the days of exceedences for hourly ozone in Mexicali from 1997 to 2007. It may be seen that the number of exceedences per year were diminishing. The year with the highest registration was 1997.

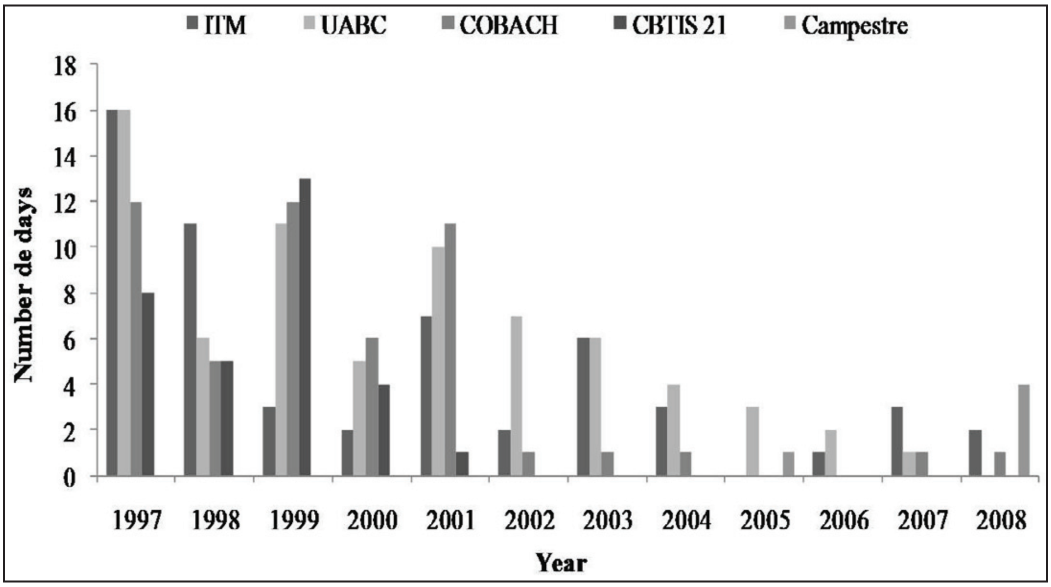

Fig. 6. Days of O3 (1 hour) exceedences are shown in Mexicali from 1997-2008

The results of the tendencies of ozone (8 hours) are not shown since it began being monitored since 2002, not in 1997 as they were the others.

5.3 Carbon monoxide (CO)

The emissions of CO estimated in the emissions inventory were 85,996 tons, out of which 63,302 tons correspond to the transportation sector, 4116 tons to the industrial sector and 18,854 tons to the commerce and services sectors. Fig. 7 shows the annual average concentration for CO per monitoring stations in Mexicali from 1997 to 2007. It is observed that were registered higher values at COBACH in 1999 and 2007.

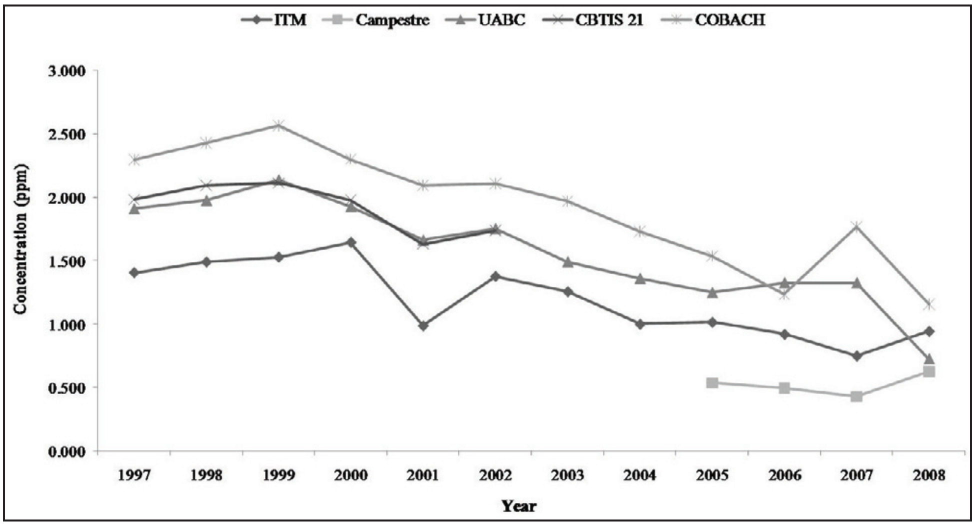

Fig.7. Annual average concentration of CO at the monitoring stations of Mexicali1997-2008

5.4 Sulfure dioxide (SO_2)

The sulphur dioxide (SO_2) has not been an important pollutant problem for Mexicali, since the city does not count with heavy industries that utilize fuels with a high content of sulphur, like thermoelectric utilities that use diesel, fuel oil, carbon or oil refineries. For that reason it was determined to make a follow up of this compound only at the UABC monitoring station at the Institute of Engineering and abandon its monitoring at the other three. Fig. 7 shows the distribution of the hourly SO_2 concentrations in Mexicali from 1997 to 2008. It is observed that the higher values were registered in 2002 and 2003.

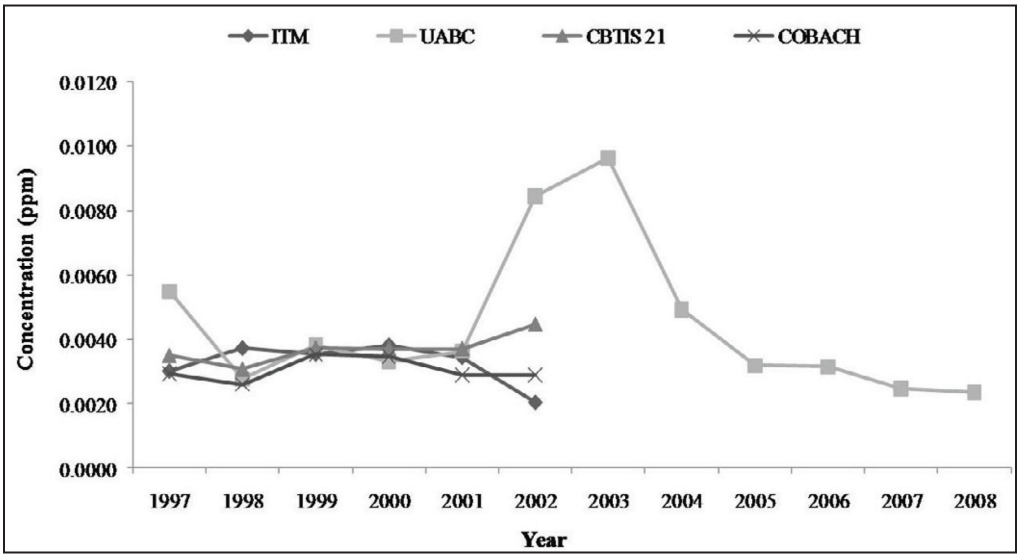

Fig.8. Annual average concentration of SO2 at the monitoring stations of Mexicali 1997-2008

5.5 Particulate matter (PM_{10})

The most important pollutant in relation to the air quality of Mexicali is the PM_{10}. Based on that pollutant, Mexicali is considered the most polluted city at the USA-Mexico border which extends for 3125 km and the third one at the national level in Mexico according to the Third Almanaque published by National Instituto of Ecology [7]. By the same token, in the last emissions inventory [8] it is reported an estimate of primary emission of PM_{10} in the range of 53,818 tons/year, out of which 87.2% would come from the eolic resuspension from paved and unpaved roads and the rest 12,8% from the industrial sector, mobile sources from road and non road origin. Fig. 9 shows and annual average concentration of PM10 per monitoring station in Mexicali from 1997 to 2008. It is observed that higher values were obtained at Progreso monitoring station in 2000, although the tendency is for the reduction of the pollutant in 2008.

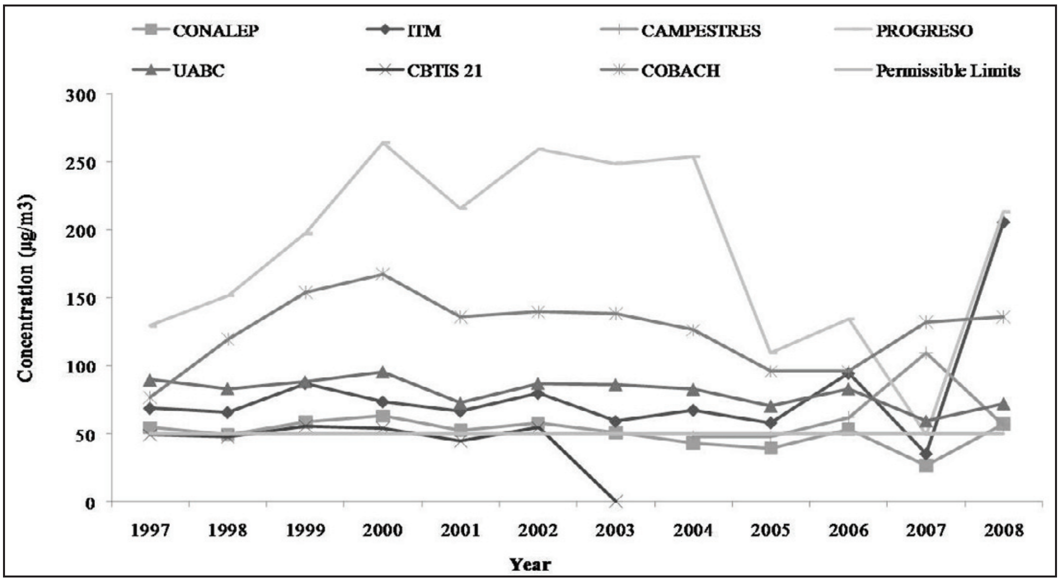

Figure 9. Annual average hourly concentrations of PM10 for all monitoring stations in Mexicali, 1997-2008.

In Fig. 10 are shown the days of exceedences of the norm for PM10, where 2000 was the year with the biggest number of observed violations at the Progreso monitoring station. The analysis of the concentrations of PM10 presented the highest values during the span of time analyzed (1997 to 2008). Closed to the monitoring station was located an unpaved road and the measuring device did not have the proper height for its sitting, thus affecting the general functioning of the PM10 measured in that particular monitor therefore upsetting the average concentrations of particulate matter in Mexicali. For that reason it is recommended [9] to review the objective of the Progreso monitoring station and once analyzed the espacial representativity that is desirable, rethink about the possibility of a relocation in a more representative site.

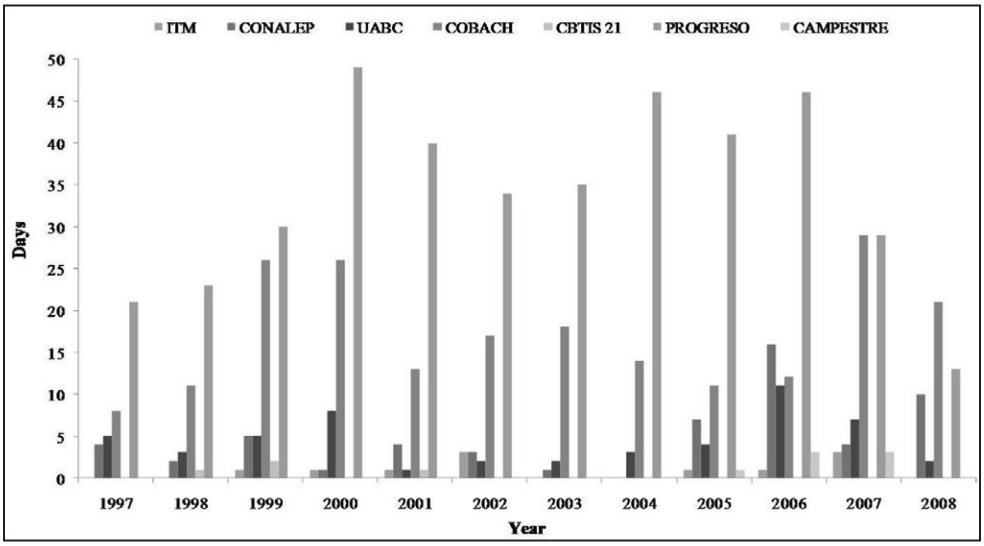

Fig.10 Number of days where the norm for PM10 was exceeded at the different monitoring stations of Mexicali

5.6 Particulate matter ($PM_{2.5}$)

Fig. 11 shows the annual concentration of $\mathbf{PM_{2.5}}$ since 2003 when sampling was started at the UABC monitoring station using the BAM technique (Beta Attenuation Mechanism). Is important to point out that discontinued values were sampled during the year, out of which 2004 was the most complete.

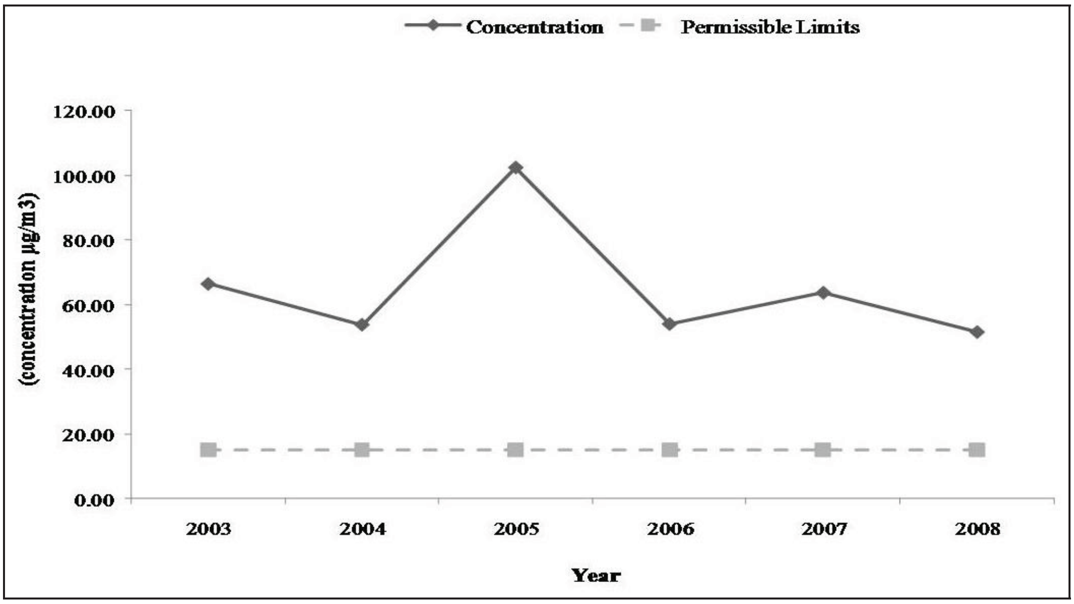

Fig.11. PM 2.5 concentration for the monitoring station at UABC

Fig. 12 is very illustrative where it is seen that 2008 was a case of exceptional non-attainment status.

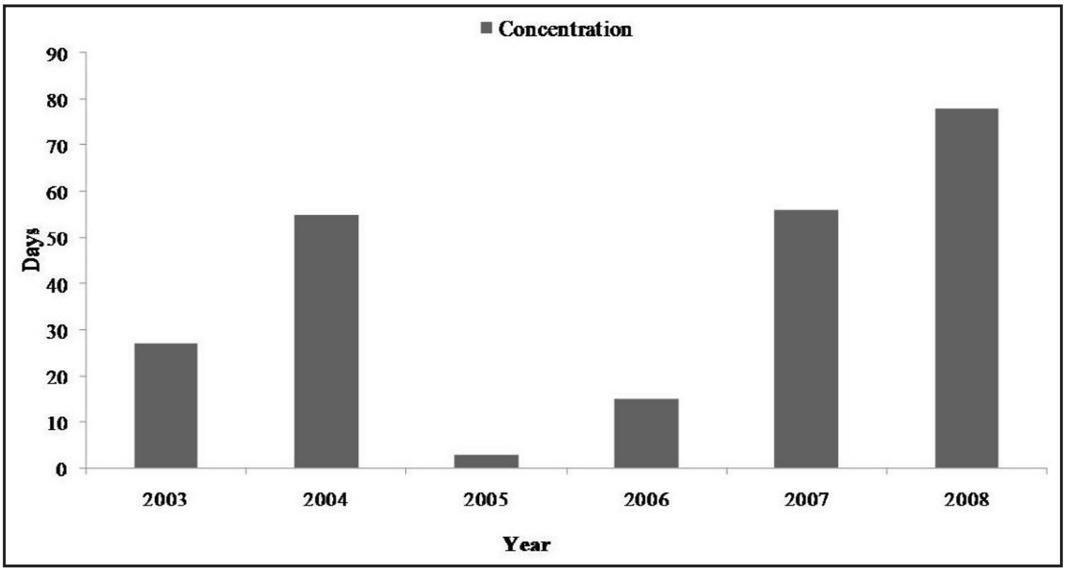

Fig. 12. Exceedences days of the PM2.5 norm. 2008 was the year with the highest number of violations observed.

6. Analysis of the tendencies of the "reference" pollutants in Mexicali from 1997 to 2008

It is important to mentioned that this air quality tendency analysis was realized with a data base information (AQS from USEPA) accumulated for 11 years from the start of the operations of the air quality monitoring stations located in Mexicali. The results of the observed tendencies may be considered complete representative of the behaviour of the pollutants. Some conclusions may be obtained on the air quality of Mexicali during the last 11 years:

The exceedences to the hourly ozone norm have been diminishing since 1997 as a general tendency. From 16 exceedences per year in 1997 it went down to 3 in 2007. Exceedences of the hourly ozone have been reduced since 2007 as a general tendency. Out of 16 exceedences in 1997 it was reduced to only three in 2007. For 8 hourly ozone, which started being evaluated in 2002 the tendency has been towards a decrease, but less drastic. The ozone average concentration (1 and 8 hours), have been constant through the years

In so as far the behaviour of the exceedences of NO_2 norm they were detected in a range of 2 to 3 from 1998 to 2004, respectively. From 2005 to 2007 there were no violations. During the annual average concentration analysis were observed two relevant periods, one in COBACH with high values, and another one at the CAMPESTRE with lower values. The historic tendency of the concentrations was very similar in 1997 and 2007, with slight increments in the intermediate years.

The CO annual average concentration showed a tendency towards a reduction in all monitoring stations, with only one exception at COBACH that presented an isolated event in 2008. It is the pollutant with the biggest number of exceedences in that period (1997-2008) and major contrast: 144 violations in 1999 and 0 excedences in 2008. The period where the levels of CO were higher took place in the coldest period of the year, due to condition of a high atmospheric stability that remained during those months.

The sulphur dioxide did not exceeded the norm in the period of analysis. For that reason the follow up for SO2 in all the automatic stations was abandoned (at ITM y COBACH in 2002, and at CBTIS in 2001), with one exception, as UABC was the only one that up to date is still measuring SO2.

The PM10 exceeded the norm mainly during winter time when there was no rain. The Progreso monitoring station measured the biggest annual hourly average, followed up by COBACH, which may be explained for its geographical position. In the case of the Progreso monitoring station is important to consider its repositioning, taking into account the height of the sampler, and the vicinity of an unpaved street. This makes Mexicali to be classified as one of the most polluted cities in Mexico by PM10 at the mexican- American border and third at the national level.

The $PM_{2.5}$ have been exceeding the norm from the beginning of the measurements. 2007 has been the year with more exceedences reaching 63. Whereas, 2005 was a year with more dispersed measurements. In so far the behaviour of the pollutants by zone, in Mexicali has been detected that the non-attainment state by ozone and carbon monoxide is very frequent in the West of the city (COBACH). Nitrogen dioxide exceedences occur more frequently in the East of the city (UABC, Instituto de Ingeniería). In relation to PM_{10} the West area shows more than 50% of the sampling with exceedences (PROGRESO and COBACH). PM2.5 is only sampled in UABC monitoring station, therefore can not be compared with other monitors, but they are associated with PM10 as its occurrence is very similar.

7. Conclusions

-It is recommended to appoint a Committee to follow up the air program from the start. The permanent follow up of the advancement in the development of the PROAIR 2010-2016 will allow to evaluate its efficiency and to orient its course in a dynamic way.

-The solution to the problem of atmospheric pollution in this airshed would be possible if it involves the people that live and work in the region and the adequate coordination of the authorities in the application of the necessary measures.

-Strengthen the citizens' conscience on the importance of their role for protecting the environment and achieving a bigger participation, will be necessary.

-Instrument mechanisms that promote the participation of the private sector through economic incentives including cross border investment.

-Binational programs such as Border XXI, and Border 2012 [10] established between USA and Mexico are extremely important to have a cleaner air.

-Out of the 5 strategies considered in the air program some actions are urgently needed to be fulfilled:

- <u>Industry, commerce and services</u>: recovery of vapor in storage terminals and gasoline service stations; environmental impact assessment at Cerro Prieto geothermal power plant; implantation of a program to reduce VOC's at industry.
- <u>Motor vehicles:</u> condition the importation from U.S.A. of pre-owned vehicles to the certification of smog check of the original country

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Silvia E. Ahumada-Valdéz received her Ph.D. in Environmental Sciences from the Autonomous University of Baja California (UABC) where she taught and has done research for 15 years. Her research work is focused on the study of aerobiological, $PM_{2.5}$ and PM_{10} particles in the atmosphere.