CONTENTS

1. FOREWORD

The Program to Improve Air Quality in Mexicali 2000-2005 represents the joint effort between the public, the local economic sector, and the three levels of government, to design and implement a set of actions with the purpose of controlling the sources of pollutants that affect air quality in the city.

Mexicali plays an important role in the Mexican national economy due to its urban, demographic, manufacturing and entrepreneurial dynamics, as well as its proximity to the United States. This makes Mexicali, along with Tijuana and Ciudad Juárez, one of the most important border cities. The city's growth brings along social and economic benefits, but also problems related to urban development and the provision of infrastructure and services, which generate environmental problems, in particular the deterioration of air quality.

The proliferation of a large number of industrial, commercial and service activities, as well as the accelerated growth of its vehicular fleet, have had an adverse impact on air quality in Mexicali. This is especially due to the poor condition of privately owned vehicles and the public transportation system; and, especially because of the importation of used vehicles that are generally found in poor working condition. Furthermore, the situation is accentuated through particulate matter and dust emissions generated by urban clandestine burns, agricultural burns, and unpaved road emissions. Although there have been isolated attempts at solving this problem, these have not always been successful, nor have they come up as a result of coordinated strategic planning by the three levels of government. This has caused resources and efforts to fade away, decreasing the effectiveness of these efforts.

Furthermore, the presence of Mexican and US authorities with different responsibilities and jurisdictional structures in the Mexicali-Imperial Valley Region; the existence of urban conglomerates with varying levels of development; and, the diversity of agricultural, commercial and service activities; require the need for integrated and complex approaches toward solving the air pollution problem.

The Program to Improve Air Quality in Mexicali 2000-2005 proposes 27 concrete measures that will allow, in the interim, the gradual reduction of air pollution in the city, until air quality standards are eventually met. The development of these measures was a joint effort between municipal, state and federal environmental authorities, members of the academic community, and non-government organizations. The program seeks to become a set of guidelines to be followed, whose benefit will not only impact Mexicali but also the rest of the binational airshed.

The solution to atmospheric pollution in this airshed will only be feasible if people living and working in the region become involved and if the authorities coordinate their efforts adequately to enforce the necessary measures. The continuing follow-up of the achievements in the development of the Program will help evaluate its efficiency and provide direction.

This document consists of two separate parts; the first includes chapters two to four and presents a general overview and a diagnosis of the current air quality situation, as well as a review of the major efforts undertaken to this date to control air pollution. The second part includes the first emissions inventory that was developed for Mexicali, in its entirety, as well as a description of the Program's objectives, goals, and proposed actions. The contents of each chapter are briefly described in the following paragraphs.

Chapter 2 includes a general frame of reference of the reasons for developing the Program.

Chapter 3 addresses the general characteristics of Mexicali, briefly outlining the city's historical evolution, as well as the socioeconomic, urban and transit characteristics. Also, it includes a summary of the air quality research studies of recent years and the main conclusions that have been drawn regarding the understanding of pollutant emissions, formation and behavior in the binational airshed.

Chapter 4 presents a discussion of Mexico's current air quality standards and a review of the general health impact from pollutants, as well as statistics and trends for the different pollutants measured by the monitoring network. It also contains a brief description of the prevailing meteorological conditions.

Chapter 5 presents the energy balance for the different fuels and the emissions inventory identifying de-segregated pollution sources in four different sectors: industry, commerce and services, transportation, and, soils and vegetation. This inventory was developed with the financial and technical support from the Western Governors Association (WGA), California Air Resources Board (CARB), and the US Environmental Protection Agency. (USEPA).

Chapter 6 explains the objectives and goals of the Program; it also describes specific control measures for each sector, naming the parties responsible for implementing these measures, as well as an estimate of the expected emissions reduction.

Finally, the document has a bibliographic section and a series of technical annexes in support of each chapter.

The *Program To Improve Air Quality in Mexicali 2000-2005* is available on the web page of Instituto Nacional de Ecología, at: *http://www.ine.gob.mx*. The document can be downloaded from this site.

2. INTRODUCTION

Economic development and air quality in the region

The city of Mexicali, Baja California, is set in a strategic location along the United States-Mexico border, emerging as a farming zone of great potential in the first part of the twentieth century. Agricultural activity in Mexicali began in 1904, with the first use of irrigation. The first crop that was introduced at that time was cotton, with disastrous results during the first several years. It was not until 1912 that production of this crop was strengthened and consolidated.

During the 1930s and 1940s, the seeding of cotton and manufacture of vegetable oils and fat were the main manufacturing industries. In 1937, the agreements to declare the border region a "duty-free zone" were established, allowing Mexicali to begin with the substitution of imports and the exportation of cotton. Undoubtedly, this prompted the economic growth in the region. Thus, by the 1940s Mexicali already had 117 manufacturing industries, and the number rose to 525 industrial establishments in the 1950s.

In the 1960s, when the program to hire Mexican laborers for agricultural activities came to an end in the United States, Mexicali began to experience a significant demographic growth, since many of the people who had come to Mexicali to cross into the US, stayed in the city. It was then that the first industrial parks were developed and the first maquiladoras were established, bringing about a demand for labor.

The Border Program started promoting the development of the northern border to link it with the rest of the country. This program sought the use of domestic merchandise to supply the region and oriented the industrial focus toward production of goods for local consumption. The Program to Develop the Northern Border began in the 1980s as a federal and state government strategy to turn this region into a source of foreign currency and jobs.

The location of the Valley of Mexicali, adjacent to Imperial Valley, where the cities of Calexico, El Centro and Brawley are located, is the reason why this region is considered a single international airshed. Its location, coupled with an increase in production, especially due to the development of the maquiladora industry, makes Mexicali a significant region both in the international as well as the national arena.

Similar to other areas along the United States-Mexico border, the efforts to improve environmental quality in the *Mexicali-Imperial Valley Region,* have binational connotations, historically characterized by the economic and social interdependence between these two countries. This interdependence is characterized by a permanent exchange, or bi-directional flow, ranging from habits, jobs, goods and services, to pollutants. In this sense, the peculiar nature of the border region determines that, although the amount and type of emissions can be different, the effects are felt on both sides of the border. Thus the need to understand the environmental conditions through an integrated binational focus.

The development and evolution of the region has resulted in the deterioration of air quality in recent years. Currently, Imperial Valley is in violation of US air quality standards for particulate matter (PM10), and Mexicali is in violation of Mexican Official Standards for PM10, carbon monoxide and ozone.

In fact, in 1987 the United States Environmental Protection Agency designated Imperial Valley as a non-attainment area for PM10, prompting the development and implementation of a State Implementation Plan (SIP) in 1990. This plan includes a set of control measures for the emission of pollutants.

In contrast, efforts in Mexicali to abate pollution have been sporadic and have not been part of a strategic plan. The main actions that have been taken until now have been the result of local and federal government efforts, or derived from the technical cooperation within the Border XXI Binational Air Workgroup. Recently, municipal authorities have sought a long-term plan for the development of the city, through a set of actions and lineaments contemplated under *Programa de Desarrollo Urbano de Centro de Población de Mexicali, B.C. 2010*.

As far as government responsibilities are concerned, the following Mexican agencies are involved: Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP) at the federal level, the Government of the State of Baja California, and Mexicali's Municipal Government. For the United States, the following are involved: US Environmental Protection Agency (EPA), at the federal level; California Air Resources Board (CARB), at the state level; and, Imperial County.

This institutional arrangement makes it complex to deal with environmental issues, due to the fact that pollution sources must adhere to a different legal framework on each side of the border, whether it is at the local, state or federal level. For example, all major industries in Mexico are required to submit an environmental impact assessment to obtain permission to build a new facility. Then, they must obtain an operating license, comply with the atmospheric regulations from LGEEPA and with some Official Mexican Standards regulating industrial emissions; Mexican regulations also allow the setting of limits for certain individual emission sources. On the other hand, in the United States, major sources may be required to comply with a number of regulations and programs concerning atmospheric emissions, as well as particular limits that are set for them. Some of these regulations include the following: attainment and maintenance of air quality standards; regulation of hazardous substances; acid rain program; and, emissions reduction of substances that destroy the ozone layer. At the same time, industry must participate in the State Implementation Plans (SIPs).

Some of the most noticeable contrasts between the two countries are found in their vehicular fleets. This is evident by the fact that Imperial Valley has a large number of late model vehicles equipped with state of the art emissions control technologies, whereas Mexicali has a large number of highly polluting vehicles, older than 15 years and lacking adequate emission controls. Other differences are found in road networks and road paving. In Mexicali approximately 40% of the roads are unpaved. Furthermore, some stationary pollution sources such as brickyards, are unique to Mexicali. On the other hand, similar to other border cities and border corridors, the waiting time of motor vehicles at border bridges and crossings generates a significant volume of pollutants.

Although in some cases the level of technological development can be an important factor in the degradation of air quality (e.g., an outdated vehicular fleet in Mexicali and in many cases the lack of emissions control equipment), fuel consumption increases contribute just as much to atmospheric emissions. The prior example can be compared to the existence of a larger vehicular fleet which implies more miles per vehicle traveled, a greater use of fuel and thus a larger amount of pollutants emitted into the atmosphere; even when vehicles are equipped with emission control devices in good working condition.

It is not likely for legal and policy frameworks to become harmonized in the short-term. This makes it more realistic to assume that binational action in the next several years will take place under different legal and policy frameworks, as far as administrative requirements, compliance with requirements and pollutant emissions limits are concerned. However, this is not a barrier to implementing a solution but rather, it represents a challenge to the imagination and creativity of those involved in solving the problem.

Within this framework, the Program to Improve Air Quality in Mexicali proposes a working agenda with concrete measures that will allow, within a reasonable period of time, compliance with air quality standards, thus ensuring the protection of public health. Public authorities were involved in the development of this agenda, which should be considered a dynamic instrument that must be continuously built upon and updated.

Legal Basis for the program

Legal framework

Mexico's Political Constitution is the legal instrument that supports environmental law in Mexico. The constitutional reforms of 1983, 1987 and 1992 incorporate general provisions regarding environmental protection, as well as preservation and restoration of the ecological balance. These include the right to live in a healthy environment; the drive toward productive development through conservation of the environment and natural resources; the ability of Congress to enact laws that establish an agreement between the federal, state, and municipal governments in the area of their respective authority; impose requirements on private property; and, restore ecological balance. These provisions are included in the following articles[1]:

Article 4, Fourth paragraph: "Every person has the right to have their health protected". The deterioration of resources due to pollutants affects human health. The fifth paragraph states that every person has the right to an environment that is conducive to his/her good health and well being.

Article 25, Sixth paragraph: "Under the criteria of social and productive equity, companies belonging to the public and private sectors of the economy will be supported and promoted, and they will be subjected to the requirements that are dictated by the public interest and public use, for the general benefit of production resources, guarding their conservation and the environment." This article establishes the basis on which environmental legislation rests, under the principle of "sustainable development."

Article 27, Third paragraph: "The nation will have, at all times, the right to impose on private property, requirements that are in the best interest of the general population. Furthermore, it will have the right to regulate, for the benefit of society, the use of natural resources that are susceptible to appropriation, with the object of equally distributing public wealth, guarding its conservation, achieving balanced development throughout the country and improving rural and urban quality of life. The appropriate measures to preserve and restore ecological balance will be enacted". Air (the atmosphere) is not a natural element subject to appropriation; however, as a common resource it constitutes by itself part of the public wealth. Therefore it is the nation's responsibility to guard its conservation to improve the quality of life of all Mexican citizens.

Article 73, Fraction XVI - 4a: "Congress has the authority to dictate the measures adopted by the general health council to prevent and fight environmental pollution...."

Article 73, Fraction XXIX-G: "Congress has the authority to enact laws that establish agreement between the federal, state and municipal governments, in the area of their respective authority, regarding environmental protection as well as the preservation and restoration of ecological balance".

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1 Secretaría de Ecología del Gobierno del Estado de México, Secretaría de Medio Ambiente Recursos Naturales y Pesca, 1997. *Aire Limpio Programa para el Valle de Toluca 1997-2000.*

Article 115, Fraction V: "Municipalities, in terms of relative federal and state laws, have the power to formulate, approve and manage municipal urban development zoning and planning; participate in the management of their territorial reserves; control and oversee soil use within their territorial jurisdictions; intervene in regulating urban land ownership; issue construction licenses and permits; and, participate in the creation and management of ecological reserve zones. For that effect and in accordance with the objectives pointed out in the third paragraph of Article 27 of this Constitution, they will issue the necessary regulations and administrative dispositions".

In the same manner as Mexico's Political Constitution, the Constitution of the Free and Sovereign State of Baja California establishes in Chapter Four, Article 7, that, in the subject of *individual, social and human rights protection guarantees*, the State of Baja California fully complies with, and assures the individual and social guarantees and other rights awarded by Mexico's Political Constitution.

On its part, "Ley General del Equilibrio Ecológico y la Protección al Ambiente" (the General Law of Ecological Balance and Environmental Protection), establishes the distribution of authority between the three branches of government in articles 5, 7 and 8. Article 7 describes the duties that correspond to federal entities regarding air pollution prevention and control, and other issues related to the actions contained in *The Program to Improve Air Quality in Mexicali 2000-2005.*

- Formulation, enforcement and evaluation of state environmental policy (Fraction I);
- Enforcement of environmental policy instruments provided by local laws regarding the subject, as well as preservation and restoration of ecological balance and environmental protection conducted in state property and zones of state jurisdiction, on subjects not directly assigned to the Federation (Fraction II);
- Prevention and control of atmospheric pollution generated by fixed sources operating as industrial facilities, as well as those mobile sources, which according to this law, do not fall under federal jurisdiction (Fraction III);
- Establishment, regulation, management and oversight of protected natural areas as provided by local law, with the participation of municipal governments (Fraction V);
- Formulation, issuance and execution of regulated ecological programs in the territory... with the participation of the respective municipalities (Fraction IX);
- Prevention and control of pollution generated by substances that are not reserved to the Federal government, consisting of deposits of similar nature to those of ground components, such as rocks or byproducts which can only be used in the manufacture of construction materials or landscape decoration materials (Fraction X);
- Attention to issues that affect the ecological balance or the environment of two or more municipalities (Fraction XI);

- Participation in environmental emergencies and contingencies, in accordance with public protection policies and programs established for that purpose (Fraction XII);
- Oversight of compliance with the official Mexican standards issued by the Federation, on the subjects and assumptions referred to in Fractions III, VI and VII of this article (Fraction XIII);
- Enforcement of state policy regarding environmental information and outreach (Fraction XIV);
- Promotion of public participation in environmental matters, in accordance with this law (Fraction XV);
- Formulation, delivery and evaluation of a State environmental protection program (Fraction XVIII);
- Issuance of recommendations to the proper authorities regarding environmental matters, with the object of promoting compliance with environmental regulations (Fraction XIX).

Likewise, article 8 of this law establishes the power that is given to the municipalities. Fractions III, V, VIII, X, XI, XII and XV are the basis for the municipal government's participation in the actions established under the *Program to Improve Air Quality in Mexicali 2000-2005:*

III.- Enforcement of laws related to air pollution prevention and control from fixed sources operating as commercial or service establishments, as well as air pollutants originating from mobile sources that do not fall under federal jurisdiction, with the involvement of state government as defined by state law;

V.- Creation and management of ecological preservation zones in populated areas, urban parks, public gardens, and other similar areas considered under local legislation;

VIII.- Formulation and issuance of local ecological arrangement programs, referred to in article 20 BIS 4 of this law, as well as control and oversight of the use and changes in use of the soil, as established in those programs;

X.- Involvement in taking care of issues affecting the ecological balance of two or more municipalities and having environmental effects of territorial dimensions;

XI.- Involvement in emergency response and environmental contingencies in accordance with public protection policies and programs established to that effect;

XII.- Oversight of compliance with the official Mexican standards issued by the Federal government, in matters and assumptions referred to in fractions III, IV, VI and VII of this article;

XV.- Formulation, implementation and evaluation of the municipal program for environmental protection.

Baja California's Law of Ecological Balance and Environmental Protection, published on February 29, 1992, establishes in Article 130 that, regarding air pollution, it is the responsibility of the local Director of Ecology or the City Council (within the scope of its competence and through an agreement with the Director of Ecology) to:

I.- Implement atmospheric pollution prevention and control actions;

II.- Apply the ecological criteria for the protection of the atmosphere in the statements of use, destination, reserves, and supplies, determining the zones where emitting agents are allowed to be installed, taking into account topographic, weather and meteorological conditions, in order to ensure the adequate dispersion of emissions;

III.- Coordinate actions related to the preservation of the environment with similar agencies of the federal and municipal branches;

V.- Integrate and update the atmospheric emissions inventories for the different sources, requesting all the necessary information from persons, agencies and official organizations;

IX.- Establish and operate air quality monitoring, oversight and control systems; conduct the necessary scientific research and studies, directly or through third parties, in a way that both society and the ecological council are kept widely informed about air quality conditions in the State.

Policy framework

The General Law of Health (Ley General de Salud) establishes that, in the subject of protecting the health of the general population from environmental effects, health authorities are responsible for setting standards, establishing measures, and conducting activities that tend to protect human health from the risks and harms that may be caused by environmental conditions, as well as determining the maximum permissible concentration levels of air pollutants for humans.

Based on the above, Secretaría de Salud (Ministry of Health) issued the Official Mexican Standards, which establish air quality criteria as related to health.

The standards that for the basis to this Program are the following:

Official Mexican Standard	Pollutant
NOM-020-SSA1-1994	Ozone

NOM-021-SSA1-1994	Carbon monoxide
NOM-022-SSA1-1994	Sulfur dioxide
NOM-023-SSA1-1994	Nitrogen dioxide
NOM-024-SSA1-1994	Total suspended particles
NOM-025-SSA1-1994	Particulate matter < 10 microns
NOM-026-SSA1-1994	Lead

These Official Mexican Standards were published on December 23, 1994 in the Official Federal Newspaper, and they are to be enforced by the federal and local authorities in charge of air quality oversight and assessment, with the purpose of protecting the health of the general public.

Likewise, these norms establish that within a period of 180 days after their issuance, the federal government will propose plans for the verification, follow-up, and control of the established concentrations.

Article 111, Fraction I of the Law of Ecological Balance and Environmental Protection, points out, regarding prevention and control of atmospheric pollution, that SEMARNAP has the authority to issue Official Mexican Standards that establish the environmental quality of the different areas, zones, or regions of the country, based on the maximum permissible concentration values of certain pollutants determined by the Health Ministry, in order to ensure public health.

The Rule that covers Air Pollution Control and Prevention points out in article 7, fraction IV, that it is SEMARNAPs responsibility to issue standards for the "certification of the competent authority, of the emissions levels of pollutants generated by particular sources." To that effect, SEMARNAP has issued official Mexican standards that are applicable to the current Program, with respect to environmental monitoring, fixed sources, fuel and mobile source characteristics; Annex F contains a list of the current standards.

The Environmental Protection Regulation for the Municipality of Mexicali, B.C., published on December 8, 1997, establishes in article 4, the following responsibilities for the Municipal Office of Ecology, related to the preservation and restoration of ecological balance and environmental protection:

I.- Environmental policy:

a) Formulate, issue and conduct the municipal environmental protection program and the ecological and municipal arrangement programs, referred to in the General Law of Ecological Balance and Environmental Protection, under the terms outlined in such law.

Air quality management in the binational airshed

The following is a discussion of some aspects that have an effect on air quality management in the binational airshed, and the opportunities for the development and joint application of actions by the cities.

Air pollution must be first characterized based on its physical, chemical and climatological aspects, in order to understand its spatial and temporal behavior. Then, it is necessary to understand this behavior with respect to the sources that produce these emissions of pollutants, in order to identify, quantify their involvement in the problem, and identify opportunities to reduce them in an efficient manner and at a low economic, social and political cost. The importance of progressing in the following areas should be highlighted:

- The integration and development of a complete emissions inventory, spatially and temporally desegregated, for the entire binational airshed,
- The availability of a regional air quality monitoring network that allows an integrated vision of air quality, and
- Measurement and evaluation of the benefits achieved by a reduction of emissions.

It is also relevant to improve the estimation of volumes of pollutants emitted by the major sources, particularly those related to transportation and soils. In this process it is essential to standardize the methods and techniques used in the development of the emissions inventories for the airshed as a whole.

Based on this environmental framework, the premise for any activity that is carried out in the Mexicali-Imperial Valley airshed should be to reduce emissions, or at least avoid an increase of emissions. This falls under a scheme that has the ultimate objective of reducing the levels of fine particulate matter, carbon monoxide, and ozone in the binational airshed. This concept is illustrated in Figure 2.1, where the Air Quality Workgroup appears as the common point for particular and joint activities conducted in Mexicali-Imperial Valley.

Figure 2.1. Interrelation and objectives of the programs and activities to improve air quality in the Mexicali-Imperial Valley region

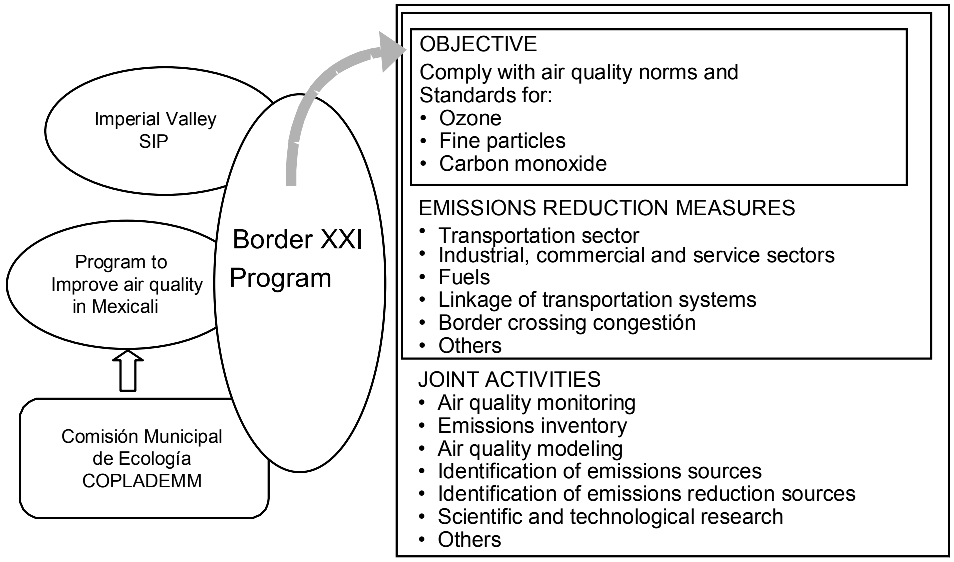


Table 2.1, shows some of the air quality activities for the Mexicali-Imperial Valley region. As can be seen, some of these activities contribute to the knowledge of the problem and others correspond to concrete measures for emissions reduction. Many of them are being applied already and the measures covered under this Program, are added to this list.

With this information developed in a joint and shared manner, each level of government, federal, state, and local, will be able to establish the appropriate cost-effective measures.

Finally, it is important to mention that the Border XXI Air Quality Workgroup, has opted to carry out its work under these lineaments. Currently, efforts are centered on improving the scientific and technical knowledge of the problem. Complex models will be developed with these results, in order to identify the appropriate measures to reduce emissions in the Mexicali-Imperial Valley airshed. Hopefully, these measures will result in compliance with air quality standards within the next few years.

Table 2.1. Examples of activities to improve air quality in the Mexicali-Imperial Valley airshed

Knowledge and follow-up of the problem in the airshed
• Air quality monitoring and characterization • Emissions inventory • Air quality mathematical modeling of the binational airshed • Identification of sources and pollutants
Emissions reduction measures
• Vehicular verification • Fuel quality • Linkage of transportation systems • Congestion at border crossings • Emissions reduction in industries and services • Vapor recovery in service terminals and service stations • Reforestation • Road paving
Support activities
• Acquisition of financial resources • Scientific and technological research on control measures • Training, capacity building, education • voluntary initiatives and social participation

3. GENERAL CHARACTERISTICS

1. Historical background

The region that covers the lower basin of the Colorado River, where Imperial Valley and the valley of Mexicali are located, has been inhabited for several thousand years. There is evidence of settlements by groups of hunters in that region since approximately 10,000 years ago, in what is known today as the archeological complex of “San Dieguino”, where a cooler and moister climate than today’s prevailed. These paleoindigenous people were not only hunters of the great mammals that are now extinct, but also included smaller animals, plants and marine resources as part of their diet. This leads us to assert that these settlers made broad use of the region since those times.

In the period between 5000 BC and 900 AD, including the eras known as “Pinto” and “Amargosa”, there was a transition from groups that were predominantly hunters to those that were hunters/collectors. The manufacturing of grinding tools, such as mortars and metals, makes us conclude that these people had a diet that included an important part of grains and seeds. During the period known as Yuman I (800 to 1050 AD) the use of ceramics appeared. The period known as Yuman II (1050 to 1450 AD) is characterized by the practice of cremations; and, during the period known as Yuman III (1450 to the 19^{th} century) there is a process of dispersion due to the drying up of lake Coahuilla. It was during this period that the Cucapa people settled in the Colorado delta region adopting agricultural practices.

The first Spanish explorers to arrive in the Colorado River delta were Hernando de Alarcón and Melchor Díaz. In 1540, they made the first contact with the local people, members of the Cucapa tribe. In 1700 and 1701, Jesuit priests Kino and Salvatierra explored the mouth of the Colorado River. Finally, it was Francisco Garces who, during his expeditions of 1771 and 1776, gave the river its name, which is still used today.

The City of Mexicali

It is considered that Mexicali was established on March 14, 1903, with the appointment of the town’s first public official, assistant judge Manuel Vizcarra, by the City Council of Ensenada.

At the end of the Mexico-American War, on February 2, 1848, the Treaty of Guadalupe Hidalgo established new territorial limits between the two nations, thus setting the stage for the future placement of border cities in Baja California.

Although the war between the two nations had very little presence in Baja California, that was not the case with filibuster invasions. On October 16, 1953, William Walker accompanied by a group of adventurers left the port of San Francisco aboard the Carolina, a Mexican vessel. He arrived at La Paz Bay the same month, taking over the city and imprisoning Governor Espinosa. From there, Walker left for Ensenada where he established his general headquarters and made his proclamation to make the Baja Califonia Peninsula an independent republic. From the time of his arrival at the port of Ensenada, Walker was confronted by the patriot Antonio Meléndrez who, after several encounters, finally defeated him at Cueros de Venado Ranch, on May 6, 1854 making Walker flee to the City of San Diego.

The history of Mexicali is closely linked to both countries' settlement policies of the second half of the 19th century. In Mexico, settlement was the federal government's answer to poverty, political upheaval, and the constant threat of foreign invasions.

The federal government pretended to develop the country by encouraging new settlements. In 1857, the Administration of Ignacio Comonfort issued the Law of Settlement of Vacant Lands. It included regulations related to the endowment of land, tax exemptions and requirements for setting boundaries. This Law was reformed in several occasions, culminating on 1883s Law of Settlement. This law established a maximum limit of 2,500 hectares per settler and equal sale conditions for Mexican nationals and foreigners. As a result of this law, foreign speculators were able to acquire large amounts of land. In Baja California, investor Luis Hüller, he was able to appropriate 18 million acres, which he then sold in public auctions in the city of Hartford, Connecticut. This was added to a twenty-year tax exemption and a grant of 12,000 pesos per mile of railroad tracks that were projected for construction to connect the peninsula with the United States. The denounce of such irregularities by the newspaper "Diario del Hogar" and their verification by the Commissioner that was sent to Baja California by Minister Carlos Pacheco, resulted in the cancellation of the contract and the capture of Luis Hüller.

One decade later, the Administration of Porfirio Díaz enacted a legislative package on settlement with the Laws of December 1893, March 1894 and the Regulation of June 1894. This was a more liberal policy on the subject of settlement. Restrictions of 2,500 hectares per settler as well as the obligation to cultivate and populate the delimited lands were lifted, thus favoring private speculation and abandoning the official policy on settlement, in favor of a latifundium system. As a result of the disconformity and constant criticism of these measures in the newspapers of the time, in 1902 the delineation of land by private companies was repealed. Afterwards, and as a consequence of the numerous irregularities in land ownership, the authority of the Executive branch to transfer the title of national land, was revoked pending the ratification of prior transfers by officially nominated Commissions.

As was mentioned earlier, the rise of Mexicali is strictly linked to settlement and agricultural development of the region on both sides of the border. At the end of the 19th century and the beginning of the 20th century, California Development Company carried out irrigation and urban development work in the cities of El Centro, Imperial and Heber. The development of the Colorado Desert, later known as Imperial Valley, was financed and directed by a Canadian entrepreneur, George Chaffey, who founded the city of Calexico in 1901. H. Heber replaced Mr. Chaffey in 1902 as director of the companies Imperial Land and California Development. On October 17, 1902 Mr. Heber purchased the *Sociedad de Irrigación y Terrenos de la Baja California* (Irrigation and Land Association of Baja California) with the support of American investors. This consisted of 187.6 hectares of land in Mexican territory, neighboring the new town of Calexico. Charles Rockwood, an engineer, was commissioned to develop the urban plan for the town of Mexicali.

Between 1904 and 1905, the company known as Colorado River Plant acquired most of the irrigation land in the valley of Mexicali. Concurrent with the sale of lots for agriculture, the entrepreneur started the sale of urban lots. The commitment of the American entrepreneurs with the new settlers of Imperial Valley and Mexicali included the delivery of water for irrigation which would be taken from the Colorado River and would be charged at the rate of 50 cents of a dollar per acre. Mr. Chaffey's original project considered taking water from the river and transporting it through a canal to the dry riverbed of El Álamo wash in Mexican territory. This would greatly reduce the cost of the irrigation project. The settlement project suffered a serious setback with the Colorado River floods of 1905 and 1906, which proved to be a hard test for the existence of the town of Mexicali.

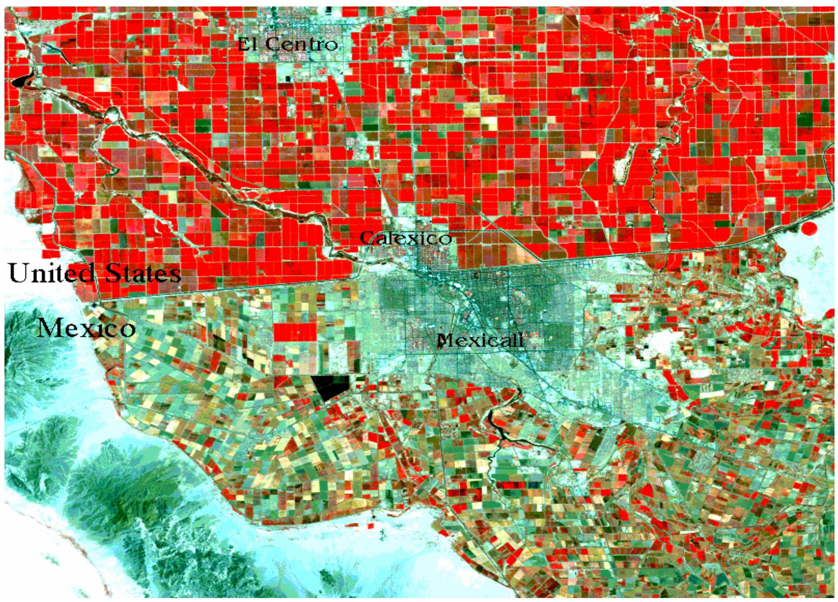
Another important event in the history of Mexicali is the taking over of the city by anarchist groups on January 29, 1911. From the start of the revolutionary movement, the Organizing Board of the Mexican Liberal Party, led by Ricardo Flores Magón, considered the Northern District of Baja California a suitable zone for armed conflict. However, this uprising did not work and the city wars recovered by federal forces in June of the same year.

In 1914, under the leadership of Colonel Esteban Cantú, a decree was enacted recognizing the city of Mexicali as head of the municipality that bears the same name. The following year it became the capital of the territory and on January 16, 1952, it became the capital of the new state of Baja California (INEGI, 1997b).

In the second half of the century, Mexicali received a great push through the Program to Industrialize the Northern Border, in the 1960s. The first industrial parks were built during this period to establish the maquiladora industry. This created a change in the economy of the city, turning its primarily agricultural character into one of greater diversity and stability, as a consequence of the demand for labor by the maquiladora industry. That situation brings about an increase in the immigration rate, mainly from the states with greater unemployment and poverty in the Republic of Mexico.

The city of Mexicali currently has an extension of approximately 11,372 hectares, plus 795 peripheral hectares of rural land. In 1996, Mexicali had 504 hectares of territorial reserve for its urban growth.

Figure 3.1. The region of Mexicali-Caléxico-El Centro

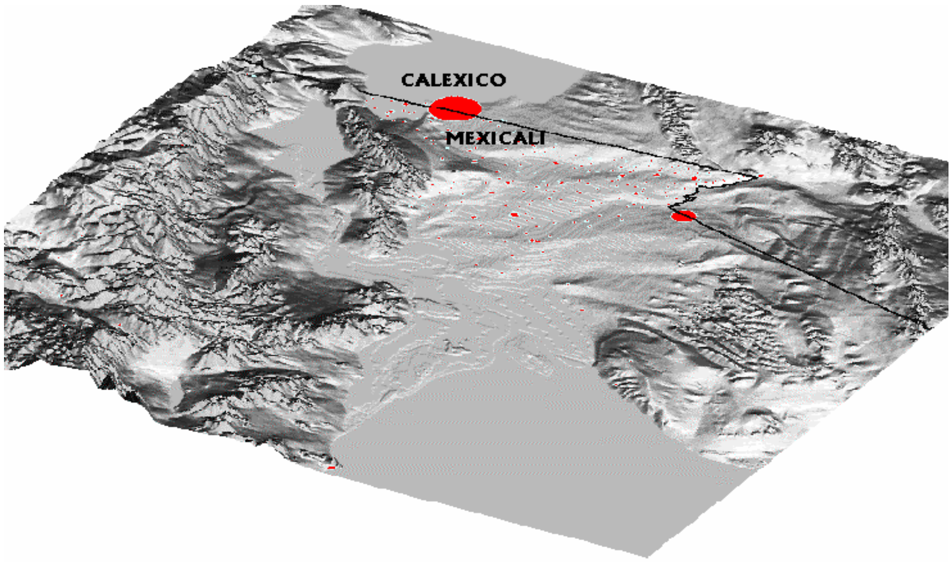


Source: http://gort.ucsd.edu/mw

2. Socioeconomic characteristics

The city of Mexicali headquarters the state government and serves as head of the municipality of Mexicali. It is located along the international border at 32° 40' north latitude and 115° 28' west longitude, at an average elevation of 10 meters above sea level. The region is part of the Colorado River watershed, which has a surface area of 632,000 km² extending from the southern part of the state of Wyoming, including parts of Utah, Colorado, California, Nevada, New Mexico, and most of Arizona. In Mexico it includes the northeast portion of Baja California and the northwest portion of Sonora (Figure 3.2). In spite of its size, this watershed receives a relatively small volume of water estimated at an annual mean of 16.6 km³ (Keller, 1996). The water resources of this watershed have been totally appropriated by different users including the seven States of the American Union and the two Mexican States.

Figure 3.2. Topography of the region



Source: http://gort.ucsd.edu/mw

In 1944 an agreement was signed between the two countries with the purpose of regulating the volume of water that should be allowed to flow into Mexico. This volume was set at 1.85 km^3 per year. However, due to the high rate of evaporation from agricultural uses north of the border, water flowing into Mexico contained a high rate of salt, which occasionally would reach 2,700 ppm, when the maximum permissible level for human consumption is 550 ppm and 750 ppm for agricultural irrigation. As a result, in 1973 a new a new agreement was signed between the two nations, setting a limit of 115 ppm for the salinity of the water crossing into Mexico and being stored at Imperial Dam.

The region covering the valleys of Imperial and Mexicali is part of the Saltón depression. This started forming with the deposition of sand along the mouth of the Colorado River, creating embankments that raised the elevation of the area around the delta above the northeastern watershed. Because of this, the river discharged in the deepest part of the watershed, forming a lake. This lake disappeared when the elevation of the Salton region allowed the river to regain its course toward the Gulf. During this process, the lake dried up leaving behind a plain of deep alluvial soils. In most of the valley these soils were high-grade medium sand, silt and alluvium with very good drainage capacity. There were also some soils with high clay content and less drainage capacity and a gentle slope in the northeastern part of the valley (SPP-INEGI, 1984).

Population

The municipality of Mexicali covers an area of approximately 13,935.6 km^2. According to 1990 census data, the population of the city of Mexicali for that year was 505,016 and 601,938 for the entire municipality. This implies that 84% of the population in this municipality resides in the city of Mexicali. INEGIs estimated population for 1995 was 696,034 for the municipality, and 586,324 for the city of Mexicali. This implies a demographic growth of 16%. Currently, it is believed that the annual demographic growth for this city is 2.6%, which places it as the city with the smallest population growth in the State of Baja California.

On the other hand, the number of births for the 1995-96 period was only 17,383, implying that the growth is due to the large number of immigrants that come to Mexicali to get across the border, and stay in the city to live and work, temporarily or permanently.

The following is an estimate of the projected demographic growth trends for the municipality of Mexicali, according to the rate used by INEGI. Based on this, the population by the year 2010 will be a little over one million people, 50% higher than the population for 1995, as shown in Figure 3.3 and Table 3.1.

Figure 3.3 Projection of demographic growth in Mexicali

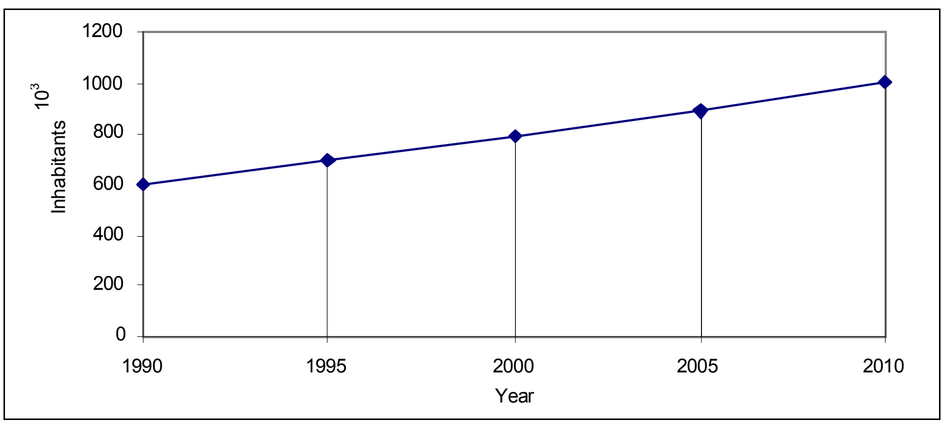


Table 3.1 Projection of demographic growth

Year	Population
1990	601,938
1995	696,043
2000	786,500
2005	888,700
2010	1,004,300

Source: INEGI, 1996. Cuaderno Estadístico Municipal.

On the other hand, Imperial Valley includes several cities. Calexico and El Centro, California are the two cities that are closest to the Mexican border. Imperial Valley has a surface area of 6,911 km^2, with a population of 137,400 people and a vehicular fleet of 70 thousand units. Table 3.2 compares some of these characteristics with the city of Mexicali. As far as population is concerned, there are almost six times as many people in Mexicali as there are in Imperial Valley. This difference can also be observed in the vehicular fleet, which is almost three and a half times larger in Mexicali. It is important to mention that most vehicles in Imperial Valley are late model units, whereas in Mexicali the age of the vehicular fleet is greater than 15 years.

Table 3.2. Comparison of some urban and demographic characteristics of Mexicali and Imperial Valley

	Unit	Mexicali	Imperial Valley
Land mass	km^2	13,936	6,911
Population	Inhabitants	696,034	137,400
Population density	Inhabitants/km^2	50	20
Vehicular fleet	Number of vehicles	241,000	71,000
Inhabitants per vehicle	Inhabitants/vehicle	2.9	1.9

Economic activity

In spite of its roots and the fact that it is a municipality with agricultural land for irrigation, agricultural production in Mexicali did not represent an important component of the regional economic activity in the first part of the twentieth century. In the 1920s, the brewing industry showed a peculiar growth. However, in spite of the production levels, this did not turn Mexicali into an industrial center. Industrialization did not start automatically in Mexicali with the introduction of cotton. It was not until the 1940s that the agricultural industry transformed significantly the city's spatial growth pattern with 117 industrial establishments. The main industries included cotton-seeding facilities, the production of oil and vegetable fats, canning of fish and seafood, production of wines and liquors, bottling of water and carbonated drinks, meatpacking, and pasteurization of milk. By the beginning of the 1950s Mexicali already had 525 industrial establishments and by the end of 1950, construction of the first maquiladora plants began in Mexicali; by 1996 there were 182 maquiladoras.

As far as agriculture is concerned, this was the first type of activity that took place in the valley of Mexicali, reaching its peak in the 1950s. However, agricultural industry has been displaced as the major activity due to the shift of the active labor force to the maquiladora industry. The main crops in terms of surface area covered in the valley of Mexicali, are wheat, cotton, alfalfa, and vegetables, among others.

Currently, 14% of the economically active population is employed in the primary sector, 18% in the secondary sector, and 36% in the tertiary sector, which covers trade and services.

Table 3.3 shows the main activities related to the transformation of goods and resources divided by subsectors. All economic activities that use machinery, equipment and substances that may emit some kind of air pollutant are included in this table.

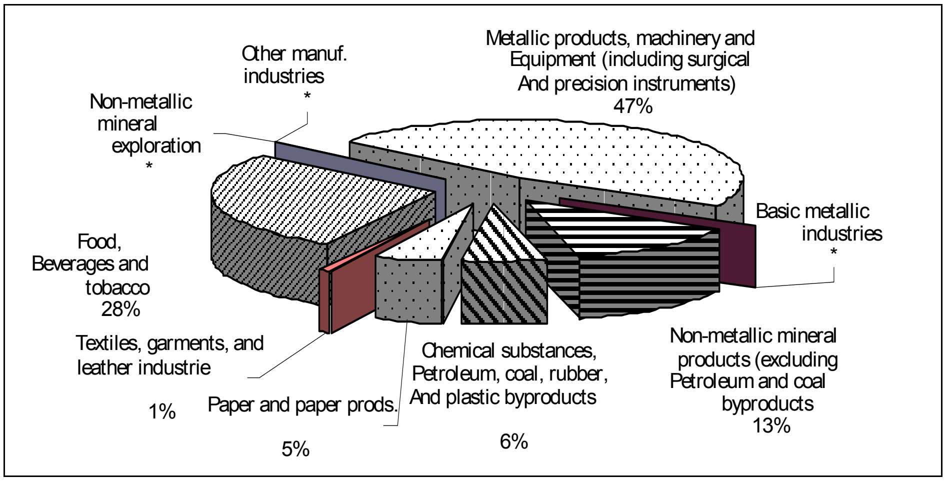
Table 3.3 Manufacturing establishments by subsector, 1993

Subsector	**Economic units**	**Work force**	**Total production (1,000 pesos)**
Non-metallic mineral exploitation	27	118	4,111
Food products, beverages and tobacco	111	1,025	252,7030
Textiles, garments and leather	5	292	3,974
Paper and paper products	21	985	187,992
Chemical substances, and byproducts of petroleum, coal, rubber and plastics	22	1,750	293,616
Non-metallic mineral products, excluding coal and petroleum byproducts	52	1,677	408,517
Basic metallic industries	*	437	94
Metallic products, machinery and equipment, including surgical and precision instruments	185	9,885	868,032
Other manufacturing industries	*	63	2,073

* Data was omitted to preserve confidentiality.
Source: XIV Censo Industrial, Censos Económicos 1994, Baja California, INEGI.

As shown in Figure 3.4, the subsector including metallic products, machinery and equipment in Mexicali, represents 47% of the manufacturing sector in Mexicali. This reflects the large number of establishments that manufacture metallic structures, tanks and industrial ovens. Food products, beverages and tobacco represent 28%; non-metallic mineral production, 13%; chemical substances and petroleum and coal byproducts, 6%; paper industry 5%; and, textiles garments and leather, 1%.

Figure 3.4. Manufacturing economic units by subsector



Another source of jobs are small industries and commercial establishments, which employ a small number of individuals (Table 3.4).

Table 3.4. Service establishments by type of activity

Activity	Number of establish-ments	# of employ-ees	Total income (thousands of pesos)
Dyeing and laundry services	*	30	12,541
Equipment and machinery repair and maintenance services (including transportation equipment).	76	242	16,489
Motor vehicle repair and maintenance services	1,383	3,164	88,241
Land transportation related services	24	185	7,259
Air transportation related services	*	78	7,635

* Data was omitted to preserve confidentiality.
Source: XI Censo de Servicios, Censos Económicos 1994, Baja California, INEGI.

3. Urban and roadway characteristics

Roadways

The urban zone of the city of Mexicali consists of a network of irregular streets, located on predominantly flat terrain, with a total length of 1,800 kilometers. There are several ways to access the city. From the north, it can be accessed by any of the streets leading to the border with the US. From the east, the main access is the highway to San Luis Río Colorado. From the south, the highway that leads to San Felipe; and, from the west, the highway to Tijuana. The roadways that carry the largest volume of vehicular traffic include the following boulevards: Lázaro Cárde-

Cárdenas, López Mateos, Benito Juárez, Francisco L. Montejano, Anáhuac, and Carranza; causeways: Justo Sierra, Independencia, Cuauhtémoc and Manuel Gómez Morín; avenues: Madero, Colón, Sinaloa, Zaragoza; and, Río Culiacán street. These roadways have different lengths and have a different number of lanes. It is important to mention that in 1996, only 62% of the roadways were paved.

Vehicular fleet

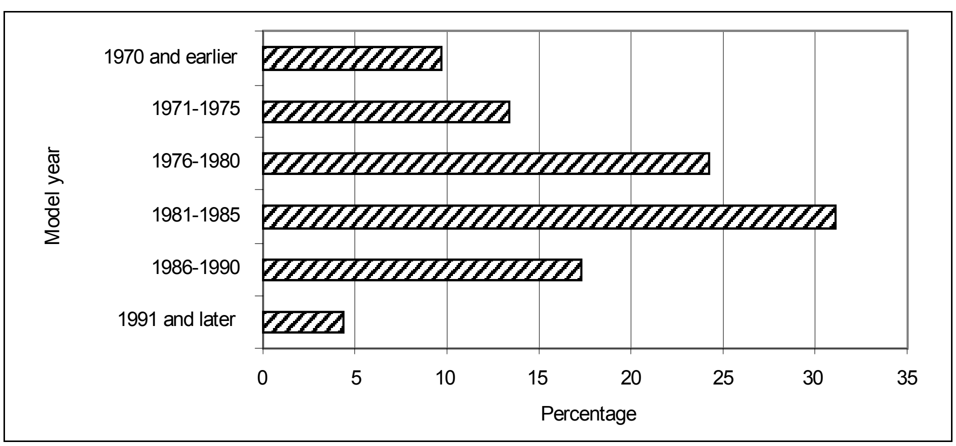
The number of officially registered vehicles in Mexicali is 240,810. 90% of those vehicles are registered in the state and are restricted to circulate in the northern border zone. In general, vehicles have several years of use and the majority of them have had their pollution control systems tampered with. As can be seen in Table 3.5, private vehicles comprise 70% of the vehicular fleet and pick-up trucks 19%. Likewise, Figure 3.5 shows that more than 45% of the vehicular fleet are vehicles from 1980 and earlier, 48% are from 1981 to 1990, and almost 4% are from 1991 to the present.

Table 3.5. Vehicular Fleet in Mexicali

Type	Number of vehicles	%
Private Vehicles	168,160	69.8
Taxi Cabs	1,105	0.5
Pick-up Trucks	46,005	19.1
Passenger Trucks	1.060	0.4
Freight Trucks	23,529	9.8
Motorcycles	951	0.4
Total	240,810	100.0

Source: Secretaría de Planeación y Finanzas del Gob. del Edo., 1996.

Figure 3.5. Age of the vehicular fleet

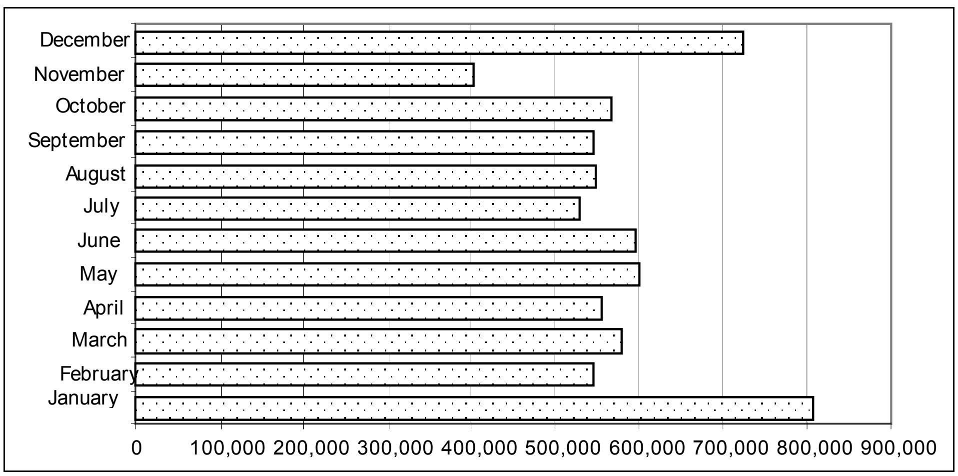


International border crossings

This zone has two ports of entry (POE). The first of these is located in downtown Mexicali and connects with the commercial area of Calexico. Only private vehicles and pedestrians are allowed to use this POE. The US Immigration and Naturalization Service keeps track of the number of vehicles crossing the border through this station, with the greatest flow occurring in the months of December and January. In 1996 a total of 6,989,639 vehicles crossed the border (Figure 3.6). Considering an average idle time of 3.5 minutes per vehicle, this part of the city would be impacted by air pollutant emissions totaling 400,000 hours-engine per year.

Unlike other border cities, it is believed that the majority of people using the Mexicali-Imperial Valley border crossings do it to go shopping and visit relatives, with very few people crossing to study on the US side or for work purposes.

Figure 3.6. Number of vehicles that crossed into the US in 1996



Source: US Immigration and Naturalization Service, 1996.

Soil Uses

As mentioned earlier, the municipality of Mexicali has a total surface area of 13,936 km^2, 115 km^2 of which correspond to the urban area in the city of Mexicali. Of this area, 61% is occupied by houses, 6% by commerce and services, 7% by industry, 4% green areas, 6% roadways, and 16% barren lots (Table 3.6).

Table 3.6. Soil Uses

Soil uses	**Area in km^2**	**%**

Houses	70.2	61
Commerce and services	6.9	6
Industry	8.1	7
Green areas	4.6	4
Roadways	6.9	6
Barren lots	18.4	16

Source: Ayuntamiento de Mexicali, Programa de Desarrollo Urbano 1993-2007.

Urban development

Urban growth in the city of Mexicali during the last few years has been balanced. Most of the expansion has taken place on the east and southeast sides of the city, with a less noticeable growth on the western part of the city. Much of the growth in housing has been in the form of social and public housing developments, equipped with all the basic urban utilities, with the exception of road paving. Commercial and service zones are located in the central part of the city, with adequate traffic flow in most parts of the city.

4. Air quality management in Mexicali and its binational airshed

Air quality management in the Mexicali-Imperial Valley binational airshed includes the joint work of different agencies at the three different levels of government, in order to achieve the objectives that have been set for different projects. These activities are coordinated by the Federal Delegation from SEMARNAP in the State of Baja California, which presides over the air quality meetings. In order to accomplish its tasks, SEMARNAP receives support from the National Institute of Ecology (INE) and the Federal Attorney's Office for Environmental Protection (PROFEPA). INE accomplishes its policy functions through the Subdelegation on the Environment. This Subdelegation issues annual operating permits, which are used to develop the emissions inventory for industrial sources that fall under federal jurisdiction. Furthermore, this office provides air quality monitoring data. PROFEPA is in charge of enforcement in the industrial sector for those emissions that are generated by different industries that fall within the norm.

The State Government, through "Dirección de Ecología", regulates those sources that fall under state jurisdiction. In order to accomplish its functions, it delegates responsibility to the Municipal Director of Ecology. These two agencies work together to integrate the air emissions inventory for the city.

As far as Border XXI is concerned, Region IX of the US Environmental Protection Agency (which includes California, Arizona, Nevada, Hawaii and the Pacific Islands, with headquarters in San Francisco) is actively involved in Mexicali's air quality program, supporting with the installation and operation of the Air Quality Monitoring Network. Region IX has also granted resources to the Western Governors' Association for the development of the emissions inventory, and to other organizations such as the Center for Information on Air Pollution (CICA), to conduct other studies. The

California Air Resources Board (CARB) is the US state organization that has supervised the operation of the air quality monitoring network in Mexicali and it is involved in the air quality projects that are conducted in the binational airshed.

The following is a brief description of the 1983 La Paz Agreement, its BEIP programs, and Border XXI; as well as the activities of the Border XXI Air Quality Workgroup in the region of Mexicali-Imperial Valley.

1983 La Paz Agreement 1983

The formal joint efforts of the US and Mexico to protect and improve the environment in the border zone began in 1983. That year, both countries signed the *Agreement between the United States of America and the United Mexican States on Cooperation Regarding the Protection and Improvement of the Environment in the Border Area*, known as “La Paz Agreement”.

This agreement establishes a series of objectives in the subject of border environmental cooperation, a mechanism for additional agreements, annexes and technical actions, as well as carrying out high level meetings, and special techniques for promoting and fostering cooperation between the two countries. Likewise, it establishes formal communication procedures between the two countries and orders the nomination of National Coordinators to direct and supervise its activities.

The La Paz Agreement regulates the framework of cooperation between Mexican and US authorities to prevent, reduce and eliminate air, water and soil pollution sources in the 100 km zone on either side of the international border. The Agreement creates the general structure for the specific projects contained in its five technical annexes. Some air quality issues are covered in Annex IV: *Agreement between the United States of America and the United Mexican States on Cooperation Regarding Transboundary Air Pollution caused by Copper Smelters Located Along their Common Border, and in Annex V: Agreement between the United States of America and the United Mexican States on Cooperation Regarding International Transport of Urban Air Pollution.* The 1992-94 Border Environment Integration Program and the Border XXI Program, both of which are described in the following pages, were developed under the auspices of the La Paz Agreement. It is important to mention that all air pollution related binational activities are currently being developed through the Air Quality Workgroup, and fall under the two previously mentioned annexes.

Annex G includes a copy of the La Paz Agreement and Annex V.

Border Environment Integration Program 1992-1994

Starting with the signing of the La Paz Agreement, began a series of technical activities channeled through and incorporated to the *Border Environment Integration Program 1992-1994 (BEIP)*, unveiled in February, 1992. During this collaborative stage, PIAF made the commitment of tackling the most serious border environmental problems. It also recognized the lack of a complete knowledge regarding environmental conditions along the border, which turned it into a plan that would gradually evolve in light of the new findings that were acquired during its development.

PIAF also recognized that its success depends on collective effort and that it is necessary to involve state and municipal governments, businesses and commercial associations, NGOs, academic institutions, and the public, in order to achieve its formulated goals.

The objectives set forth by PIAF were the following: i) enforcement of compliance with existing legislation, ii) pollution reduction through new initiatives, iii) increase in cooperation for planning, training and education, and iv) greater knowledge of the border environment.

Some relevant actions taken regarding air quality include the creation of workgroups to comply with environmental regulations, pollution prevention, and particularly, the actions taken to reduce pollution through new initiatives concerning industrial source control. Likewise, paving projects were created to reduce particulate emissions, and to improve roads, bridges and vehicular flow, mainly in urban areas with heavy traffic.

Specifically, PIAF led the way for a series of joint activities in the Mexicali-Calexico region, such as the first air quality studies.

Border XXI Program

As mentioned earlier, Annex V to the La Paz Agreement directs the US and Mexico to assess the causes of and develop solutions to air quality problems in border sister cities.

The Border XXI Program, unveiled in 1996, is an innovative binational effort which brings together the diverse US and Mexican federal entities responsible for the shared border environment to work cooperatively toward sustainable development through protection of human health, the environment, and proper management of natural resources in both countries.

The Border XXI Program defines medium and long-term environmental objectives, as well as the mechanisms to implement them in the border region; it is the product of a broad public participation process, including the public, state and local governments, federal agencies, non-governmental organizations, and public advisory committees. During its development, important efforts were made to incorporate public comments.

The Program reflects a new institutional arrangement created with the signing of the North American Free Trade Agreement (NAFTA), in 1993. It also relies on a close coordination with the Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADB), both of which support the development of environmental infrastructure along the border. Also, Border XXI will coordinate its efforts with the Commission for Environmental Cooperation (CEC), which was created within the framework of NAFTA with the purpose of promoting environmental cooperation in the border region.

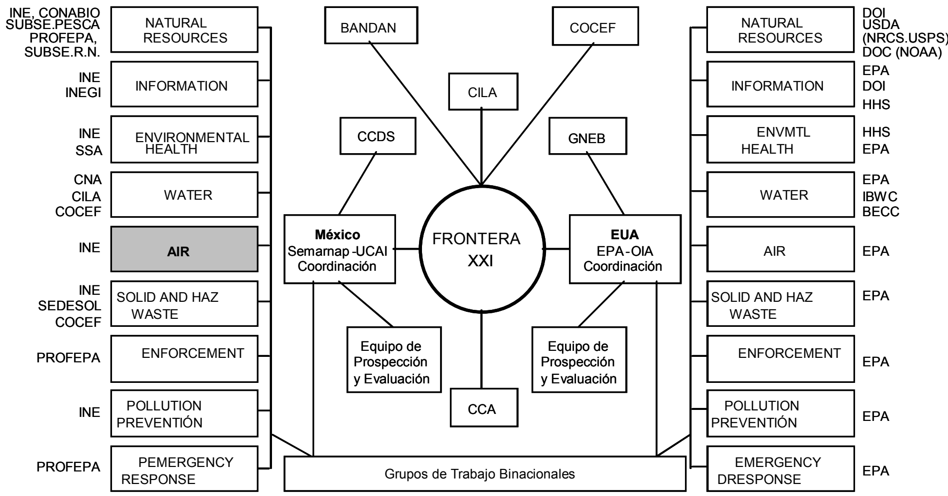
The Program considers three strategies in advancing its goal of sustainable development:

- Ensure public involvement in the development and implementation of the Border XXI Program.
- Build local capacity and decentralize environmental management in order to augment the participation of state and local institutions in implementing the Border XXI Program.
- Ensure interagency cooperation to maximize available resources and avoid duplicative efforts on the part of government and other organizations, and reduce the burden that coordination with multiple entities places on border communities.

The way this Program operates is shown on the organizational chart in Figure 3.7. The direction of the Program is entrusted on the National Coordinators. There are currently nine workgroups, six of which are coordinated by the National Institute of Ecology (INE), as shown in Figure 3.7. The Co-Chairs of the binational Workgroups are responsible for coordinating the activities of the different technical workgroups. Particularly, the Air Quality Workgroup is coordinated by one representative each, from EPA and INE.

Mexico's National Institute of Ecology and the United States Environmental Protection Agency, have respectively developed a set of national strategies to improve air quality; those strategies are based on the air quality standards for each country. Both countries have established similar air quality standards for carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, PM10, and lead, although recently the EPA revised and updated its standards for ozone and particulate matter.

Figure 3.7. Border XXI Program Organizational Chart



The parties involved in the Border XXI Air Quality Workgroup seek greater collaboration between border environmental entities, in order to improve air quality along the US-Mexico border zone. In order to accomplish this, the Workgroup continues its efforts through the Sub-Workgroups, one of which is the Mexicali-Imperial Valley Sub-Workgroup.

Due to the nature of the air quality problem, there is a close link between the Air Quality Workgroup and the Pollution Prevention, Environmental Information Resources, and Environmental Health Workgroups, since they are all transverse subjects requiring joint analysis and action.

A prime element of Border XXI is the development of goals and environmental indicators or success measures to monitor progress in the achievement of long-term objectives within the Program, as well as the agreements to accomplish decentralization actions along Mexico's northern strip.

The air quality objectives formulated in the Program for the next five years, from the time the Program was established, were the following:

- Develop air quality assessment and improvement programs (monitoring, emissions inventories and modeling, among others).
- Continue to build institutional infrastructure and expertise in the border region.
- Encourage public involvement.
- Review and recommend implementation of air pollution abatement strategies, geared toward vehicular, industrial and natural sources.
- Study the potential of using financial incentive programs to reduce air pollution.

As mentioned earlier, the Air Quality Workgroup conducts its activities through Sister City Sub-Workgroups and through projects that extend along the length of the border, as indicated in Table 3.7.

Table 3.7. Subworkgroups and projects led by the Border XXI Air Quality Workgroup

Subgroups
• Air Programs in San Diego-Tijuana • Air Programs in Imperial Valley-Mexicali • Air Programs in Ambos Nogales • Air Programs in Douglas-Agua Prieta • Air Programs in El Paso-Sunland Park-Ciudad Juárez • Air Programs in Brownsville-Laredo • Aire Quality and Energy • Vehicular Traffic at Border Crossings • Air Quality in Big Bend
Projects
• Air Quality Monitoring in Mexicali and Tijuana • Intensive Air Quality Monitoring Study in California-Baja California • Program to Develop an Emissions Inventory for Mexico • Project to develop an Emissions Inventory for Mexicali • Project to develop an Emissions Inventory for Tijuana • US-Mexico Border Information Center on Air Pollution (CICA) • Air Pollution training program for Mexico • Methods to Calculate Emissions from Unique Sources in Mexicali • Joint Advisory Committee to Improve Air Quality in Ciudad Juárez-El Paso-Doña Ana County

The Workgroup continues its regional efforts to promote and reinforce air quality monitoring networks, develop emissions inventories, and model air quality in order to analyze pollutant dispersion and formation. The Workgroup also promotes the development of air quality improvement programs and strategies that can be used as tools by local environmental managers to characterize the interrelations between air quality, land use, transportation planning, and economic development.

The Air Quality Workgroup works closely with the state and local governments, the public, the private sector, academic institutions, as well as non-governmental organizations for the management of air quality in the region. Several of the studies developed under the Workgroup's coordination will be described later in this chapter.

Some of the most relevant projects include: the creation of the US-Mexico Border Information Center on Air Pollution (CICA), which operates under the EPA's auspices, providing free advice and information on air pollution related matters and sponsoring technical studies about border-specific subjects; and, the development of the Emissions Inventory Methodology for Mexico, with the support of the Western Governors Association (WGA), which has allowed for the first time in Mexico, the development of a series of manuals, a training course that has been successfully taught in different cities around the country, and the integration of the emissions inventories for Mexicali and Tijuana. These activities are described in greater detail in

INEs web page (http://*www.ine.gob.m*x) and the necessary links to access CICA and WGAs web pages are provided.

As a result of the public comments received for the Border XXI Program, the Air Quality Workgroup directed some resources to form two new sub-workgroups. The energy sub-workgroup, whose objective is to promote energy efficiency and thus air pollution reduction, and the border vehicular congestion sub-workgroup, which will provide possible mechanisms for reducing air pollution resulting from motor vehicle congestion at the border crossings.

5. Previous air quality studies and programs in Mexicali-Imperial Valley

The following is a summary of results from research and studies conducted during the last few years to characterize air pollution sources and the air quality situation in the Mexicali-Imperial Valley region. Special attention is given to those studies that tend to provide a better understanding of the processes leading to a high concentration of particulate matter and a brief description is given of those studies that are currently underway or about to get underway.

Imperial Valley Environmental Project: Air Quality Assessment (Ermak *et al*, 1979)[1]

According to this report, “the use of geothermal resources in Imperial Valley will begin in 1980, with the building of the first geothermal power plants, with an approximate generating capacity of 50 megawatts (MW).” Also, it emphasizes that during the next 20 to 30 years, energy production would increase by several thousand MW.

The study includes an assessment of the potential impact this project would have, based on predictions from the model ATMAS (A Three-dimensional Atmospheric Transport Model to Treat Multiple Area Sources). The main assessment corresponds to the scenario that assumes total production of 3,000 MW, generated by 30 geothermal power plants, each with a capacity of 100 MW, distributed throughout the valley in the following manner: 14 in Salton Sea, 6 in Brawley, 7 in Heber, and 3 in East Mesa.

The input used for the transport model consisted of meteorological data gathered through one year of continuous monitoring at six different locations in the Valley, and emissions data calculated on the basis of energy conversion efficiency consis-

[1] Ermak, D.L., Nyholm, R.A. and Gudiksen, P.H. (1979). Imperial Valley Environmental Project: Air Quality Assessment. Work performed under the auspices of the U.S. Department of Energy by the University of California-Lawrence Livermore Laboratory, under contract number W-7405-ENG-48. Distribution category UC-66 (UCRL-52699).

tent with the temperature of the geothermal fluid. It is important to mention that this study does not consider any emissions reduction, as a result of the use of some control strategy, and that the concentration levels of the different pollutants, calculated using the atmospheric transport model, are only due to the proposed geothermal sources. The contaminants that were evaluated in this study included carbon dioxide, sulfhydric acid, ammonia, mercury and radon.

In addition to the results obtained from simulations, the authors reviewed the environmental records that were available at the time, for sulfhydric acid and sulfur dioxide. They found out that, with the exception of occasional episodes, sulfhydric acid concentrations were less than 15 $\mu g/m^3$. The referred episodes showed a random occurrence throughout the year and could be due, at least in part, to agricultural fertilization activities. With respect to sulfur dioxide concentrations, these were generally below 50 $\mu g/m^3$, with occasional exceedances of this value.

Program plan for the study of PM10 source apportionment in Mexicali/Imperial Valley (Watson *et al,* 1991)[2]

In 1991, the EPA decided to sponsor a study to assess PM10 source apportionment in Mexicali Imperial Valley, taking into consideration that, since 1985, PM10 ambient concentrations in Imperial Valley have exceeded the US air quality standard; at the time there was not enough information available to estimate the specific contribution of the different sources; and, consequently, it was not possible to develop control strategies for this pollutant. The general objective was to develop a monitoring and data analysis plan aimed at: 1) estimating the spatial and temporal distribution of PM10 concentrations in Mexicali-Imperial Valley; 2) estimating PM10 apportionment for the different emissions sources; 3) estimating PM10 transboundary transport.

Generally, existing monitoring, meteorology and emissions data are reviewed, in order to identify information needs and to design the plan. Some of the most relevant information includes the fact that, according to Imperial Valley's 1987 emissions inventory, the daily emissions rate for total organic gases was 31 tons, 28 tons/day of reactive organic gases, 130 tons/day of carbon monoxide, 31 tons/day of nitrogen oxides, 2 tons/day of sulfur oxides, and 950 tons/day of PM10. According to the same inventory, 98% of PM10 total emissions correspond to fugitive emissions, originating mainly from agricultural, construction and demolition activities, paved and unpaved roads, suspended dust.

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[2] Watson, J.G., Chow J.C., Egami T.R., Frazier A.C. and Lowenthal D. (1991). Program Plan for the Imperial Valley/Mexicali PM10 Source Apportionment Study. DRI document No. 8623.1d2. Draft Report prepared by Desert Research Institute for EPA Region IX, San Francisco, California.

The document also points out the need for developing an emissions inventory of Mexicali, since most of the Valley's population lives in that region. However, this important air quality management tool was still lacking at the time.

Regarding climatology, this document points out that Imperial Valley is hot and dry. In the same manner, it indicates that the meteorology of the zone can be well represented by the data obtained at the Yuma airport in 1987. These data establish that stable or light wind conditions prevail at midnight throughout the year, with fall (represented by the month of October) being the season of greater stability, since 70% of the time light winds were recorded. At night, winds are from the west in the spring and fall seasons, from the north in the winter, and from the southwest in the summer. During the morning hours the prevailing wind direction is from the north and northeast throughout the year, except in July when winds come from the east and southeast. Generally, 50% of the wind velocities in the morning hours fall below 0.5 m/s. In the afternoon hours, light winds are recorded less than 5% of the time. Prevailing winds are from the north during the winter, from the west during the spring and fall, and from the south during the summer.

Even though there was no information available regarding the vertical profile of temperature, it is possible that inversions at the lower levels are formed quickly after sunset, due to heat loss through radiation on the surface of the Imperial Valley Desert. During the winter, spring and summer months, the mixing layer probably does not reach the atmosphere until the end of the morning, which could keep pollutants trapped during this period.

Another important characteristic regarding meteorology that is emphasized in this document is that, according to the estimated wind pattern for Imperial Valley, it is possible that transport occurs from Imperial Valley to Mexico during the winter and from Mexico to Imperial Valley during the summer.

As far as historical environmental data are concerned, the document mentions that the average annual and 24-hour PM10 concentrations measured at Imperial Valley in 1989 (at the Brawley, El Centro and Mexicali stations), are the highest in the state of California. PM10 24-hour concentrations frequently exceed 150 $\mu g/m^3$. In fact, the average PM10 24-hour reading for Calexico in 1989 was 606 $\mu g/m^3$. Regarding the PM10 annual average, 50% of the samples exceeded the US standard of 50 $\mu g/m^3$, with 138 $\mu g/m^3$ being the highest reading of 1989.

Furthermore, this document describes in detail the models to use in estimating PM10 source apportionment, the period, frequency, duration, and the sampling sites, laboratory activities and quality control and quality assurance procedures that would be considered in the development of the study.

Imperial Valley-Mexicali Cross-Border PM10 Transport Study (Chow *et al*, 1995)[3]

The EPA sponsored a three-year study (1991-94), as part of the 1983 La Paz Agreement between Mexico and the United States, to determine the effects from the transport of suspended particles across the border between Imperial Valley and Mexicali, on recorded exceedances of the United States' PM10 standard. The technical objectives of the study were the following: a) create a database to determine the contribution of the different sources to high concentrations of PM10; b) estimate the spatial and temporal distribution of PM10 in Imperial Valley and Mexicali; and, c) estimate the transboundary transport of PM10.

This study included a source apportionment assessment, which required the measurement and characterization of emissions from each of the main emissions sources, in Imperial Valley as well as Mexicali. The emissions profiles obtained were used in receptor models with the purpose of estimating the contribution from each source to the measured concentrations of PM10 in each of the receptor areas. This study also included different periods of intensive monitoring to characterize the meteorological conditions and the emissions during different times of the year (winter, spring and summer).

The main conclusions that were drawn from this measuring and modeling effort are summarized as follows:

- PM10 mass, ions (e.g. nitrate, sulfate, ammonium), crustal species (e.g. aluminum, silicon, potassium, calcium, manganese, iron, zinc), and combustion/motor vehicle related species (e.g. organic carbon, elemental carbon, light absorption, soluble potassium, chorine, bromine, lead), were found above the lower quantifiable limits (LQLs), in more than 95% of the PM10 samples. Nickel and vanadium were detected in 65% and 36% of the samples, respectively. Other metals (e.g., molybdenum, palladium, indium, tin, antimony, thallium) were detected in less than 10% of the samples, which is consistent with amounts reported in other US urban areas.
- Industrial-source-related toxic species such as arsenic, cadmium, selenium, and mercury were detected in less than 5% of the samples with the exception of selenium, which was found above the LQLs in more than 50% of the samples.
- PM_{10} mass concentrations at the Calexico base site were only moderately correlated ($0.49<r<0.55$) with PM_{10} measured at the Mexicali base site. This implies that local sources within a few kilometers of the site have a major impact on PM_{10} measurements. According to this study, PM_{10} mass concentra-

[3] Chow, C.J. and Watson, G.J. (1995). Imperial Valley/Mexicali Cross Border PM10 Transport Study. Draft Final Report. Prepared for U.S. Environmental Protection Agency, Region IX, by Desert Research Institute. DRI Document No. 8623.2D1.

tions at the Mexicali site were consistently 30% to 50% higher than those observed at the Calexico site.

- During the monitoring program, the twenty-four hour PM_{10} standard of 150 $\mu g/m^3$ was exceeded on eight days at one or more of the measurement locations. The standard was exceeded twice at the Brawley site, once at the El Centro site, six times at the Calexico Police and Fire Station site, and three times at the Calexico base site. For the same monitoring period, PM_{10} concentrations exceed 150 $\mu g/m^3$ on 23 occasions at the Mexicali base site.
- At the Calexico base site, the highest PM_{10} concentration measured of 223 $\mu g/m^3$ occurred on December 2, 1992. The second highest PM_{10} concentration of 194 $\mu g/m^3$ at the Calexico site occurred on October 9, 1992. At the Mexicali site, the highest concentration of 462 $\mu g/m^3$ occurred on December 24, 1992. The second highest concentration at Mexicali was 452 $\mu g/m^3$ on December 16, 1992.
- Annual average PM_{10} mass concentrations at the Calexico site exceeded the federal annual PM_{10} standard of 50 $\mu g/m^3$ by more than 20%. Unstratified annual average PM_{10} mass concentrations between 09/03/92 and 08/29/93 were 62 " 43 $\mu g/m^3$ at the Calexico site and 126 " 106 $\mu g/m^3$ at the Mexicali site. Crustal species accounted for approximately 32% to 35% of the annual average PM_{10} mass, whereas organic carbon accounted for approximately 15% to 20% of the annual average PM_{10} mass at the two sites. Although the relative proportions of the major source types were similar at the two base sites, the absolute PM_{10} chemical concentrations for soil-related species (e.g. aluminum, silicon, potassium, titanium, calcium, iron, zinc), motor vehicle related species (e.g. bromine, lead), residual oil combustion related species (e.g. nickel, vanadium), and organic and elemental carbon, were a factor of two to three higher at the Mexicali site than the corresponding measurements at the Calexico site.
- Hourly PM_{10} concentrations at Calexico showed a distinct and reproducible diurnal pattern, with elevated peaks appearing between 7 and 8 o'clock in the morning and 8 and 9 o'clock in the evening. These peaks corresponded to the morning and evening traffic patterns and evening cooking activities (note that dinnertime in Mexico is generally between 8 and 9 o'clock in the evening). Six-hour average PM_{10} concentrations often varied by more than a factor of two through the day, with the lowest concentrations generally observed during the afternoon hours.
- Spatial receptor modeling with Receptor Model Applied to Patterns in Space (RMAPS) reported three source vectors: 1) combustion sources such as motor vehicle exhaust and vegetative field burning; 2) industrial and marine aerosol; and 3) geological material.
- Principal component analysis (PCA) identified four source types: 1) geological material; 2) combustion sources (i.e. a combination of motor vehicle exhaust and vegetative burning emissions); 3) marine aerosol; and 4) secon-

dary sulfate. Geological material is the most significant source, followed by combustion sources, marine aerosols, and secondary sulfates.

- Chemical mass balance (CMB) receptor modeling confirmed the PCA modeling results with quantitative source contribution estimates. The CMB results show that the relative source mix at the two base sites was similar, on average, even though the absolute PM_{10} mass concentrations and source contributions were approximately twice as high at the Mexicali site compared to the Calexico site.
- Primary geological material was the single largest contributor during all periods, accounting for over 70% of the PM_{10} mass on average. Significant day-to-day variations were found in geological material source contributions. For example, on a windy day like August 23, 1993, geological material accounted for over 90% of the PM_{10} mass at the Calexico site.
- Primary motor vehicle exhaust was the second largest contributor, accounting for 10% to 15% of the PM_{10} mass, whereas primary vegetative burning accounted for 4% to 8% of the PM_{10} mass. Finally, contributions from primary marine aerosols accounted for 2% to 3%, whereas the contribution from industrial sources was insignificant or undetectable.
- For the summer and winter intensive sampling periods, maximum source contributions were found mostly during nighttime periods (between 6 o'clock in the evening and midnight), with the lowest contributions found during afternoon periods (between noon and 6 o'clock in the evening). For the spring intensive sampling period, maximum source contributions usually occurred during morning periods (between 6 o'clock in the morning and noon), with lowest contributions found during the early morning hours (between midnight and 6 o'clock in the morning).
- Meteorological analysis shows that air flow in the study area is channeled by the Imperial Valley and is usually from the northwest or southeast, with northwesterly winds prevailing. Hourly PM_{10} concentrations were larger during southerly flow than during northerly flow.
- This analysis also showed that during light wind conditions (winds velocity less than 2 m/s), there was no prevailing wind direction. However, during moderate (1.1 to 5 m/s) or strong (>5 m/s) wind conditions, wind direction was mainly from the northwest or southeast, and rarely from the southwest or northeast. The transport of air pollutants across the US-Mexico international border is a consequence of the distribution in wind direction. In Calexico, northerly flow (i.e. transport into Mexico) occurred approximately two thirds of the time, whereas southerly flow (i.e. transport from Mexico) occurred only one third of the time. Wind flow from Mexico was slightly more frequent in the summer than in the winter.
- During the study period, eight days had 24-hour PM_{10} concentrations exceeding the US standard of 150 $\mu g/m^3$ at one or more Imperial Valley monitoring sites. Two of those days (i.e., January 25 and March 14, 1993) had consistent flow from the northwest, which rules out PM_{10} transport from Mexico.

- Five of the exceedance days (i.e. March 13, October 9, December 2, 1992; and, January 19 and March 20, 1993) were associated with atmospheric stagnation conditions. On these days, Calexico and Mexicali emissions might mingle on both sides of the border. It is unlikely, however, that sites in El Centro and Brawley would receive significant contributions from Mexican sources. For example, on January 19, 1993, the concentration in Brawley exceeded the standard, but concentrations were low in Calexico, so this exceedance cannot be attributed to Mexican sources. On March 13, 1992, only the Calexico Fire and Police Station site measured an exceedance, and this cannot be attributed to transport from Mexico because concentrations were low at the Mexicali site. On October 9 and December 2, 1992, high values were reported at all sites. Therefore, only the episode on August 23, 1993 seems to have been dominated by transport from Mexico.
- Finally, winter PM_{10} concentrations were generally higher than spring and summer PM_{10} concentrations, and meteorological conditions significantly affect PM_{10} concentrations.

PM10 State Implementation Plan for Imperial Valley (Fields *et al*, 1993)[4]

In 1987, the US Environmental Protection Agency designated Imperial Valley as a PM10 non-attainment area, which led to the development of a State Implementation Plan (SIP), in accordance with the 1990 Amendment to the Clean Air Act.

This SIP had the purpose of showing how US air quality standards could be met in Imperial Valley by 1994. It was developed based on a 1989 emissions inventory, another emissions inventory projected for 1994, and PM10 ambient measurements collected from December 1986 through November 1992 at three monitoring sites (Brawley, El Centro y Caléxico).

The methodology used in the development of the SIP included the following: a) PM10 ambient data analysis, b) review of relevant meteorological data to determine if meteorological conditions had an impact on ambient PM10 levels, c) PM10 design value calculations based on ambient data for this pollutant (design values provide base concentrations used to determine the necessary reduction in PM10 to comply with current standards), d) emissions inventory review, e) determining the relative contribution of fugitive dust emissions to PM10 ambient levels; and, f) determining control strategies.

Some of the most relevant results of this study indicate that the PM10 problem in this zone is mainly due to dust emissions originating from sources such as paved

[4] Fields, G.P., Houdashelt, C.L. and Carlson, P. (1993). State Implementation Plan for PM10 in the Imperial Valley. Final report prepared for Imperial County Air Pollution Control District, by E.H. Pechan and Associates, Inc. Pechan report No. 93.04.006/449.

and unpaved road vehicular traffic, wind erosion in agricultural fields and construction. Likewise, the emissions inventory indicated that natural sources (wind erosion on agricultural fields and unpaved roads) were the main source of PM10 emissions in Imperial Valley (860 tons/day or 90% of total PM10). It is also emphasized that the maximum PM10 historical readings for a 24-hour period were recorded on July 9, 1989 in Brawley (645 μg/m^3) and on June 15 of the same year in El Centro (287 μg/m^3). However, it is important to note that the reading that was recorded in Brawley was probably due to equipment malfunction and that the second highest reading for that site (368 μg/m^3) occurred on September 18, 1988.

A series of control measures were identified and recommended for the four main sources of PM10 emissions: (1) wind erosion, (2) unpaved roads, (3) paved roads, and (4) construction activities. These control measures came as a result of data analysis and consultation with staff from the following agencies: Imperial County Department of Public Works, California Department of Transportation, Agricultural Soil Conservation Service, and the Imperial Valley Irrigation District. The net control efficiency for each strategy was estimated taking into account the efficiency of the specific control measures and the percentage of the total emissions from the object category (this was calculated based on the total area and vehicle miles traveled, among others.)

Table 3.8 shows the recommended control strategies and the efficiency of each of them.

Table 3.8 Control strategies recommended in the PM10 SIP for Imperial Valley

Emissions source	Control strategy	Net control efficiency
Wind erosion	• Restrict the use of off-road vehicles. • Establish dust control measures for stockpiling material. • Reduce the silt content in unpaved areas through paving or gravel.	0.2 %
Unpaved roads	• Prohibit the circulation of unauthorized vehicles in unpaved roads associated with irrigation canals. • Install automatic control gates at irrigation canals. • Reduce the silt content in unpaved roads through paving, gravel, vegetation, or chemical stabilization. • Reduce speed limits for vehicles.	32.2 %
Paved roads	• Repave damaged roads/batting. • Improve roads adjoining highways. • Reduce the amount of mud through the cleaning of paved, paving access ways and covering truckloads.	74.1 %
Construction	• Require dust control plans for construction or land cleaning projects including chemical treatment or paving of inactive sites; cleaning of paved roads and loading and unloading sites; covers over truck loads; and/or, use of wet dust suppressants for material handling and storage.	50 %

Methods to estimate emissions from various unique sources in Mexicali, Mexico (project No. CICA-96-02, under development)

The preliminary report titled "Mexican Emissions Inventory Methodology", prepared by Radian Corporation for the US Western Governors' Association and the Binational Air Workgroup, identifies several types of air polluting sources that may contribute significantly to the degradation of air quality in the border zone. The purpose of this study is to provide the necessary information to the appropriate agencies, in ordern to decide which methodologies must be used to establish emissions factors and develop emissions inventories for: 1) particulate matter less than 10 microns in diameter (PM10), hazardous air pollutants (HAPs), volatile organic compounds (VOCs) and nitrogen oxides (NOx), originating from cooking devices used by street vendors, and 2) VOC and HAP emissions originating from open lagoons and canals that store or carry wastewater.

Currently, this project is receiving comments on the Spanish and English versions of the first report that was prepared and should be soon finalized, distributed and made available through the CICA web site at: (http://www.epa.gov/ttn/catc/cica).

Study participants included: from Mexico, Instituto Nacional de Ecología; and, from the United States, US EPA Region 9 and Imperial County Air Pollution Control District.

Emissions from street vendor cooking devices (charcoal grilling) (project No. CICA-97-06, in progress)

The purpose of this project is to assess, through tests, the emissions from street vendor cooking devices, in accordance with the preliminary report CICA-96-02, described above. The following pollutants will be tested: particulate matter smaller than 2.5 microns in diameter (PM2.5), volatile organic compounds (VOCs), nitrogen oxides (NOx), and sulfur oxides (SOx). Also, cost-effective control technologies for these devices will be researched and tested. Street vendor cooking devices include a wide variety of activities where food is cooked on portable or fixed structures. The types of food that are prepared in these units include charbroiled beef to make tacos, burritos and other regional foods. These devices use charcoal or compressed gas and are found throughout the city. In some places, at dinnertime, street vendors set-up their food stands along the road, next to each other.

Study participants include: from Mexico, Instituto Nacional de Ecología and Dirección General de Ecología de Baja California; and, from the United States, US EPA Region IX, California Air Resources Board, Imperial County Air Pollution Control District and Air Pollution Control Division, National Risk Management Research Laboratory, and, Office of Research and Development.

Intensive air quality monitoring study in California-Baja California (in progress)

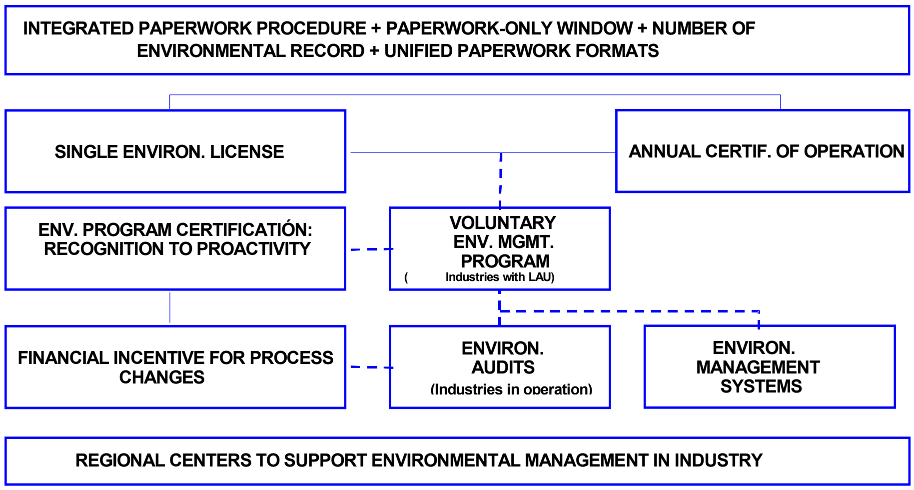
The objective is to carry out a special air quality monitoring study to provide the required additional information to develop the ozone, PM and carbon monoxide studies in accordance with the plans for the California-Baja California region. Furthermore, the study will generate the data to be used for integrating the Mexican northern border region into the regional photochemical modeling study of Southern California.

In order to verify and evaluate the emissions inventory developed for Baja California, CARB will consider the information generated by the Tijuana and Mexicali air-monitoring networks. The first phase of this study will provide ambient data on hydrocarbons and meteorological conditions, which will allow the use of source/receptor mathematical models to estimate the uncertainties in the emissions inventory. The second phase will provide meteorological data for the top layer of the atmosphere, as part of Southern California's ozone study. The third and fourth phases of this project will include the acquisition of equipment for emissions testing and will establish the basis for the voluntary emissions testing study in the ports of entry along the California-Baja California border. The vehicular emissions testing program will provide useful information to refine the emissions inventory for Mexicali-Imperial County and Tijuana-San Diego, and will provide additional information for the development of the Mobile-Mexico model.

Industrial regulation and environmental management in Baja California

In Baja California, like the rest of the country, a *Direct Regulation and Environmental Management Integrated System for the Industrial Sector (SIRG)* has been developed. This system has been formulated as an efficient instrument in formulating environmental policies and has the primary objective of fostering and facilitating the coordination, as far as direct regulation of the industrial sector is referred, between INE, CNA and PROFEPA. SIRG also promotes pollution prevention and minimization using a mullet-media approach, as well developing environmental management programs, generating annual integrated information for the National Environmental Information System, and contributing to the establishment of National Environmental Certification System, homologous to that of other countries. Its long-term perspective is to achieve coordination between the three levels of government, so that both federally as well as locally regulated industry are treated as a whole.

Figure 3.8. Basic components of SIRG



SIRG has as its main predecessor the Environmental Program 1995-2000, within the framework of the new approach to environmental policy that has been defined by SEMARNAP, and it incorporates the changes that were introduced through the December 1996 reforms to the General Law of Ecological Balance and Environmental Protection. When it was conceived, the precepts of the Environmental Protection and Industrial Competitiveness Program, signed by SEMARNAP, SECOFI and CONCAMIN in July 1995, were taken into account. Figure 3.8 shows the components of SIRG and the interrelationships between them.

SIRG, has three basic elements that are intimately related: Licencia Ambiental Única (Sole Environmental License), Cédula de Operación Anual (Annual Operation Certificate), and Programa Voluntario de Gestión Ambiental (Voluntary Environmental Management Program).

- *Sole Environmental License (LAU)* is the main component of the system. The Voluntary Environmental Management Program, a self-regulatory program to reduce industrial emissions, and other SIRG components, are developed around it. LAU is a direct regulatory instrument that integrates in a single procedure, the different environmental licenses issued by the federal authority.
- *Annual Operation Certificate (COA)*, is a follow-up instrument that must be complied with by industrial facilities, which provides information regarding emissions, discharges, and transfer of air, water and soil pollutants and waste. It also allows the evaluation of a company's environmental performance. The information obtained through the LAU and the COA will help integrate the Registry of Emissions and Pollutant Transfer (RETC), a basic component of the National Environmental Information System.

- *Voluntary Environmental Management Program (PVG),* has the main objective of favoring and fostering self-regulation in the industrial sector, emphasizing private interests in favor of productivity and competitiveness, and public interests in favor of environmental protection, based on compliance with current laws.

The following industrial sectors falling under federal jurisdiction must have an LAU: oil, petrochemical, chemical, paints and dyes, iron and steel, metallurgy, automotive, cellulose, paper, cement, lime, asbestos, glass, electric power generation, and hazardous materials treatment.

In order to be applied, SIRG requires the Integrated Paperwork Procedure, the Paperwork-Only Window, the Environmental Record Number, and the Unified Paperwork Formats.

Like the States of Querétaro and Chihuahua, INE has been promoting the State and Municipal integration of RETCs that allow authorities at the three levels of government to initiate the integrated regulation of the industrial sector.

For example, on April 10, 1998, the Federal Official Newspaper published the Coordination Agreement that was reached between SEMARNAP (INE), SEMARNAPs Federal Delegation in the State of Baja California, the State of Chihuahua, the Municipality of Juárez, and Juárez' Municipal Board on Water and Sanitation Issues. This agreement was reached with the purpose of conducting a pilot project in Ciudad Juárez to apply SIRG principles, incorporating industries of local jurisdiction and those with federal jurisdiction. This agreement will help support decentralization and institutional strengthening of environmental management, for the benefit of the industrial sector in Ciudad Juárez.

Another objective of the project is promoting pollution prevention in the local industrial sector, through the implementation of voluntary self-regulation programs that tend to reduce pollutant emissions and waste in the source, emphasizing process technologies in pollution control equipment, and corrective actions. The National Institute of Ecology will evaluate, issue a guidance, or agree with the interested parties, on the use of these technologies in their Voluntary Environmental Management Program.

The State of Chihuahua and the Municipality of Juárez are bound under this agreement to provide information regarding emissions sources within their jurisdiction, to the National Institute of Ecology (INE) for the integration of the RETC of the municipality.

4. AIR QUALITY

1. Air quality standards and effects from pollutants

In 1994, the government established standards for the concentration of air pollutants, with the purpose of providing an adequate margin of safety to protect the health of the general population and of the population at highest risk. The economic and technological aspects were not considered as determining factors in their design. The current air quality standards were published by Secretaría de Salud (the Ministry of Health) in the *Federal Official Newspaper* on December 23, 1994.

Air quality standards set maximum permissible values for the concentration of pollutants that are commonly present in urban areas. When these standards were developed, the resources and the infrastructure to conduct epidemiological, toxicological, and exposure studies, on animals as well as humans, were non-existent in Mexico. Those standards were developed basically taking into account the criteria and standards adopted in other countries. Currently, Secretaría de Salud is conducting epidemiological studies that value the dose/response relationship, between the different pollutants and the health of the population in some areas of the country, and is reviewing the standards for ozone and particulate matter.

Air pollutants present in Mexicali are measured through internationally accepted standardized procedures, which provide representative values for the air quality of Mexicali. Advances in technology and scientific knowledge about the health effects from air pollution set the stage for equipping continuous monitoring stations with far reaching remote sensors and other instruments to measure other toxic compounds.

Table 4.1 provides a summary of the current Official Mexican Standards related to ambient air quality, for ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), total suspended particles (TSP), particulate matter less than 10 microns in diameter (PM10), and lead (Pb).

US air quality standards are also provided due to the fact that the city of Mexicali is located along the US-Mexico border.

The US environmental Protection Agency (EPA), through Congress, issued the first amendments to the 1970 Clean Air Act to set, within a short period of time, National Ambient Air Quality Standards (NAAQS) and National Emissions Standards for hazardous air pollutants. Data used to develop these amendments were the result of occupational exposure studies and laboratory studies, rather than ambient exposure to these pollutants.

Table 4.1. Standardized values for air pollutants in Mexico

Pollutant	Boundary concentrations			Official Mexican Standards
	Acute exposure		Chronic exposure	
	Concentration and average time	Maximum acceptable frequency	(To protect the health of the population at highest risk)	
Ozone (O_3)	0.11 ppm (1 Hour)	once every 3 years	-	NOM-020-SSA1-1993
Carbon monoxide (CO)	11 ppm (8 Hours)	once a year	-	NOM-021-SSA1-1993
Sulfur dioxide (SO_2)	0.13 ppm (24 Hours)	once a year	0.03 ppm (annual arithmetic mean)	NOM-022-SSA1-1993
Nitrogen dioxide (NO_2)	0.21 ppm (1 Hour)	once a year	-	NOM-023-SSA1-1993
Total Suspended Particulate (TSP)	260 $\mu g/m^3$ (24 Hours)	once a year	75 $\mu g/m^3$ (annual arithmetic mean)	NOM-024-SSA1-1993
Particles less than 10µm (PM10)	150 $\mu g/m^3$ (24 Hours)	once a year	50 $\mu g/m^3$ (annual arithmetic mean)	NOM-025-SSA1-1993
Lead (Pb)	-	-	1.5 $\mu g/m^3$ (3-month arith. mean)	NOM-026-SSA1-1993

Source: Diario Oficial de la Federación – December 23, 1994.

In 1997 the EPA revised its standards for ozone and PM10, changing the former to a value of 0.08 ppm in a mobile average of 8 hours, instead of one hour, and proposed the use of a new standard for particulate matter less than 2.5 microns in diameter (PM2.5). On July 18, 1997, the EPA published the reforms to these standards; the revision of the concentrations set through these standards was mainly due to the important adverse health effects that these two pollutants have on the population. US standards are, in the most part, similar to those from Mexico and are shown in Table 4.2.

The EPA estimates that, by changing the value of these standards, it will be protecting 125 million people from the adverse health effects related to air pollution, including the prevention of approximately 15 thousand premature deaths and 350 thousand cases of asthma per year.

As was mentioned earlier, in Mexico Secretaría de Salud is currently revising ozone and PM regulations to determine the suitability of modifying current standards and/or introducing new PM2.5 standards in Mexico.

Table 4.2. Primary ambient air quality standards in the US

Pollutant	Boundary concentrations (Concentration and average time)	Compliance criterion
Ozone (O_3)	0.12 ppm* (1 hour)	Average of 1 exceedance over a 3 year period
	0.08 ppm (8 hours)	The 4th greatest daily exceedance, three year average
Carbon monoxide (CO)	9 ppm (8 hours)	Once a year
	35 ppm (1 hour)	Once a year

Sulfur dioxide (SO_2)	0.14 ppm (24 hours)	Once a year
	0.03 ppm (Annual average)	
Nitrogen dioxide (NO_2)	0.053 ppm (Annual average)	
Lead (Pb)	1.5 μg/m^3 (Quarterly average)	Once a year
Particles less than 10μm (PM10)	150 μg/m^3 (24 hours)	98% percentile of the annual distribution, 3-year average
	50 μg/m^3 (Annual average)	3-year average
Particles less than 2.5μm (PM2.5)	65 μg/m^3 (24 hours)	98% percentile of the annual distribution, 3-year average
	15 μg/m^3 (Annual average)	3-year average

Source: National Ambient Air Quality Standards, www.rtpnc.epa.gov/naaqsfin.

* Still in force in non-attainment areas, until these comply with the standard.

Effects of air pollutants on human health

Based on their origin, air pollutants can be classified as primary or secondary. *Primary pollutants* are those that are directly emitted into the atmosphere (nitrogen oxides, sulfur oxides, hydrocarbons, carbon monoxide, etc.). *Secondary pollutants* form in the atmosphere through photochemical reactions, hydrolysis or oxidation (ozone, peroxiacetyl nitrate, etc.).

Those pollutants can be classified as particulates or gases depending on the physical state of the material in which they are found. *Particulates* are finely divided liquids and solids that can be sedimented, including dust, smoke and ashes. *Gases* which also include vapors, are many times invisible and sometimes cannot be detected by smell. Some of the most common gaseous pollutants include carbon monoxide, hydrocarbons, ozone, nitrogen oxides and sulfur oxides.

Unlike particulates, gases are not sedimented but rather tend to remain in the atmosphere and turn into more simple or more complex compounds, or become a part of biogeochemical cycles.

The effect of air pollutants on human health as well as the severity of the effect can vary depending on the age of the individual. Table 4.3 summarizes the effects from some pollutants, such as ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter less than 10 microns in diameter (PM10), acid aerosols, and lead (Pb). These are broken into age groups and risk groups. Annex C expands on the effects of the pollutants listed.

Table 4.3. Health effects from atmospheric pollutants

Pollutant	Exposed population and at-risk groups	Health effects
O_3	Adults y healthy children	• Reduction in pulmonary function • Increase in air reactivity • Swelling of the lungs
	Athletes, outdoor workers	• Increase in respiratory symptoms (effects that are enhanced with exercise)

	Asthmatics and people with other respiratory diseases	• Decrease in the ability to exercise (Effects occur in conjunction with particulate matter and acid aerosols) • Increase in the number of hospitalizations
CO	Healthy adults	• Decrease in the ability to exercise
	Patients with ischemic disease	• Decrease in the ability to exercise (Increase in the number of effects including anemia or chronic lung disease) • Angina pectoris
NO_2	Healthy adults	• Increase in air reactivity
	Healthy children	• Decrease in lung function • Increase in respiratory symptoms (increase in the number of respiratory infections) (Effects are found in homes that use combustion sources)
SO_2	Adults and patients with chronic obstructive pulmonary disease	• Increase in respiratory symptoms (highly soluble gas with little long-distance penetration) • Increase in mortality an number of hospitalizations due to respiratory illnesses • Decrease in respiratory function (Observations were done at low exposure levels)
PM10	Children	• Increase in respiratory symptoms • Increase in respiratory illnesses • Decrease in pulmonary function (effects are seen in conjunction with SO_2)
	Chronic effects	• Excess of mortality
	Asthmatic	• Increase in exacerbation of asthma
Acid aerosols	Healthy adults	• Alteration of the mucoceles
	Children	• Increase in the number of respiratory illnesses (effects are seen in conjunction with ozone and particulate matter)
	Asthmatics and others	• Decrease in pulmonary function (increase in the number of hospitalizations)
Pb	Children	• Alteration of neurological function
	Adults	• Increase in blood pressure(associated with lead levels in gasoline)

Source: Dirección General de Salud Ambiental, SSA, 1999.

Recommendations on public health and epidemiological monitoring for the population

The measurement of air quality in Mexicali has identified high pollution levels for ozone, particulate matter less then 10 microns in diameter and carbon monoxide. Even though these concentrations are not as high as those found in other cities around the country, they could pose a future potential risk for the health of the population.

Unfortunately, there is not enough information to evaluate the harm, if any, that is being caused by air pollution in Mexicali. For that matter, it is necessary to establish an epidemiological oversight program associated with air pollution, that will allow the availability of permanent and up-to-date information about the health status of the population.

An oversight program of this kind will allow us to learn more about the pathologies and symptoms related with air pollutants, both during days with low pollutant levels as well as days where there might be environmental contingencies.

Table 4.4 lists a series of recommendations and measures to prevent health damage caused by air pollutants.

Table 4.4. Recommendations to oversee and prevent health damage caused by air pollutants

Health measures
1. Establish an oversight system for health effects.
2. Conduct epidemiological studies.
3. Disseminate measures that contribute to the abatement of air pollutants.
4. Disseminate preventive measures in the population.
Individuals at higher risk due to exposure to pollutants
1. Children.
2. Elderly.
3. Individuals with heart disease.
4. Individuals with pulmonary and bronchial pathology.
5. Smokers.
Recommendations for the general population and at-risk groups
1 Consume 5 portions of previously washed vegetables and dry fruit per day.
2. Avoid smoking or being nearby smokers.
3. During the winter, remain indoors closing air passages; wear adequate clothing; do not light portable ovens to heat up enclosed areas; avoid sudden changes in temperature; and, pay special attention to children and the elderly in light of any respiratory infection (insignificant as it may seem.)
4. Drink lots of fluids.
General control measures for pollution sources
1. Improvement and replacement of motor vehicle fuels.
2. Improvements in motor vehicle technology.
3. Incorporation of anti-pollution technologies in the industrial and service sectors.
4. Cost-effective instruments to abate pollution.
5. Industrial and vehicular inspection and oversight.
6. Creation of environmental norms.

Source: Dirección General de Salud Ambiental, SSA, 1998.

Effects on the ecosystem

Air pollutants also have adverse effects on vegetation; they damage wooded areas and decrease the productivity of agricultural fields. Damage is mainly due to the effects from gases, particulates, acid rain and fog, and photochemical oxidants. An important characteristic of this type of activity is that their impact goes beyond the local scale, affecting vast regions, which at times cross the borders of the country generating those pollutants.

Air pollutants affect atmospheric conditions causing poor visibility, fog and precipitation, a reduction in solar radiation, and alterations in temperature and wind distribution. Currently, the possible effects of some air pollutants (for example, carbon dioxide and particulates) on global climate changes are being analyzed.

The most evident effect of air pollution on the atmosphere is a reduction in visibility, which is the result of the light absorption and dispersion caused by gaseous and particulate molecules. The absorption of certain light wavelengths by gaseous and particulate molecules is often responsible for the different tonalities in the atmosphere. However, light dispersion is the main phenomenon that is responsible for the deterioration of visibility.

In addition to this effect, air pollution affects urban climates with an increase in the formation of fog and a decrease in the reception of solar radiation. It has been observed that the frequency of fog formation is greater in cities than in the countryside, in spite of the fact that air temperature tends to be higher and relative humidity tends to be lower in the cities than in the countryside. The explanation of this behavior lies in the fog forming mechanism. For example, with high concentrations of sulfur dioxide, sulfuric acid droplets formed by the oxidation of dioxide, serve as the condensation nuclei for the formation of fog. In addition to this phenomenon, high precipitation has been linked to high concentrations of particulate matter.

2. Meteorological conditions

The prevailing weather in the city of Mexicali, as well as most of the valley, is very arid, with temperature extremes and winter and summer rains. (García, 1988).

Arid conditions in the valley of Mexicali are due, in part, to the general atmospheric circulation patterns, which at that latitude generate descending air movements that do not cause precipitation. The orographic shadow effect from Sierra de Juárez can be added to this. Moist winds coming from the Pacific Ocean unload in the western slope of the mountain, thus causing an extreme arid condition.

In general, it can be highlighted that the climatological conditions of this region are determined to a great extent by the presence of the semi-permanent subtropical cyclic system from the Pacific Ocean. In fact, this is the reason why the surroundings of the California coast and Imperial Valley have clear skies, low humidity, extremely hot summers, mild winters, and low precipitation (Fields *et a*l, 1993).

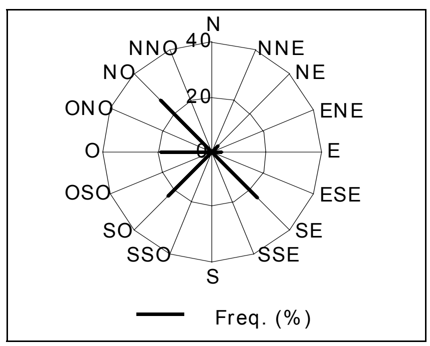
The following is a brief meteorological analysis that was conducted based on information provided by Comisión Nacional del Agua (National Water Commissions) (CNA), which was collected through station # 24, located at the international border with the US. These data are for 1996 and, in the particular case of the wind speed and wind direction variables, it must be pointed out that information was recorded only for those days when there were wind speeds exceeding 3.4 m/s. Likewise, the information generated by the Air Quality Monitoring Network in Mexicali, which began operating in 1997, was analyzed. Finally, a bibliographic review was done to support such analysis.

Wind Rose and general patterns of air circulation

Figure 4.1 shows a wind rose for 1996, generated with information provided by Comisión Nacional del Agua. It can be seen that the prevailing winds are from the northeast (27% of the time), followed in order of importance by southeasterly winds (24%), southwesterly (22%) and west (19%). Winds from the northeast and from the east occur with lesser frequency.

Wind flow throughout the year can be differentiated by two patterns. Westerly winds with a frequency of 69%, appear from the northwest, west and southwest, and occur mainly from October through June. The pattern of easterly winds, with a frequency of 31%, appears from the northeast, east and east directions, mainly in the months of July through September.

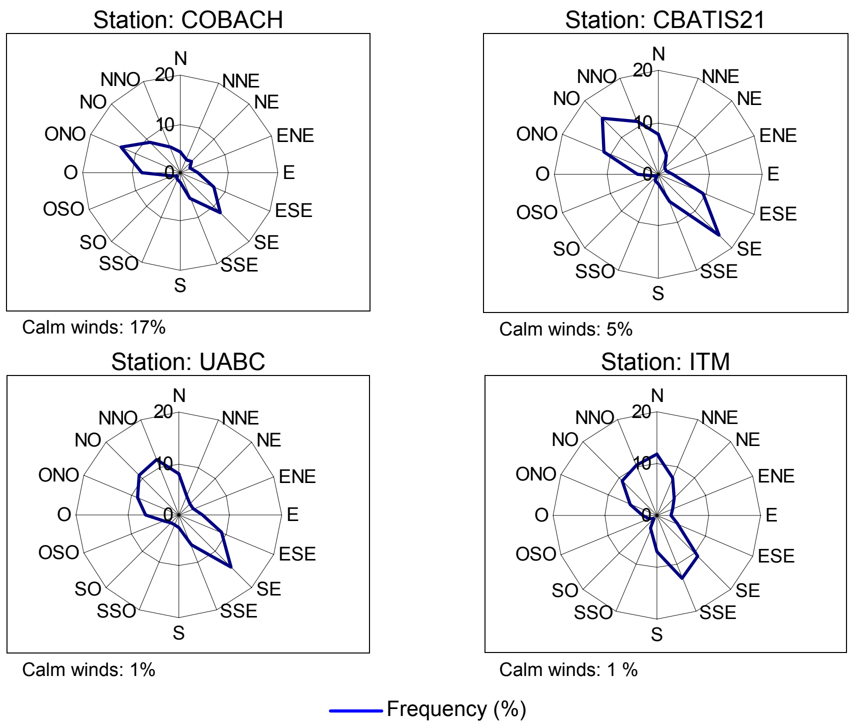
Figure 4.1. Wind Rose showing prevailing winds in Mexicali, 1996 (percentage and direction)



Source: INE with data from CNA, 1998.

As far as meteorological data generated by Mexicali's Air Quality Monitoring Network during 1997, the following figure shows the wind roses that were obtained for the stations at Colegio de Bachilleres (COBACH), Centro de Bachillerato Técnico Industrial y de Servicios (CBATIS21), Universidad Autónoma de Baja California (UABC) and Instituto Tecnológico de Mexicali (ITM).

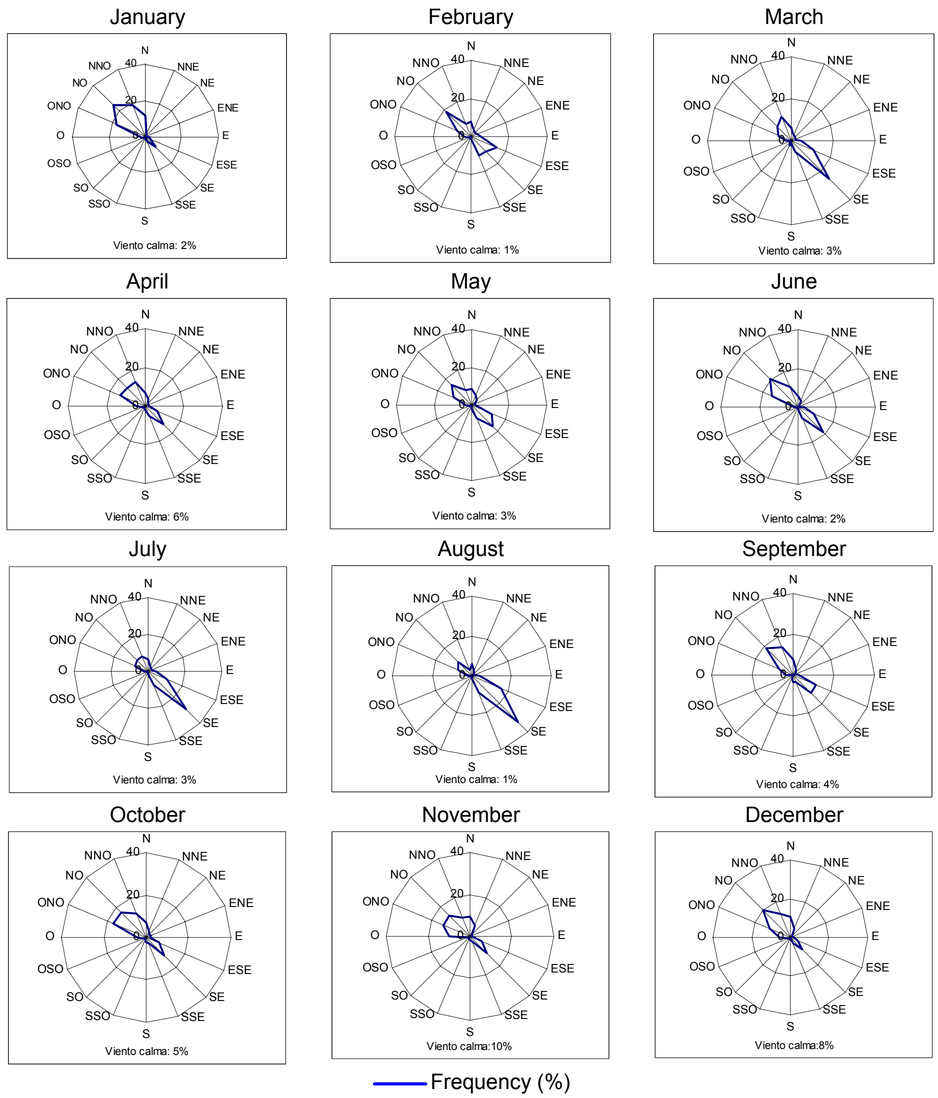
Figure. 4.2. Wind Rose for Air Quality monitoring stations in Mexicali, 1997 (percentage and direction)



The analysis shows that:

- The wind behavior at the four monitoring stations is very similar, with prevailing winds coming from the southeast and the northwest.
- In general, it can be said that the frequency of southeasterly winds is 14%, whereas the frequency of northwesterly winds is approximately 12%.
- The frequency of calm winds (those with a speed less than or equal to 0.5 m/s), is significantly higher at COBACH (17%). This is probably due to malfunctioning equipment (although this could not be confirmed by staff in charge of the operation of the Monitoring Network), or by the location of the equipment. It is also possible that the topography of the area may have some influence on the readings obtained at this station, since COBACH is the only station that monitors meteorological conditions on the western side of the city. This side of the city is a short distance away from El Cerro del Centinela to the northeast, La Rumorosa to the west and a small mountain range to the southwest. On the other hand, on the eastern side of the city, where the other three monitoring stations equipped with meteorological devices are located, the countryside is wide open for hundreds of kilometers to the north, east and south.

Figure 4.3 Wind Rose by month for Mexicali, 1997



Starting from the fact that the prevailing wind patterns at the four stations are similar, in their annual as well as monthly behavior, Figure 4.3 shows wind roses by month for CBATIS21, with the purpose of illustrating the monthly variation of wind flow in Mexicali. That station was selected because it has the most complete database.

Figure 4.3 shows that:

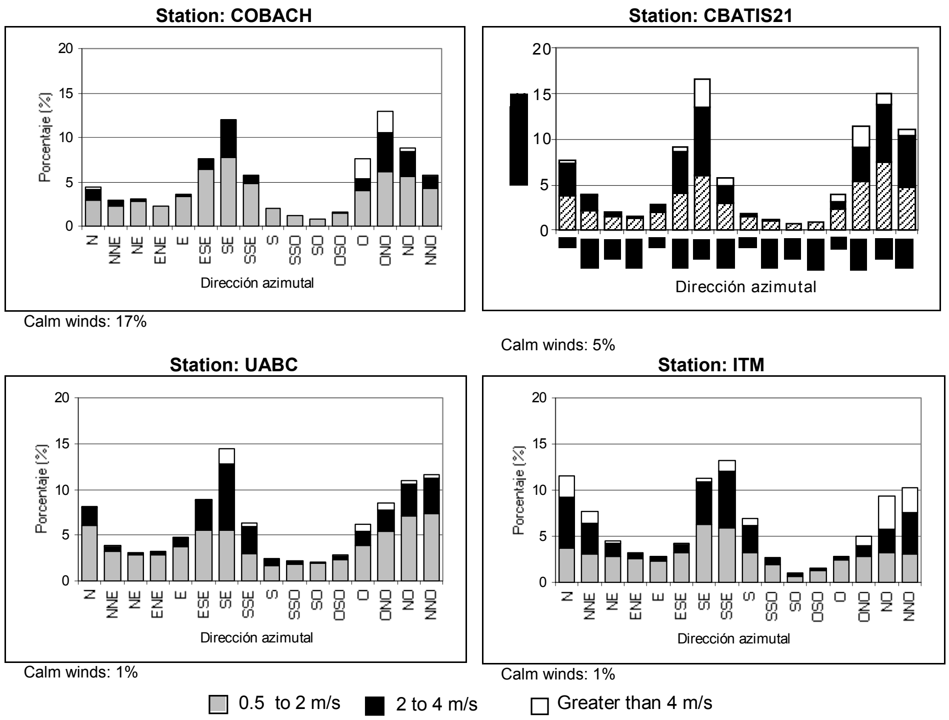
- Northerly winds, including those from the north-northwest, northwest and west-northwest, show throughout the year a greater frequency of occurrence than southerly winds. This is particularly noticeable during the periods from September through January, and April through June. During these periods, northerly winds accounted for as much as 61% of the total frequency for the month (January).
- Southerly winds, including those from the south-southeast, southeast y east-southeast, were more prevalent during the periods from February-March and July-August, accounting for as much as 58% of the total monthly occurrence (August).
- The months with the highest frequency of calm winds were November and December, with 10% and 8% respectively.

As far as wind speed, it was found the prevailing intensity at all the monitoring stations, falls below 2 m/s (Figure 4.4). In fact, approximately 50% the wind has a velocity that is less than 2 m/s (including calm winds). Winds with an intensity between 2.1 and 4.0 m/s represented between 17% (COBACH station) and 38% (CBATIS21 station) of the total frequency, and this intensity was most frequently shown in winds from the southeast and from the north-northwest. Finally, winds with intensity higher than 4 m/s represented a 7% average of the total occurrence. However, it is important to mention that those winds that exceeded that speed generally fell between 4 and 6 m/s, and only occasionally did higher speeds occur.

It is important to highlight the fact that, even though this analysis considers the data of only one year, the described wind pattern is consistent with that reported by other studies in the area, which consider a longer period for analysis. For example, the PM10 State Implementation Plan for Imperial Valley (Fields *et al*, 1993), which considers meteorological data collected at the Naval Auxiliary Air Station for a 15-year period (1945 a 1960), indicates that the prevailing winds are from the west-northwest and from the southwest. The second most important flow is from the southeast. This behavior is similar to that shown in the wind rose of Figure 4.1.

In another study that was conducted between 1992 and 1993, with the purpose of estimating transboundary PM10 transport in Mexicali and Imperial Valley, it is indicated that under light wind conditions (less than 2 m/s), the winds came practically from any direction. However, under moderate (1.1 to 5 m/s) or strong (> 5 m/s) wind conditions, the winds mainly came from the northwest or the southeast, and rarely from the northeast or the southeast. The transport of pollutants across the US-Mexico international border occurs as a consequence of this distribution of wind directions. In Calexico, northerly winds (transport into México) occurred approximately two thirds of the time. Whereas southerly winds (transport from Mexico) only occurred one third of the time. The flow from Mexico was slightly more frequent during the summer than during the winter. (Fields *et a*l, 1993)

Figure 4.4. Wind speed and direction in Mexicali, 1997
(Percentage of incidence by direction and velocity)



Temperature

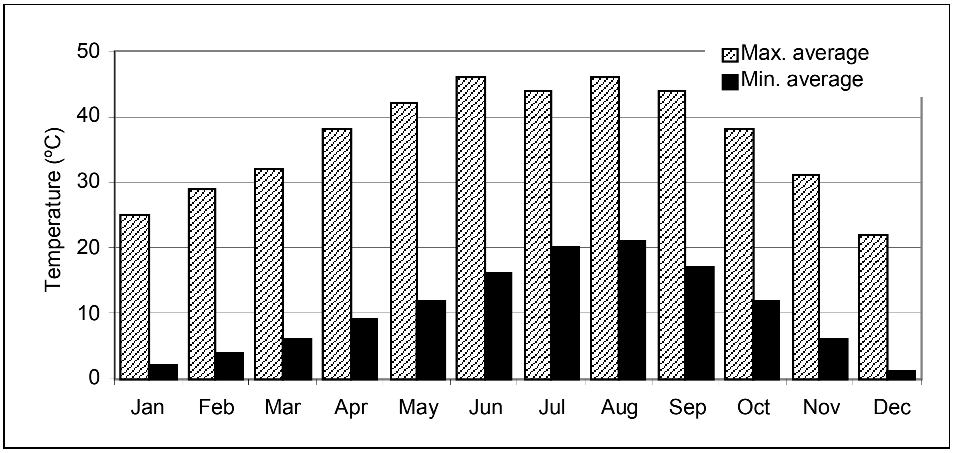
The temperature in this zone is very variable; for example, temperatures in the summer occasionally reach 50°C, whereas in the winter some temperature readings fall below 0°C.

Figure 4.5 shows information regarding the maximum and minimum temperature readings as monthly averages for 1981-1997. During this period a mean annual temperature of 23°C was recorded, with the mean temperature for the coldest month being 12°C and the mean temperature for the hottest month being 34°C.

The warmest months are April to October with an average temperature above 29°C. December through February are the coldest months with an average temperature, for this period, of 14ºC and average minimum temperatures of 2°C.

The annual range between average minimum temperature of the coldest month and the average maximum temperature of the hottest month was 45°C. The maximum average temperature recorded, 46°C, was for the months of June and August..

Figure 4.5. Average for the monthly maximum and minimum temperatures in Mexicali, 1981-1997

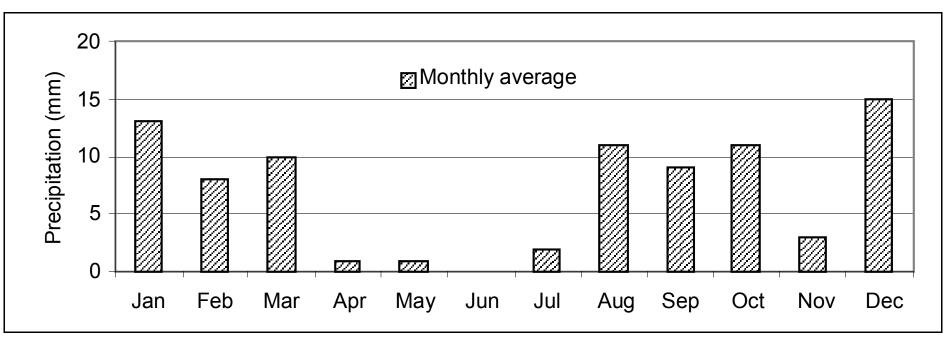


Precipitation

The flat terrain in the valley and the steep temperature gradients created by the intense solar heat produce moderate winds and a profound thermal convection. The combination of subsidence with the protecting effect from the mountains, and the distance with respect to the ocean, severely limits precipitation, which is highly variable and, at times, a strong rain can account for much of the annual precipitation.

Figure 4.6 shows the monthly average precipitation for 1981-1997. It shows that, in general, precipitation is very low, with the general average for these seven years being around 85 mm. The months with the largest amount of precipitation were December and January, with 15 and 13 mm, respectively. The driest months were April and July.

Figure 4.6. Monthly average precipitation in Mexicali, 1981-1997



Stability and atmospheric dispersion

Atmospheric stability regulates the vertical and horizontal exchange of air that can occur in a given airshed. A limited mixture and low wind velocities are generally associated with a high degree of stability in the atmosphere. These conditions are also characteristic of thermal inversions. A thermal inversion is formed when the air layer that is in contact with the ground acquires a temperature lower than that of the upper layers. It becomes more dense and heavier, such that air layers found at higher elevations, which are relatively warm, act as a cover preventing the ascending movement of polluted air.

The presence of the semipermanent cyclonic cell of the Pacific Ocean can cause the fall of air masses. When these air masses descend, they undergo heating by compression, reaching temperatures that are higher than those of the layers that are closer to the ground surface. This highly stable atmospheric condition, called inversion by subsidence, can act as an impenetrable layer that prevents the vertical mixture of pollutants, including particulates. The force of these inversions makes their break-up difficult and consequently can persist for one or more days, causing air stagnation and accumulation of pollutants. In Imperial County, inversions by subsidence are common between November and June, reason why they are considered an important factor related to the high concentrations of PM10 that are recorded in the zone. This type of inversion seems to be relatively absent between July and October (Fields *et al*, 1993).

3. Air quality diagnostics

The current phase of the air quality monitoring network in Mexicali started in July of 1996, with work related to the installation, configuration, and acceptance tests for equipment operation. The network began operating properly in January of 1997, within the framework of cooperation of the Border XXI Program, with resources from the US Environmental Protection Agency (EPA), California Air Resources Board (CARB), and SEMARNAP.

The monitoring network is comprised of six stations, four of which measure the concentration of O_3, NO_2, SO_2 and CO, as well as temperature, relative humidity, wind speed and direction, in addition to manually collected samples of PM10 and TSP. The two remaining stations are only equipped with PM10 and TSP samplers. The monitoring stations include: Centro de Bachillerato Técnico Industrial y de Servicios (CBATIS21), Universidad Autónoma de Baja California (UABC), Instituto Tecnológico de Mexicali (ITM), Centro de Estudios COBACH, Centro de Salud, Centro de Estudios Técnicos (CONALEP). This network is operated and financed by the State of California. The different activities developed for the operation of this network have been in charge of TEAM-TRACER, and supervision over the development of the project has been led by SEMARNAPs State Delegation, with INEs technical assistance.

The EPA has provided approximately 320 thousand dollars in equipment and 160 thousand dollars for the operation of the network. Based on these agreements, the financial resources provided by the EPA for this program will last through the end of 2001. This was done with the idea that these moneys would serve to provide a drive for these activities to continue under the control and with the resources of the Mexican government and Mexican organizations. Approximately 80% of the equipment was provided by US agencies and the rest by INE.

Data generated through the operation of the monitoring system are directly transmitted by radio to CARB headquarters, where they undergo a preliminary evaluation. Data are then loaded onto AIRS, where they are validated in accordance with methodologies established by EPA, for quality assurance. Finally, they are sent quarterly to INE and CICA, remaining available through Internet.

Monitoring network configuration

The following is a brief description of each of the stations that integrate the monitoring network. It is important to mention that by January of 1997, four of the stations measured the concentration of O_3, CO, SO_2 and NO_2; gradually, PM10 samplers were introduced.

CBATIS21 became fully operational in February of 1997. It is located in the facilities of Centro de Bachillerato Industrial y de Servicios # 21, on Calzada Cuauhtémoc and Río Elota, Colonia Santa María. Air samples are collected from a height of 15 meters, surrounded by grass and concrete. This station is located in a mixed zone (industrial, commercial, housing and services), with some eroded areas approximately 30 meters away. The population density is medium and there is a high density of traffic approximately 50 meters away. The equipment at this station is installed in a mobile unit and consists of the following: DASIBI 3008 CO analyzer, TECO 43 SO_2 analyzer, DASIBI 1003-AH O_3 analyzer, TECO 42 NOx analyzer, and WEDDING PM10 high volume manual sampler.

UABC incorporated the measurement of PM10 in February of 1997. It is located in land owned by Universidad Autónoma de Baja California on Boulevard Benito Juárez s/n, Col. Independencia Magisterial. Some of the neighboring facilities include: a sports complex, Escuela Normal Fronteriza, and some residential developments. The equipment at this station consists of the following: DASIBI 3008 CO analyzer, TECO 43 SO_2 analyzer, DASIBI 1003-AH O_3 analyzer, TECO 42 NOx analyzer, and WEDDING PM10 high volume manual sampler.

ITM began operations in November of 1996. It is located at Instituto Tecnológico de Mexicali, on Av. Instituto Tecnológico s/n, Col. Plutarco Elías Calles. It is located in a mixed-use zone (industrial, commercial, housing and services), has medium population density, and is outside the central zone. There are some nearby eroded areas (approximately 15 meters away). Vehicular traffic is low on a 50-meter radius and high on the highway to San Luis Río Colorado, Sonora, located more than 150 meters away from the equipment. Air samples are taken from a height of 10 meters. The analytical equipment is located inside a classroom and includes: DASIBI 3008 CO analyzer, TECO 43 SO_2 analyzer, DASIBI 1003-AH O_3 analyzer, TECO 42 NOx analyzer, and WEDDING PM10 high volume manual sampler.

COBACH began collecting PM10 samples in May of 1997. It is located at Colegio de Bachilleres, on calle Heroico Colegio Militar and Av. Checoslovaquia, Col. Orizaba. The station is located in a mixed-use zone (industrial, commercial, housing, and services), is well populated and centrally located. There is an eroded zone approximately 20 meters away, and is nearby sports fields, parking lots and green areas. There is high vehicular traffic flow approximately 20 meter away and industrial facilities 3 km away. The analytical equipment is located inside a classroom and includes: MONITORING LABS 8830 CO analyzer, MONITORING LABS 8850 SO_2 analyzer, TECO 49 O_3 analyzer, TECO 42 NOx analyzer, and WEDDING PM10 high volume manual sampler.

The monitoring station at Centro de Salud also began collecting PM10 samples in March of 1997. It is located on Highway Heriberto Jara s/n, Col. Progreso, Valley of Mexicali. It is located in a mixed-use zone (industrial, agricultural, service, commercial and housing), with low population density and outside the urban zone. There are some eroded areas approximately 200 meters away, low vehicular flow on the street locate 10 meters away, and high vehicular flow 200 meters away. Air samples are collected from a height of six meters. The existing monitoring equipment includes: GMW for the measurement of PST and WEDDING for the measurement of PM10.

Finally, the station at CONALEP began collecting PM10 samples in February of 1997, and is located in the facilities of CONALEP No.1, in Ejido Puebla, Valley of Mexicali. It is located in a low population density zone, outside the central zone, in a highly eroded area surrounded by agricultural fields (30 meters away), and low vehicular traffic flow (15 meters away). Air samples are collected from a height of six meters. The existing monitoring equipment includes: GMW for the measurement of PST and WEDDING for the measurement of PM10.

Figure 4.7 and Table 4.5 show the location and characteristics of the monitoring stations in Mexicali.

Figure 4.7. Location of air quality monitoring network stations in Mexicali

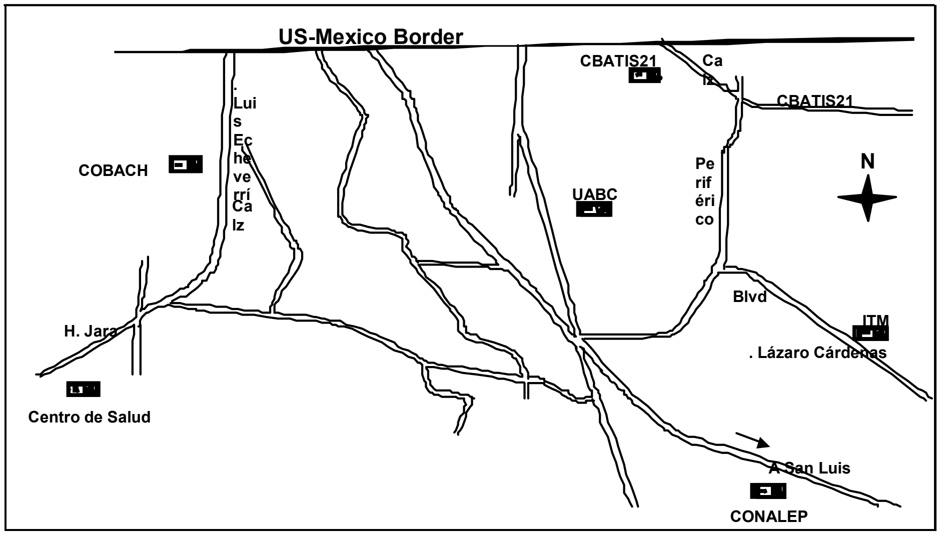


Table 4.5. Location of monitoring stations in Mexicali

Station	Zone	Address	Predominant soil use	Monitored Parameters	Meteorological Parameters
CBATIS21	North	Calzada Cuauhtémoc y Río Elotla	Urban	O_3, CO, SO_2, NO_2, PM10	Temperature, wind speed and direction, relative humidity.
UABC	Central	Blvd. Benito Juárez s/n	Urban	O_3, CO, SO_2, NO_2, PM10	Temperature, wind speed and direction, relative humidity.
ITM	Southeast	Av. Instituto Tecnológico	Urban	O_3, CO, SO_2, NO_2, PM10	Temperature, wind speed and direction, relative humidity.
COBACH	West	Heroico Colegio Militar y Av. Checoslovaquia	Urban	O_3, CO, SO_2, NO_2, PM10	Temperature, wind speed and direction, relative humidity.
CENTRO DE SALUD	Southwest	Carr. Heriberto Jara	Urban Housing, Agricultural	PM10, PST	
CONALEP	Southeast	Ejido Puebla	Agricultural	PM10, PST	

The monitoring equipment is continuously calibrated and the information is validated using quality control methods established by the US Environmental Protection Agency.

The following is an analysis of the information generated by the air quality monitoring network during 1997 and 1998.

Air quality trends

Figure 4.8 shows the IMECA maximum daily values for ozone, for the period between January 1997 and December 1998. During this period, there were several days when the standard for ozone was exceeded, with the highest values being recorded in October 1997 (151 IMECA points) and December 1998 (170 points.)

Figure 4.8. IMECA daily maximum for O_3 in Mexicali during 1997-1998

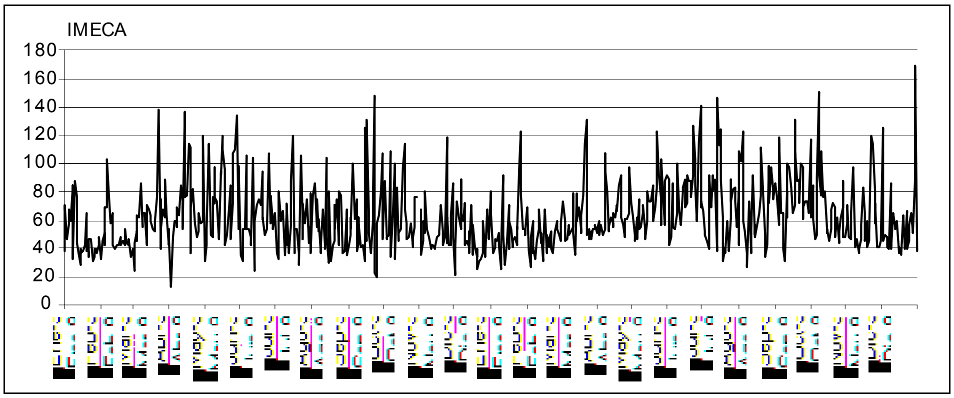


Figure 4.9. IMECA daily maximum for CO in Mexicali during 1997-1998

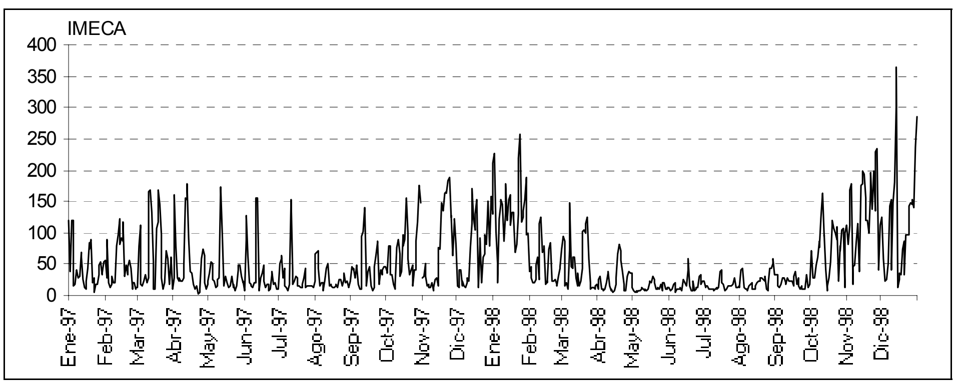


Figure 4.9 shows the trend for the IMECA maximum daily values for carbon monoxide. It can be seen that during 1997 there were frequent violations to the standard for that pollutant, with a maximum value of 190 IMECA points, in the month of November. In 19987 there was a similar number of violations to the standard, with some days exceeding 200 IMECA points. The highest value for 1998 was 363 IMECA points.

Figure 4.10 shows the trend of the IMECA maximum daily values for nitrogen dioxide during 1997 and 1998. It can be seen that in 1997, the value always fell below

81 IMECA points; this maximum value was recorded in the month of December. For 1998, the NO_2 standard was slightly exceeded in October and December.

Figure 4.10. IMECA daily maximum for NO_2 in Mexicali during 1997-1998

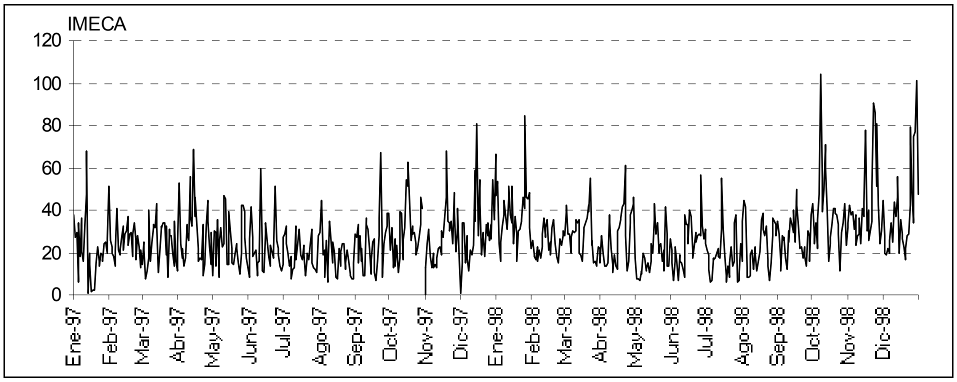


Figure 4.11. IMECA daily maximum for SO_2 in Mexicali during 1997-1998

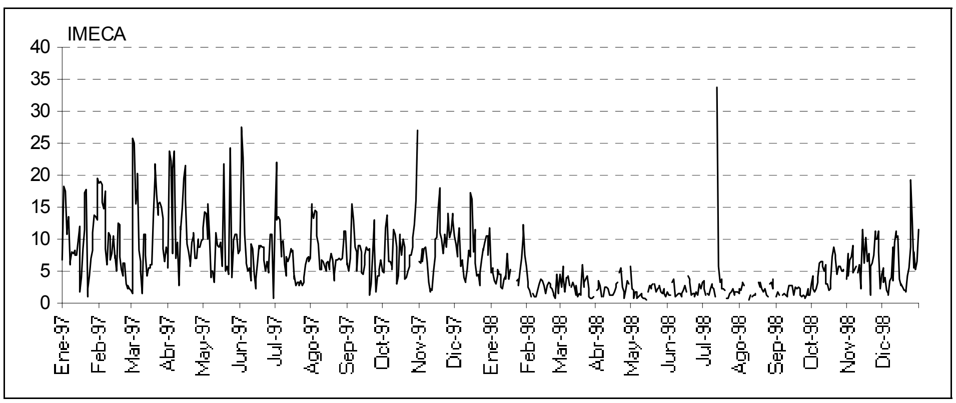
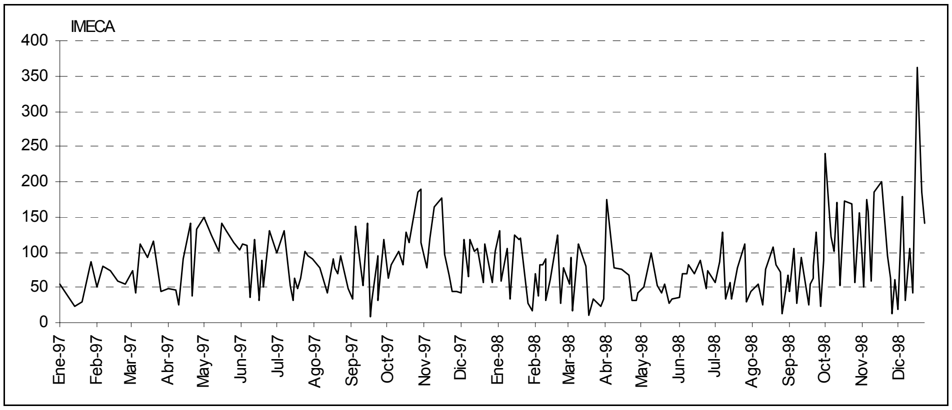


Figure 4.11 shows the trends of IMECA maximum daily values for sulfur dioxide from January 1997 to December 1998. The concentrations of this pollutant are very low, as shown by maximum concentrations falling below 35 IMECA points. The annual average for SO_2 in Mexicali for 1997 was 0.007 ppm, which is almost one fourth of the value established for its annual standard. For 1998 the values recorded were less than 15 IMECA points for almost every month and the annual average was 0.003 ppm.

Figure 4.12 shows the trends of IMECA maximum daily values for PM10 during the same period. The standard for this pollutant was exceeded almost every month, reaching a maximum of 189 IMECA points in October of 1997, and 362 points in December of 1998.

Figure 4.12. IMECA daily maximum for PM10 in Mexicali during 1997-1998



The annual average for PM10 in 1997 was 93 $\mu g/m^3$ and in 1998 it was 86 $\mu g/m^3$, both of which are values that exceed the air quality standard for this pollutant.

Table 4.6 shows the percentage and number of days during which the different IMECA levels were exceeded in Mexicali, during 1997. In general, the frequency of exceedance of the air quality standard was 27 % (98 days); the 150-point level occurred 7% of the time (27 days) and the 200-point level was never reached.

Table 4.6. Percentage and number of days when the 100, 150, 200 and 250 IMECA points were exceeded in Mexicali during 1997

	>=100		>=150		>=200		>=250		Total # of days
	%	No.	%	No.	%	No.	%	No.	
O_3	7.7	28	0.0	0	0.0	0	0.0	0	363
PM10*	37.4	34	5.5	5	0.0	0	0.0	0	91
CO	14.0	51	6.3	23	0.0	0	0.0	0	364
NO_2	0.0	0	0.0	0	0.0	0	0.0	0	363
SO_2	0.0	0	0.0	0	0.0	0	0.0	0	364
General	26.9	98	7.4	27	0.0	0	0.0	0	364

* Percent and number of samples

Analyzing the behavior of pollutants, it is seen that during this year, 37% of PM10 samples exceeded the standard; followed by carbon monoxide with 14% of the days exceeding the standard, and ozone with 8% of the days.

Table 4.7 presents the analysis for 1998, and shows that the PM10 standard was exceeded 30% of the time (108 days), the 150-point level was exceeded 11% of the time (41 days), and the 200-point level was exceeded 3% of the time (12 days). It is important to clarify that during this year there were also five exceedances of the 250-point IMECA value. With respect to the pollutants, their behavior was similar to that of 1997. The pollutant that exceeds the standard with greater frequency is PM10, with 27% of the samples exceeding the standard; followed by CO with 20% (75 days) and O_3 with 8% (30 days); during this year, NO_2 exceeded its standard two days.

Table 4.7. Percentage and number of days when the 100, 150, 200 and 250 IMECA points were exceeded in Mexicali during 1998

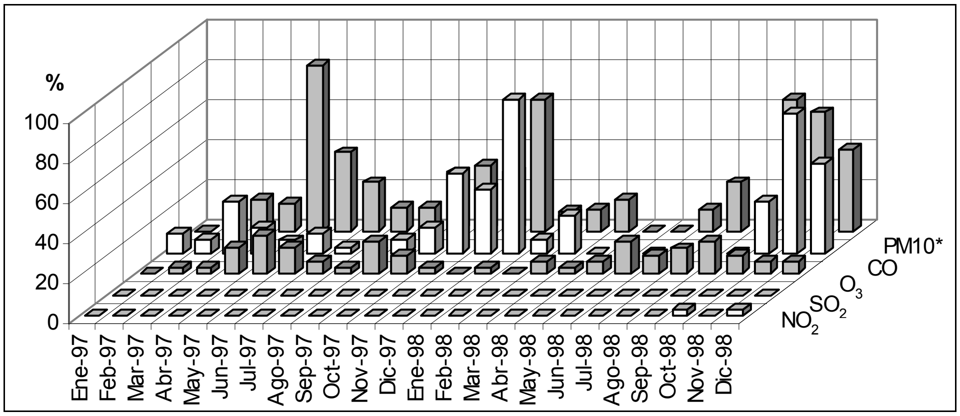
	>=100		>=150		>=200		>=250		Total # of days
	%	#	%	#	%	#	%	#	
O_3	8.2	30	0.5	2	0.0	0	0.0	0	365
PM10*	27.3	30	11.8	13	1.8	2	0.9	1	110
CO	20.5	75	8.2	30	2.7	10	1.1	4	365
NO_2	0.5	2	0.0	0	0.0	0	0.0	0	365
SO_2	0.0	0	0.0	0	0.0	0	0.0	0	337
General	29.6	108	11.2	41	3.3	12	1.4	5	365

* Percentage and number of samples

Comparing the two years that were monitored, it can be observed that during 1998, carbon monoxide violated the standard almost twice as many days as in 1997, going from 14% to 21% exceedances. For ozone, the behavior during both years was pretty much the same, with only 2 more exceedances being recorded in 1998. In the case of PM10, the percentage of samples above the standard decreased from 38% to 27% of the days when samples were collected.

Figure 4.13 shows the percentage of days and samples by month (for 1997 and 1998), when there were exceedances of the air quality standards. In the case of carbon monoxide, the largest number of exceedances tends to occur in the coldest months. Ozone exceeds its standard most frequently from May to October, covering the hottest months of the year. The PM10 standard was most frequently exceeded during the dry, winter months. Nitrogen dioxide exceeded its standard in October and December of 1998; and, sulfur dioxide did not exceed its standard during the period of analysis.

Figure 4.13. Percentage of days with violations to the standard by pollutant and by month in Mexicali during 1997-1998



*Percentage of samples above the standard.

Pollutant behavior by zone

Keeping in mind that not all the stations measure all 5 pollutants, the following is a description of the spatial behavior of ozone, carbon monoxide and particulate matter (PM10.)

Figure 4.14 shows the percentage of days when the standard for ozone was exceeded during 1997 and 1998. This pollutant violated its standard with greater frequency in the western zone, followed by the southeastern zone.

Figure 4.14. Percentage of days when the O_3 standard was exceeded in the different zones of Mexicali during 1997–1998

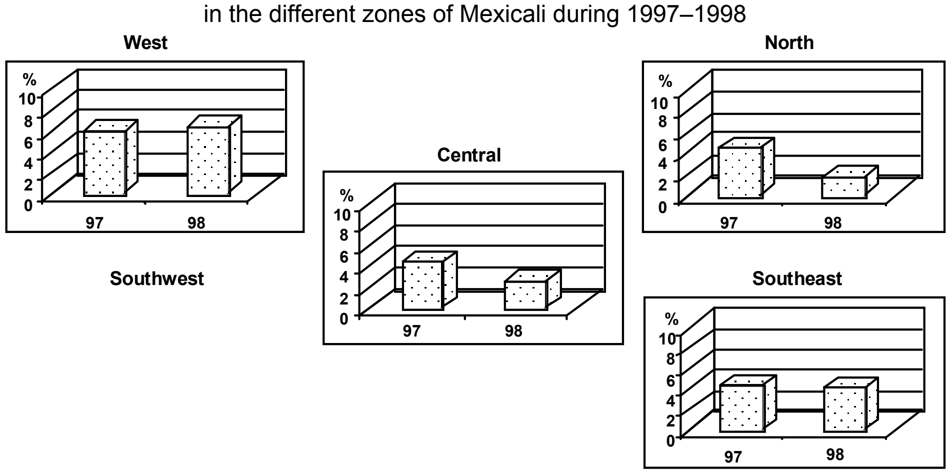


Figure 4.15 shows the percentage of days by zone, when the CO standard was exceeded during 1997 and 1998. It can be observed that the most exceedances occurred in the western and northern zones of the city.

Figure 4.15. Percentage of days when the CO standard was exceeded in the different zones of Mexicali during 1997-1998

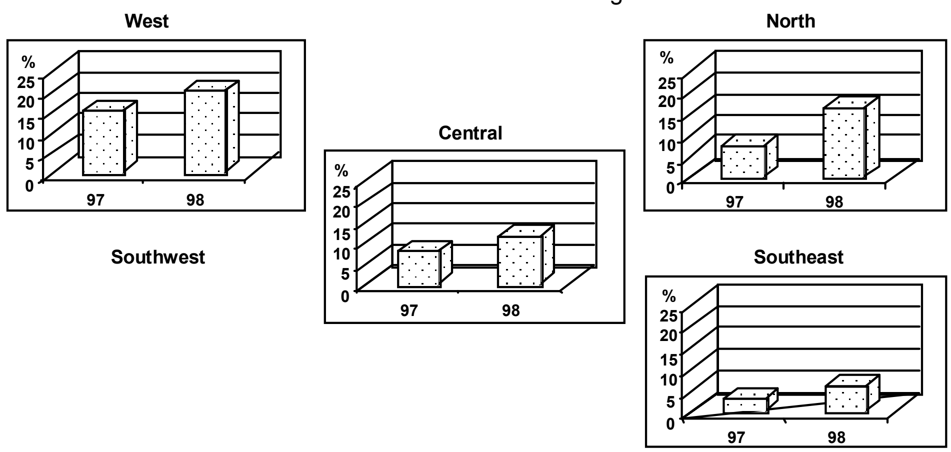
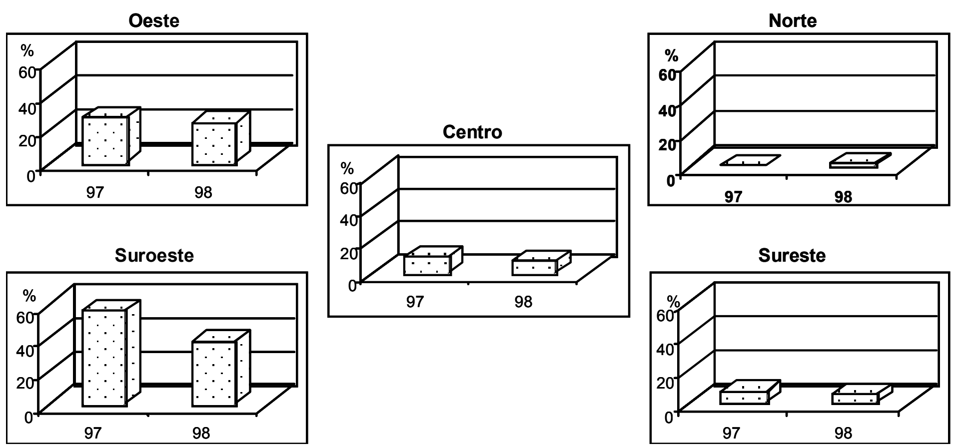


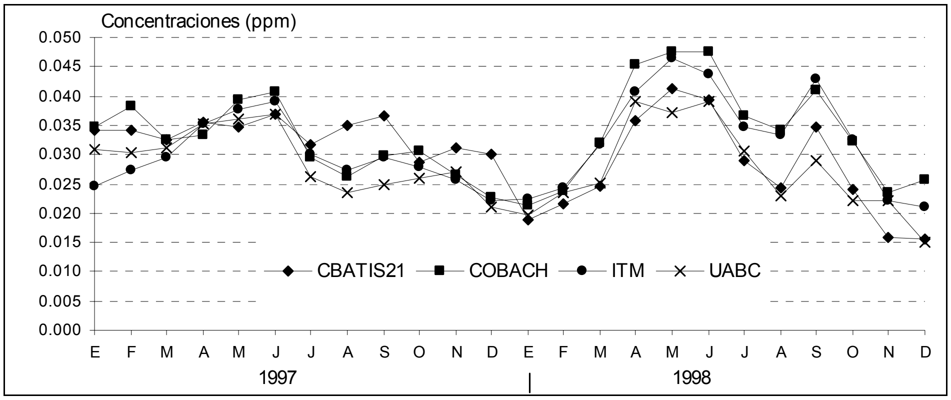
Figure 4.16 shows for each zone of the city, the percentage of samples that exceeded the air quality standard for PM10 in 1997 and 1998. This pollutant exceeded its standard with greater frequency in the southwestern zone, followed by the western zone.

Figure 4.16. Percentage of samples that exceeded the PM10 standard in the 5 zones of Mexicali during 1997 - 1998



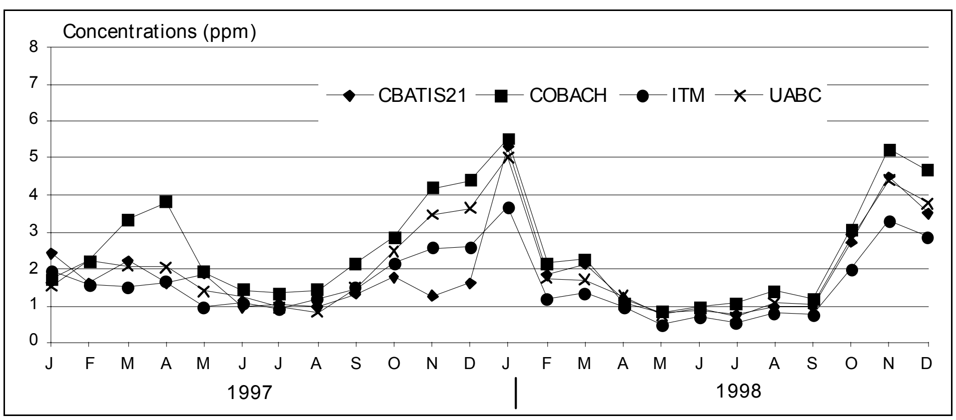
With the objective of identifying the seasonal behavior of pollutants, Figure 4.17 shows the monthly average variation for ozone, recorded at the different stations of the air quality monitoring network in Mexicali. In general, the highest average values for this pollutant for this 2-year period were recorded at COBACH, and the highest concentrations were recorded in 1998. All the stations show a very similar seasonal behavior, with a tendency for presenting the highest values during the spring and summer.

Figure 4.17. Monthly average of hourly readings for O_3 by station, 1997–1998



Likewise, 4.18 shows the monthly average for carbon monoxide at the four stations of the monitoring network. The station where the highest averages for this pollutant are recorded is COBACH and there is a noticeable seasonal behavior for this pollutant, with the highest levels during the coldest months of the year.

Figure 4.18. Monthly average of hourly data for CO by station, 1997–1998



In the same manner as the previous graphs, Figure 4.19 shows the monthly average for PM10 recorded at the 6 stations of the monitoring network. During this period, noticeable differences in the concentrations recorded at the different stations were observed, with COBACH and Centro de Salud showing the highest concentrations of this pollutant. This reflects the characteristics of the zone where they are located (i.e. large amounts of dust). In contrast, ITM and CBATIS21 are not directly influenced by particulate matter pollution due to their location in more urbanized areas. There is also a seasonal trend where the highest levels of PM10 are recorded during the last 3 months of the year.

Figure 4.19. Monthly average for PM10 samples by station, 1997–1998

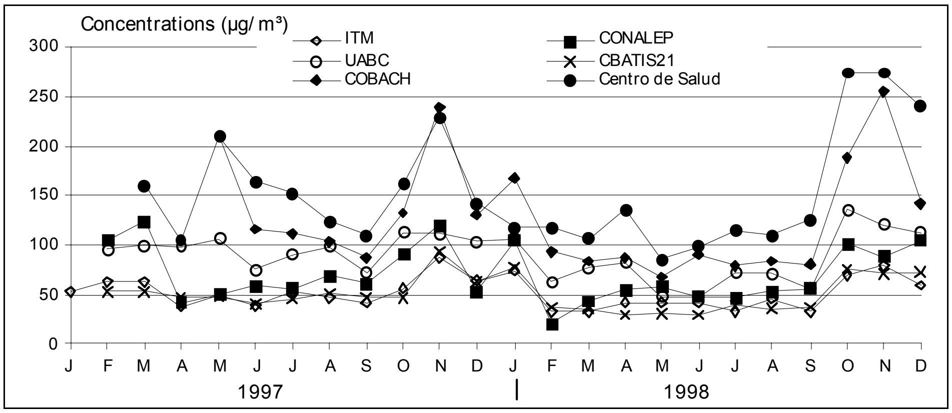
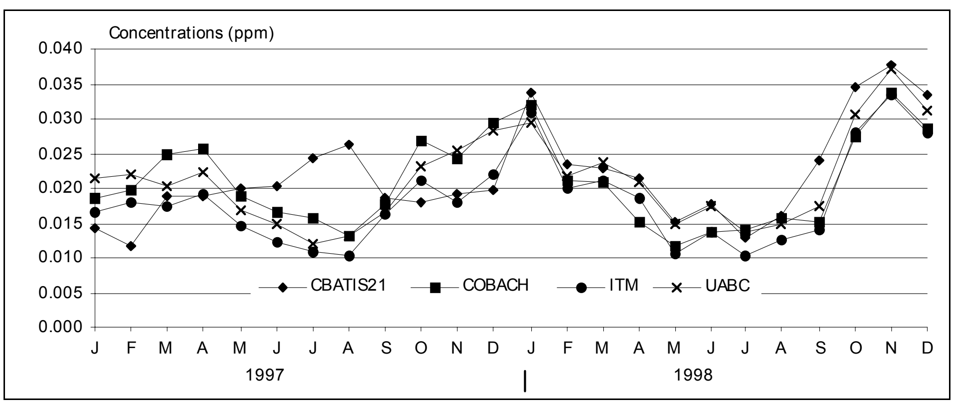


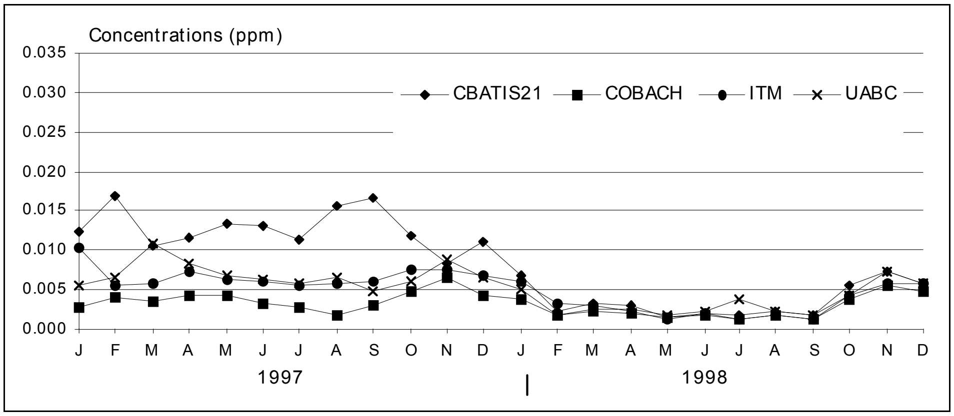
Figure 4.20 presents the monthly average for nitrogen dioxide showing, in the same way as particulate matter, a seasonal behavior and similar levels in general, at the four different monitoring stations.

Figure 4.20. Monthly average of hourly readings for NO_2 by station, 1997–1998



Finally, Figure 4.21 shows the monthly average for sulfur dioxide during the two years that were monitored. It can be seen that, starting in November 1997, the SO_2 concentrations recorded at the four stations are very similar and decrease due to the introduction of gas such as fuel, in some of the main industrial facilities of Mexicali.

Figure 4.21. Monthly average of SO_2 hourly data by station, 1997–1998



Hourly behavior of ozone and carbon monoxide

The concentration of each pollutant measured at ground level, at a determined site, fluctuates as a function of a variety of factors involved in urban dynamics. These factors include vehicular flow intensity, industrial and commercial activity, among others; the daily cyclic meteorological conditions and their seasonal variation; and, the physical and chemical characteristics of those pollutants. The following is a description of the average hourly behavior for carbon monoxide and ozone during 1997 and 1998, at the four stations where these pollutants are measured. As mentioned earlier, these pollutants substantially violate their air quality standards.

CO emissions are directly linked to fuel consumption. Pollutant emissions from vehicles in circulation are generally higher than those for new vehicles off the lot, and vary as a function of mileage, fuel quality, and maintenance. Due to the age and excessive wear of the vehicles that circulate in Mexicali, it is important to implement, as soon as possible, a vehicular emissions testing program, since it is a key component to achieve a reduction of air pollution in the city of Mexicali. One of the main benefits of vehicle emissions testing is the reduction in CO, a pollutant that is mainly generated by motor vehicles.

Another important problem is the large amount of pollution emitted by vehicular sources (cars, trucks, buses) at the moment they cross the border, especially during peak hours, when long lines of idling vehicles form. This is aggravated by the poor condition of a large number of vehicles and the long waiting times to cross into the United States.

Figure 4.22 shows that the annual average of the hourly concentrations (from 0:00 to 24 hours) of carbon monoxide for 1997-1998, are relatively low and similar at all 4 stations that comprise the monitoring network. Starting at 16:00 hours there is a gradual increase that reaches its maximum level at 20:00 hours, with COBACH and CBATIS21 recording the highest values; the lowest values were recorded at ITM. The highest values for CO are produced in the nighttime hours, possibly due to a decrease in the atmospheric mixture layer and emissions form vehicular traffic, which is intense during those hours. Likewise, there is a rise in CO levels around 6 o'clock in the morning, decreasing by 10 o'clock, when the temperature and mixture of pollutants are high.

Figure 4.22. Average hourly variation of carbon monoxide
by station during 1997-1998

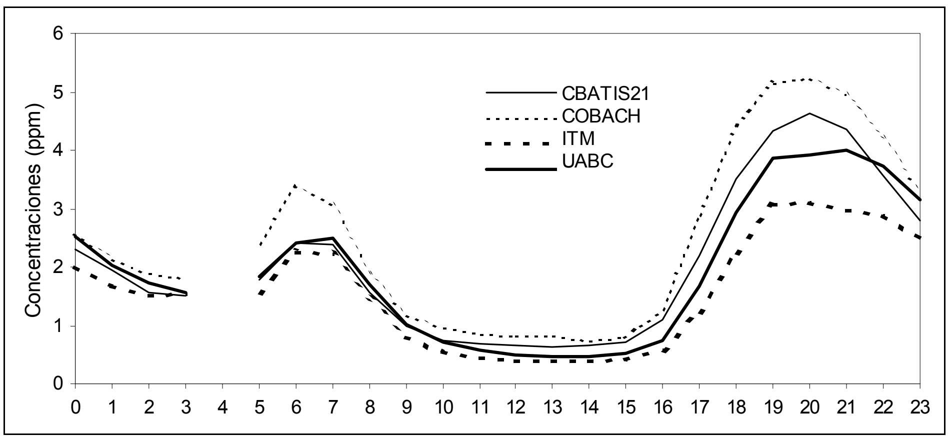
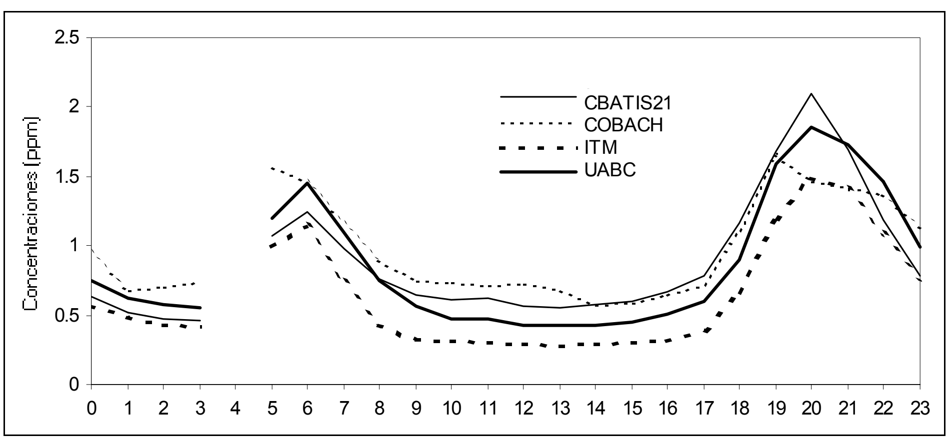


Figure 4.23. Average hourly variation of carbon monoxide
by station from April to July 1998



Figures 4.23 and 4.24 show the hourly variation for carbon monoxide from April to July, 1997, and from December, 1997 to February, 1998. It can be seen that the concentrations of pollutants reached during the cold season (December-February) are much higher than those reached during the hot months (April-July.) However, the peaks occur during the same times of the day in both seasons. The graphs also show the great influence from vehicular emissions on the following monitoring stations: COBACH, CBATIS21 and UABC, and to a lesser degree at ITM.

Figure 4.24. Average hourly variation for carbon monoxide by station from December 1997 to February 1998

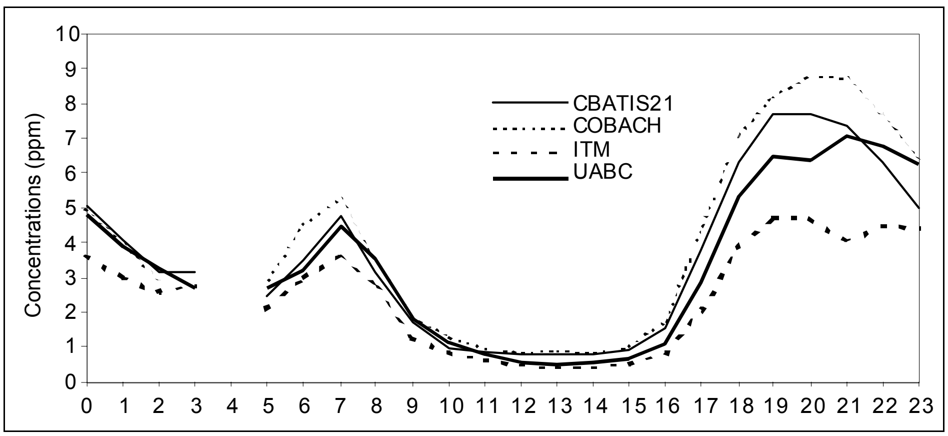
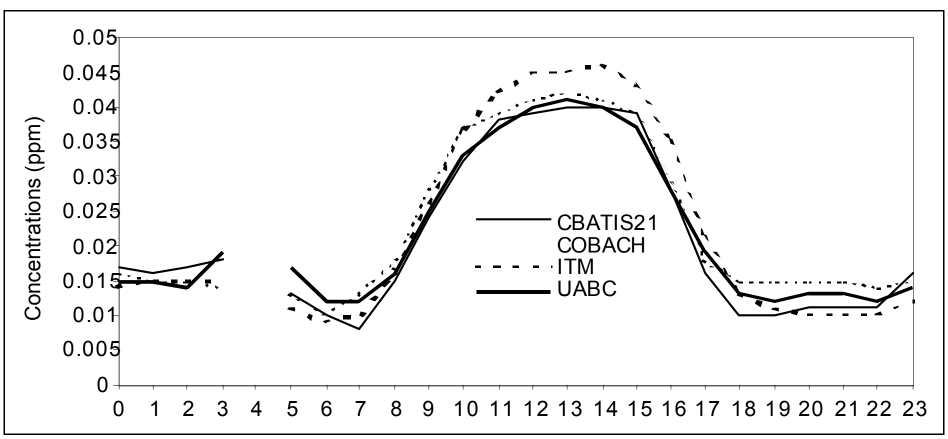
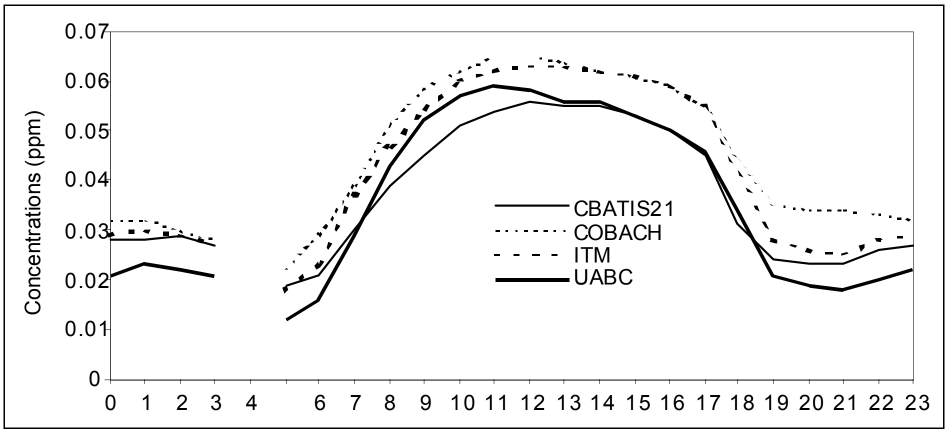


Figure 4.25. Average hourly variation of ozone by station from December 1997 to February 1998.



In the same manner as for CO, the following graphs show the behavior of ozone during those two years, split into two periods. The first period covers from December 1997 to February 1998, and the second period covers from April to July, 1998 (the hot season.) Figure 4.25 shows the hourly variation of the average concentrations of ozone recorded during the cold season (December-February). It can be seen that the hourly concentrations from 0:00 hours to 6:00 hours are low, and from that time on they rise until they reach their maximum value at 13:00 hours, subsequently decreasing until 18:00 hours.

Figure 4.26. Average hourly variation for ozone by station from April to July 1998.



On the other hand, Figure 4.26 shows the hourly variation of the average values of ozone from April to July 1998. Like in the cold season, ozone concentrations are low from 0:00 to 6:00 hours and start rising at 7:00 hours, reaching their maximum value between 11:00 and 15:00 hours. However, the drop in concentration is slower and the higher concentrations tend to remain for several hours. It is important to note that the higher concentrations of ozone occur during the hot summer months.

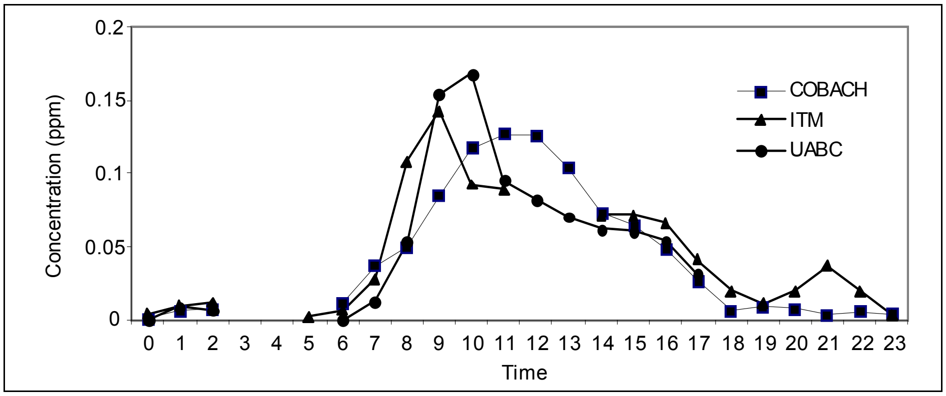
Analysis of high pollution level episodes

The following is a brief analysis of some of the high pollution level episodes during 1997 and 1998. These occurred on September 23 1997 (149 IMECA points for ozone); November 24 1997 (190 IMECA points for carbon monoxide, as an 8-hour mobile average); November 6 1997 (189 IMECA points for PM10); December 30 1998 (170 IMECA points for ozone); December 14 1998 (363 IMECA points for carbon monoxide, as an 8-hour mobile average); and, December 25 1998 (362 IMECA points for PM10).

Ozone episode of September 23, 1997

The maximum ozone concentration of 0.17 ppm (149 IMECA points) was recorded at 10:00 AM, at UABC. All the monitoring stations (see Figure 4.27) equipped with ozone analyzers, recorded high levels of this pollutant, particularly between 9:00 and 12:00 hours, with values exceeding the standard.

Figure 4.27. Hourly concentrations of ozone in Mexicali
(September 23, 1997)

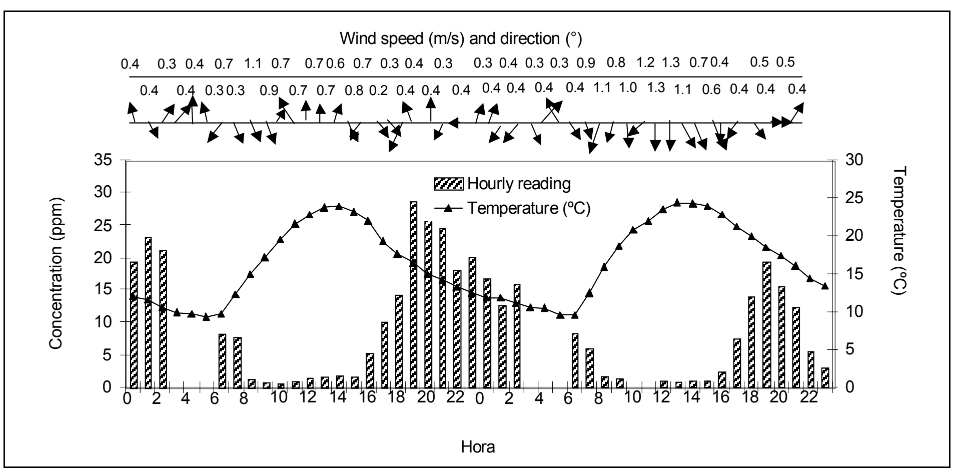


From the early morning hours until noon, wind speed was less than 2 m/s and temperature exceeded 30ºC from 9:00 AM, reaching 35ºC by 11:00 AM, and wind direction was variable with atmospheric stability conditions.

Carbon monoxide episode of November 24, 1997

The maximum value for carbon monoxide as an 8-hour mobile average in 1997 was approximately 190 IMECA points and was recorded at 2:00 AM on November 24, at COBACH. The hourly readings that led to this high concentration of ozone are presented in Figure 4.28.

Figure. 4.28. Hourly records of carbon monoxide at COBACH
(November 23 and 24, 1997)

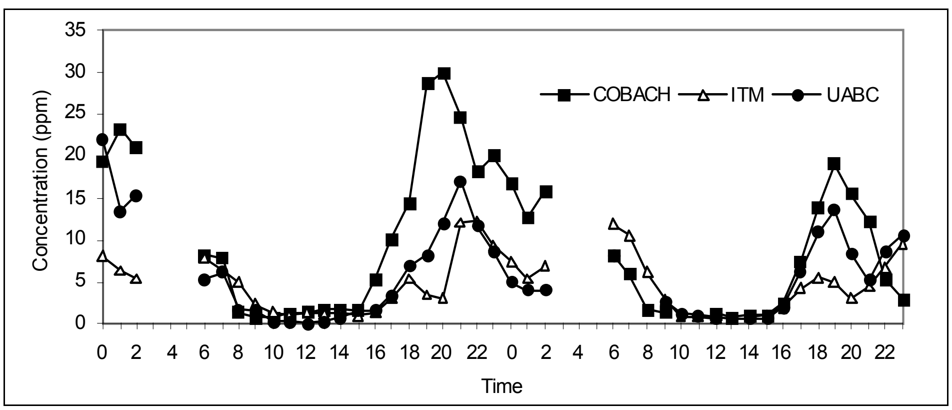


This Figure shows that the highest hourly readings (29 and 30 ppm) for carbon monoxide were recorded between 7 PM on November 23 and 1 AM on November 24. The fact that the high concentrations of carbon monoxide stretched until the early morning hours of the following day, could have been caused by atmospheric stability conditions. This is supported by the fact that the same Figure shows that, in addition to the lack of a defined wind pattern, the intensity of the wind was very low on both days, and the majority of the time it was less than 1 m/s.

These atmospheric stability conditions were also reflected at the other monitoring stations equipped with CO analyzers, recording high values of CO, but none as high as those from COBACH (Figure 4.29).

It is possible that the high concentrations of CO recorded at COBACH, may have been caused by the accumulation of local emission sources, and that mobile source emissions could have been the main cause of this CO episode, since temperatures were not low enough to make us think that residential combustion could have had a considerable impact.

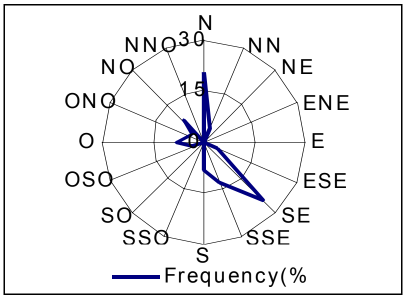
Figure 4.29. Hourly concentrations of carbon monoxide in Mexicali
(November 23 and 24, 1997)



PM10 episode of November 6, 1997

The maximum reading of 328 $\mu g/m^3$ (189 IMECA points) was recorded at COBACH and corresponds to the 24-hour sample that is collected at the different monitoring stations every sixth day. Figure 4.30 shows the prevailing wind rose that was recorded for this day.

Figure 4.30. Prevailing wind rose at COBACH
(November 6 1997)

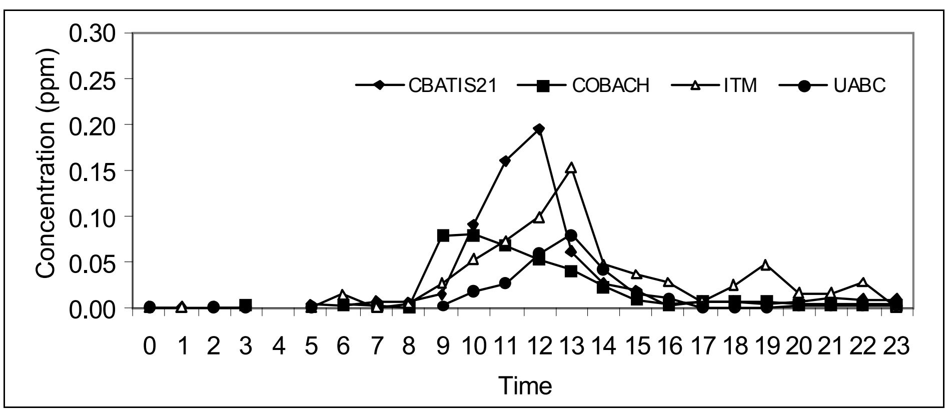


Analysis of the readings indicates that, on this day, the prevailing wind flow was from the southeast (25% frequency), with speeds less than 2 m/s, followed by northerly winds (20% frequency), with speeds between 2 and 3 m/s. Like the previous case, this episode was probably caused by local emission sources, since there are eroded zones and sports fields less than 30 meters away from the station.

Ozone episode of December 30, 1998

As shown in Figure 4.31, on this day, ozone concentrations were high between 9:00 AM and 2:00 PM, at all the monitoring stations. However, the standard was exceeded only at ITM and CBATIS21, with the latter recording the highest value of 0.194-ppm (approximately 170 IMECA points).

Figure 4.31. Hourly concentration of ozone in Mexicali
(December 30, 1998)



Wind speed was very low during the day, indicating atmospheric stability. Likewise, wind direction does not show a clearly dominant pattern, with southerly, northerly and northeasterly flow occurring with the same frequency, thus making it difficult to assume the transport of this pollutant from a particular point. On that day, temperatures reached up to 24 ºC at noon, enough for ozone formation (Figure 4.32).

Figure 4.32. Hourly concentration of ozone in Mexicali at CBATIS21
(December 30, 1998)

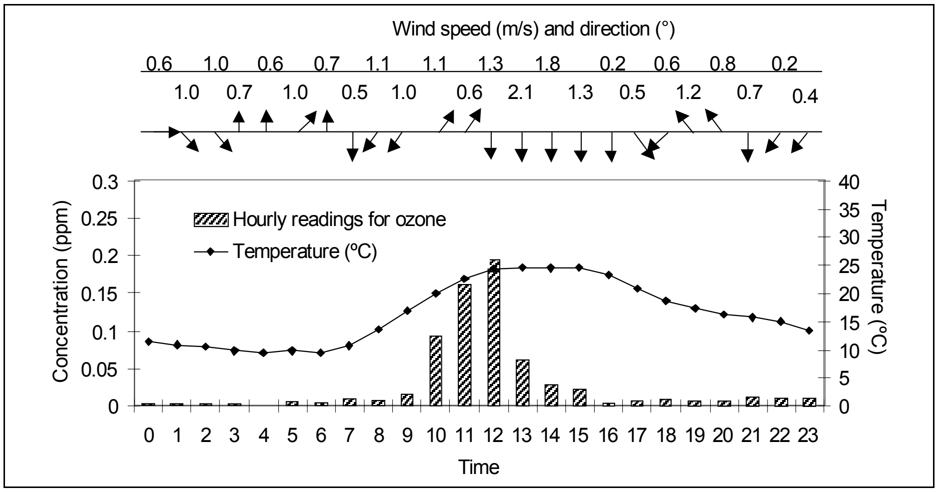
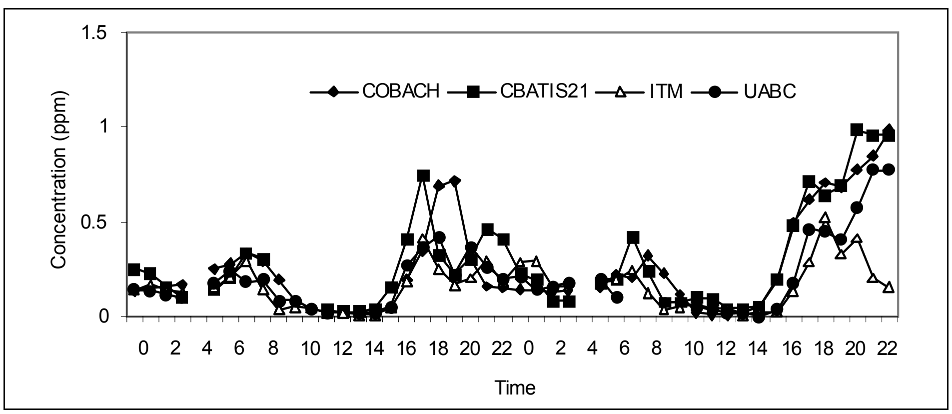


Figure.33. Hourly concentrations of NOx in Mexicali
(December 29 and 30, 1998)



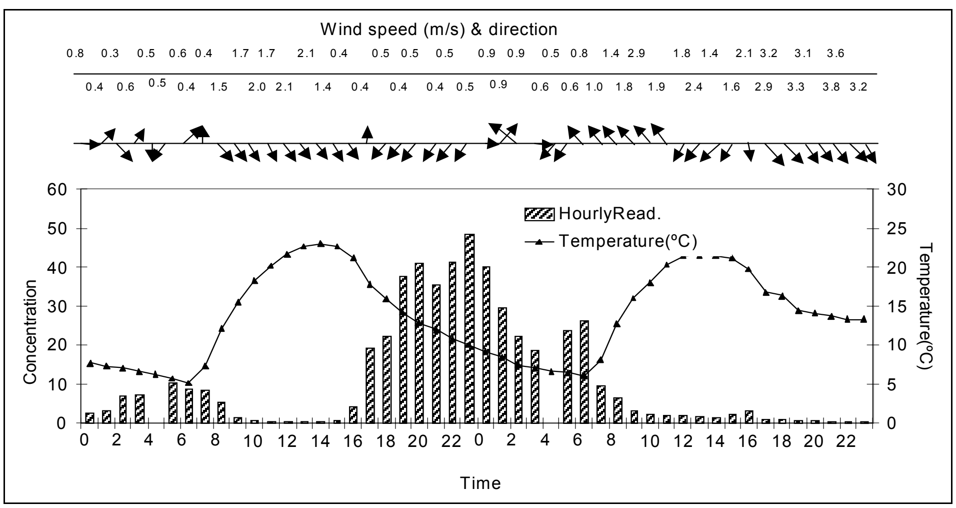
During this season the use of vehicles increases because of the approaching New Year's celebration. This makes us assume that the high concentrations of ozone were due to high emissions of its precursors (i.e., nitrogen oxides and volatile organic compounds), originating mainly from mobile sources during the hours leading to this episode. This assumption is partially supported by the high concentrations of NOx that were recorded from the afternoon to the evening on December 29, adding to the emissions of December 30, and causing high NOx concentrations between 6 and 9 in the morning (Figure 4.33). Later that day, between 6 PM and 11 PM on December 30, even higher concentrations of NOx were recorded. However, these concentrations did not have an important impact on the ozone concentrations that were recorded the following day. This is because wind speed was between 2 and 4 m/s starting at 7 AM. The maximum ozone reading for December 31 was 0.042 ppm (approximately 38 IMECA points).

Carbon monoxide episode of December 14, 1998

Figure 4.34 shows the hourly concentrations for carbon monoxide at COBACH, as well as the wind speed and wind direction. It can be seen that CO concentrations rose substantially from 5 PM on December 13 to 6 AM on the 14th, with hourly concentrations exceeding 30 ppm, and up to 48 ppm. It is important to mention that, in the United States, the hourly standard for CO is 35 ppm, value that was exceeded for 5 hours during this high pollution episode.

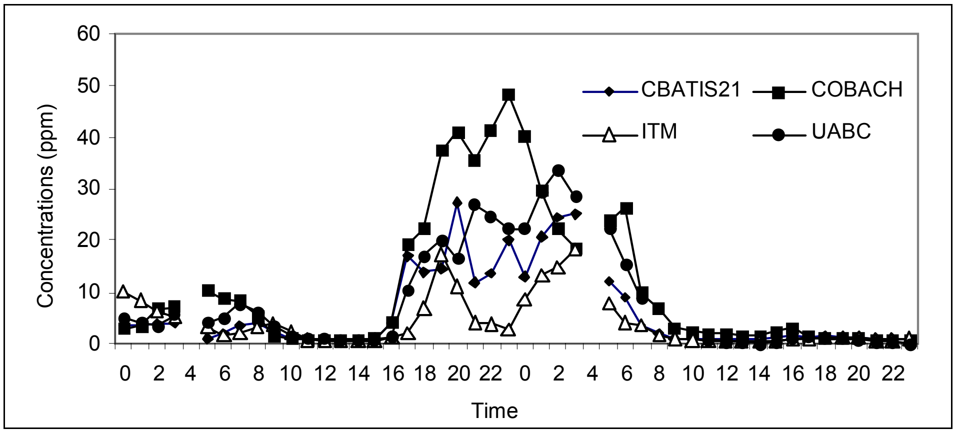
Regarding meteorological conditions, the graph shows that during the hours leading to this episode, as well as during the period of high CO concentrations, the wind originated consistently from the north, with speeds varying between 0.4 and 2.1 m/s. During the hours of high concentration, wind speed was very low and temperatures were relatively low in the early morning hours.

Figure 4.34. Hourly concentrations of carbon monoxide at COBACH (December 13 and 14, 1998)



When analyzing the hourly readings of CO at the other monitoring stations, (Figure 4.35), it was found that concentrations of this pollutant were equally high, especially at CBATIS21 and UABC, varying between 11 and 33 ppm.

Figure 4.35. Hourly concentrations of carbon monoxide in Mexicali
(December 13 and 14, 1998)



The fact that carbon monoxide concentrations were so high in almost all the stations at the same time, makes us assume that, in addition to the CO sources that are commonly identified in the zone, there was some exceptional phenomenon that generated high emissions of this pollutant. In this sense, it can be mentioned that agricultural burns have been identified as an important source of pollution in Mexicali and Imperial Valley, and it is possible that such an event may have caused the high concentrations of CO that were recorded. In fact, local informants point out that it is common to see agricultural burns in fields were asparagus and grass are grown, in Imperial Valley. Also, Chow *et al* (1995) in their study titled "Imperial Valley/Mexicali Cross Border PM10 Transport Study", point out that burning of vegetable remains in agricultural fields are one of the main emitters of pollutants into the atmosphere, especially particulate matter. They include a profile to determine emissions generated by burns carried out in asparagus fields. In order to estimate this profile, samples were collected on December 14 and 15, 1992, when a large number of asparagus fields were burned. In the emissions profile that was obtained, it was observed that organic carbon is the most abundant species, representing approximately 56 ± 15% of the total mass.

Unfortunately, in Mexicali there no records are kept for agricultural burns, making it difficult to establish if during this time, like in Imperial Valley, agricultural burns took place in Mexicali's agricultural fields.

PM10 episode of December 25, 1998

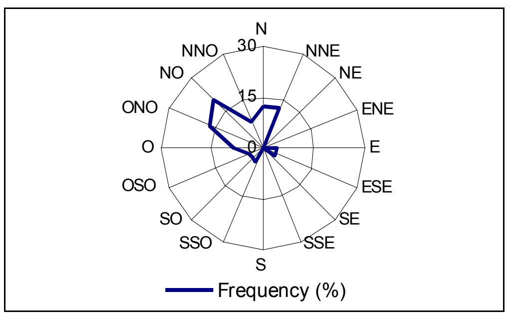
The maximum PM10 reading for 1998 was 476 μg/m^3 (362 IMECA points), and took place on December 25, at the station located in Centro de Salud, also known as Progreso. This reading corresponds to the 24-hour samples that are collected every sixth day at the different monitoring stations.

Unfortunately, for this same day there is only one other PM10 record, corresponding to CBATIS. That value was 103 μg/m^3 (68 IMECA points). As can be seen, the difference between the two values is considerable. The samples collected at the other monitoring stations (ITM, UABC, CBATIS21 and CONALEP) were invalidated by field technicians or at the laboratory, either because of equipment malfunction or leaks in the system.

Since no meteorological data is collected at Centro de Salud, Figure 4.36 shows the prevailing wind rose for COBACH, which is the nearest meteorological station. This wind rose shows that the prevailing winds were form the north and northeast, with speeds varying between 0.5 and 1.3 m/s.

It is important to point out that staff in charge of operating Mexicali's Air Quality Monitoring Network, have identified the general trend that, PM10 levels at Centro de Salud, tend to be higher than those recorded at the other stations. This is due to the proximity of this station to emissions from agricultural fields and unpaved roads.

Figure 4.36 Prevailing wind rose at COBACH station
(December 25, 1998)



Conclusions regarding air quality

It is important to mention that this analysis was performed using the information from only two years (1997 and 1998). Therefore, the trends that were observed are not yet completely representative of the behavior of pollutants. However, some conclusions can be drawn regarding air quality in Mexicali during these two years:

- The frequency of violation of any of the air quality standards was greater than 25% of the days; for the IMECA 150-point value it was close to 10% of the days, in 1997 as well as 1998. In 1997 the 200-point IMECA value was not reached but, in 1998, it was exceeded 12 days.
- During this period, there was an increase in the number of CO exceedances, from 14% in 1997 to 21% of the days in 1998. Ozone showed a similar behav-

ior, exceeding the standard almost 10% of the time during both years. Exceedances of the PM10 standard decreased almost by half, to a little more than 25% of the samples in 1998.

- During the cold season, carbon monoxide levels rose above 250 IMECA points, due to the atmospheric stability condition that prevails during these months.
- Ozone showed higher concentrations with greater frequency during the hot summer months.
- The PM10 standard was exceeded mainly during the winter season, in the dry months.
- Nitrogen dioxide showed exceedances to its standard only in January of 1998, and sulfur dioxide did not exceed its standard during the study period.
- As far as the behavior of pollutants by zone, in Mexicali, the ozone standard is exceeded with greater frequency in the western zone, followed by the southeastern zone. The carbon monoxide standard is exceeded with greater frequency in the western zone, reaching values as high as 300 IMECA points, followed by the northern zone. The PM10 standard is most frequently exceeded in the southwestern zone of the city (>50% frequency), followed by the southeastern and western zones.
- The monitoring network station that exceeds air quality standards with greatest frequency is COBACH, followed by CBATIS 21.
- The situation in Mexicali in terms of atmospheric pollution, particularly carbon monoxide and PM10, can be considered one of alert. This makes it necessary to design and implement measures to improve air quality in the zone, within a short period of time.

5. EMISSIONS INVENTORY

The air emissions inventory is a strategic tool for air quality management, since it allows us to learn the volume and type of pollutants produced by an emissions source. Based on this emissions inventory it is possible to assess the impact from some of the actions included in the Program. The following is a description of the energy balance for fuels and the estimation of emissions in Mexicali for 1996.

1. Energy balance

The magnitude of commercial, industrial, agricultural, and in general, economic activity of a city or region, can be expressed, among others, in terms of the way in which energy demand is distributed. According to several studies, there is a significant correlation between the gross domestic product and energy demand. The way in which this demand impacts air quality depends to a large extent on the energy balance, the type and quality of fuel, and the technological level of industry and the vehicular fleet.

Table 5.1 presents the energy balance for Mexicali, considering the main economic sectors and the different types of fuel. Fuel consumption data were provided by PEMEX Refinación and by the Mexicali branch of Gas Silza, and was supplemented with information taken from the annual certificate of operation from several companies under the jurisdiction of SEMARNAPs Federal Delegation in Baja California.

Table. 5.1. Annual energy consumption by sector in the urban area of Mexicali, % with respect to total consumption * 1996

Fuel	**Transportation**	**Industry**	**Services**	**Total**
Gasoline	62			62
Diesel	19	2		21
Gasavión (airplane fuel)	CD			CD
Turbosina	2			2
Combustóleo (industrial oil)		4		4
LP Gas		3	8	11
Coke		CD		CD
Total	**83**	**9**	**8**	**100**

CD: Negligible consumption. The volume consumed of gasavión and coke is less than 1%.
* Total annual consumption: 8.1 X 10^{12} kcal, equivalent to 971,247 m^3 of gasoline.

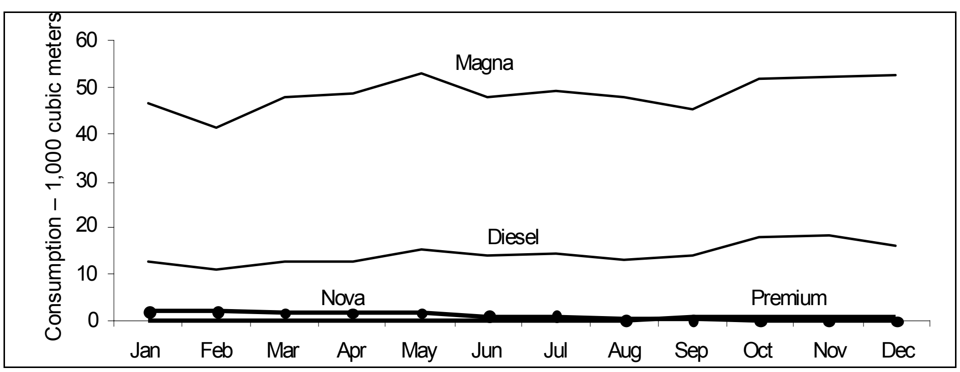
Source: INE, 1999, with information from PEMEX Refinación and Gas Silza S.A. de C.V.

The previous Table highlights the large energy consumption for vehicular uses, with gasoline representing 62% of the total fuel consumption and diesel 21%. Likewise, liquefied gas usage in the services sector is very important. Globally, it can be seen that energy consumption in transportation is the highest (83%), followed by the industrial sector (9%) and services (8%).

Given that gasoline and diesel for vehicular use have the highest energy demand, more dramatic overload trends for emissions in the airshed should be considered, due to a likely increase in the consumption of these fuels. This can also be explained by the demand on kilometers traveled by private vehicles, the number of vehicles in circulation, vehicular congestion at border crossings, urban surface area occupied by roadways, and energy efficiency of vehicles, as well as the type and quality of fuels used and emissions control technologies.

Figure 5.1 presents the evolution in the monthly consumption of vehicular fuels in Mexicali during 1996, which shows that gasoline demand was covered 97% by Pemex Magna which, along with diesel, were the two most widely used fuels. It can also be observed that there was little variation in its demand throughout the year, with the highest demand occurring in May, November, and December. The daily average consumption of gasoline was 1.6 million liters and that of diesel 470 thousand liters. Concerning the remaining types of vehicular fuel, the distribution of leaded gasoline (Nova) was stopped in October 1996, and commercial sales of Premium gasoline in the border region started in August of the same year.

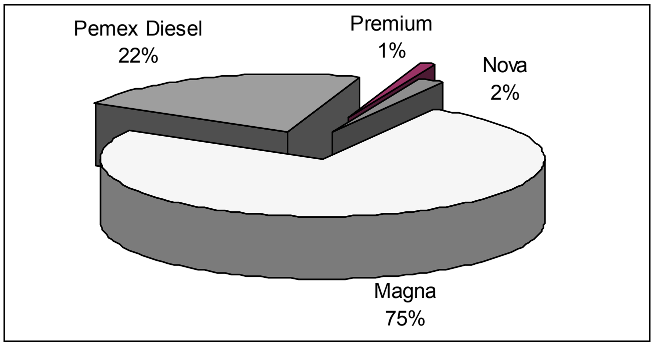
Figure 5.1 Consumption of gasoline and diesel for vehicular use in Mexicali, 1996



Source: PEMEX Refinación, Gerencia Comercial Zona Norte, 1998.

Figure 5.2 shows that within the transportation sector, there is also an important energy demand related to diesel consumption, since it represents 22% of the total vehicular fuel consumption.

Figure. 5.2. Vehicular gasoline and diesel consumption in Mexicali, 1996 (percentage)



2. Fuel characteristics

The quality of fuels consumed in Mexicali is established by NOM-ECOL-086-1994 (Published in the Official Federal Newspaper on December 2, 1994). This norm sets the specifications that must be met by liquid and gaseous fossil fuels used in fixed and mobile sources around the country, and in particular in the northern border. No specifications were established for PEMEX Premium gasoline in this norm. The gasoline that is sold in Mexicali is transported from Salina Cruz Refinery, Oaxaca, like Pemex Diesel and low sulfur Industrial Diesel.

A study commissioned by the US National Research Council considers that fuel quality improvements can offer positive results for air quality in urban zones (Calvert *et al*, 1993).[1] Particularly, it is believed that the most promising changes that can take place in the quality of gasoline from the environmental perspective consist of lowering the sulfur content and Reid vapor pressure. Sulfur reduction improves and extends, for a longer period of time, the efficiency of the catalytic converter. A reduction in vapor pressure has a direct effect in lowering evaporative emissions. It is also recommended to lower the content of olefins and the T_{90} value, that is, the temperature at which 90% of the gasoline is distilled. The addition of oxygenated compounds is of benefit when trying to maintain the octane level and reduce the level of carbon monoxide. However, this action seems to offer no benefits with respect to ozone reduction.

These observations indicate the need to conduct specific studies and analyses to define the specifications and quality of suitable gasoline for a determined zone, in order to achieve a cost-benefit balance.

As mentioned earlier, leaded gasoline is no longer distributed in Mexicali and

[1] Calvert, J.G.; Heywood, J.B.; Sawyer, R.F.; Seinfield, J.H. (1993). Science, vol. 261, p.37. Citado en el Programa para Mejorar la Calidad del Aire en el Valle de México 1995-2000.

Premium gasoline consumption is very low. Thus Table 5.2 only offers a comparison of Mexican specifications for Pemex Magna and details the specifications for Regular gasoline that came into effect in California, in 1996. For illustrative purposes, the typical values reached in recent years by the different properties that characterize Pemex Magna gasoline in Mexicali, Ciudad Juárez Mexico City, were included.

Table 5.2. Comparison of specifications and typical values of Mexican and US unleaded gasoline

	Pemex Magna	**Regular**	**PemexMagna**	**Pemex Magna**	**Pemex Magna**	
	ZFN NOM-086* 1994	**CARB** June 1996**	**Cd. Juárez Typical value in 1997**	**ZMVM*** Typical value in 1997**	**Mexicali Typical value in 1996**	**Mexicali Typical value in 1997*******
Reid vapor pressure, lb/pulg^2	7.8 – 13.5	6.8 max.	7.5	7.5	8.3	8.7
10% distills at ^oC (maximum):	55 – 70		56	55	59.6	58
50% distills at ^oC:	77min	93 max	97	95.7	109.6	108.4
90% distills at ^oC (maximum):	185 – 190	143	157	167	173.8	173.4
Final temperature boiling, ^oC:	225		197	212.7	215.0	214.5
Sulfur, % weight (maximum)	0.10	0.003	NA	0.037	0.090	0.089
Lead, kg/m^3 (maximum)	0.0026		NA	0.00026	0.000026	0.00026
Highway octane number, (R+M)/2 (minimum)	87.0	87.0	87.2	87.3	87.3	87.2
Aromatics, % volume (maximum)	NA	22	NA	21.3	37.4	36.0
Olefins, % volume (maximum)	NA	4	NA	8.2	12	11.0
Benzene, % volume (maximum)	NA	0.8	NA	0.7	2.4	1.82
Oxygen, % by weight	NA	2 min	NA	1.1	NA	NA

Notes: * Standard published by INE in the Official Federal Newspaper on December 2, 1994.
** California Regular. *** Typical value through March.
****Typical average through August NA.- Value not available.

From the previous table it can be inferred that PEMEX Magna gasoline distributed in Mexicali generally complied with the specifications from NOM-086-ECOL-1994 for the Northern Border Zone (ZFN), during 1996. Gasoline from California has stricter parameters than Mexican gasoline, with respect to the percentage of distillation, vapor pressure and sulfur content. In the case of gasoline from the ZFN, NOM-086 does not set reference values for the content of olefines, aromatics and benzene, but for these parameters, California gasoline also has stricter values.

In the Mexico Valley Metropolitan Zone (ZMVM), oxygenated Magna gasoline, with a lower content of aromatics and olefines, is distributed. This gasoline also has a lower Reid Vapor Pressure and lower boiling temperature than the gasoline distributed in Mexicali. Finally, gasoline distributed in Ciudad Juárez has a lower distillation temperature and vapor pressure than gasoline distributed in Mexicali.

In several US cities along the border, there is a program to reduce evaporative emissions from volatile organic compounds (VOCs), by using low RVP (maximum value is 6 psi). That measure is beneficial when trying to reduce ozone levels. NOM-086 specifies that Magna gasoline at storage and distribution terminals in the Western Portion of the Northern Border Zone, where the city of Mexicali is included, RVP varies through the year with respect to the type of volatility of the zone. For example, during the period from June through October, the lowest value (10 psi) is used, whereas the highest value (13.5 psi), is used in the months of November, December, January, February, and March.

This standard does not specify any value for this parameter with respect to oxygen content and it is not reported by Salina Cruz Refinery. In some US cities, gasoline is oxygenated during the winter season, with a minimum content of 2.7% O_2 by weight, with the purpose of improving combustion and reducing carbon monoxide emissions.

As far as Pemex Diesel is concerned, this type of fuel largely satisfies Mexican specifications. The average sulfur content of Pemex Diesel distributed throughout Mexicali in 1996 was 0.04% by weight, whereas the value for this parameter for 1997 in the Valley of Mexico Metropolitan Zone (ZMVM) it was 0.03% (see Table 5.3).

Table 5.3. Specifications of Mexican diesel with low sulfur content

Property	**Diesel Sin**		
	Mexico NOM-086* 1995	**ZMVM Typical value in 1997***	**Mexicali Typical value in 1996**
10% distills at ºC (maximum): 90% distills at ºC (maximum):	275 345	223 335	219 333
Water and sediment, % by volume (maximum):	0.05	0.010	0.009
Ashes, % by volume (maximum):	0.01	0.001	ND
Ramsbotton carbon, % by weight (maximum):	0.25	0.080	0.09
Sulfur, % by weight (maximum):	0.05	0.03	0.04
Cetane index (minimum):	48	55	52.8
Viscosity, (SU), seconds	32 – 40	NA	NA
Aromatics, % by volume	30	27.5	27.9

Note: * Standard published by INE in the Official Federal Newspaper on December 2, 1994.
* Through March NA = Parameter not available.

In accordance with NOM-086- ECOL-1994, starting in January of 1998, combustóleo (Table 5.4), must have a maximum sulfur content of 4% by weight. Combustóleo that was distributed in Mexicali, sent by Pemex from the Salina Cruz refinery in Oaxaca, complied with the norm in 1996, since the average sulfur content was 3.9 % by weight.

As far as gas consumption in Mexicali is concerned, only Liquefied Petroleum Gas (LPG) was consumed in 1996. The characteristics and composition specified in NOM-086, are shown on Table 5.5. These specifications do not detail the propane content that the gas must have. Pemex sends LPG to Mexicali from Rosarito, Baja California. In fewer cases Pemex will send it from Salina Cruz, Oaxaca; and, when there is a shortage, LPG is imported from the United States.

Table 5.4. Specifications for Mexican combustóleo

Property	Mexico NOM-086* 1995	Mexicali Typical Value, 1996
Specific Weight (20/4 ^{0}C)	NA	1.001
Viscosity SSF (50^{0}C)	475-550	533.6
Sulfur (% by weight)	4%	3.86
Water and sediment, (% by volume):	1.0 max	0.050
Temp. Infl. (^{0}C)	66 min.	98.3
Temp. Escurr. (^{0}C)	15 max	13.0
Ashes (% by weight)	NA	0.05
Vanadium (ppm)	NA	355.9
Nickel (ppm)	NA	69.1
Sodium (ppm)	NA	2.4
Asphaltenes (% en peso)	NA	14.0
Conradson Carbon(% en peso)	NA	15.60
Kinematic Viscosity	1008-1166	1132

Note: * Standard published by INE in the Federal Official Newspaper on December 2, 1994.
NA = Parameter not available

Table 5.5. Specifications for LP Gas

Property	Specification
Vapor pressure in excess of the atmosphere 37.8 ^{0}C (kPa, lb/pulg^2)	551 (80) minimum 1,379 (200) Maximum
95% distills at: (^{0}C)	2 maximum
Ethane (% volume)	2 maximum
Pentane (%volume)	2 maximum
Evaporation residue of 0.100 dm^3 (cm^3)	0.05 maximum
Specific weight at 20/4 ^{0}C	Inform
Copper plate corrosion, 1 hour at 37.8 ^{0}C	#1 standard maximum
Total sulfur (kg/ton)	0.140 maximum
Free water	Nothing

Note: * Standard published by INE in the Federal Official Newspaper on December 2, 1994.

3. Emissions Inventory

The development of a desegregated, precise and updated emissions inventory is a complex task, demanding the systematic integration of information in framework of institutional agreement, between the local and federal government. Some international and national experiences indicate the need of spending years doing research, and considerable financial resources, in order to develop a complete emissions inventory. In general, a basic inventory is used as the starting point, which is built on with information of better quality, more detailed, and specific.

In order to develop this Program, the first emissions inventory for Mexicali was integrated, as part of the activities of the Border XXI Binational Air Quality Workgroup. The US Environmental Protection Agency, through the Western Governors Association, granted the resources to carry out this effort. This was done as part of the Project for the Development of Emissions Inventory Methodologies for Mexico. This project contemplated proving the methodology in a Mexican city. Radian International was hired to carry out this effort, and ICAR Ambiental de Mexicali was subcontracted by Radian to develop the emissions inventory for Mexicali.

Several meetings were held in order to develop this inventory. The first of these meetings was to plan the development of the program and the following meetings were held for follow-up and evaluation purposes. The information used for the development of this inventory dates back to 1996. The quality assurance and quality control (QA/QC) effort, was led by the National Institute of Ecology (INE), with support from Radian International.

The approximate cost of the project to develop the air emissions inventory was US$200,000, and it took a year and a half to complete it. Table 5.6 shows the methods used for calculating emissions by source type.

For greater detail of the calculations used to estimate emissions, you may consult the final report of the project, titled: "Inventario de emisiones al aire de Mexicali, B.C., ICAR Ambiental, Noviembre de 1999".

Table 5.6 Methods used for the calculation of emissions by source type

Type of Source	**Method used for estimating emissions**
Industrial Sector	
Energy generation	Emissions factors
Chemical industry	Emissions measurement and emissions factors
Metallic minerals	Emissions measurement and emissions factors
Non-metallic minerals	Emissions measurement and emissions factors
Wood and by-products	Emissions measurement and emissions factors
Vegetable and animal products	Emissions measurement and emissions factors
Food products	Emissions measurement and emissions factors
Clothing industry	Emissions measurement and emissions factors
Various consumer products	Emissions measurement and emissions factors
Metallic products	Emissions measurement and emissions factors
Medium-life consumer products	Emissions measurement and emissions factors
Long-life consumer products	Emissions measurement and emissions factors
Area Sources	
Commercial, institutional and service combustion	Emissions factors
Locomotives/train engines	Emissions factors
Airplanes	FAAED 2.0 Model
Other non-road mobile equipment	Emissions factors
Border crossings	MOBILE5 Juárez Model
Bus terminal	MOBILE5 Juárez Model
Car body paint	Emissions factors
Architectural surface coating	Emissions factors
Road/traffic paint	Emissions factors
Industrial surface cleaning	Emissions factors
Dry cleaners	Emissions factors
Graphic arts	Emissions factors
Application of asphalt	Emissions factors
Commercial and domestic solvent use	Emissions factors
Fuel commercialization and distribution	Emissions factors
Airplane refueling	Emissions factors
LP Gas Distribution	Emissions factors
Bakeries	Emissions factors
Charbroiling	Emissions factors
Pesticide application	Emissions factors
Cattle feed yards	Emissions factors
Agricultural Burns	Emissions factors
Agricultural tilling	Emissions factors
Municipal waste fires	Emissions factors
Wastewater treatment	Emissions factors
Structural fires	Emissions factors
Paved roads	Emissions factors
Unpaved roads	Emissions factors
Transportation Sector	
Private cars	MOBILE5 Juárez Model
Taxis	MOBILE5 Juárez Model
Pick-up trucks	MOBILE5 Juárez Model
Passenger buses	MOBILE5 Juárez Model
Diesel Passenger buses	MOBILE5 Juárez Model
Light-load trucks	MOBILE5 Juárez Model
Heavy-load trucks	MOBILE5 Juárez Model
Diesel heavy-load trucks	MOBILE5 Juárez Model
Motorcycles	MOBILE5 Juárez Model
Soil and vegetation	
Soil wind erosion	Emissions factors
Vegetation	PCBEIS 2.2 Model

Tables 5.7 and 5.8 and Figure 5.3, show the volume and percentage of emissions generated by source type and by pollutant. As shown, in Mexicali approximately 426 thousand tons of pollutants are released to the air every year. 68% of those emissions comes from the transportation sector; 23% from area sources; 6% from wind erosion and vegetation; and, 3% from the industrial sector. Tables 5.9 and 5.10 contain the inventory in desegregated form, by weight and by percentage, respectively.

Table 5.7. Mexicali emissions inventory, 1996 (tons / year)

Sector	**PM10**	**SO_2**	**CO**	**NO_X**	**HC**	**Total**
Industry	1,994	2,849	4,721	1,537	1,407	**12,508**
Area sources	61,932	11	18,944	735	15,379	**97,001**
Transportation	515	937	243,073	14,927	31,184	**290,636**
Soils and vegetation	20,548			1,348	3,441	**25,337**
Total	**84,989**	**3,797**	**266,738**	**18,547**	**51,411**	**425,482**

Table 5.8. Mexicali emissions inventory, 1996
(percentage by weight, by pollutant)

Sector	**PM10**	**SO_2**	**CO**	**NO_X**	**HC**	**Total**
Industry	2	75	2	8	3	**3**
Area sources	73	1	7	4	29	**23**
Transportation	1	24	91	81	61	**68**
Soils and vegetation	24			7	7	**6**
Total	**100**	**100**	**100**	**100**	**100**	**100**

The transportation sector has considerable contributions from almost all the pollutants: it generates 91% of the carbon monoxide, 81% of the nitrogen oxides, 61% of the hydrocarbons, and 24% of the sulfur dioxide. Area sources emit 73% of the particles less than 10 µm in diameter (PM10), and 29% of the hydrocarbons. The contribution from PM10 generated by soils is 24%. 75% of sulfur dioxide emissions correspond to the industrial sector, which also contributes 8% of the nitrogen oxide emissions.

Figure 5.3. Contribution of total emissions by sector

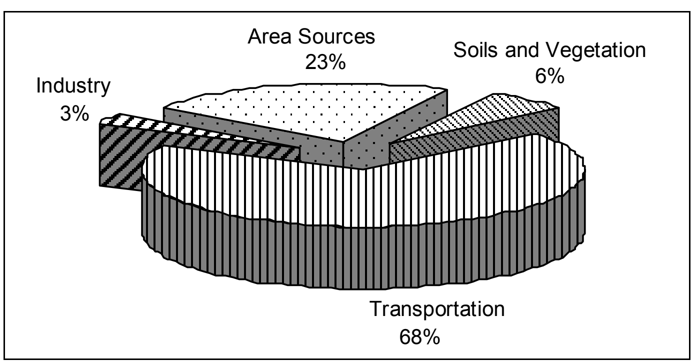


Table 5.9. Desegregated emissions inventory for Mexicali, 1996 (tons/year)

Type of Source	PM10	SO_2	CO	NOx	HC
Industrial Sector					
Energy generation	18	83	134	595	17
Chemical industry	NS	NS	NS	1	NS
Metallic minerals	105	857	4,486	153	1
Non-metallic minerals	1,669	952	59	590	733
Wood and by-products	1	12	2	8	NS
Vegetable and animal products	83	652	11	89	71
Food products	45	18	7	34	1
Clothing industry	NS	NS	NS	NS	2
Various consumer products	15	270	2	34	167
Metallic products	34	NS	2	8	124
Medium life consumer products	2	NS	3	4	95
Long life consumer products	22	5	15	20	138
Others	NS	NS	NS	1	58
Area Sources					
Combustion from the commercial, industrial and service sectors	1	NS	3	24	1
Residential combustion	4	6	79	121	8
Train engines / Locomotives	6	NE	34	237	14
Airplanes	NE	NS	111	6	12
Other mobile non-road equipment	45	NE	398	246	61
Border crossings	NS	NE	2,606	19	294
Bus terminal	2	NE	904	48	133
Industrial surface coating	NA	NA	NA	NA	254
Car body paint	NA	NA	NA	NA	458
Architectural surface coating	NA	NA	NA	NA	1,141
Road/traffic paint	NA	NA	NA	NA	22
Industrial surface cleaning	NA	NA	NA	NA	1,718
Dry cleaners	NA	NA	NA	NA	327
Graphic arts	NA	NA	NA	NA	322
Asphalt application	NA	NA	NA	NA	1,568
Commercial and domestic solvent use	NA	NA	NA	NA	2,292
Fuel commercialization and distribution	NA	NA	NA	NA	1,596
Airplane refueling	NA	NA	NA	NA	NS
Distribution of LP gas	NA	NA	NA	NA	2,260
Bakeries	NA	NA	NA	NA	76
Charbroiling	228	NE	NE	NE	28
Pesticide application	NA	NA	NA	NA	587
Cattle feed lots	1,180	NA	NA	NA	NA
Agricultural burns	2,143	NE	14,325	NE	1,949
Agricultural tilling	1,283	NA	NA	NA	NA
Municipal waste fires	88	5	460	164	33
Wastewater treatment	NA	NA	NA	NA	92
Structural fires	2	NE	24	1	2
Paved roads	3,261	NA	NA	NA	NA
Unpaved roads	53,689	NA	NA	NA	NA
Transportation Sector					
Private vehicles	80	507	143,957	6,283	18,427
Taxi cabs	1	7	2,102	92	269
Pick-up trucks	34	216	58,828	2,570	7742
Passenger buses	2	10	4,623	206	454
Diesel-fueled passenger buses	22	7	159	248	41
Light-load trucks	5	32	8,694	441	1,289
Heavy-load trucks	7	47	21,621	962	2,122
Diesel-fueled heavy-load trucks	363	107	2,638	4113	673
Motorcycles	1	4	451	12	167
Soils and Vegetation					
Streets and vacant lots	12,112	NA	NA	NA	NA
Agricultural fields	8,436	NA	NA	NA	NA
Vegetation	NA	NA	NA	1,348	3,441

Type of Source	PM10	SO_2	CO	NOx	HC
Total	**84,989**	**3,797**	**266,738**	**18,547**	**51,411**

NA: Not applicable NS: Not significant NE: Not estimated

Table 5.10. Mexicali Emissions Inventory, 1996
(Percent by weight, by pollutant)

Type of Source	PM10	SO_2	CO	NOx	HC
Industrial Sector					
Energy generation	NS	2.2	0.1	3.2	NS
Chemical industry	NS	NS	NS	NS	NS
Metallic minerals	0.1	22.6	1.7	0.8	NS
Non-metallic minerals	2.0	25.1	NS	3.2	1.4
Wood and by-products	NS	0.3	NS	NS	NS
Vegetable and animal products	0.1	17.2	NS	0.5	0.1
Food products	0.1	0.5	NS	0.2	NS
Clothing industry	NS	NS	NS	NS	NS
Various consumer products	NS	7.1	NS	0.2	0.3
Metallic products	NS	NS	NS	NS	0.2
Medium-life products	NS	NS	NS	NS	0.2
Long-life products	NS	0.1	NS	0.1	0.3
Others	NS	NS	NS	NS	0.1
Area Sources					
Commercial, industrial and service sector combustion	NS	NS	NS	0.1	NS
Residential combustion	NS	0.2	NS	0.7	NS
Train engines / Locomotives	NS	NE	NS	1.3	NS
Airplanes	NE	NS	NS	NS	NS
Other mobile non-road equipment	0.1	NE	0.1	1.3	0.1
Border crossings	NS	NE	1.0	0.1	0.6
Bus terminals	NS	NE	0.3	0.3	NS
Industrial surface coating	NA	NA	NA	NA	0.5
Car body paint	NA	NA	NA	NA	0.9
Architectural surface coating	NA	NA	NA	NA	2.2
Traffic/road paint	NA	NA	NA	NA	NS
Industrial surface cleaning	NA	NA	NA	NA	3.3
Dry cleaners	NA	NA	NA	NA	0.6
Graphic arts	NA	NA	NA	NA	0.6
Asphalt application	NA	NA	NA	NA	3.0
Commercial and domestic solvent use	NA	NA	NA	NA	4.5
Fuel commercialization and distribution	NA	NA	NA	NA	3.1
Airplane refueling	NA	NA	NA	NA	NS
Distribution of LP gas	NA	NA	NA	NA	4.4
Bakeries	NA	NA	NA	NA	0.1
Charbroiling	0.3	NE	NE	NE	0.1
Pesticide application	NA	NA	NA	NA	1.1
Cattle feed lots	1.4	NA	NA	NA	NA
Agricultural burns	2.5	NE	5.4	NE	3.8
Agricultural tilling	1.5	NA	NA	NA	NA
Municipal waste fires	0.1	0.1	0.2	0.3	0.1
Wastewater treatment	NA	NA	NA	0.2	1.1
Structural fires	NS	NA	NS	NS	NS
Paved roads	3.8	NA	NA	NA	NA
Unpaved roads	63.2	NA	NA	NA	NA
Transportation Sector					
Private vehicles	0.1	13.4	54.0	33.9	35.8
Taxi cabs	NS	0.2	0.8	0.5	0.5
Pick-up trucks	NS	5.7	22.1	13.9	15.1
Passenger buses	NS	0.3	1.7	1.1	0.9
Diesel-fueled passenger buses	NS	0.2	0.1	1.3	0.1
Light-duty trucks	NS	0.8	3.3	2.4	2.5
Heavy-duty trucks	NS	1.2	8.1	5.2	4.1
Diesel-fueled heavy-duty trucks	0.4	2.8	1.0	22.2	1.3
Motorcycles	NS	0.1	0.2	0.1	0.3

Type of Source	PM10	SO_2	CO	NOx	HC
Soils and vegetation					
Streets and vacant lots	14.3	NA	NA	NA	NA
Agricultural fields	9.9	NA	NA	NA	NA
Vegetation	NA	NA	NA	7.3	6.7
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

NA: Does not apply NS: Not significant NE: Not estimated

The following is a description of the involvement of the different sectors in the total emissions for each pollutant.

According to Figure 5.4, for area sources, 63% of PM10 emissions in Mexicali are due to vehicles circulating on unpaved roads and 4% are due to vehicles circulating on paved roads. Soil erosion contributes 24%; and the remaining 9% originates mainly from agricultural tilling and agricultural burns, the industrial and transportation sectors. Within the industrial sector, the main contribution is from non-metallic minerals. Within the transportation sector, the main contribution is from diesel-fueled heavy-load trucks. These categories and activities are taken into consideration when defining abatement control measures.

Figure 5.4. Percent contribution of particulate matter (PM10) by sector

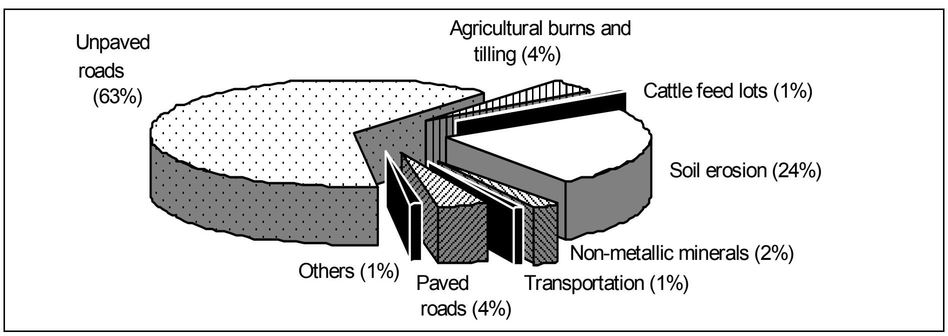
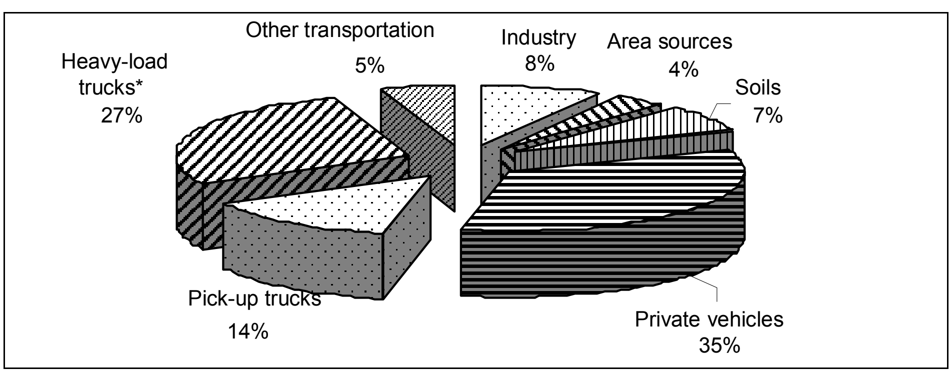


Figure 5.5. Percent contribution of nitrogen oxides by Source Type

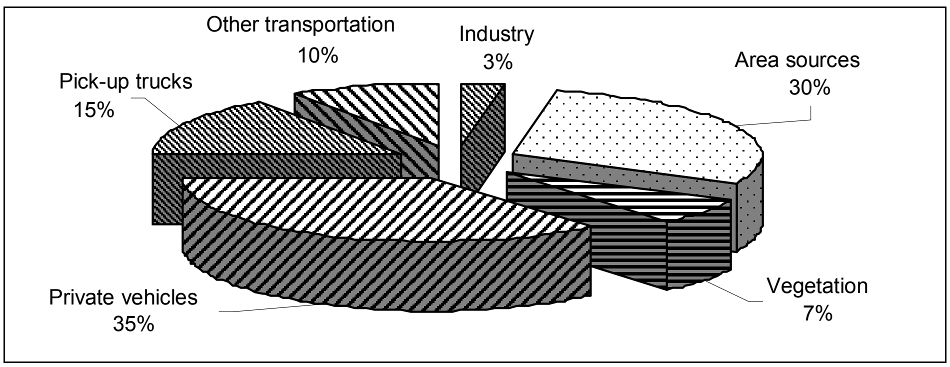


* Heavy-load trucks using gasoline or diesel as fuel

A recount of all the sources involved in the emissions inventory shows that, for nitrogen oxides (Figure 5.5), the transportation sector contributes 81% of total NO_2 emissions. Of that total, 35% of which comes from private vehicles, 27% from heavy-load trucks using gasoline or diesel as fuel, 14% from pick-up trucks; and, the remaining 5% from other types of transportation. The industrial sector contributes 8% of the total NO_2 emissions, followed by vegetation with 7%.

Similarly, Figure 5.6 shows that the transportation sector, with private vehicles and pick-up trucks, contributes the largest amount of hydrocarbon emissions (35 and 15%, respectively). Among the other sectors, area sources contribute 30% of the total hydrocarbon emissions, whereas vegetation contributes 7% and the industrial sector 3%.

Figure 5.6. Percent contribution of total hydrocarbons by source type



These contributions are relevant because, as shown earlier, the air quality standard for ozone is exceeded in Mexicali. Therefore, it is necessary to reduce the emissions of ozone precursors and identify their regional behavior in order to discern transport and dispersion mechanisms with the surrounding areas.

Figure 5.7. Percent contribution of carbon monoxide by source type

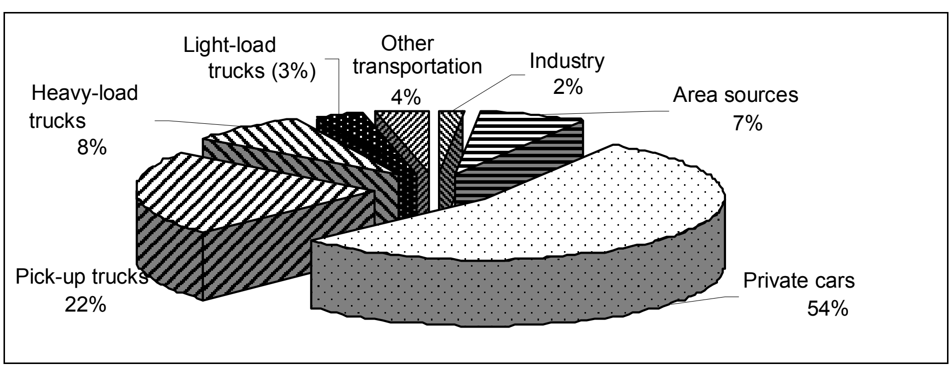


Figure 5.7 shows that private cars, pick-up trucks, and heavy-load trucks, contribute to the largest percentage of carbon monoxide emissions (54%, 22% and 8%, respectively). Among the other sectors, area sources contribute 7%, whereas the industrial sector only contributes 2% of the total CO emissions. This situation allows us to establish the need for considering within this program, control measures aimed at reducing CO emissions from the vehicular fleet.

As far as sulfur dioxide emissions are concerned, the industrial sector is responsible for 75% of these emissions, with the remaining emissions coming mainly from the transportation sector.

Industry

It is estimated that there are approximately 1100 industrial facilities in the city of Mexicali, the majority of which correspond to the micro and small industry, and only 11% correspond to the medium and large industry. Figure 5.9 shows the location of the main industrial areas in Mexicali.

112 of these facilities obtained their certificate of operation in 1996. These covered 13 different types of establishments of which, medium-life consumer products covers 24%; followed by metallic products (15%); food products (13%); long-life consumer products (10%); non-metallic minerals (7%); and, the rest comprise 21% of the establishments (Figure 5.8).

Figure 5.8 Industry breakdown in Mexicali

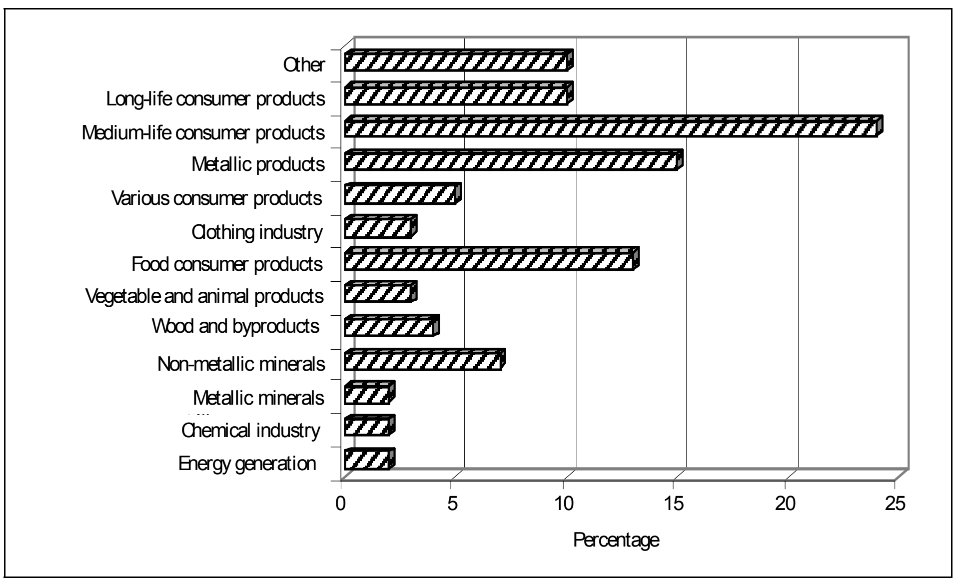
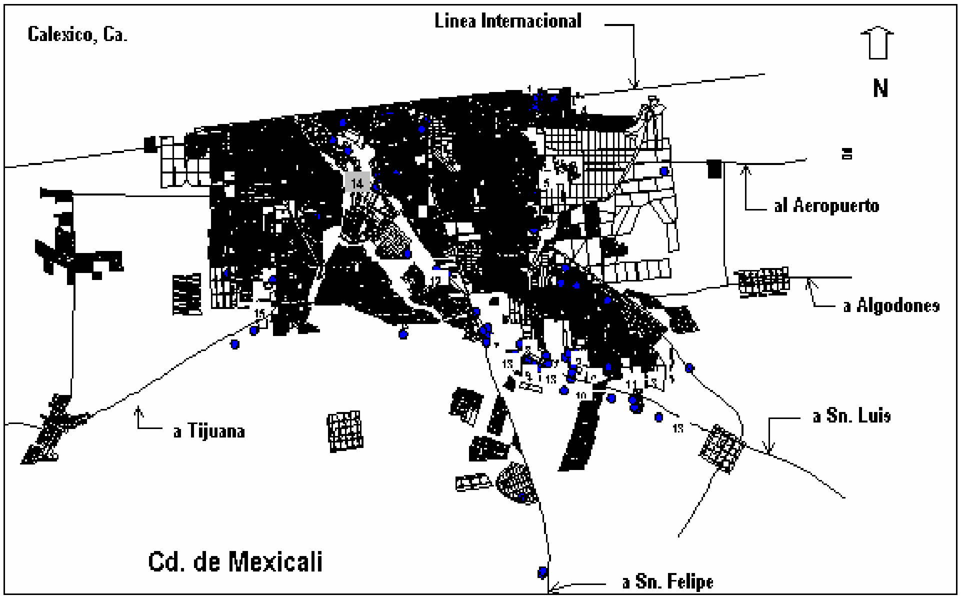


Figure 5.9. Location of industrial facilities in Mexicali



Location of the main industrial areas

1	Mexicali I Industrial Park	9	Cachanilla Industrial Park
2	Mexicali II Industrial Park	10	Cucapa Industrial Park
3	Mexicali III Industrial Park	11	Nelson Industrial Park
4	Mexicali IV Industrial Park	12	Margar Industrial Center
5	EX-XXI Industrial Park	13	González Ortega Corridor
6	El Vigía Industrial Park	14	Blvd. López Mateos
7	Maran Industrial Park	15	Progreso Industrial Park
8	Las Californias Industrial Park		

As indicated earlier, the emissions inventory for the industrial sector was developed applying the methodology used for México[2,3]. The information presented by the facilities through their Annual Certificate of Operation for 1997 was used as the basis for this inventory. The Annual Certificate of Operation was used to record the emissions trends from the previous year, and the measurements obtained with the combustion equipment were reviewed. Likewise, emissions factors[4] and material balance were used in accordance with the recommendations for methodology, depending on the type of industry, raw materials and processes used.

2 Available on INEs internet page on Air Quality, at: http://www.ine.gob.mx.

3 Radian-Semarnap, (1997). Mexico Emissions Inventory Program Manuals, Volume IV Point Source Inventory Development.

4 U.S. Environmental Protection Agency (1995). Compilation of Air Pollution Emissions Factors, Volume I Stationary Point an Area Sources. Office of Air Quality Planning and Standards. Office of Air and Radiation. AP-42 fifth edition.

The emissions for the criteria pollutants (particulate matter, sulfur dioxide, carbon monoxide, nitrogen oxides, and total hydrocarbons), were calculated for fossil fuel combustion processes and for productive processes were volatile organic compounds and/or particulates are generated.

Based on this inventory, we get a total of 12,508 tons/year of industrial sector emissions in Mexicali. Different from other cities, carbon monoxide emissions are the most prevailing. This indicates that there are some opportunities to improve the operation of combustion processes in this sector. It is also important to notice the significant contribution from sulfur dioxide.

Figure 5.10 highlights the contribution to PM10 emissions from the non-metallic minerals sector, which contributes to 84% of the 1,994 tons of PM10 released by the industrial sector. These emissions correspond mainly to the movement, handling, and crushing of materials.

Figure 5.10. Percent contribution of PM10 by type of industry

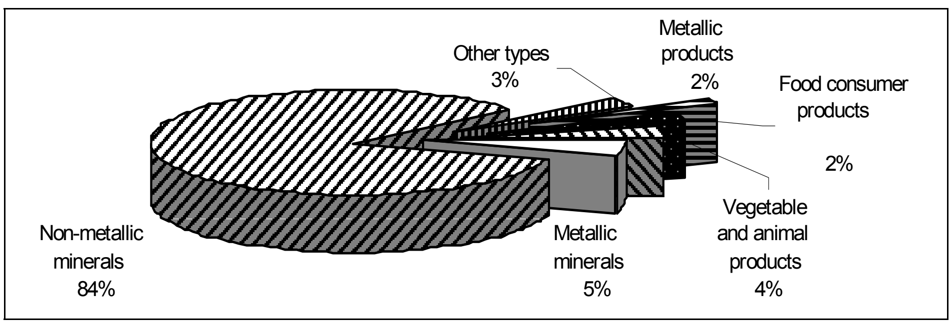
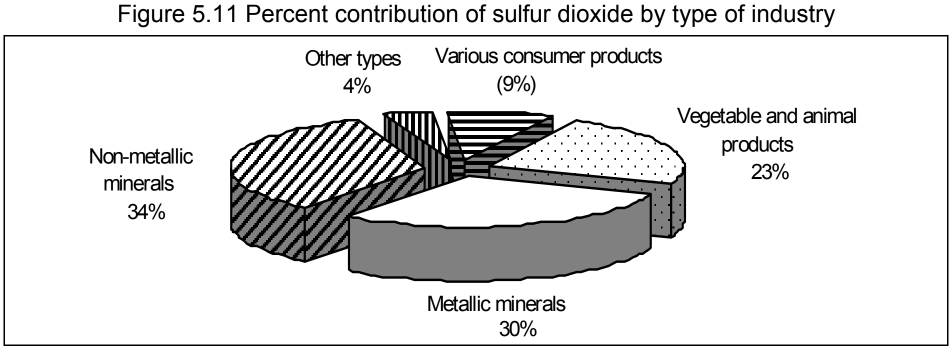


Figure 5.11 Percent contribution of sulfur dioxide by type of industry



As far as sulfur dioxide is concerned, Figure 5.11 shows three sub-sectors are responsible for much of the industrial sector emissions: non-metallic minerals (34%), metallic minerals (30%), and vegetable and animal products (23%). These three categories contribute to 87% of the 2,849 tons of SO_2 that are generated by the industrial sector. They are the product of sulfur contained in combustóleo and diesel used during combustion processes.

A more in-depth analysis of ozone precursor pollutants, with respect to the total NOx generated by the industrial sector, reveals that electric power generation facilities, non-metallic mineral facilities, and metallic mineral facilities, are the most important, contributing 39%, 38% and 10%, respectively (see Figure 5.12). These emissions are produced during the combustion processes used at these facilities. As far as HC emissions are concerned, the non-metallic mineral industries, those of various consumer products, long-life consumer products, and metallic products, are the main contributors with 51%, 12%, 10% and 9% of industrial HC emissions, respectively (see Figure 5.13).

Figure 5.12. Contribution of nitrogen oxides by type of industry

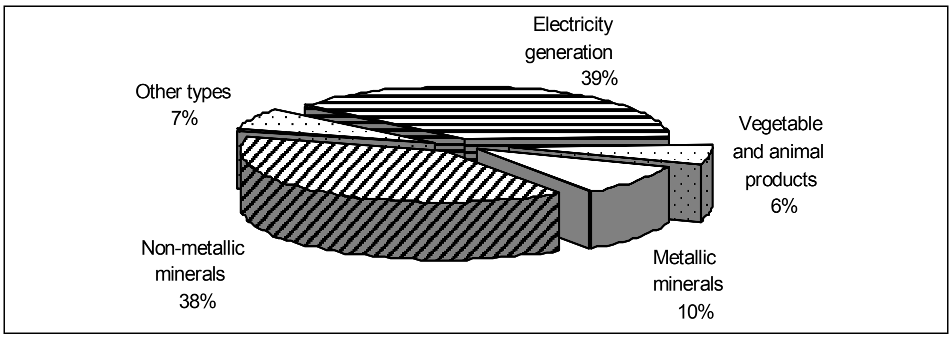


Figure 5.13. Contribution of hydrocarbons by type of industry

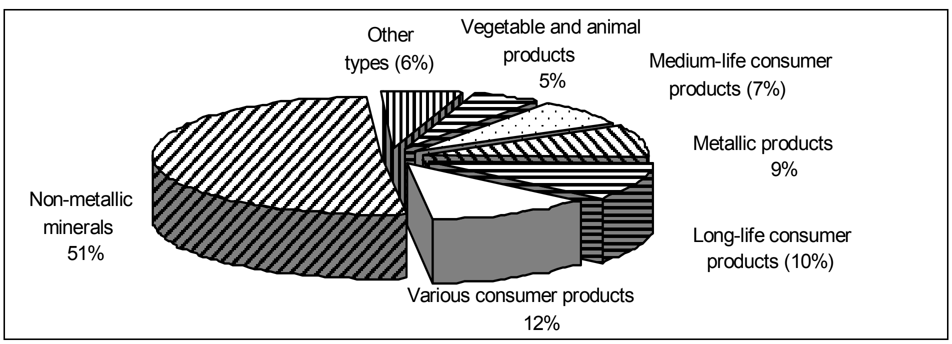


Table 5.11 shows 8 emissions strata for facilities according to the level of emissions indicated in the second column. An analysis of de NOx and HC emissions shows that stratum A, which includes all the others, is includes 42 facilities with individual emission levels greater than 2 tons per year. Stratum B, which includes all its subsequent strata, includes 36 facilities with emissions greater than 3 ton/year, and so forth.

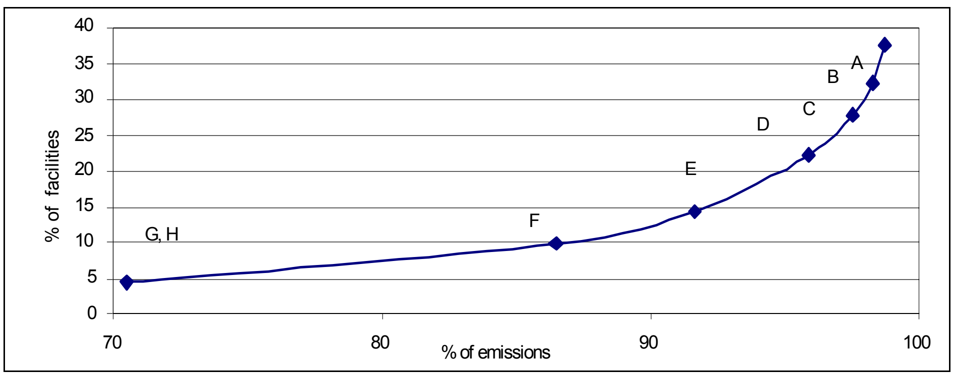
Table 5.11. Array of industrial establishments in Mexicali according to the volume of NOx and HC emissions (ton/year)

Group	Emissions strata	# of com-panies	% of total # of com-panies	NOx	HC	Emission HC+NOx	% emissions with respect to total HC+NOx for the sector
A	>2	42	37.5	1,519	1,387	2,907	98.7
B	>3	36	32.1	1,515	1,378	2,893	98.3
C	>5	31	27.7	1,508	1,364	2,872	97.5
D	>10	25	22.3	1,487	1,335	2,823	95.9
E	>20	16	14.3	1,429	1,270	2,699	91.7
F	>40	11	9.8	1,416	1,131	2,547	86.5
G	>80	5	4.5	1,308	768	2,076	70.5
H	>120	5	4.5	1,308	768	2,076	70.5

Total # of establishment on the database:	112
Total Nox emissions, ton/year:	1,537
Total HC emissions, ton/year:	1,407
Total (HC+NOx) emissions, ton/year:	2,944

This way of organizing the information included in the table allows us to observe that the 42 companies in Stratum A, represent a total volume of 2,907 ton/year of ozone precursors, corresponding to 98.7% of the total emissions generated by the industrial sector. Following the same line of reasoning, it can be observed that the 16 facilities that emit more than 20 tons/year of HC and NOx (group E), comprise 91.7% of the emissions of these pollutants produced by the industrial sector as a whole in Mexicali.

Figure 5.14. Industrial sector contribution to HC and NOx emissions



The Lorenz Curve in Figure 5.14 shows a slanted distribution for the emissions of ozone precursors from the industrial sector (very few facilitates contribute large amounts of pollution). Point A, represents the 42 establishments that generate 98.7% of ozone precursors in the industrial sector. The remaining 1.3% of these precursors, corresponds to the emissions produced by the remaining 63% of the facilities; that is, 70 establishments.

If we expand this analysis and incorporate the total emissions of SO_2, PM10 and CO, we notice that the same 11 establishments generate 94% of the total emissions from the industrial sector, as shown in Table 5.12. This type of analysis provides the elements to establish adequate industrial emissions reduction programs, as is the case for high pollution level episodes, fuel improvement and industrial plant technological updates.

Table 5.12. Facilities in the city of Mexicali ordered by total emissions volume for PM10, SO_2, CO, NOx y HC

Group	Strata	# of Companies	% of companies	PM10	SO_2	CO	NOx	HC	Total emissions (ton/year)	% of emissions with respect to the sector
A	>2	42	37.5	1,907	2,837	4,678	1,519	1,387	12,329	98.6
B	>3	36	32.1	1,894	2,832	4,677	1,515	1,378	12,296	98.3
C	>5	31	27.7	1,893	2,823	4,675	1,508	1,364	12,263	98.0
D	>10	25	22.3	1,887	2,814	4,672	1,487	1,335	12,195	97.5
E	>20	16	14.3	1,880	2,739	4,655	1,429	1,270	11,973	95.7
F	>40	11	9.8	1,875	2,664	4,653	1,416	1,131	11,738	93.8
G	>80	5	4.5	1,239	1,813	4,633	1,308	768	9,761	78.0
H	>120	5	4.5	1,239	1,813	4,633	1,308	768	9,761	78.0

Total # of facilities in database: 112
Total emissions, ton/year: 12,508

Area sources

Area source inventories group together the emissions from numerous emissions sources of similar type, which individually emit small amounts of pollutants within a specific category. For the case of Mexicali, the emissions that were inventoried come from residential, commercial and service combustion; non-road mobile sources; solvent usage; fuel storage, transportation and distribution; small commercial sources; agricultural activities (such as burning, tilling, and pesticide application); among others.

This sector is important due to the fact that Mexicali is a zone of medium population density, which implies the need for a wide variety of service and commercial establishments, in order to meet the basic needs of the population. Individually, people generate small amounts of pollutants; however, when taking them as a whole, the emissions they produce become very important, mainly those related to PM10 and HC.

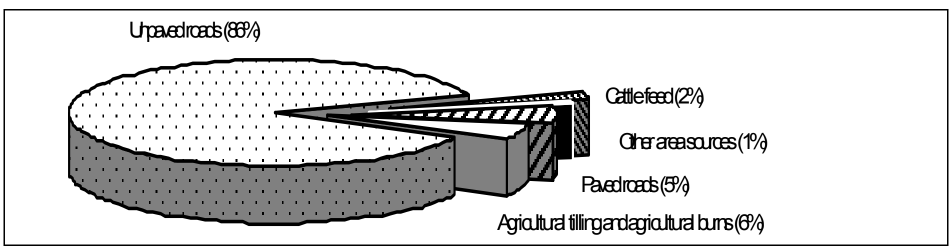
As mentioned earlier, the methodology that was developed for Mexico[5], was used to build the emissions inventory for area sources. The most reliable methods recommended for emissions calculations were used. Depending on data availability

[5] Radian-Semarnap (1997). Mexico Emissions Inventory Program Manuals, Volume V- Area Source Inventory Development.

for the different sources, the most widely used methods were the application of emissions factors and mechanical models. This inventory identified 30 trades and activities that generate PM10, SOx, CO, NOx and HC emissions. For PM10 emissions, unpaved roads and soil erosion due to the wind are the primary contributors, due to the fact that Mexicali has a very low rate of precipitation, along with the presence of many unpaved roads. It is important to point out that Mexicali is a highly agricultural area, with HC emissions originating to a large extent from agricultural burns. Fuel commercialization and distribution is another big contributor to HC emissions.

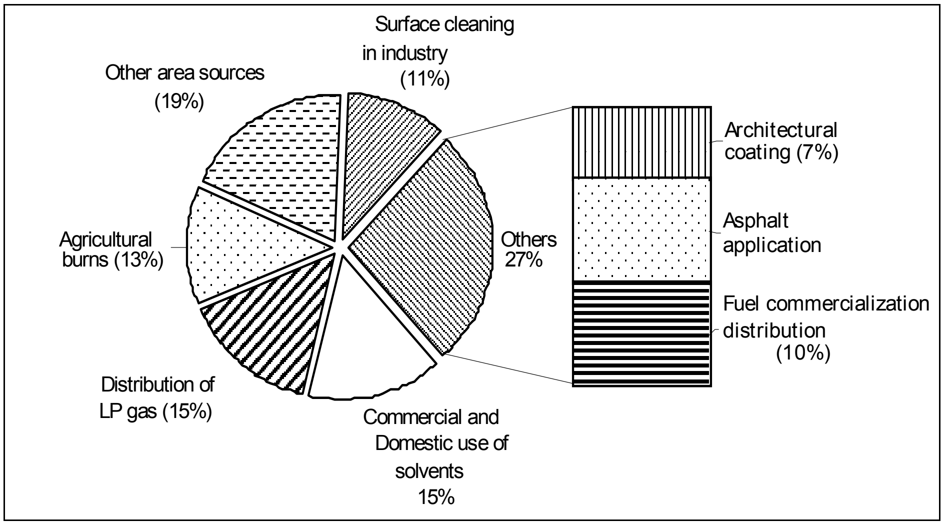
With respect to total PM10 emissions, Figure 5.15 shows that paved and unpaved roads contribute 5% and 86% respectively. This type of emissions is high because, as mentioned earlier, 40% of the streets in Mexicali are unpaved, and vehicles circulating on these roads generate a turbulence that releases the finest sediment from the surface. Furthermore, several vacant lots within the city serve as the source of dust that is transported onto the streets and is then re-suspended by passing vehicles. The force of vehicle tires crushes the material on the road surface, generating smaller particles, thus partially replenishing the sediment content released from the road. With respect to the other sources of particulate matter, agricultural burns and tilling account for 6% of the emissions. Agricultural burns are one of the activities performed with the purpose of preparing fields for new crops. Agricultural tilling is aimed at preparing the soil, and it includes plowing, grading, leveling and cutting.

Figure 5.15. Contribution to PM10 emissions by Area Source sub-category



As shown in Figure 5.16, the activities (area sources) that emit the largest amounts of hydrocarbons are the distribution of LP gas, commercial and domestic solvent use, agricultural burns, and industrial surface cleaning. Together, these activities account for 54% of the total emissions of hydrocarbons. They are followed by fuel commercialization and distribution, application of asphalt, and architectural coatings, which account for 27% of the emissions. The remaining 19% is emitted by the sum of 23 other activities included under the Area Source category.

Figure 5.16. Contribution to total hydrocarbon emissions
by Area Source sub-category



Vegetation and soil erosion

The emissions recorded under this sector depend on several factors, such as the type of soil (for this region the soil has a silty-sandy texture); precipitation (less than 100 mm per year); wind speeds; and, plant cover of agricultural crops, which vary by type of species, growth rate, plant cover, and growth period.

The first estimates of emissions generated by soil erosion were developed for the purpose of this inventory. This will allow the integration of this type of emissions to the total emissions inventory for Mexicali and will serve to define reforestation and paving programs in the zone.

Within this sector, the largest volume of emissions comes from PM10, with the main source being wind erosion of the soil. This is due to the fact that the city is located in the desert, with large expanses of land lacking vegetation several months per year. The type of soil and low precipitation in the region favor PM10 emissions. Some of the zones that have been identified as sources of this pollutant include agricultural areas, barren land surrounding the city, as well as unpaved roads and vacant lots within the city. It is estimated that soil erosion accounts for 24% of the PM10 emissions.

Furthermore, emissions of nitrogen oxides and hydrocarbons generated by soils and vegetation were considered for this inventory. Even though Mexicali is a zone with very little vegetation, it has a large area that is used for agriculture, where the emissions generated are derived from the metabolic activities of the different plants and the microbiological activities in the soil. These are directly related to the type of crops that exist in this area.

As far as the biogenic emissions generated by vegetation and soils are concerned, the PC-BEIS model was used to calculate the emissions of hydrocarbons and nitric oxide (NO). In order to do this, the different types of crops found in this area were taken into account. These include wheat, cotton, rye grass, asparagus, and alfalfa. These types of plants, with the exception of alfalfa, have a crop cycle that varies between 4 and 8 months. For this reason, the seasonality of these crops and the trees found in the region were taken into consideration.

Hydrocarbon emissions generated by vegetation account for 7% of the total hydrocarbons in the emissions inventory.

Transportation

Fuel consumption by motor vehicles is the main source of pollutant emissions in Mexicali. MOBILE5-Juárez[6,7] was the model used for calculating the emissions generated by the transportation sector. This model was found to be adequate for the characteristics of the vehicular fleet and the city. Emissions factors for NOx, HC and CO were calculated using this model. The model was run for each month, to account for the variation in maximum and minimum temperatures that are recorded throughout the year. The material balance method was used for calculating SO_2 emissions, taking into account the sulfur content of fuels. Furthermore, international emissions factors were used for calculating particulate emissions.

The emissions inventory indicates that the transportation sector generates 290,636 tons of pollutants per year, of which 243,073 tons correspond to carbon monoxide, 31,184 tons to hydrocarbons, 14,927 tons to nitrogen oxides, 937 to sulfur dioxide, and 515 tones correspond to particulates. Given the situation of the environmental problem and the level of development required for restructuring the environmental plans and programs for Mexicali, it is important to keep updated information for these types of sources.

Roadways

Mexicali northern boundary runs along the international border with the United States. It adjoins the city of Calexico and Imperial Valley, California to the north. In

6 Radian-Semarnap (1997). Mexico Emissions Inventory Program Manuals, Volume VI-Motor Vehicle Inventory Development.

7 Texas Natural Resource Conservation Commission (1994). Cd. Juárez Mobile5 Data Collection.

all other directions it adjoins agricultural fields and large expanses of vacant land.

There are several ways to access the city. From the north side the two most important accessways are the two international ports of entry. The largest volume of traffic is recorded in the port of entry that is located in the central area of the city. The other port of entry is located in the eastern part of the city, it started operating in late 1996 and is also used as a commercial port of entry. From the east, the main access to Mexicali is from the highway to San Luis Río Colorado, which connects the Baja California Peninsula with the rest of Mexico. From the south, the city is accessed through the road to the port of San Felipe and to the southern part of the valley of Mexicali. Finally, from the west, the accessway is the highway to Tijuana (Table 5.13).

Table 5.13. Mexicali access ways

Highway Access	Direction
Highway to Santa Isabel	West-East
Highway to Tijuana	West-East
Highway to San Felipe	South-North
Highway to San Luis	East-West
Highway to Islas Agrarias	East-West
Highway to the Airport	East-West
International Crossings	North-South

Source: UABC (1994). Estudio Integral de Vialidad y Transporte Urbano de Mexicali, Baja California.

In 1994, Universidad Autónoma de Baja California (UABC), conducted an integrated study of roadways and transportation for the city of Mexicali. This study included traffic counts, traffic flows into and out of the city, and a “starting point-destination” survey. The study was used to provide some recommendations to the municipal government regarding some alternative for planning new roadways throughout the city.

Mexicali’s urban zone consists of a network of irregular streets, with a total length of approximately 1,800 kilometers. The terrain is predominantly flat and the roadways show a longitudinal and transversal pattern that allows access to the different sections of the city. However, traffic flow is not totally smooth due to the existence of barriers that interrupt the continuity of roadways. These barriers include the Río Nuevo riverbed, the railroad tracks and unplanned urban growth.[8]

Table 5.14. Primary roadways in Mexicali

Roadway	Direction	Length (km)

8 XIV Ayuntamiento. Programa de Desarrollo Urbano del Centro de Población de Mexicali, B.C. 1993/2007

Roadway	Direction	Length (km)
Blv. Lázaro Cárdenas	East-West	21.7
Blv. Adolfo López Mateos	North-South	8.3
Blv. Rodolfo Sánchez Taboada (Highway to San Luis)	East-West	10.7
Calz. Justo Sierra	North-South	2.3
Blv. Francisco L. Montejano	North-South	2.5
Blv. Castellón	East-West	3.6
Highway to San Felipe (up to access to Fraccionamiento Campestre)	North-South	4.2
Calz. Independencia	East-West	9.0
Blv. Anáhuac	North-South	3.5
Av. Zaragoza	East-West	2.2
Calz. de las Américas	East-West	4.1
Calz. Cuauhtémoc	East-West	3.0
Calz. Manual Gómez Morín (Eastern Peripheral Road)	North-South	5.2
Blv Carranza	North-South	5.6
Calz. CETYS	East-West	1.9
Unión Highway	East-West	8.1
Calz. Heróico Colegio Militar	North-South	4.4
Av. Cristóbal Colón	East-West	7.7
Av. Francisco I. Madero	East-West	4.0
Av. Argentina	East-West	4.1
Av. Sinaloa	East-West	2.3
Av. Pioneros	East-West	0.9
Calle del Hospital	North-South	0.6
Diagonal Alfareros	North-South	1.2
Av. Calafia	North-South	0.9
Calle Uxmal	North-South	2.6
Calle Tuxtla Gutiérrez	North-South	2.8
Calle Ulises Irigoyen	North-South	2.3
Calle “G”	North-South	2.7
Calle “J”	North-South	3.5
Calle “K”	North-South	3.2
Calle Río Culiacán	North-South	4.8
Calle Río Mocorito	North-South	4.8
Calle Río Presidio	North-South	3.6
Calle Cuarta	North-South	2.8
Calle Novena	North-South	2.5
Total		135.9

Source: UABC (1994). Estudio Integral de Vialidad y Transporte Urbano de Mexicali, Baja California.
XIV Ayuntamiento de Mexicali. Programa de Desarrollo Urbano de Centro de Población de Mexicali, B.C 1993-2007.
INEGI (1997). Carta Urbana Base, Escala 1:25,000.

The roadways were the highest volumes of traffic were recorded include: Lázaro Cárdenas Boulevard, which connects the highways to San Luis Río Colorado and Tijuana, and internally allows the flow of traffic in the southeastern and southwestern zones; López Mateos Boulevard, which runs from the central traffic booth and the exit to the highways leading to San Luis Río Colorado and San Felipe; Calzada Justo Sierra, allowing the flow of traffic from the international line to the south, connecting with Benito Juárez Boulevard and Francisco L. Montejano

Boulevard; Calzada Independencia cuts across the middle of the city from east to west.

Other important arteries include Boulevard Anáhuac, Boulevard Carranza, Calzada Cuauhtémoc, Avenida Madero, Avenida Colón, Avenida Sinaloa, Avenida Zaragoza, Calle Heroico Colegio Militar, Calle Río Culiacán and Carretera Unión and Calzada Manuel Gómez Morin (Peripheral road), which were recently built or expanded (Table 5.14).

Due to the characteristics and location of the city, the flat terrain has allowed the construction of broad roadways, of at least 4 lanes. In 1996, approximately 1,163 million square meters of roadways were paved, representing 62% of the urban area. However, it is important to mention that pavement shows different levels of deterioration in 60% of the paved areas, including holes, cracks, separation of materials, and waves, among others.

In 1996, unpaved roadways covered an area of 779 million square meters, representing 38% of the urban area. These are mainly located on the southern, southeastern, and western portions of the city, where some of the newest, most popular neighborhoods are located. Some older neighborhoods are also found in these areas, but still they lack paved roads.

Vehicles move along these roadways at various speeds, according to the time of day, surface conditions, and the type of vehicle. In the main roadways the average speed falls within the range of 24 to 52 km/hr. These speeds are influenced by delays at intersections, which amount to 28% of the total elapsed time.

As far as the number of vehicles in circulation, the study performed by UABC indicates that traffic counts were collected at 20 of the main intersections. Based on these counts, an average maximum circulation of 175,900 vehicles was estimated for the period between 1:00 p.m. and 2:00 p.m., and an average minimum circulation of 14,800 vehicles between 3:00 and 4:00 a.m.

Table 5.15. Traffic counts at the main intersections of Mexicali

Intersection	Daily traffic counts	Maximum count for a 1-hour period
Lázaro Cárdenas Periférico	155,065	11,454
Lázaro Cárdenas – Benito Juárez (Lázaro Cárdenas Junction)	182,800	14,544
Lázaro Cárdenas – López Mateos – Francisco L. Montejano	193,794	15,510
Lázaro Cárdenas – Anáhuac	159,108	12,408
López Mateos – Alfareros	163,349	10,745
López Mateos – Independencia	141,143	12,423
Sánchez Taboada Junction	193,794	15,510

Source: UABC (1994). Estudio Integral de Vialidad y Transporte Urbano de Mexicali, Baja California.

As shown in Table 5.15, the intersections with the largest traffic counts include: Boulevard Lázaro Cárdenas, at the intersection with Periférico, Boulevard Benito Juárez, Boulevard López Mateos and Anáhuac; Boulevard López Mateos at the intersection with Alfareros and Av. Independencia; Boulevard Benito Juárez at the intersection with Independencia; and, Sánchez Taboada Junction, where the following roads intersect: Boulevard López Mateos, Boulevard Benito Juárez, Highway to San Luis, Highway to San Felipe and the accessways to Fraccionamiento Justo Sierra and Colonia Carvajal.

Vehicular fleet

The number of vehicles officially registered in Mexicali in 1996 was 240,810 vehicles[9], most of which are imported from the United States at prices that are relatively lower than those of domestic vehicles. Oftentimes these vehicles have mechanical problems and their emissions control devices have become deteriorated.

The ease of purchase of imported used vehicles has influenced an accelerated increase in the vehicular fleet, as well as the proliferation of older models with mutilated fuel injection systems and pollution control devices. This makes them more polluting than newer vehicles. On the other hand, the city if Mexicali does not have a vehicular emissions testing program, which could help correct this situation.

Table 5.16. Vehicular Fleet in Mexicali

Classification	# of vehicles	%	Km/veh/day	Km/year
1 Private cars	168,160	69.83	45	16,470
2 Taxi cabs	1,105	0.45	100	36,600
3 Pick-up trucks	46,005	19.10	70	25,620
4 Light-duty trucks	6,710	2.78	70	25,620
5 Passenger buses	802	0.33	185	67,710
6 Diesel-fueled passenger buses	258	0.10	185	67,710
7 Heavy-duty trucks	6,939	2.88	100	36,600
8 Diesel-fueled heavy-duty trucks	9,880	4.14	80	29,280
9 Motorcycles	951	0.39	70	25,620
Total	**240,810**	**100.0**	**905**	**331,230**

Sources: Compiled with information from Secretaria de Planeación y Finanzas. Sistema de Control Vehicular, 1996; Centro SCT02. Departamento de Autotransporte Federal 1996; UABC (1994). Estudio Integral de Vialidad y Transporte Urbano de Mexicali, Baja California 1994.

The distribution by type of vehicle used in for the purpose of this inventory shows that the largest percentage corresponds to private cars. Imported vehicles outnumber those of domestic manufacture by a ratio of 9 to 1[10]. Table 5.16 shows the

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9 Secretaria de Planeación y Finanzas, Centro SCT 02.

10 Cifras obtenidas del “Reporte de Estadísticas Vehiculares por Municipio, INEGI, 1996”.

classification of Mexicali's vehicular fleet, with the average number of kilometers traveled per year by each unit of each type of vehicle. The information used for this table dates back to 1996.

As can be seen in the previous table, private cars account for 70% of the vehicular fleet in Mexicali, followed by pick-up trucks, which account for 19% of the fleet. As a whole, public transportation vehicles account for only 11% of the fleet (26,645 units).

Table 5.17 shows fuel consumption in the transportation sector, for the period covering 1996-97. This table shows an increase in the use of Premium and Magna gasoline. Nova gasoline sales stopped in September 1996. In the case of Premium gasoline, sales were insignificant; however, it was taken into account in calculating emissions.

Table 5.17. Vehicular fuel consumption (m^3/year)

Fuel	1996	1997	Variation 1996-1997
Nova	12,489	0	Sales stopped
Magna	584,137	603,311	Sales increased by 3%
Premium	3,940	18,520	Sales increased by 370%
Diesel	171,506	195,076	Sales increased by 14%

Figure 5.19 shows that 58% of the emissions generated by the transportation sector originate from private vehicles, 24% from pick-up trucks, and 18% from all other types of vehicles.

Figure 5.19. Emissions by type of vehicle

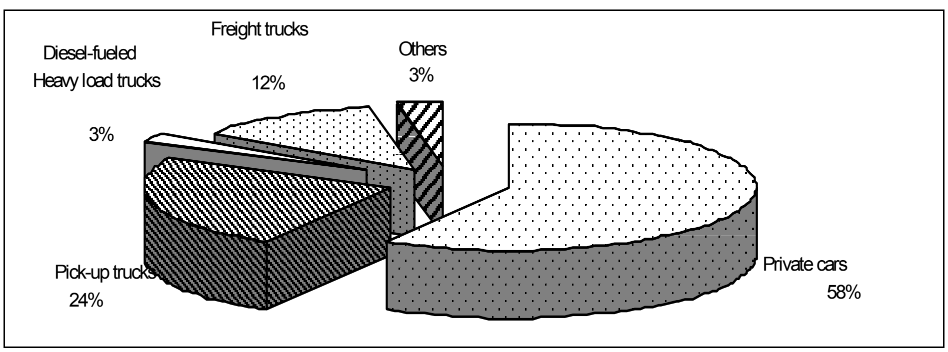
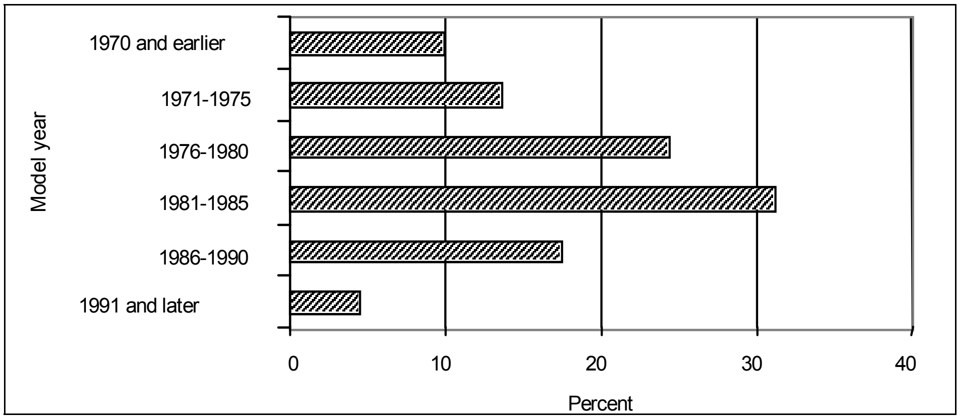


Figure 5.20 shows the age of the city of Mexicali's vehicular fleet. Approximately 30% of the units are 1981-1985 models. Almost 25% of the vehicles correspond to 1976-1980; and less than 5% are post-1991 models. In 1996, 95% of the vehicular fleet was comprised by 1990 and older models.

Figure 5.20. Age of the vehicular fleet



Imperial Valley emissions inventory

It is important to know the emissions that are generated in Imperial Valley since it is shares an airshed with Mexicali. The regional air pollution problem is product of the individual emissions produced by sources on either side of the border. For that reason, air quality improvement in the region will be achieved through the implementation of control measures in both valleys.

Table 5.18 was developed based on the emissions inventory published in CARBs web page in tons per day, multiplying each emissions outcome by 365, in order to estimate annual emissions in tons.

As can be seen, there is a certain degree of concurrence with the desegregation of the sources for the emissions inventory of Mexicali. However, in the future it will be necessary to work with both inventories in order to increase the uniformity of methods to estimate emissions and to truly put together a regional inventory that can be used as the basis for regional air quality models, and to explore emissions reduction strategies.

For illustrative purposes, Table 5.19 shows the total annual emissions for Imperial Valley and Mexicali. This table shows that, with the exception of PM10 emissions, all other types of emissions are higher in Mexicali.

Table 5.18. 1996 Imperial Valley Emissions Inventory
(ton/year)

Type of Source	PM10	SO_2	CO	NOx	HC	Total
Combustion						
Energy generation (combustion)	37	73	37	402	146	695

Type of Source	PM10	SO_2	CO	NOx	HC	Total
Industry and manufacturing (combustion)	146	37	365	2,263	110	2,921
Food and agricultural processes	-	-	37	146	-	183
Industrial Processes						
Food and agricultural processes	73	-	-	-	-	73
Mineral processes	730	-	-	-	-	730
Area Sources						
Commercial and service combustion	37	-	37	219	-	293
Residential combustion	37	-	219	37	37	330
Locomotives	73	146	365	2,446	110	3,140
Airplanes	73	110	3,066	621	949	4,819
Other non-road mobile equipment	73	37	5,037	1,862	438	7,447
Painting and related processes	-	-	-	-	256	256
Other (surface painting and cleaning)	-	-	-	-	37	37
Architectural surface coating and related processes	-	-	-	-	183	183
Degreasing	-	-	-	-	183	183
Dry cleaning	-	-	-	-	73	73
Paving/application of asphalt	-	-	-	-	548	548
Consumer products	-	-	-	-	329	329
Fuel commercialization	-	-	-	-	219	219
Pesticides and fertilizers	-	-	-	-	1,351	1,351
Agricultural tilling	-	-	-	-	9,125	9,125
Waste disposal and garbage burning	1,460	-	14,600	73	2,409	18,542
Paved roads	1,205	-	-	-	-	1,205
Unpaved roads	13,505	-	-	-	-	13,505
Construction and demolition	694	-	-	-	-	694
Fugitive dust	62,050	-	-	-	-	62,050
Utility equipment	-	-	803		73	876
Other miscellaneous processes	37	-	-	-	-	37
Transportation Sector						
Private cars	37	-	13,140	1,241	1,679	16,097
Pick-up trucks	-	-	8,395	1,095	1,059	10,549
Light-duty trucks	-	-	1,059	146	146	1,351
Gas-fueled light-duty trucks for heavy duty	-	-	1,168	329	73	1,570
Gas-fueled medium-duty trucks for heavy duty	-	-	657	110	37	804
Diesel-fueled light-duty trucks for heavy duty	-	-	146	183	37	366
Diesel-fueled medium-duty trucks for heavy duty	37	37	292	402	37	805
Diesel-fueled heavy-duty trucks for heavy duty	110	37	767	1,351	146	2,411
Motorcycles	-	-	37	-	-	37
Total	*80,144*	*477*	*50,227*	*12,926*	*19,790*	*163,834*

Source: CARB, 1996.

Table 5.19. 1996 Emissions Inventories for Mexicali and Imperial Valley (tons/year)

	PM10	**$S0_2$**	**CO**	**Nox**	**HC**	**Total**
Mexicali	71,323	3,810	266,579	18,492	51,131	411,337
Imperial Valley	80,414	477	50,227	12,926	19,790	163,834
Total	**151,737**	**4,287**	**316,806**	**31,418**	**20,921**	**575,171**

6. GENERAL OBJECTIVES, GOALS, AND STRATEGIES OF THE PROGRAM

1. Objectives

In order to integrate the Program, the air quality of the city was analyzed and a detailed emissions inventory was developed, breaking it up as follows: industrial, commercial, and services sector; and, the different motor vehicle categories. Based on that, an integral diagnostic of the air pollution problem was developed, connecting the air pollutants that are present in the air with the known sources that produce them.

Likewise, the studies and research conducted to this date in the Mexicali-Imperial Valley airshed by agencies and institutions from both countries were analyzed. Although these studies are ongoing, the results obtained thus far allowed for the identification of different elements that lead to the presence of high concentrations of fine particulate, ozone and carbon monoxide.

Based on these analyses and information, 27 actions have been incorporated into the Program, involving the participation of the municipal, state, and federal governments, institutions of higher education, non-governmental organizations, as well as industrial, commercial and service chambers and associations.

The Program to Improve Air Quality in Mexicali 2000–2005, has the general objective of protecting the health of the population by reducing the concentration of pollutants in the air, through the application of coordinated actions geared toward controlling emissions from industry, commerce, service facilities, transportation, and soils.

In order to achieve this general objective, it is necessary to fulfill the following specific objectives:

- Reduce vehicle kilometers traveled (VKT) emissions from motor vehicles.
- Reduce the emissions generated by industry as well as by commercial and service facilities.
- Reduce particulate emissions from unpaved streets, peripheral areas lacking vegetation, and vacant lots.
- Promote the supply of clean and efficient public transportation in order to reduce the use of private vehicles.

- Develop coordination mechanisms between industries, for the design of sector policies that allow the integration of environmental and urban planning, with the purpose of attaining and preserving satisfactory air quality in Mexicali, in the short, medium, and long term.
- Enhance people's awareness about the importance of their role in environmental protection activities and attain greater involvement.
- Increase technical-scientific knowledge about the processes that are suitable to the behavior of air pollutants, in order to refine the measures proposed in the Program and identify others that have yet to be contemplated.
- Orchestrate mechanisms to foster the involvement of the private sector through economic incentives, including transboundary investments in projects covered in the Program.

2. Strategies and actions

The *Program to Improve Air Quality in Mexicali 2000–2005*, includes five sets of strategies, each containing a different number of specific actions which, if applied in accordance with the Program, will aid in reducing the emissions of the different pollutants that exceed air quality standards. The strategies are geared toward the following components and work areas:

- Industry, commerce and services
- Vehicles
- Urban Management and transportation
- Ecological recovery
- Research and international agreements.

Actions	Responsible Parties
Industry, commerce and services	
1. Reduce the emissions generated by the worst polluting industries through the installation of control equipment and process re-engineering	CANACINTRA, Industry
2. Implement a vapor recovery program at storage terminals and gas stations	PEMEX, Owners, SEMARNAP
3. Strengthen the inspection and oversight of industrial, commercial, and service establishments	SEMARNAP, State Gov., Mpal. Gov.
4. Reach an agreement with industry on the implementation of a program to reduce Volatile Organic Compounds (VOCs)	Maquiladora Association, SEMARNAP
5. Request that the Federal Electric Power Commission (CFE) conduct a study to assess the impact from emissions generated by the geothermal power plant in Cerro Prieto and, if necessary, implement a program to reduce them within a year	CFE
6. Conduct environmental audits and self-regulatory actions in the industrial sector	SEMARNAP, State Gov., Mpal. Gov., CANACINTRA and Maquiladora Association
7. Develop an Integrated Registry of Emissions and Transfer of Pollutants (RETC) for Mexicali	SEMARNAP, State Gov., Mpal. Gov., CANACINTRA and Maquiladora Association
Vehicles	

Actions	Responsible Parties
8. PEMEX will evaluate the possibility of supplying low Reid vapor pressure (RVP) oxygenated gasoline	PEMEX
9. Design a model, reach a consensus, and put into effect the Vehicle Emissions Testing Program	Mpal. Gov., SCT
10. Require all imported vehicles to pass vehicle emissions testing in their country of origin	SHCP, SECOFI
11. Promote the use of LP gas and natural gas in public transportation	Private sector
12. Design and implement a program to stop and penalize visibly polluting vehicles	Mpal. Gov., SCT
Urban Management and Transportation	
13. Apply soil stabilizers for the control of PM10 emissions on streets, unpaved and heavily traveled areas	SEMARNAP, State Gov., Mpal. Gov.
14. Intensify a paving program for streets and roads	State Gov., Mpal. Gov.
15. PEMEX involvement in providing preferential prices for fuel and asphalt to be used in paving projects	PEMEX
16. Come to an agreement on the transfer, operation and funding of the air quality monitoring network	Mpal. Gov.
17. Develop an integrated study and carry out improvements in public transportation	Mpal. Gov.
18 Promote public involvement and environmental education programs	State Gov., Mpal. Gov.
19. Consolidate an epidemiological program to monitor diseases associated with air pollution, as well as implement preventive and corrective measures	SSA
20. Develop a program of financial incentives for individuals, institutions and organizations that develop programs to prevent and control air pollution	SHCP
21. Integrate COPLADEMMs Municipal Ecology Commission in the follow-up of the program	Mpal. Gov.
Ecological Recovery	
22. Study and set emissions factors and control measures for agricultural burns and practices	SEMARNAP, Sagar, State Gov.
23. Design a reforestation and preservation program for wooded areas	State Gov., Mpal. Gov., SEMARNAP, Sedena
Research and International Agreements	
24. Review and update periodically the emissions inventory and PROAIRE	SEMARNAP, State Gov., Mpal. Gov.
25. Reach agreements with institutions of higher education to conduct air pollution related studies	State Gov., Mpal. Gov., SEMARNAP
26. Reach agreements with international institutions to conduct training activities and air pollution related studies	State Gov., Mpal. Gov., SEMARNAP
27. Reinforce the actions of the Border XXI Program and subsequent binational programs	SEMARNAP, State Gov., Mpal. Gov.

CANACINTRA – Cámara Nacional de la Industria de la Transformación (National Chamber of the Transformation Industry)
SECOFI – Secretaría de Comercio y Fomento Industrial (Ministry Commerce and Industrial Development)
CFE – Comisión Federal de Electricidad (Federal Electric Power Commission)
SAGAR – Secretaría de Agricultura y Desarrollo Rural (Ministry of Agriculture and Rural Development)
State Gov. – State Government
SCT – Secretaría de Comunicaciones y Transportes (Ministry of Communications and Transportation)
Gob.Mpal. – Municipal Government
SHCP – Secretaría de Hacienda y Crédito Público (Ministry of the Treasury and Public Credit)
PEMEX – Petróleos Mexicanos (Mexican Oil)
SSA – Secretaría de Salud (Ministry of Health)
SEMARNAP – Secretaría de Medio Ambiente, Recursos Naturales y Pesca (Ministry of the Environment, Natural Resources and Fisheries)

Actions applicable to industry, commerce and services

1. Reduce the emissions generated by the worst polluting industries through the installation of control equipment and process re-engineering

Objective. Reduce the emissions generated by the worst polluting industries.

Description. Based on the emissions inventory for the industrial sector, the most significant pollutants include carbon monoxide (38% contribution); followed by sulfur dioxide (23%); particulate matter (PM) (16%); nitrogen oxides (12%); and hydrocarbons (11%). The business sectors which contribute the most to industrial emissions are: non-metallic minerals, metallic minerals, vegetable and animal products, and maquiladoras.

It is important to mention that, based on the data recorded for specific industries, 22 facilities generate 99.7% of the PM emissions; 6 of those generate PM emissions as part of their processes and the rest generate this pollutant during combustion. Because of this, the installation of cyclones, bag houses, and electrostatic precipitators is recommended as control methods that can lead to a 70% reduction in PM emissions. As far as SO_2 emissions are concerned, 19 facilities generate 98.8% of the industrial emissions of this pollutant. In order to control this type of emissions it is recommended to assess the suitability of installing gas cleaners to achieve an 80% reduction in the emissions of this pollutant. Likewise, for the control of NOx emissions, the redesign of burners or the use of low NOx burners is recommended for the 22 facilities that generate 98.5% of these emissions. This method could lead to a 60% reduction in NOx emissions. An option that may be considered to reduce SO_2 and PM emissions is the use of natural gas in those facilities that are not using it yet. An increase in gas supply will be promoted for this purpose, and SHCP will study the possibility of reducing the IEPS in the price of natural gas. At the same time, SEMARNAP will strengthen regulations for industrial processes with the greatest emissions contribution.

Goal 1: Establish a frame of reference between specific actions and the annual results from the monitoring network.

Goal 2: Reduce industrial emissions to the atmosphere in Mexicali.

Responsible Parties: CANACINTRA, Industrial sector.

Other Participants: SEMARNAP Delegation, State Gov.

2. Implement a vapor recovery program at storage terminals and gas stations

Objective. Reduce the emissions of Volatile Organic Compounds (VOCs) generated from fuel storage and commercialization.

Description. Vapor recovery at service stations has proven to be a cost-effective measure compared to the required investment: technical studies performed on-site have shown the environmental advantages of the installation of these types of systems and their effects on reducing Volatile Organic Compounds (VOCs), which are ozone precursors.

Currently, new gas stations authorized by PEMEX must comply with this requirement. For this reason, installation of these systems at all service stations must be promoted and their operation must be strictly controlled, whether it is for new, remodeled, or existing gas stations. The installation of vapor recovery systems at gas stations must be accompanied by the start-up of Phase 0 of fuel vapor recovery at PEMEX stations, in order to complete the cycle of evaporative emissions control in the storage and distribution of gasoline.

There are 130 service stations in Mexicali, with combined annual distribution of approximately 600,000 m^3. The State Government and SEMARNAP will request that all new PEMEX facilities be furnished with that equipment. For existing facilities, financing mechanisms will be explored to create a fund that will be used to award credits to gas station owners to help them install vapor recovery systems at their service stations.

Currently, there is no policy to regulate fuel vapor emissions, thus making it necessary for SEMARNAP to first develop an Official Mexican Standard to regulate this type of emission.

Goal 1. Develop and publish an Official Mexican Standard for hydrocarbon vapor emissions to the environment.

Goal 2. Reach an agreement with, and monitor service stations and storage and distribution terminals, to make sure that they have in place vapor recovery systems and zero phase systems, respectively.

Responsible Parties. PEMEX, Private parties, INE.

Other participants: State Gov., Mpal. Gov.

3. Strengthen the inspection and oversight of industrial, commercial, and service establishments

Objective. Improve the enforcement of current policy to reduce air pollutant emissions generated from industrial, commercial and service facilities.

Description. In order for current air quality regulations to be effective and to standardize the criteria employed, it is necessary for the State and Municipal Governments to update their regulations so that they match those included in the new Law of Ecological Equilibrium and Environmental Protection. In this way, their application can be efficient and compliance can be strictly enforced. In the same manner, SEMARNAP, the State Government and the Municipal Government, within their scope of authority, will continue monitoring sources for compliance with the following standards: NOM-085-ECOL-1994, NOM-043-ECOL-1993 and NOM-097-ECOL-1995, particularly for those operations and activities that emit the largest volumes of pollutants.

Goal. Establish a permanent program of observance and compliance with Official Mexican Standards related to air quality and air pollution sources.

Responsible Parties: Profepa, State Gov.,Mpal. Gov.

4. Reach an agreement with industry on the implementation of a program to reduce Volatile Organic Compounds (VOCs)

Objective. Reduce volatile organic compound emissions in the maquiladora industry, through a change in raw materials or the use of control equipment or control systems.

Description. A large part of the industry established in Mexicali belongs to the maquiladora sector, which deals mostly with the assembly of electronic components. Large volumes of solvents are used for cleaning the pieces, parts, and components of electronic devices. Because of this, the generation of volatile organic compounds is very important, since it is estimated that more than 90% of the volume used is emitted into the atmosphere. Currently, there is no NOM in place to regulate the emissions of these types of activities. Therefore, SEMARNAP and the State Government will promote a program to reduce these emissions, through the replacement or substitution of raw materials or through the installation of control equipment and control systems. At the same time, SEMARNAP will develop the corresponding standard. 32 of the facilities that were inventoried in Mexicali emit 98.4% of the total emissions of Volatile Organic Compounds.

Goal 1. Develop and publish an Official Mexican Standard or the emission of Volatile Organic Compounds.

Goal 2. Once a standard is issued to regulate Volatile Organic Compounds, come to an agreement with the industrial sector on the implementation of systems to reduce those emissions.

Responsible Parties: INE, Maquiladora Association.

Other participants: State Gov., SEMARNAP Delegation.

5. Request that the Federal Electric Power Commission (CFE) conduct a study to assess the impact from emissions generated by the geothermal power plant in Cerro Prieto and, if necessary, implement a program to reduce them within a year

Objective. Assess the impact of emissions generated by the geothermal power plant in Cerro Prieto and, if necessary, implement the necessary actions to reduce those emissions.

Description. SEMARNAP makes the commitment to take the necessary steps before CFE, to develop a modeling study to learn the potential impact of sulfur dioxide and other pollutant emissions during the generation of electricity. This will serve to learn the volume of pollutants that are emitted through this activity, the receptor area of dispersed emissions, and the necessary control measures that need to be implemented to reduce these emissions. The study will include a review of the emissions' estimates for the geothermal facility.

If necessary, once the emissions dispersion modeling study has been completed, CFE shall implement within a year, an intensive program that will lead to the reduction of SO_2 and other pollutant emissions generated by the geothermal facility in Cerro Prieto. The implementation of this program will be evaluated periodically by SEMARNAP in coordination with local authorities.

Goal. Conduct a study to assess the impact of SO_2 emissions and emissions of other pollutants from the geothermal power plant and, if necessary, reduce those emissions.

Responsible Parties: CFE.

Other participants: SEMARNAP Delegation, INE, Profepa, State Gov., Mpal. Gov.

6. Conduct environmental audits and self-regulatory actions in the industrial sector

Objective. Reduce emissions from the industrial sector.

Description. PROFEPA in coordination with SEMARNAPs state delegation, INE, the Municipal and State Governments will promote voluntary environmental audits and the signing of self-regulation agreements before the chambers of industry, commerce and service. These instruments have proven to be cost-effective, since facilities themselves identify and carry out actions to reduce emissions in those process components where it is possible to do so.

Goal. Implement environmental and self-regulation programs.

Responsible Parties: SEMARNAP Delegation, Profepa, INE, State Gov., Mpal. Gov., CANACINTRA, Maquiladora Association.

7. Develop an Integrated Registry of Emissions and Transfer of Pollutants (RETC) for Mexicali

Objective. Reduce emissions from the industrial sector.

Description. The Government of Baja California, the Government of Mexicali, and SEMARNAP, will establish the mechanisms for the modernization of environmental regulation and management for the industrial sector through a coordination agreement. Such coordination will ensure the homologation of duties between industries with federal jurisdiction and those with local jurisdiction. Local regulations will be updated and made compatible with the instruments developed by the three levels of government.

This will allow participants to agree on the benefits provided by the Registry of Emissions and Transfer of Pollutants (RETC).

Goal. Rely on instruments and procedures for industrial environmental regulation and management that are compatible at the different levels of government, and orchestrate a Registry of Emissions and Transfer of Pollutants (RETC) based on information provided by industry to the environmental authorities.

Responsible Parties: SEMARNAP Delegation, Profepa, INE, State Gov., Mpal. Gov., CANACINTRA, Maquiladora Association.

Actions applicable to motor vehicles

8. PEMEX will evaluate the possibility of supplying low Reid vapor pressure (RVP) oxygenated gasoline

Objective. Reduce emissions generated by the vehicular fleet during the summer and winter months.

Description. The city consumes an average of 600 thousand m^3 of gasoline per year; most of this is supplied by PEMEX, using gasoline from the refinery in Salina Cruz, Oaxaca. More than 95% of this gasoline is Magna, with an average vapor pressure of 8.3 lb/in^2 throughout the year; only on few occasions is fuel imported from the United States. Gasoline supplied to Mexicali is not oxygenated more than a standard level. Considering the climatological conditions present in Mexicali, as well as the ozone and carbon monoxide concentrations recorded through the monitoring network, PEMEX makes the commitment of developing a study to assess the need to introduce low Reid vapor pressure fuels for the summer and oxygenated fuels for the winter. This is done with the purpose of reducing hydrocarbon and carbon monoxide emissions generated by the vehicular fleet. If necessary, PEMEX makes the commitment to supply ecological fuels.

Goal. Reduce hydrocarbons and carbon monoxide vehicular emissions.

Responsible Parties: PEMEX.

Other participants: INE, SEMARNAP Delegation.

9. Design a model, reach a consensus and put into effect the Vehicle Emissions Testing Program

Objective. Reduce motor vehicle emissions through vehicle emissions testing.

Description. There is an initiative led by the State and Municipal Governments to promote a vehicle emissions program in the city of Mexicali. In the legal aspect, this is covered under the Municipal Regulations. It is necessary to start by designing a model that can later be agreed upon and applied. The average age of the vehicular fleet in Mexicali is 15 years and over 90% of the vehicles were acquired in the United States. The emissions controls of these vehicles have been altered since entering the country, thus making them even worse polluters. These emissions are even more noticeable with the lack of maintenance. Emissions can be reduced considerably if one considers that, in order to pass an emissions test, all gasoline and diesel vehicles must undergo routine maintenance. For that reason, an intensive tune-up program should be promoted to go along with emissions testing; especially for visibly polluting vehicles. This program should be promoted through the Cab Drivers' Union, UCAN, and used car dealers.

As far as emissions testing for federal public transportation vehicles is concerned, the Municipal Government and SCT commit to signing a coordination agreement to have emissions testing for these units fall under the jurisdiction of municipal authorities.

Goal. Promote the vehicle emissions testing program to reduce carbon monoxide, PM and hydrocarbon emissions.

Responsible Parties: Mpal. Gov., SCT.

Other participants: Unión de Taxistas (Cab Drivers' Union), UCAN, used car dealers.

10. Require all imported vehicles to pass vehicle emissions testing in their country of origin

Objectives. Monitor the strict compliance with environmental requirements on the importation of motor vehicles.

Description. Currently, vehicle importation into the border zone, especially that of used vehicles, does not fully comply with current regulations in the environmental aspect. Therefore, the Ministries of the Treasury, Commerce and Industrial Development, and Mexicali Customs, will strictly enforce compliance with regulations for used vehicles and Mexican and "country of origin" emissions standards for vehicles imported into Mexicali. Furthermore, as a supplementary action, SHCP will study the feasibility of establishing a program of financial incentives to promote the renovation of the taxi cab and passenger bus fleets.

Goal. Regulate the importation of vehicles to the border region regarding compliance with air pollution regulations, in order to keep vehicles that generate large amounts of carbon monoxide, hydrocarbons, nitrogen oxides, and particulate, from entering the municipality.

Responsible Parties: SHCP, SECOFI.

Other participants: INE, SEMARNAP Delegation, State Gov., UCAN, used car dealers.

11. Promote the use of LP gas and natural gas in public transportation

Objective. Reduce vehicular emissions generated by freight and passenger public transportation.

Description. Similar to private vehicles, most public transportation vehicles, both passenger as well as cargo, are imported from the US. These vehicles are older models with altered engines and lack emissions control systems. The use of natural gas and LP gas as alternate fuels should be promoted, preferably for public transportation. Authorities will monitor to make sure that all alterations are made under strict compliance with safety regulations, issuing the proper authorization. In the case of LP gas, its possible contribution to ozone precursors and its impact in the formation of ozone will be studied.

Goal. Promote the use of clean fuels by public transportation grantees.

Responsible Parties: Private parties.

Other participants: State Gov., Mpal. Gov., SCT, INE.

12. Design and implement a program to stop and penalize visibly polluting vehicles

Objective. Reduce the emissions generated by visibly polluting motor vehicles.

Description. Currently, there is only one emissions testing station for federal transport vehicles. Due to the advanced age of the vehicular fleet there are several units with highly visible emissions. For this reason, at the time the emissions testing program is started, a separate monitoring program can be implemented to penalize those vehicles that show visible emissions. This measure will serve to support the vehicle emissions program and would be enforced by municipal authorities, once an agreement has been signed with SCT. It would also cover federal public transportation units operating in the municipality of Mexicali. SEMARNAP commits to making the necessary requests to SCT.

Goal. Operate a vehicle circulation retirement program for highly polluting vehicles, in order to reduce emissions of carbon monoxide, hydrocarbons, and nitrogen oxides.

Responsible Parties: Mpal. Gov., SCT.

Other participants: INE, SEMARNAP Delegation.

Actions applicable to urban management and transportation

13. Apply soil stabilizers for the control of PM10 emissions on streets, unpaved and heavily traveled areas

Objective. Reduce PM emissions from unpaved roads and vacant lots.

Description. Unpaved roads and vacant lots are two of the main sources of PM emissions in Mexicali. Approximately 40% of the roads within city limits are unpaved. The high volume of traffic circulating in those roads, coupled with low precipitation in the region, and soil texture, is conducive to the detachment of particles from the upper layer of the soil, even under low wind conditions. It is important to mention that road paving has been done to some extent by all three levels of government. However, this is a costly activity that prompts us to propose the assessment of some chemical substances and materials, which can be used as soil stabilizers and can reduce dust emissions.

SEMARNAP will conduct a study to prioritize the streets, unpaved areas, and heavily traveled roads that need to be stabilized, within the urban area and its surroundings in the Valley of Mexicali. SEMARNAP will then present this study to the Municipal and State authorities, for their use in scheduling the soil stabilization Program. This study will also be used to prioritize paving (measure 14) and reforestation (measure 23) activities.

Goal 1. Carry out a study to prioritize roads and areas to stabilize their surface.

Goal2. Apply soil stabilizers to unpaved roads in Mexicali.

Responsible Parties: INE, SEMARNAP Delegation, State Gov., Mpal. Gov.

14. Intensify a paving program for streets and roads

Objective. Reduce PM emissions generated in from unpaved streets and avenues, as an improvement to environmental conditions.

Description. Currently, approximately 40% of the streets in the city of Mexicali are unpaved and it is estimated that 20% of the vehicle-kilometers-traveled (VKT) in Mexicali, is done on unpaved roads. This, coupled with the low precipitation and soil texture of the region, contributes to a total of 53,689 tons/year of PM emissions in the Valley of Mexicali, generated from urban roads and those in the vicinity of the city. This makes it necessary for the Sate and Municipal Governments to promote road paving, using support programs from SEDESOL and prioritizing those streets with the largest vehicular traffic flow. SEMARNAP will conduct a study to prioritize roads and streets that need paving and will make it available to the Municipal Government, SAHOPE and PECR, to be used as the basis for scheduling and carrying out the street and road paving program.

The State's Bureau of Ecology will consider the inclusion of mitigation measures for activities that generate PM emissions, as part of its criteria for issuing permits for new commercial, urban, and housing developments.

Goal 1. Acquire additional federal resources considering the high priority that must be given to Mexicali to fight air pollution generated from the lack of paving.

Goal 2. Based on Goal 1, pave 360,000 m^2 of streets to reduce PM emissions.

Responsible Parties: SAHOPE, Promotora Estatal de Comunidades Rurales (PECR) (State Promoter of Rural Communities), Mpal. Gov.

Other participants: SEMARNAP Delegation, INE.

15. PEMEX involvement in providing preferential prices for fuel and asphalt to be used in paving projects

Objective. Acquire the necessary means for an efficient combat of pollution generated from the lack of asphalt.

Description. PEMEX makes the commitment to donate approximately 4 thousand cubic meters per year of asphalt, as well as approximately 3 thousand liters per year of gasoline, to be used exclusively for road paving projects, for as long as the paving and road stabilization program is in force. Street maintenance will be done using pavement from other sources. The Municipal Government's paving programs can be carried out more effectively with these actions.

Goal. Support paving programs in Mexicali with asphalt and gasoline, among others.

Responsible Parties: PEMEX.

Other participants: Mpal. Gov., INE.

16. Come to an agreement on the transfer, operation and funding of the air quality monitoring network

Objective. Continue with the operation of the monitoring network by local authorities.

Description. The air quality monitoring network started operating in early 1997 under the framework of the Border XXI Program, with funding from the US Environmental Protection Agency (EPA) and California Air Resources Board (CARB), in collaboration with the Delegation from SEMARNAP and INE. The network consists of 6 monitoring stations, 4 automated and equipped with O_3, NO_2, SO_2, CO analyzers and some meteorological parameter capabilities. Manual air samples are collected as well; only PM10 and TSP samples are collected at the two remaining stations. As mentioned earlier operation of the monitoring network has been funded by US agencies. This has made it necessary to find the means to fund and maintain the network, since support from US agencies will only last through the end of 2001. In the meantime, a program to gradually transfer operation of the network to the local government has been put into place, with the support of the aforementioned agencies. The transfer process will pay particular attention to the training of technical staff to operate and manage information, so this can be provided frequently to the population. Likewise, equipment will be added to the network and personal monitoring will be started to determine air pollution exposures.

Goal 1. Come to an agreement on the involvement from SEMARNAP, the State Government, Municipal Government and Institutions of Higher Education for the maintenance, operation and funding of monitoring stations.

Goal2: Transfer the operation and maintenance of the Air Quality Monitoring Network to the local authorities of the city of Mexicali.

Responsible Parties: Mpal. Gov.

Other participants: INE, SEMARNAP Delegation, State Gov., Institutions of higher education, EPA, CARB.

17. Develop an integrated study and carry out improvements in public transportation

Objective. Make available an integrated study on transportation that can be used as the basis for the design of mass transportation programs reducing the use of private vehicles.

Description. Only one transportation study has been completed to date in Mexicali; a 1993 joint study between Universidad Autónoma de Baja California and the State Government. This study sets the stage for this type of analysis; however, it is necessary to carry out projects with a broader scope that identify the general transportation problems. This would help orchestrate a series of policies and projects that favor the circulation, times, movements, and routes, to optimize the existing routes and to create new ones. Likewise, it is important to improve mass transport of passengers with the purpose of reducing the use of private vehicles.

Goal. Reduce the emissions generated by transport.

Responsible Parties: Mpal. Gov.

Other participants: State Gov., Academic Institutions.

18. Promote public involvement and environmental education programs

Objectives. Develop awareness in the population to seek their contribution and involvement in emissions reduction actions and integrate social programs to prevent air pollution.

Description. The State Government in coordination with the agencies, the Border XXI environmental information workgroup, and academic institutions, will promote a program to integrate the different population groups with the purpose of increasing awareness and outreach on air pollution prevention and control activities. These types of activities have been proven to be necessary to accomplish the goals of environmental programs, since knowledge about pollution prevention and control does not only concern the authorities; it also must be the product of the sum of the efforts of all the members of the community.

Goal. Develop a public involvement and environmental education program.

Responsible Parties: State Gov., Mpal. Gov.

Other participants: SEMARNAP Delegation, Academic Institutions, non-government organizations.

19. Consolidate an epidemiological program to monitor diseases associated with air pollution, as well as implement preventive and corrective measures

Objective. Availability of permanent and updated information regarding the health condition of the population of Mexicali, through the start-up of the epidemiological monitoring program.

Description. Environmental and health authorities, and the community in general, need to have permanent information available about the effects on health from the environment. This information is important in the decision-making process and to consistently apply the Program to Improve Air Quality in Mexicali. The activation of this monitoring system should lead to the development of the necessary information to learn and evaluate the harm and adverse effects on human health, and thus focus efficiently on appropriate prevention, protection and care measures.

As part of the epidemiological monitoring program, health authorities in coordination with the corresponding authorities, and the Border XXI environmental health group, will carry out outreach activities to inform the population in a timely manner about the preventive and corrective measures that must be followed to avoid the health effects originating from exposure to pollutants.

Goal. Have in place an epidemiological monitoring system that can be used permanently and for critical air pollution episodes.

Responsible Parties: SSA.

Other participants: INE, SEMARNAP Delegation, State Gov.

20. Develop a program of financial incentives for individuals, institutions and organizations that develop programs to prevent and control air pollution

Objective. Encourage the use of emissions control technologies through the award of financial incentives and other economic instruments.

Description. Authorities from the three branches of government will orchestrate a program to promote and award financial incentives to individuals, institutions, or organizations that develop initiatives to reduce air pollution. This will serve as an incentive, for those who are interested, to propose programs and reduce their pollutant emissions in a cost-effective manner. For this purpose, information on existing programs will be provided through the treasury authorities and development organizations.

Goal. Award financial incentives to those engaged in air emissions reduction.

Responsible Parties: SHCP.

Other participants: INE, SEMARNAP Delegation, State Gov., Mpal. Gov.

21. Integrate COPLADEMMs Municipal Ecology Commission in the follow-up of the program

Objective. Strengthen the Municipal Ecology Commission to follow-up on the actions to improve air quality in Mexicali.

Description. Strengthening the Ecology Commission to follow-up on the actions proposed by the Program to Improve Air Quality in Mexicali, will be an important tool in achieving these actions, since this will allow, if necessary, the redirection of strategies and measures, and the identification of others that may be necessary. It will be even more important that all the achievements be assessed and put into perspective by the different sectors involved; in particular, non-governmental groups. Strengthening this Commission will also allow for the continuation of the current Program.

Goal. Establish the Ecology Commission's follow-up program to assess the progress in the Program to Improve Air Quality in Mexicali.

Responsible Parties: Mpal. Gov.

Other participants: COPLADEMMs Ecology Commission, State Gov., SEMARNAP

Delegation.

Actions applicable to ecological recovery

22. Study and set emissions factors and control measures for agricultural burns and practices

Objective. Reduce PM emissions generated from soil erosion resulting from some agricultural practices.

Description. Another pollutant that often exceeds air quality standards is particulate matter (PM10). It is important to consider that the type of soil in this region is silty, with at least 20 % clay content, associated with low precipitation. Due to the way crop cycles are planned in this region, three to four months a year the soil lacks any vegetation. Likewise, it can be noted that soil preparation begins in the months of November through January, the season when varying wind speeds easily erode fine particles in the soil, generating large amounts of dust emissions. Because of this, it is important to make a proposal to the agricultural authorities about the convenience of redefining the season when soils are prepared for crops. SEMARNAP commits to making the proper request before SAGAR.

Another problem that is present in the region are agricultural burns, which generate large quantities of pollutants that affect the residents of Mexicali. However, the lack of an emissions factor for this type of activity makes it necessary to develop one, which can serve as a frame of reference. This way it will be possible to know with certainty the amount of pollutants generated by this type of activity. These activities occur on both sides of the border. For that reason, SEMARNAP commits to working with SAGAR and the corresponding United States authorities, on any studies and projects regarding agricultural burns. Likewise, it is necessary to promote better agricultural practices in the use of pesticides and fertilizers to reduce emissions from this type of activity.

Goal 1. Study emission factors for agricultural burns on both sides of the border.

Goal 2. Reduce PM emissions generated from soils and agricultural practices.

Responsible Parties: INE, SEMARNAP Delegation, SAGAR, SEFOA.

Other participants: Mpal. Gov., DGE, EPA, CARB, Imperial Valley Authorities.

23. Design a reforestation and preservation program for wooded areas

Objective. Reduce PM10 emissions originating from soil erosion.

Description. Due to its location, Mexicali is still a city with urban and rural characteristics. As mentioned in the previous action, agricultural practices, soil type, and climatological conditions are unfavorable to air quality due to the resulting dust emissions. Because of this, it is proposed that the three levels of government work together to design a reforestation program for those areas where dust emissions are generated. SEMARNAP will conduct a soil study in the urban area and surrounding agricultural zones that need reforestation, prioritizing those that contribute the most to PM10 emissions. A scheduled program will be developed, using fast-growing species that can easily adapt to the existing soil. Planting must be done using a windbreak curtain pattern, and technically viable distances that will be recommended by SEMARNAPs study.

Goal. Reduce PM10 emissions.

Responsible Parties: DGE, Mpal. Gov., INE, SEMARNAP Delegation, Sedena.

Actions applicable to research and international agreements

24. Review and update periodically the emissions inventory and PROAIRE

Objective. Have a reliable emissions inventory that can be used as the basis for designing control measures to reduce emissions from the different sectors..

Description. The emissions inventory is a dynamic instrument that needs to be updated periodically. In the case of Mexicali, 3-4 year updates are suggested. For this purpose, SEMARNAP can train technicians from the other levels of government to integrate the inventories of their corresponding jurisdictional sectors. It is also important to seek the involvement of academic and research institutions to conduct some of the studies necessary to update the inventory.

Future inventories must be developed with modeling purposes in mind. To this end, SEMARNAP will promote the development of a regional emissions inventory, including all the relevant sources in Mexicali and Imperial Valley, such as emissions generated from agricultural practice, airports, and others.

Likewise, PROAIRE must be updated in a way that includes the strategies that are relevant to the air quality problems found in Mexicali. Therefore, the emissions inventory and the data generated by the air monitoring network, can be reflected in the Air Quality Program.

Goal 1. Have an updated emissions inventory that can be used as a decision-making instrument.

Goal 2. Have an Air Quality Program that can be adapted to the changing conditions in the City.

Responsible Parties: State Gov., Mpal. Gov., SEMARNAP Delegation, INE.

25. Reach agreements with institutions of higher education to conduct air pollution related studies

Objectives. Reach agreements with research institutions and institutions of higher education about conducting air pollution related studies.

Description. Until now, the city of Mexicali has been the subject of relatively few environmental pollution related studies. This makes it necessary for authorities at the three levels of government to seek the cooperation from research institutions and institutions of higher education to conduct specific studies. These studies can be used to update and integrate a better emissions inventory; characterize the presence of agrochemicals and pesticides in the air; and, conduct research on strategies to reduce pollutant emissions in support of the decision making process. In particular, a study of methods and techniques to reduce emissions from paved roads will be sought. Also, measurement and control techniques for odors originating from facilities such as wastewater oxidation lagoons, water treatment plants, stables and drainage, whose odors can be bothersome to Mexicali's residents, will be researched. This measure will be initiated through the development of a list of potential projects that will be prioritized, identifying the costs and possible funding sources.

Goal. Reach agreements with institutions of higher education to conduct studies to prevent and reduce air pollution.

Responsible Parties: State Gov., Mpal. Gov., SEMARNAP Delegation.

Other participants: Academic Institutions, INE.

26. Reach agreements with international institutions to conduct training activities and air pollution related studies

Objectives. Reach agreements with international institutions to conduct special studies and obtain funding for those studies.

Description. The city of Mexicali has been the subject of different studies that have been funded by international organizations. Some of these studies include the development of the emissions inventory, the PM10 study, the study of unique sources, and the study of emissions generated from taco stands. Likewise, support has been given for the installation and operation of the monitoring network. Because of this, it is necessary to continue promoting cooperation agreements with the international institutions that have supported these initiatives. Some of those institutions include the US Environmental Protection Agency (EPA), California Air Resources Board (CARB), Western Governors' Association (WGA) and the EPAs Center of Information on Air Quality (CICA), among others. It is important to continue with these studies and start working on regional air quality modeling, to identify and quantify the contribution and impact of the most important sources.

Goal. Establish agreements to acquire resources to carry out pollution prevention and reduction studies.

Responsible Parties: INE, DGE, Mpal. Gov.

Other participants: EPA, CARB, WGA, CICA.

27. Reinforce the actions of the Border XXI Program and subsequent binational programs

Objective. Strengthen the joint efforts being undertaken by the Border XXI Air Quality Workgroup to improve air quality in the Mexicali-Imperial Valley airshed.

Description. Continuity will be given to a series of binational efforts that were initiated under the framework of the Border XXI Program. Some of these activities include the operation of the air quality monitoring network, updating the emissions inventory, air quality modeling studies, and, regional studies for prevention and control of polluting sources.

Goal. Obtain the support from the governments of both countries to conduct regional studies, programs and activities that will lead to a reduction and control of atmospheric emissions.

Responsible Parties: INE, SEMARNAP Delegation.

Other participants: State Gov., Mpal. Gov., EPA, CARB, Autoridades de Valle Imperial.

3. Goals

Based on the objectives, strategies, and specific actions described earlier, the pollutants emitted by a wide variety of sources will tend to decrease gradually. Thus the Air Quality Program, in compliance with the aforementioned measures, will provide a frame of reference with the purpose of restructuring future actions to fight air pollution in Mexicali.

Therefore, the implementation of actions geared toward the abatement of the main sources of air pollution can be established as the general goal. These actions should be quantifiable in such a way that their effectiveness can be measured annually by the Air Quality Monitoring Network. This will generate a frame of reference that provides feedback and strengthens the current program, at the same time that it identifies the best environmental management strategies that lead to the sanitation of air quality in Mexicali.

It is estimated that, with the application of the Program's measures, there will be an approximate 20% reduction in hydrocarbon, nitrogen oxide, and carbon monoxide emissions; 30% reduction in PM10 emissions; and, 40% reduction in sulfur dioxide emissions by the year 2005 (Annex D). It is contemplated that with these reductions in anthropogenic emissions, compliance with air quality standards will be attained.

A preliminary estimate of the costs involved in 10 of the measures contemplated by the Program leads to an approximate investment of 400 million pesos from the public sector, and the same amount from the private sector. This implies that, even though the air that we breathe is a common domain with free access, its care and sanitation have significant costs involved that must be considered by society as a whole.

Estimate of emissions reduction due to the program (ton/year)

	Nox	**HC**	**SO_2**	**CO**	**PM10**
Industry, commerce and services	757	2,613	1,707	NE	1,392
Vehicles	3,580	9,868	NE	58,230	123
Urban management and transportation	NE	NE	NE	NE	22,335
Ecological recovery	NE	NE	NE	NE	6,178
Research and international agreements	NE	NE	NE	NE	NE
Total (ton/yr)	**4,337**	**12,481**	**1,768**	**58,230**	**30,028**
Total (%)	**23**	**24**	**45**	**22**	**35**

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ANNEX A. AIR QUALITY MONITORING AND METROPOLITAN INDEX

A.1. Air pollutant monitoring methods

Standardized techniques and procedures published as Official Mexican Standards (NOMs), are used to measure pollutant concentrations in the air, with the availability of equivalent reference methods. Reference methods are more precise and selective but, for some pollutants, their use is only practical in the laboratory but not in the field. For this reason, equivalent methods that are feasible for field use, in addition to being permanent and reliable, are used to provide the appropriate precision and selectivity under ambient conditions. The following Table summarizes the principles considered by the methods used for measuring air pollutant concentrations.

Table A.1. Air pollutant measurement methods

Pollutant	Reference Method	Equivalent Method
SO_2	Pararrosanillin (manual)	Fluorescence (automatic)
CO	Infrared Photometry (automatic)	None
O_3	Chemoluminescence (automatic)	UV Photometry (automatic)
NOx	Chemoluminescence (automatic)	Wet Chemistry
PST	High volume sampling (manual), includes Pb	None
PM10	High volume sampling (manual)	Beta attenuation (automatic)

Description of methods

Sulfur dioxide: The reference method for determining SO_2, is the wet chemistry process developed by West and Gake, known as the "pararrosanillin process". A volume of air passes through the bubbler at a constant and controlled flow rate, during a set period of time. The bubbler contains an absorbing solution that retains molecules from the pollutant and reacts with the solution components. At the end of the sampling period, generally 24 hours, the solution is transported to the laboratory to be analyzed using colorimetry. The larger the concentration of SO_2, the more intense the color of the solution, which varies from light pink to purple.

The equivalent method is a fully automated process. Even though it is not as accurate as the reference method, it offers acceptable precision and consistency. In this case, the ability of SO_2 to absorb UV light and release it as fluorescent light is utilized. The intensity of the fluorescence is directly proportional to the concentration of SO_2. The entire process takes place under controlled conditions, inside an analyzer.

Carbon monoxide: This pollutant is measured taking advantage of its ability to absorb infrared light when exposed to an optical path where this type of energy is displaced. The measurement takes place inside a chamber equipped with a device that detects the different variations of infrared light and, it calculates the concentration of this pollutant through the use of an electronic processor. This is the only method that is recognized for continuous monitoring of CO in ambient air.

Ozone: In order to measure ozone concentrations in ambient air, the reference method involves a chemical reaction between ozone and ethylene, which is provided specifically inside a specially designed chamber containing optical devices. These optical devices catch the light signals resulting from this reaction. These light signals are amplified and turned into an electrical signal that is proportional to the concentration of ozone in the air sample.

The equivalent method uses the property of ozone to absorb a portion of an ultraviolet light beam directed through an optical path, confining an air sample containing the pollutant. The variations in light intensity that are detected in the system are associated with ozone concentrations.

Nitrogen dioxide: This pollutant is measured through the reaction that takes place, inside a specially designed and conditioned chamber, between NO_2 and ozone, which is generated in excess by the same instrument. As a result of this reaction there is an emission of a variable number of photons, depending on the concentration of the pollutant that enters the chamber as one of the components of the air sample. The photon current is amplified and turned into voltage in order to be interpreted.

Some alternative methods include a few wet chemistry techniques, which are not widely used in practice due to a large diversity of factors of error that accumulate when used on the field.

Total suspended particles and PM10 particles: The high volume method is used in order to collect samples of the solid matter that floats in ambient air. This method consists of passing an air flux at a high rate of speed, through a teflon filtering medium, which retains particles with aerodynamic diameters between 0.1 and 100 micrometers. This method requires keeping a constant flow and knowing the total volume of air sampled during a 24-hour period, which is the amount of time that is usually recommended for this type of sample. It is also necessary to know the weight of the filter before and after the sample is collected. In order to do this the filter is conditioned for 24 hours in a chamber, where temperature and relative humidity are controlled. After determining the mass of the material, the sample becomes susceptible to undergoing physical and chemical analyses to determine the content of lead and other heavy metals, as well as sulfates and nitrates.

This same method is used to collect samples of total suspended particles and PM10, using a different kind of head in the sampler to separate the fine from the coarse particles.

Quality assurance and quality control (QA/QC) of the measurements

In order to evaluate the quality of the analytical results obtained from an air pollutant monitor, it is necessary to conduct audits during all the phases of the monitoring process. An audit program must contemplate the following activities:

- Calibration.
- Zero span and subsequent adjustments.
- Review of the data that results from testing.
- Preventive and/or corrective maintenance.

Calibration

The calibration of monitoring equipment consists of determining the instrument's response to known concentrations and adjusting it to the corresponding curve. Calibration is done at the time of installation and activation of the monitor, as well as during its operation:

- In time intervals not greater than three months from the most recent calibration or audit.
- Immediately after an interruption of more than three days in the operation of an analyzer.
- After any repair involving the replacement of one or more major components.
- When physically moving the analyzer from one place to another.
- Whenever there is evidence of a significant lack of precision in the analyzer.

Zero and span checks

These checks are a key component of quality assurance and quality control programs that apply to continuous monitors of gaseous pollutants and are useful to:

- Indicate when it is necessary to adjust the analyzer to its zero and/or span levels.
- Provide the criteria for deciding when an instrument must be calibrated.
- Establish the basis for making the decision to invalidate data that are generated by the monitor.

Zero and span checks must be done at least once every other week or more often, if the instrument's performance calls for it.

A.2. Air Quality Metropolitan Index (IMECA)

An air quality index weighs and transforms the concentrations of a set of pollutants into a non-dimensional number that indicates the level of pollution present in a determined location and can be easily understood by the public.

The procedure to manipulate the concentrations of pollutants, with the objective of obtaining a significant number, basically depends on the algorithm used, particularly on the index. The problem faced by those who develop air quality indicators consists in determining how to weigh the effects of pollutants.

Among the different indexes used around the world, a certain number of weight factors has been proposed, the most acceptable being the one that considers air quality standards as the basis for determining the effects from pollutants. That approach has been used in developing the following indexes: PINDEX, Oak Ridge Air Quality Index (ORAQI), Mitre Air Quality Index (MAQI), Extreme Value Index (EVI), Pollutant Standard Index (PSI).

In 1975, Thom and Ott researched all the air pollution index structures being used in the US and Canada, as well as those mentioned in the literature, in order to compare and evaluate more than 50 different types. They developed a system to classify indexes and, using that system, they identified the optimal characteristics that should be considered by the PSI index. That index was later modified and adopted by the US government.

The PSI includes 6 air pollutant variables {CO, NO_2, O_3, PST, SO_2 and the product of PST x SO_2}, it uses segmented linear functions to calculate sub-indexes, incorporating a simple form of the maximum permissible concentrations set by the government, and calculating the "Maximum Mode". This consists of reporting only the sub-index of the highest resulting pollutant. The sub-indexes utilize the US primary air quality standards, episode criteria, and significant damage levels as their break points.

The PSI system is based (in part), on pollution levels set as federal episode criteria (i.e. concentrations associated with alert, danger and emergency levels). These are not totally based on purely scientific information but rather, they are recommended to direct actions to reduce air pollution in metropolitan areas, in the short term.

Table A.2. PSI Descriptive Categories

Good	0 – 50
Moderate	51 – 100
Unhealthy	101 – 199
Very unhealthy	200 – 299
Harmful	300 or more

In Mexico, based on the bibliographic review that took place prior to defining air quality indexes, the decision was made to use an approach that would include air quality standards as well as significant harm levels, as the basis for measuring the effects from pollutants. Instead of using an approach that is solely based on air quality standards, IMECA uses a more realistic approach, allowing the use of measurement factors that change according to different pollution levels and also allows the generation of daily air quality reports.

The Metropolitan Air Quality Index (IMECA), is based on the use of segmented linear functions, similar to those used by PSI. Thus we must not forget that the segmented linear functions used by this system correspond to the US primary air quality standards, episodic criteria, and significant harm levels. When IMECA was first developed, there were no Official Mexican Standards for air quality, episodic criteria, or significant harm. However, this was overcome through the development of break points based on local information, using the same philosophy that was used for defining PSI.

The variables that were selected to be included in the air quality index were the same as those for PSI, taking into consideration the information available in Mexico. Those variables include CO, O_3, NO_2, PST, PM10 and SO_2.

The equation that defines IMECA can be expressed in the following manner:

$$\text{IMECA} = \max (I_1, I_2, I_3, \ldots, I_n)$$

Where $I_1, I_2, I_3, \ldots, I_n$ are individual sub-indexes for each of the pollutants. The sub-indexes are calculated using segmented linear functions based on the break-point values included in the following Table:

Table A.3. IMECA break points

IMECA	**PST (24 hr) μg/m³**	**PM10 (24 hr) μg/m³**	**SO_2 (24 hr) Ppm**	**NO_2 (1 hr) ppm**	**CO (8 hr) Ppm**	**O_3 (1 hr) Ppm**
100	260	150	0.13	0.21	11	0.11
200	546	350	0.35	0.66	22	0.23
300	627	420	0.56	1.1	31	0.35
400	864	510	0.78	1.6	41	0.48
500	1000	600	1.00	2.00	50	0.60

Table A.4. Health effects at different IMECA levels and some recommendations to prevent them

IMECA level	Possible health effects	Preventive type measures
0 to 100	• No negative effects are present in the health of the population. • All individuals can perform all types of physical activities.	• At this level, non-preventive type measures are necessary.
101 to 250	• Conjunctivitis or headaches in any group of the population. • People who suffer from heart or pulmonary disease reactivate the symptoms of their illnesses. • Nursing children, the elderly and smokers, show dysfunction of the respiratory and cardiovascular system, as well as an increase in respiratory frequency, shortness of breath, and palpitations. • The generally healthy population shows adverse effects such as itchy eyes, headaches, increase in respiratory function, shortness of breath and palpitations, especially when performing an intense physical activity.	• At this level, general behaviors conducive to low exposure to air pollutants must be adopted, especially by the population at-risk or with greater susceptibility, such as children, the elderly, pregnant women and individuals with chronic heart disease and chronic pulmonary disease. Adopting the following measures is recommended for the population as a whole: > Avoid exposure to polluted air. > Do not perform intensive outdoor exercises or physical activities. > Remain indoors for the duration of the high pollution episode.
251 a 350	• Nursing children, the elderly, and smokers, can show the symptoms described in the previous level, in addition to inflammatory alterations (coughing, expectoration, and bronchial spasms) in their respiratory system. • The generally healthy population can show dysfunction of the respiratory and cardiovascular system, such as an increase in cardiac and respiratory frequency, shortness of breath and palpitations, especially when performing outdoor exercises or physical activities.	• Starting at this level of pollution, the following measures are recommended for the population as a whole, and especially for higher risk groups: > Avoid exposure to polluted air. > Do not perform outdoor exercises or physical activities. > Remain indoors for the duration of the high pollution episode. > Avoid additional damage to the respiratory system. > Avoid smoking and exposure to smoke from tobacco. > Avoid abrupt changes in temperature. > Decrease contact with individuals that present signs of respiratory infection.
351 and up	• Starting at this level of pollution, some investigative reports indicate the possibility that: > Individuals with chronic heart disease or pulmonary disease will reactivate their basic illness. > Nursing children, the elderly and smokers, will show inflammatory type alterations in their respiratory system (coughing, expectoration, and bronchial spasms). > The generally healthy population is at risk of showing inflammatory type alterations in their respiratory system, even without performing any outdoor exercise or physical activity.	• Reinforce the body's natural defense mechanisms through: > Abundant ingestion of liquids, preferably natural fruit juices. > Consume lots of fruit and vegetables. • Timely medical attention. • Susceptible individuals must see a doctor if they show signs of reactivation of their illnesses. • Masks, air purifiers or oxygen inhalers are not scientifically-proven protective measures in the presence of rising levels of air pollution, and their discriminatory use may result in a higher risk for the susceptible groups. • Be aware of the recommendations from the National Health System Institutions, through the media.

Air quality is considered to be unsatisfactory if the IMECA value is between 101 and 200, poor between 201 and 300; and, very poor if it is above 300.

IMECA reports the maximum mode and its descriptive terms are based on the short-term threshold effects and on significant harm levels. When IMECA was first developed, the Air Quality Criteria values published on November 29, 1992 were used to set the 100 level. The concentrations for the 200, 300 and 400 IMECA values were arrived at dividing the interval between the air quality criterion and the level of significant harm (IMECA 500 value), into 4 equal parts. Correlation studies were conducted to determine the break points for particulate measurements, and thus the PM10 sub-index was developed.

The substitution of the 1982 air quality criteria with the Official Mexican Standards on December 24, 1994, resulted in an update of the air quality metropolitan index with the new values.

Table A.4 shows a list of health effects at different IMECA levels along with some recommendations that are suggested to avoid further harm. This table highlights the fact that children and the elderly are the most affected groups by air pollution episodes.

ANNEX B. AIR QUALITY SUMMARY TABLES FOR 1997-1998

Table B.1. Percentage and number of days with exceedances of IMECA 100, 150 and 200 points

Station: CEBATIS21 (1997)

	>= 100		>= 150		>= 200		Total # of days
	%	#	%	#	%	#	
O_3	4.3	3	0.0	0	0.0	0	69
PM10	0.0	0	0.0	0	0.0	0	46*
CO	6.9	6	1.1	1	0.0	0	87
NO_2	0.0	0	0.0	0	0.0	0	73
SO_2	0.0	0	0.0	0	0.0	0	83

Station: CEBATIS21 (1998)

	>=100		>=150		>=200		>=250		Total # of days
	%	#	%	#	%	#	%	#	
O_3	1.6	5	0.3	1	0.0	0	0.0	0	309
PM10	1.7	1	0.0	0	0.0	0	0.0	0	59*
CO	16.2	52	5.0	16	0.9	3	0.3	1	321
NO_2	0.0	0	0.0	0	0.0	0	0.0	0	344
SO_2	0.0	0	0.0	0	0.0	0	0.0	0	111

Station: COBACH (1997)

	>= 100		>= 150		>= 200		Total # of days
	%	#	%	#	%	#	
O_3	6.0	14	0.0	0	0.0	0	234
PM10	26.7	8	6.7	2	0.0	0	30*
CO	14.9	36	6.6	16	0.0	0	242
NO_2	0.0	0	0.0	0	0.0	0	235
SO_2	0.0	0	0.0	0	0.0	0	224

Station: COBACH (1998)

	>=100		>=150		>=200		>=250		Total # of days
	%	#	%	#	%	#	%	#	
O_3	6.3	21	0.3	1	0.0	0	0.0	0	335
PM10	23.4	11	8.5	4	0.0	0	0.0	0	47*
CO	19.9	67	6.5	22	2.4	8	0.9	3	337
NO_2	0.6	2	0.0	0	0.0	0	0.0	0	337
SO_2	0.0	0	0.0	0	0.0	0	0.0	0	227

Station: ITM (1997)

	>= 100		>= 150		>= 200		Total # of days
	%	#	%	#	%	#	
O_3	4.2	15	0.0	0	0.0	0	361
PM10	0.0	0	0.0	0	0.0	0	51*
CO	2.8	10	0.0	0	0.0	0	358
NO_2	0.0	0	0.0	0	0.0	0	355
SO_2	0.0	0	0.0	0	0.0	0	364

Station: ITM (1998)

	>=100		>=150		>=200		>=250		Total # of days
	%	#	%	#	%	#	%	#	
O_3	3.9	14	0.0	0	0.0	0	0.0	0	355
PM10	0.0	0	0.0	0	0.0	0	0.0	0	58*
CO	5.9	18	1.0	3	0.0	0	0.0	0	306
NO_2	0.0	0	0.0	0	0.0	0	0.0	0	362
SO_2	0.0	0	0.0	0	0.0	0	0.0	0	172

Station: UABC (1997)

	>= 100		>= 150		>= 200		Total # of days
	%	#	%	#	%	#	
O_3	4.3	13	0.0	0	0.0	0	301
PM10	10.2	5	0.0	0	0.0	0	49*
CO	7.7	25	2.2	7	0.0	0	323
NO_2	0.0	0	0.0	0	0.0	0	278
SO_2	0.0	0	0.0	0	0.0	0	324

Station: UABC (1998)

	>=100		>=150		>=200		>=250		Total # of days
	%	#	%	#	%	#	%	#	
O_3	2.5	6	0.0	0	0.0	0	0.0	0	239
PM10	7.5	4	0.0	0	0.0	0	0.0	0	53*
CO	11.4	35	1.6	5	0.3	1	0.3	1	306
NO_2	0.0	0	0.0	0	0.0	0	0.0	0	335
SO_2	0.0	0	0.0	0	0.0	0	0.0	0	170

Station: CONALEP (1997)

	>= 100		>= 150		>= 200		Total # of days
	%	#	%	#	%	#	
O_3	-	-	-	-	-	-	-
PM10	9.3	4	0.0	0	0.0	0	43*
CO	-	-	-	-	-	-	-
NO_2	-	-	-	-	-	-	-
SO_2	-	-	-	-	-	-	-

Station: CONALEP 1998

	>=100		>=150		>=200		>=250		Total # of days
	%	#	%	#	%	#	%	#	
O_3	-	-	-	-	-	-	-	-	-
PM10	7.8	4	0.0	0	0.0	0	0.0	0	51*
CO	-	-	-	-	-	-	-	-	-
NO_2	-	-	-	-	-	-	-	-	-
SO_2	-	-	-	-	-	-	-	-	-

Station: CENTRO DE SALUD (1997)

	>= 100		>= 150		>= 200		Total # of days
	%	#	%	#	%	#	
O_3	-	-	-	-	-	-	-
PM10	55.8	24	7.0	3	0.0	0	43*
CO	-	-	-	-	-	-	-
NO_2	-	-	-	-	-	-	-
SO_2	-	-	-	-	-	-	-

Station: CENTRO DE SALUD (1998)

	>=100		>=150		>=200		>=250		Total # of days
	%	#	%	#	%	#	%	#	
O_3	-	-	-	-	-	-	-	-	-
PM10	37.7	23	18.0	11	3.3	2	1.6	1	61*
CO	-	-	-	-	-	-	-	-	-
NO_2	-	-	-	-	-	-	-	-	-
SO_2	-	-	-	-	-	-	-	-	-

* Number of days sampled (manual monitor)

Table B.2. IMECA daily maximum by station and by contaminant

1997

	O_3	PM10	CO	NO_2	SO_2
CBATIS21	139	99	169	46	27
COBACH	133	189	190	81	24
ITM	138	95	131	69	27
UABC	149	141	176	66	22
CONALEP	-	112	-	-	-
CENTRO DE SALUD	-	185	-	-	-

1998

	O_3	PM10	CO	NO_2	SO_2
CBATIS21	170	107	258	86	14
COBACH	151	184	363	104	11
ITM	137	94	189	75	19
UABC	122	120	254	80	34
CONALEP	-	119	-	-	-
CENTRO DE SALUD	-	362	-	-	-

Table B.3. IMECA monthly maximum by contaminant

1997

	O_3	PM10	CO	NO_2	SO_2
January	88	55	120	68	20
February	103	87	122	41	19
March	139	115	169	43	26
April	138	141	178	69	24
May	133	150	174	46	24
June	107	117	156	60	27
July	119	130	153	33	22
August	104	101	71	44	16
September	149	141	140	67	16
October	114	129	176	62	27
November	118	189	190	68	18
December	89	118	170	81	17

1998

	O_3	PM10	CO	NO_2	SO_2
January	122	130	258	84	12
February	69	125	124	36	5
March	131	111	147	55	6
April	107	174	82	61	6
May	122	100	31	43	3
June	141	89	58	57	4
July	147	129	40	55	34
August	122	112	58	44	4
September	130	105	38	50	3
October	151	240	164	104	9
November	120	200	235	90	11
December	170	362	363	101	19

ANNEX C. HEALTH EFFECTS FROM POLLUTANTS

Ozone (O_3)

Ozone is the main photochemical oxidant present in the atmosphere, along with peroxiacetyl nitrate, alkyl nitrates, and other compounds. In nature, ozone is one of the main components of the chemical make-up of the stratosphere and has the important function of protecting the earth's surface from solar ultraviolet radiation. However, the presence of ozone in the lower layer of the atmosphere (known as the troposphere), where most living organisms develop, is due to the photochemical reactions that transform hydrocarbons and nitrogen oxides.

Even though O_3 is a very unstable pollutant, destroyed as easily as it is formed, it has been proven that, regardless of its brief stay, it causes irritation in the respiratory system, coughing, phlegm, breathing pain, and inflammation of the lung tissue, reducing its ability to respond to foreign agents. Furthermore, it reduces lung capacity, mucocilliar capacity, weakening the natural defenses of the respiratory system. Also, it has been proven that respiratory illnesses are more prevalent among children who are exposed to ozone. Likewise, it has been observed that during periods of environmental contingency with high ozone concentrations, there is a noticeable increase in school absences in pre-school and elementary school-age children (Romieu, 1995).[1]

Gong[2] believes that ozone also causes problems in healthy people, since it makes breathing more difficult while working and exercising, and it causes general respiratory irritation. Furthermore, it can scar the lungs causing permanent damage. It is thought that irritation symptoms tend to disappear with repeated exposure to ozone. However, this "attenuation of the response" is not something positive, since the fact that there are no obvious reactions to the exposure, does not mean that the body has adapted to it. There is evidence to support the fact that the pulmonary lesion remains even during attenuation.

A significant problem with ozone pollution is the fact that the lungs do not stop developing until a person turns 18. Therefore, lungs that are not fully developed suffer early damage that can increase the risk of contracting a respiratory illness in the adult years.

Particulate Matter (TSP, PM10 and PM2.5)

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[1] Romieu, I. (1995). Effects of urban air pollutants on emergency visits for childhood asthma in Mexico City. Am. J. Epidemiol.

[2] Gong, H. M. (1987). "Effects of ozone on exercise performance". Journal of Sports Medicine and Physical Fitness.

Some behaviors that lead to particulate matter pollution include the destruction of vegetation, which in turn causes erosion; fires; some dust generating industrial processes; and, human activities requiring the burning of fuels such as coal, firewood, and petroleum byproducts. The inadequate disposal of garbage and fecal matter are also important sources of emissions of microorganisms, cysts, spores, pollen, etc. that stick to dust. With this in mind, it is necessary to tackle these problems directly to reduce the pollution generated by suspended particles.

Depending on their size, particles can float or form sediments. Particles that are constantly floating are known as total suspended particles (TSP). Particles with a diameter less than, or equal to 10 µm are known as breathable particles or PM10, and can be formed by aerosols, dust, metals, combustion products, or microorganisms such as protozoa, bacteria, virus, fungi, and pollen, that can cause different kinds of illnesses. When particles are inhaled they are not always expelled by the body's defense systems, thus causing problems in the respiratory system.

Particulate matter contamination can cause, in the short and long-term, a reduction in lung function, which contributes to the incidence of respiratory illnesses and premature death.

Exposure to PM10 has generated a great deal of concern during the last several years, because more studies have been published that reveal a significant link between PM concentration in ambient air, and mortality and morbidity. Consistently, many studies have revealed a 3% increase in daily mortality for every 10 $\mu g/m^3$ of PM10 above the standard. The most significant link appears to be with cardiopulmonary and lung cancer. Of special concern is the fact that there does not appear to be a minimum concentration at which adverse health effects become undetected.

The link between mortality and air pollution tends to be stronger when PM2.5, also known as fine particles or breathable fraction particles, is used for comparison purposes. These particles penetrate deeper into the respiratory system and thus are more damaging to human health. Because of their size (light wavelength location), they interfere with light dispersion contributing to poor visibility. Approximately 40% of these particles become embedded in the bronchi and alveoli, causing acute respiratory symptoms, including severe pain and coughing. PM2.5 can be directly emitted into the atmosphere or it can form in the atmosphere through photochemical reactions and physical processes.

Lead (Pb)

Lead is not only naturally discharged into the environment, (i.e., through soil erosion and volcanic eruptions), but also through anthropogenic processes. In the latter case, it occurs during the extraction, smelting and refining of non-ferrous minerals, and fossil fuel combustion. The latter is the main source of emissions into the atmosphere, since an increase in the concentration of lead in the atmosphere is largely due to the introduction of lead organic compounds, such as gasoline additives. In Mexico, at the end of 1997, leaded gasoline sales were discontinued.

Lead generated by motor vehicle fuels is associated with particles less than 1 μm in diameter. These particles can easily reach the inner portion of the lungs, where lead is introduced into the blood stream. Once in the blood stream, lead invades all the body tissues and organs, becoming embedded in the bones, liver, cerebral cortex and kidneys, as well as the brain and fatty tissue. The main human body systems that are affected by lead poisoning include the hematopoietic system, renal system, central nervous system, and the peripheral nervous system.

Symptoms of chronic intoxication become evident through the absorption of oxides, carbonates and other soluble compounds in water through the digestive tract. There is evidence to support the fact that children with high lead concentrations in their blood stream show restricted mental development and a higher incidence of behavioral problems. These effects are attributed to the irreversible inhibition in the development of the nervous system. Acute intoxication is usually caused by the inhalation of lead tetraethyl, which is highly volatile and lyposoluble. Symptoms of acute intoxication may include diarrhea, colic, nausea, vomiting, weariness, sleeplessness, convulsions and headaches (California Air Resources Board, 1983).[3]

Airborne lead is very important because it is a source of exposure through inhalation for living organisms. Like other pollutants, it is transported by the wind to other regions, and is deposited in the soil, water and vegetation.

Hydrocarbons (HC)

Hydrocarbons are chemical compounds that contain carbon and hydrogen in their chemical structure. Many gasoline components and petroleum byproducts are hydrocarbons. These react with nitrogen oxides, through photochemical reactions, to form peroxiacetyl and ozone, among other compounds.

Some types of hydrocarbons are toxic, others are not, and many of them do not have a significant potential to cause adverse health effects. However, since they contribute to ozone formation, they are considered important pollutants.

Aromatic hydrocarbons are potential carcinogenic agents. Some studies indicate that these hydrocarbons are formed during the incomplete combustion of almost any organic material, including fat, meat, coffee, sugar, rubber, and cigarette smoke.

Anthropogenic sources of hydrocarbons may vary widely. The transportation indus-

[3] California Air Resources Board (1983). "How Air Pollution Demages Health".

try is responsible for a large part of these emissions, whereas fuel consumption by stationary sources occupies a secondary position. Finally, we find different processes such as agricultural practices and garbage dumps, which also contribute to the generation of these pollutants.

Transportation is considered the major source of hydrocarbon emissions into the atmosphere, due to the incomplete combustion in motor vehicle engines. Likewise, evaporative emissions during the loading and unloading of fuel at gas stations or in large storage containers also contribute to the emissions of hydrocarbons into the atmosphere.

Hydrocarbons include volatile organic compounds (VOCs) such as benzene, xylene, toluene, ethylbenzene, propane, and aldehydes, among others, which are important precursors to the formation of ozone and other oxidants. Volatile organic compounds are of special concern due to their high toxicity in humans. Mexico lacks a continuous, widespread air quality program for VOCs, and it has not established an air quality standard for these pollutants. In the United States, even though VOC measurements are taken in different cities, these do not constitute by themselves an air quality parameter, due to the diversity of species, toxic properties and high reactivity. Even though there are some difficulties in establishing standards for VOCs, some of these toxic pollutants such as benzene, formaldehyde, acetaldehyde, and 1,3-butadiene should be periodically analyzed to identify and prevent potential environmental health problems.

Carbon monoxide (CO)

Carbon monoxide is a colorless, flavorless and odorless gas, which is chemically inert under normal conditions. Carbon monoxide is not harmful in low concentrations. However, when present in concentrations exceeding the standard, this pollutant can seriously affect the metabolism of the respiratory system, due to the high affinity of hemoglobin toward this compound.

CO emissions in an enclosed area can cause death through cardiac arrest or asphyxiation. This is because CO absorption increases with its concentration in the environment, an increase in the time of exposure, and an increase in physical activity. Exposure to low levels of CO can also cause health damage when individuals are taking medications, consume alcoholic beverages or live at high elevations.

Some studies show that CO concentrations found in micro-environments, such as sidewalks that are adjacent to streets that carry large volumes of traffic, or inside vehicles, are much greater than those found at fixed, continuous monitoring stations. This means that even though the standard is not exceeded at those stations, there can be a considerable number of individuals exposed to hazardous levels of this pollutant. This was supported by two intensive studies conducted by the US Environmental Protection Agency, in Denver and Washington, D.C. (Akland *et al*, 1985).[4]

Sulfur oxides (SOx)

Sulfur dioxide (SO_2) is a colorless, non-flammable and non-explosive gas, with a very strong odor, and is highly soluble in water. It can remain in the atmosphere from 2 to 4 days. During this time it can be transported for thousands of kilometers forming sulfuric acid, which then precipitates as acid rain in another region, distant from its source.

Sulfuric acid, sulfur dioxide, and sulfate salts irritate the mucous membrane and the respiratory tract. They can even cause chronic illnesses of the respiratory system, such as bronchitis and emphysema.

The harmful effect of sulfur oxides increases in an environment where there is a high concentration of suspended particles. Sulfur dioxide and sulfuric acid paralyze the cilia of the respiratory tract, allowing dust particles containing sulfur compounds to penetrate the lungs. This may cause serious harm and even death. It has been confirmed that the acid component of particulate matter was involved in the mortality episodes of the 1940s and 50s in London, England.

In plants, SO_2 causes irreversible tissue damage, especially during sunny days. On the other hand, sulfuric acid attacks building materials such as marble, quarry, lime, and mortar. A large number of monuments, buildings, sculptures, and churches have deteriorated because of this. Sulfuric acid also damages fabrics such as cotton, linen, rayon, and nylon. Libraries also have a problem with this compound, since it makes paper turn yellow. The same compound causes leather items to dry up and metals to corrode.

Fossil fuels containing sulfur are the main source of sulfuric oxide emissions. Therefore, fixed sources that consume fuel with a high sulfur content are the main cause of sulfur emissions into the atmosphere.

Air pollution has global and regional effects; it is not only restricted to large cities. Acid rain is an example of this. Acid rain originates when sulfur oxide and nitrogen oxide emissions react with water vapor; with the help of solar light they turn into sulfuric acid and nitric acid. These compounds are deposited on the earth's surface as aerosols and particles (dry deposition) or as rain, hail and dew (wet deposition). Pollutants can be emitted from one point and remain there for days, until the wind carries them for a long distance, and then fall in areas that can be impacted accord-

[4] Akland, G.G.; Hartwell, T.D.; Johnson, T.R.; Whitmore, R.W. (1985). "Measuring human exposure to carbon monoxide in Washington, D.C., and Denver, Colorado, during the winter of 1982-1983". Environ. Sci. Technol. 19: 911-918.

ing to the sensitivity of the ecosystem.

Nitrogen oxides (NOx)

Nitrogen forms seven different types of oxides, two of which, nitric oxide (NO) and nitrogen dioxide (NO_2), are important air pollutants. NOx are formed during combustion and are the product of atmospheric nitrogen oxidation or the oxidation of organic oxygen from fuel. In the first case, NOx formation is enhanced as temperature rises. As a result of this, NO and NO_2 production is also a function of the air/fuel ratio in the mixture. Nitrogen dioxide can form nitric or nitrous acid with the presence of water. Both can be precipitated with rain or combine with ammonia in the atmosphere to form ammonium nitrate.

Nitric oxide, like carbon monoxide, can mix with hemoglobin in the bloodstream reducing its capacity to transport oxygen.

Nitrogen oxide irritates the alveoli. Occupational health studies show that this gas can be fatal in high concentrations. Unlike ozone, NO_2 can be more abundant indoors than outdoors. This is due to the fact that one of the sources of this contaminant is LP gas as well as industrial burners and ovens that use the same type of fuel.

Nitrogen oxides, along with hydrocarbons, generate secondary type pollutants known as photochemical pollution, whose main component is ozone (O_3). Nitrogen oxides are mainly produced by industrial fuel transport and consumption, as well as power generation.

Benzene

Benzene is a compound that has been classified by the International Agency for Cancer Research as a Group 1 carcinogen, meaning that there is sufficient scientific evidence to prove a positive relationship between exposure to that toxic compound and developing cancer. More specifically, it has been found that workers who are exposed to benzene have a greater probability of developing acute leukemia than the general population. Likewise, it is known that benzene has hematological and immunological effects, as well as effects on the nervous system.

Environmental exposure studies conducted in Los Angeles, revealed that the main source of exposure to benzene are cigarettes (39%), and the main source of benzene in the atmosphere are motor vehicle emissions (82%), and the loss of hydrocarbon vapors while driving, and while distributing, storing and dispensing gasoline. Even though gasoline sold in the City of Mexicali in 1996 had relatively low (2.4%) benzene content, its toxicity and the large volume of gasoline consumption make it necessary to install monitoring stations and conduct exposure studies. These studies can help develop a human health risk assessment to reveal the percentage of the population that is exposed to high concentrations of this hydrocarbon. Likewise, it is necessary to install vapor recovery systems to prevent these emissions.

Formaldehyde

Formaldehyde can be emitted by motor vehicles or be produced by photochemical reactions in the atmosphere. Formaldehyde emissions generated by vehicles are increased with the use of oxygenated gasoline.

The fact that formaldehyde causes eye, nose and throat irritation, as well as coughing, nausea, and other respiratory symptoms has been well documented. Formaldehyde has been associated with lung and nasopharyngeal cancer mainly in individuals that work in the environmental field. Exposure to formaldehyde must be reduced not only because of its carcinogenic effect, but also because of its potential effect for causing tissue damage. Some recent epidemiological studies on formaldehyde suggest that the threshold for damage to the tissue is 1.0 Fg/m^3; however, it is difficult to make a formal risk assessment of its carcinogenic effect due to the limited amount of data currently available (Wark and Warner, 1994).[5]

Polycyclic Aromatic Hydrocarbons (PAH)

PAHs are a group of chemical compounds formed during the incomplete combustion of wood and other fossil fuels. Concentrations of these compounds can be fairly high in the emissions from diesel-fueled vehicles. One of the best known PAHs is benzo-α-pyrene. These compounds can be absorbed in the intestines and the lungs.

There is sufficient experimental evidence to suggest that PAHs are mutagenic and carcinogenic. Specific studies indicate that those individuals who are exposed to PAHs in the work environment are at a greater risk of developing cancer. More specifically, it has been found that truck drivers and messengers are at a greater risk of developing bladder cancer (Wark and Warner*,* 1994).[5]

[5] Wark, K. y Warner, C. (1994). Contaminación del Aire, Origen y Control. Limusa Noriega Editores, México D.F.

ANNEX D. SUMMARY OF THE CALCULATION OF EMISSIONS REDUCTIONS, INVESTMENTS AND COSTS

The following is a summary of the calculations that were performed to determine emission reductions, as well as the cost and investment necessary to achieve those reductions. Estimates are presented only for those control measures where these parameters could be quantified. The number associated with each measure is the same number used in Chapter Six.

I. Industry

1. Reduce the emissions generated by the worst polluting industries through the installation of control equipment and process re-engineering

Emissions: This measure consists of installing electrostatic precipitators, cyclones, gas cleaners, and low NOx burners in facilities that generate more than 1 ton/year of particulate matter or sulfur dioxide, and more than 2 tons/year of NOx. According to the emissions inventory, there are 23 facilities that emit PM10, 19 that emit sulfur dioxide, and 22 that emit NOx.

Considering global reductions of 70% for PM10, 50% for sulfur dioxide and 60% for NOx, using the appropriate control devices, we have the following:

- PM10 reduction = 1,988 ton/year x 0.70 = 1,392 ton/year
- SO_2 reduction = 2,845 x 0.60 = 1,707 ton/year
- NOx reduction = 1,514 x 0.50 = 757 ton/year.

Cost: The following investment costs were considered for the purchase of emissions control equipment: 1,400 dollars/ton for sulfur dioxide, 1,000 dollars/tom for PM10, and 2,500 dollars/ton for nitrogen oxides.

2. Implement a vapor recovery program at storage terminals and fuel service stations

Emissions: Within the service sector, transportation and gasoline sales generate 1,596 tons/year of hydrocarbons. Installing vapor recovery systems at service stations, the goal is to achieve a 90% reduction in that type of emissions. This would result in the following:

- HC Reduction = 1,596 ton/year x 0.90 = 1,436 ton/year.

Cost: The objective of this action is to install vapor recovery equipment at each of the 130 service stations. The unit cost for this type of equipment is 25,000 dollars.

4. Reach an agreement with industry on the implementation of a program to reduce volatile organic compounds (VOCs)

Emissions: Within the industrial sector, and particularly within those facilities that generate the largest amounts of volatile organic compound emissions, 32 facilities were identified that generate a total of 1,385 tons/year of volatile organic compounds. Applying this measure, we estimate an 85% reduction in VOC emissions by installing vapor recovery systems or catalytic converters. The estimated reduction is as follows:

- HC Reduction = 1,385 tons/year x 0.85 =1,177 tons/year.

Cost: a cost of 4,000 dollars per ton of HC emissions reduction was considered for the type of equipment considered.

II. Vehicles

9. Design a model, reach a consensus and put into use the Vehicle Emissions Testing Program

Emissions: Mexico Valley Metropolitan Zone (ZMVM) studies suggest an approximate 30% reduction in PM10, CO, NOx, and HC emissions when gasoline-powered vehicles in the worst possible mechanical conditions are given complete tune-ups (i.e. spark plug replacement, carburetor check, timing adjustment, spark plug cable replacement, filter replacement, etc.). If we assume that 80% of the vehicular fleet complies with the emissions testing requirement, we arrive at the reductions shown in Tables D.1 through D.4. Likewise, if we assume the same rate of compliance for diesel powered vehicles, considering a 30% emissions reduction for all pollutants the resulting reductions are shown in Tables D.5 through D.8.

Table D.1. PM10 reductions for gasoline-powered vehicles

Type of Vehicle	Particulate Emissions (tons/year)	Applicable Particulate Emissions	% Reduction	Reduction (tons/year)
Private vehicles	80	64.0	30	19.0
Pick-up trucks	34	27.0	30	8.0
Taxi cabs	1	0.8	30	0.2
Passenger trucks	2	1.6	30	0.5
Light duty trucks	5	4.0	30	1.0
Heavy duty trucks	7	6.0	30	1.8
Total				**30.5**

Table D.2. CO Reductions for gasoline-powered vehicles

Type of Vehicle	CO emissions (ton/year)	Applicable CO emissions	% reduction	Reduction (ton/year)
Private vehicles	143,956	115,165	30	34,550
Pick-up trucks	58,828	47,062	30	14,119
Taxi cabs	2,102	1,682	30	505
Passenger buses	4,623	3,698	30	1,109
Light duty freight trucks	8,694	6,955	30	2,087
Heavy duty freight trucks	21,621	17,297	30	5,189
Total				**57,559**

Table D.3. HC Reductions for gasoline-powered vehicles

Type of Vehicle	HC emissions (ton/year)	Applicable HC emissions	% reduction	Reduction (ton/year)
Private vehicles	18,427	14,742	30	4,423
Pick-up trucks	7,742	6,194	30	1,858
Taxi cabs	269	215	30	65
Passenger buses	454	363	30	109
Light duty freight trucks	1,289	1,031	30	309
Heavy duty freight trucks	2,122	1698	30	509
Total				**7,273**

Table D.4. NOx Reductions for gasoline-powered vehicles

Type of Vehicle	NOx Emissions (ton/year)	Applicable NOx emissions	% reduction	Reduction (ton/year)
Private vehicles	6,283	5,026	30	1,508
Pick-up trucks	2,570	2,056	30	617
Taxi cabs	92	73	30	22
Passenger buses	206	165	30	50
Light duty freight trucks	441	353	30	106
Heavy duty freight trucks	962	770	30	231
Total				**2,534**

Table D.5. PM10 Reduction for diesel-powered vehicles

Type of Vehicle	PM10 emissions (ton/year)	Applicable PM10 emissions	% reduction	Reduction (ton/year)
Passenger buses	22	18	30	5
Freight trucks	363	290	30	87
Total				**92**

Table D.6. CO Reduction for diesel-powered vehicles

Type of Vehicle	CO emissions (ton/year)	Applicable CO emissions	% reduction	Reduction (ton/year)
Passenger buses	159	127	30	38
Freight trucks	2,638	2,110	30	633
Total				**671**

Table D.7. HC Reduction for diesel-powered vehicles

Type of vehicle	HC emissions (ton/year)	Applicable HC emissions	% reduction	Reduction (ton/year)
Passenger buses	41	33	30	10
Freight trucks	673	538	30	161
Total				**171**

Table D.8. NOx Reduction for diesel-powered vehicles

Type of vehicle	NOx emissions (ton/year)	Applicable NOx emissions	% reduction	Reduction (ton/year)
Passenger buses	248	198	30	59
Freight trucks	4,113	3,290	30	987
Total				**1,046**

Cost: Testing of 183,777 gasoline powered-vehicles and 8,110 diesel-powered vehicles was considered. For gasoline-powered vehicles it was considered that all of them have a carburetor and require minor tune-ups, with an average cost of 100 dollars per unit; for diesel-powered vehicles a tune-up cost of 800 dollars per unit was considered. The estimated cost includes the test.

III. Urban management and transportation

13. Apply soil stabilizers for the control of PM10 emissions on streets, unpaved and heavily traveled areas

Emissions: In order to calculate emissions reduction from soil stabilization in unpaved roads, it was considered that vehicular emissions in unpaved roads amount to 53,689 tons/year. It was assumed that 30% of the unpaved roads would be stabilized, and that this practice reduces emissions by 90%. Emissions would then be reduced by 27%, which equals 14,496 tons/year of particulate matter (PM10).

Cost: A cost of 250 dollars per ton of PM10 emissions reduction was considered.

14. Intensify a paving program for streets and roads

Emissions: It was considered that there are 797 hectares of unpaved surface area in Mexicali and that vehicular traffic accounts for 53,689 tons/year of PM10 emissions. If the emissions reduction achieved from soil stabilization (14,496 tons/year) is subtracted from this, we are left with 39,193 ton/year of PM10 emissions. This implies that paving 20% of the streets will reduce PM10 emissions by 7,839 ton/year.

Cost: An estimated cot of US$5,000 per ton of particulate matter emissions reduction through paving.

IV. Ecological recovery

23. Design a reforestation and preservation program for wooded areas

Emissions: wind-generated emissions over open spaces and eroded areas amount to 20,548 ton/year of PM10. This is the equivalent of 10.4 tons per hectare. Considering that in Mexicali there are 1,980 hectares of open space that are influenced by the wind, and that only 30% of this surface area will be reforested (i.e. 594 hectares, PM emissions will be reduced by 6,178 tons.

Cost: A cost of US$1,000/hectare was considered for estimating the total cost.

ANNEX E. TECHNICAL LINEAMENTS OF A VEHICULAR EMISSIONS TESTING PROGRAM

E.1. Introduction

Information collected through Mexicali's air quality monitoring network indicates that the air quality standards for nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO) and particulate matter less than ten microns in diameter (PM10), have been exceeded in the last few years. Furthermore, it is a known fact that the main pollutants emitted by internal combustion engines are: CO, NOx, HC, SOx, carbon particles, and heavy metals such as lead in gasoline containing lead-based additives. Some pollutants, such as NOx and HC, are precursors of photochemical oxidants such as O_3. The vehicular fleet in Mexicali consists of approximately 241 thousand vehicles, with estimated daily emissions of 666 tons of CO, 85 tons of HC and 41 tons of NOx. This is the equivalent of approximately 289 thousand tons of annual emissions, representing 70% of all atmospheric emissions.

Likewise, there are other factors that contribute to vehicular emissions such as: the use of inadequate fuels, the number of vehicles in circulation, inefficient vehicle maintenance, tampered emissions control systems, and inefficient or insufficient public transportation, among others.

Based on this information, we can assert that motor vehicles in Mexicali represent one of the main sources of air quality degradation, thus making it necessary to promote control measures that lead to a decrease in vehicular emissions.

In Mexico, there has been progress as far as controlling the most important atmospheric pollutants in urban areas. Currently, there are 30 Official Mexican Standards, related to industrial and vehicular atmospheric pollution control.

Motor vehicles play an important role in the degradation of air quality, particularly when the concentration of certain pollutants exceeds a particular standard. Some of these standards establish maximum permissible levels for air pollutants emitted by vehicular exhaust, as well as the procedure for certifying the emission levels of air pollutants, commonly known as vehicle emissions testing. This consists of measuring vehicle emissions with gas analyzers.

The following is an outline of the legal aspects that can be used as the basis for implementing a vehicle emissions testing program in Mexicali, and an illustration of a series of technical elements that this program might take into account. This information was adapted from the Air Quality Management Program for Ciudad Juárez, which shares several characteristics with Mexicali as far as the condition of its vehicular fleet. However, the time has come for local and state government authorities to clearly define the emissions testing program.

E.2. Legal basis for vehicle emissions testing

The Political Constitution of the United Mexican States establishes in Article 4 a person's right to health protection and requires assurance of a satisfactory air quality for the well being of the population and ecological balance.

At a national level, the legal framework for air quality management is the General Law of Ecological Balance and Environmental Protection (LEGEEPA), with its accompanying Air Pollution Prevention and Control Regulation.

On February 29, 1992 the Ecological Law and Regulation for the State of Baja California came into effect. The contents of this document are in accordance with those of LEGEEPA. In Title Two, Chapter I, Section V, Article 19, of this State Law, the following are listed as the City Councils' responsibilities:

XI. Establish and operate emissions testing systems to comply with the technical ecological standards of maximum permissible emissions of pollutants into the atmosphere, by sources that fall under municipal jurisdiction.

XII. Apply the appropriate transit and roadway measures to keep motor vehicle emissions into the atmosphere from exceeding the maximum permissible levels determined by the applicable regulations and technical ecological standards.

XIII. Set measures for retiring motor vehicles that exceed the maximum permissible levels of emissions into the atmosphere, established by the applicable regulations and technical ecological standards.

The following is mentioned in Title Five under Environmental Protection, Chapter I, dealing with atmospheric pollution prevention and control:

Article 136. Motor vehicles that emit visible gases, smoke or dust, or whose air pollutant emission levels exceed the maximum permissible levels established under the technical ecological standards, will not be allowed to circulate.

Article 137. Car dealers must obtain proof of compliance with emissions testing prior to the sale of motor vehicles. The sale of any motor vehicle will be subject to any administrative penalties on the part of the competent municipal traffic and transportation authorities.

Article 138. The municipalities must show the administrative ability to:

I. Establish or grant the rights to establish vehicle emissions testing facilities, in such fashion that the number of these facilities is enough to readily test and monitor the performance of all registered motor vehicles currently in circulation.

II. Establish and control a quick mechanism for testing the emissions of vehicles currently owned by car dealers.

III. Develop a regulation describing the procedure for issuing emissions testing vouchers to vehicles owned by car dealers.

Article 139. Traffic and transportation authorities will require that the owner or person in possession of a motor vehicle show the vehicle emissions testing voucher prior to obtaining license plates and all other required documentation for that vehicle.

Article 140. It is the responsibility of the owner or person in possession of a motor vehicle to maintain that vehicle in good working condition, to ensure that the emissions of carbon monoxide, other gases, smoke and particulate matter, fall within the established technical ecological standards. Non-compliance with the above requirements, under any circumstances, will result in penalties to be determined by the appropriate traffic and transportation authorities.

Article 141. Owners or individuals in possession of any motor vehicle, public or private, have the responsibility of passing the emissions test once a year, with the purpose of controlling those emissions and determining all the appropriate repairs as necessary. Such testing must be done at one of the authorized facilities as determined by the local governments.

Article 142. Owners and individuals in possession of public transportation vehicles, or other vehicles used for commercial purposes, must have the emissions of those vehicles tested with the frequency established in the regulations issued by the local governments for that purpose. Such frequency must not exceed six months. Non-compliance with the above requirements will result in penalties, as established by the local competent traffic and transportation authorities.

The environmental protection regulation for the Municipality of Mexicali, Baja California, published on December 8, 1997, assigns the following responsibilities to the municipality on issues related to motor vehicle pollution prevention and control:

a) Joint participation with the State Government in formulating the regulations and programs that set the basis for conducting vehicle emissions tests in municipal jurisdiction;
b) Apply the standards related to atmospheric vehicular emissions prevention and control, not considered to fall under federal jurisdiction;

c) Establish the basis for operating vehicle emissions testing facilities, as well as to control and oversee the operation of those facilities;
d) Authorize those who comply with the requirements from the Ministry of the Environment, Natural Resources and Fisheries (SEMARNAP) and other competent authorities, to provide vehicle emissions testing services; inspect and oversee compliance with the conditions of such authorization; and, when necessary, revoke that authorization.
e) Propose to the City Council measures for retiring motor vehicles that exceed the maximum permissible limits established by the applicable regulations and standards. Also, join the Municipal Department of Public Safety in enforcing the measures that have been approved for this purpose;
f) Collaborate with the competent municipal authorities in establishing traffic flow and roadway design criteria and lineaments that will be conducive to a reduction in motor vehicle emissions.

The following conditions, among others, must be agreed upon with the Municipal Department of Public Safety and the State Finance Ministry:

Any vehicle circulating in State public roadways must have a license plate, circulation card, vouchers and/or stickers, as proof of registration and compliance with the applicable environmental requirements. In order to obtain the above, the following requirements must be met:

I. Present proof of ownership of the vehicle;
II. Present the federal certificate of registration for the vehicle;
III. Present proof of payment of taxes for the vehicle for the current and previous year;
IV. Present proof of residence in the State;
V. Turn-in the previous circulation card and the previous set of license plates;
VI. Pay the corresponding duties for the issuance of license plates, stickers and circulation card, as well as all fines for violating this Law and its Regulations; and
VII. Present proof of compliance with vehicle emissions test.

E.3. Components of a vehicle emissions testing program

Objectives

- Achieve the required compliance with Mexican Official Standards by limiting the emission of air pollutants for vehicles currently in circulation;
- Promote the appropriate maintenance of engines and emissions control systems in the vehicular fleet of the Municipality of Mexicali; and
- Incorporate permanent actions for public involvement in the Vehicle Emissions Testing Program.

Goals

- In the short term, establish an Emissions Testing Program and achieve compliance from the entire community;
- Abate the levels of HC and CO from vehicular emissions.

Testing location and frequency

Testing will be performed at facilities authorized by the Municipal Ecology Department or at the emissions testing center owned by the Municipal Government. These facilities will be located according to the needs of the population. The frequency of testing will be once a year.

Testing centers

The purpose of these centers or facilities is to officially certify the emissions levels of motor vehicles. This is achieved by using a gas analyzer for vehicular exhaust.

The technical staff will perform a visual inspection of the different devices in the vehicle, in order to determine the potential source of problems in the test results. This is done because maintenance, both of the engine as well as the emissions control system, plays an important role in the test results.

Comparison of test results is made against the parameters established under the Official Mexican Standard for maximum permissible levels of vehicular pollutants. This Standard is known as NOM-041 and is reproduced in Annex H.

Infrastructure and equipment

A vehicle emissions testing facility must comply with a series of requirements, determined in accordance with technical and functional criteria:

- The minimum surface area for installing a vehicle emissions testing center will be 300 square meters and it will be used exclusively for vehicle emissions testing;
- Display the logos of both the Direction of Ecology as well as the Vehicle Emissions Testing Program in a visible billboard. The number that was assigned to the facility by the Direction of Ecology should appear next to these logos, along with the maximum permissible limits established under the Official Mexican Standards, the devices to be inspected, and the total, official service fee;
- The testing center must be equipped with the following public service areas:

  a.- Vehicle reception and visual inspection area

  b.- Measurement and analysis area

c.- Payment area

d.- Restroom and public service area.

- The area to be used for testing and diagnostics will have a total of 30 m² for each piece of equipment used at the center. This is based on the minimum surface area required for handling any vehicle. This area cannot be used for any other purpose;
- Access to testing or diagnostic areas will be exclusively for this purpose.
- The decision to approve the proposed facility will be based on pictures of the proposed facility and its corresponding plan. The plan must indicate the area that will be occupied by the emissions testing center, the public reception office, restrooms, parking area, access to the facilities from the road, as well as the surrounding structures and nearby streets.
- The facility must be equipped with gas analyzers to determine the concentration of hydrocarbons, carbon monoxide, carbon dioxide and oxygen in the exhaust gases of the vehicle, set at 90 bars and authorized by the Municipal Department of Ecology.
- This equipment must have a total measuring scale between 0 and 10% by volume, for carbon monoxide; 0 a 2000 ppm, for hydrocarbons; 0 to 16% by volume, for carbon dioxide; and 0 to 22% by volume, for oxygen.
- The analyzer must be designed to handle continuous heavy work for a minimum period of 8 hours per day.

Procedure for establishing an emissions testing center

A request to create a vehicle emissions testing center must comply with the following requirements:

a) The format of the request to establish a vehicle emissions testing center can be obtained from the Municipal Department of Ecology;
b) Once the request has been received, the Department of Ecology will develop the appropriate response, determining whether or not the facility will be authorized.

The owners of the vehicle emissions testing and diagnostic facilities must submit a copy of all the requested documents to the Department of Ecology, as well as the agreement reached with the City Council of Mexicali, which will be valid for two years. This agreement may be renewed.

Only the owners of the vehicle emissions testing centers, or authorized staff carrying a notarized letter, can apply for renewal of the agreement before the Municipal government. The Department of Ecology must have knowledge of this request.

The number of devices to be used in the vehicle emissions testing center will be included in the request, along with the brand, serial number, and other technical information regarding the equipment.

The authorization to renew the agreement granted by the Department of Ecology to the emissions testing and diagnostic centers, can only be transferred to another individual if that individual complies with all the established requirements.

Technical staff

All vehicle emissions testing centers must have qualified technical staff to operate the testing equipment and follow the proper procedures. For this reason, all technical staff must obtain a certificate of accreditation, asserting that they have received the proper training for handling the emissions testing equipment.

It is the facility owner's responsibility to provide technical training to all staff in charge of operating the testing equipment, as well as making sure that their accreditation is kept current.

The Municipal Department of Ecology will request all emissions testing centers to submit the proper documentation for authorized personnel, reserving the rights to make this request as often as it deems it necessary. This is done with the objective of verifying the certification and validity of the training received by all the staff hired to provide this service.

The certificates or vouchers of accreditation for all the emissions testing technicians must always be displayed in plain view, must not have any erasures or amendments, and can be issued by any official educational institution in the country, or by any technical school in Mexicali.

Emissions measurement procedure

The authorized vehicle emissions testing centers must have signs indicating the current vehicle emissions standards, in accordance with NOM-047 (reproduced in Annex H), considering the dimensions indicated in previous paragraphs. Visibly polluting vehicles cannot be tested.

The information about the vehicle and its owner must be recorded. All information will be entered into a database, which will be requested and compiled by staff from the Department of Ecology.

The hours of operation for all vehicle emissions testing centers must cover a 10-hour period per day, from Monday through Saturday. This schedule can be modified only with prior approval from the Municipal Department of Ecology.

Testing method

The static test will be the method of choice for this mandatory program. It will apply to all vehicles that are powered by gasoline, liquefied petroleum gas, natural gas, or other fuels.

The static test consists of three stages: a visual smoke inspection, a cruise-speed test, and a slow-speed idle test.

For the visual smoke inspection the tachometer of the testing equipment is connected to the ignition system of the vehicle. The engine is run at 2,500 $\pm$ 250 revolutions per minute. If black or blue smoke emissions are observed, and if these emissions remain for more than 10 seconds, the test must be stopped. In this case, the maximum permissible limits established by the corresponding Official Mexican Standard are exceeded.

For the cruise-speed test, a probe is placed in the tailpipe, making sure that it is perfectly secured. The engine is run at 2,500 $\pm$ 250 revolutions per minute, for at least 30 seconds.

For the slow-speed idle test, the engine is decelerated to the speed specified by the manufacturer, which will not exceed 1,100 revolutions per minute during a period of at least 30 seconds.

Visual inspection of the vehicle prior to the test

The conditions that must be met by the vehicle in order to undergo the testing procedure specified by the Official Mexican Standard are the following:

- The technician performing the test must inspect the manufacturer installed emissions components and design elements to ensure compliance with the applicable emissions control standards, making sure that these components have not been:

    a) Removed from the emissions control system of the vehicle
    b) Tampered to keep the emissions control system from working properly
    c) Replaced with a component that was not sold by the manufacturer for this purpose
    d) Replaced with a component that does not have the ability of being connected to other emissions control components
    e) Disconnected, even though the element is present and mounted correctly in the vehicle.

- The technician must ensure that the tailpipe of the vehicle is in perfect operating condition and that it does not have any other exits in addition to the one from the original design, which may cause dilution of exhaust gases or a leak of those gases.

- The visual inspection will be aimed at the following devices:

  a) Tailpipe (not defective, not noisy, not perforated)
  b) Air filter
  c) Gasoline tank cap
  d) Oil tank (cap and level rod)
  e) Carburetor (free of gasoline leaks and spills)
  f) Thermometer with normal operating temperature
  g) Vacuum hoses connected and in good working condition
  h) Engine water hoses in good condition
  i) Cables in good condition
  j) Activated carbon filter
  k) Housing ventilation
  m) Hot air admission system
  n) PCV valve
  o) EGR valve.

For vehicles equipped with double exhaust systems, the test must be done on each of those systems. The result will be the average of the readings recorded for each exhaust system.

The testing equipment is to be handled exclusively by the assigned technician. The technician must operate this equipment in accordance with the instructions in the manufacturer's manual. The technician must calibrate the equipment according to the instructions and specifications included in this procedure, removing any foreign matter and/or water or moisture that may accumulate in the filters and probes.

Analysis of results

A vehicle passes emissions when none of the values recorded during the tests, at slow speed, idling, and at cruise speed, exceed the maximum permissible levels established by the corresponding Official Mexican Standard.

Based on these results, the technician will give a simple explanation to the user regarding the test results. If the vehicle fails the test, the driver will receive guidance on authorized diagnostic centers where he can be given a better explanation about the necessary adjustments and repairs, with the purpose of having the necessary improvements done within the period of time authorized for a second test.

Recommendations for users of the emissions testing service

The owner or driver taking a vehicle in for testing must:

- Present the circulation card, provisional circulation permit, or invoice letter;
- Present the vehicle in good working condition, with all additional equipment and accessories installed as specified by the manufacturer;
- Make sure that the test is conducted in compliance with official standards;
- Demand the emissions certificate and placement of the sticker in a visible location, in case the vehicle passes the test, keeping the voucher, since this will be required for the next emissions test.

Supervision of the operation and maintenance of emissions testing centers

For the purpose of supervision, the gas analyzing equipment must have an identification plate affixed to the outside of the unit, including: model, serial number, manufacturer name and address, electric power requirements, and voltage limits while operating the equipment.

The compilation of technical data from the testing and diagnostic equipment will be done on a monthly basis. The operators in charge of compiling this information will make an attempt to optimize time and effort.

During inspection visits, the work area and testing equipment will be inspected in the following manner:

- Probe, handle, and pipette: These components must not be altered, perforated, or cracked. The probe will undergo a leak test by closing the end of the pipette.
- In-line filters: their usage capacity must not allow more than 20 ppm with a flow of 7 cubic feet per hour.
- Tri-filter: this is the primary filter and the mesh filters, which must be completely clean. Furthermore, the container, the lids, and the cover must not have any leaks.
- Tongs and connection: the cables and connection to the card must not be patched or stuck together.
- Electrical installation: physical ground, voltage regulator and three-prong outlet.
- Keyboards: all the keys, including all characters, must be working correctly.
- Printing tape: legible and full lines.
- Microswitches: these must be in good condition, connected and working.

Calibration of the gas analyzer

The owner of the emissions testing center must calibrate the equipment with the frequency specified by the manufacturer. This calibration can be conducted using the test gas. The test gas must have a precision of $\pm$ 2% of the indicated concentration, guaranteed by the manufacturer.

The equipment must be calibrated to obtain the calibration curves as established by Mexican standards.

Vehicles that must be tested

Two types of facilities will be used for vehicle emissions testing:

- The first type will be exclusively dedicated to testing the emissions of public use vehicles, passenger or freight transportation vehicles, government vehicles, school buses and company vehicles used to transport employees, as well as gasoline and diesel-fueled vehicles destined for any type of service (municipal government owned testing center).
- The second type of emissions testing centers will be dedicated to all gasoline-fueled private vehicles, vehicles used by diplomatic and international organizations, motorcycles, and other vehicles not considered under the previous paragraph.

New vehicles of any type must be certified by the same distributing agency, before they are delivered and put in circulation.

Used imported and domestic vehicles that are for sale must have passed the vehicle emissions test. Imported vehicles in particular, must fully comply with the decree of Monday, February 21, 1994, published in the Official Federal Newspaper, in reference to the conditions for the importation of used motor vehicles that are destined to remain permanently within the Mexican northern border region.

The owner of the vehicle must have a document certifying that the vehicle to be imported complies with the technical requirements of maximum permissible pollution in its country of origin. In order to accomplish this, it is necessary for Mexicali Border Customs to oversee and comply with this requirement.

All car dealers, and service and repair shops, are prohibited from disconnecting or tampering with any emissions control devices.

Test fees and duties

The Municipal Department of Ecology will establish the fees. Those fees must be visibly displayed in all vehicle emissions testing stations.

In other Mexican States, the test fees for 1999 were the equivalent of three days pay at the minimum wage for the Federal District, plus tax; with the exception of federal testing centers, where the fee is the equivalent to five days pay at the current minimum wage, plus tax.

The owner of a vehicle that fails the first test will have the right to an additional test, free of charge, as long as the vehicle is brought back to the same facility where it failed the initial test.

When a vehicle fails the emissions test, the owner will have thirty days from the date of the initial test to have the vehicle re-tested and pass emissions. If the vehicle is not brought in for re-testing, or if it fails again, the owner will receive the applicable penalty.

Proof of testing

The ecological stickers and emissions testing certificates will serve as proof of compliance with the vehicle emissions test.

E.4. Proposal of strategies for the vehicle emissions testing program

The following strategies are presented as an example for achieving the objectives of the program. These strategies seek to include the shared responsibility of the parties involved.

Vehicle emissions testing program at maquiladoras and other large companies

The maquiladora industry and other large companies in Mexicali currently provide employment to a large number of individuals. This is why it is so important to establish a coordinated proposal with the Maquiladora Association and other Industrial Associations, to implement the vehicle emissions testing program.

Every participating company will reach an agreement with the municipality, through the Department of Ecology, regarding its involvement in the required vehicle emissions testing program.

The important aspects to be considered for the involvement of each company in this program are the following:

a) Knowledge of the vehicular fleet operated by its employees, as well as those vehicles that are for official use of the company. This is done with the objective of determining the amount of time that will be required for the authorized emissions testing center to test the emissions of all the vehicles from a specific facility.
b) Companies involved in this program must establish their own calendar for the participation of their employees.
c) It is important for companies to consider the need for financial support or incentives that may be requested by their employees, in case their vehicles

are in poor condition and require repairs related to their emissions control devices.

Only those vehicle emissions testing centers equipped with two or more testing bays can participate in this program. The participating facilities must inform the Department of Ecology, in writing, about the days and times when they will offer their services.

The measures to be considered will be decided jointly by the Department of Ecology, the company, and the Emissions Testing Centers' Association.

Mechanical education for car drivers

Another strategy is to release information through the media, about the importance of this program in improving vehicle maintenance and that of their emissions control devices, with the purpose of reducing air pollution levels derived from mobile sources.

This educational component of the program will address vehicle inspection and maintenance in detail, and will discourage the mutilation of emissions control devices. Car drivers will be warned about inspection operations to be conducted by the corresponding authorities, and will alert them about the purchase or sale of vehicles that lack emissions control devices, or are equipped with emissions control devices that are not in working condition. This strategy considers enlisting the services of an emissions control specialist to conduct outreach on this subject.

E.5. Authority and oversight

As mentioned in the initial paragraphs outlining this program, it is essential that the corresponding authorities, in this case the Department of Ecology and the Department of Public Safety, inspect and oversee compliance with the program requirements.

ANNEX F. MEXICAN AIR QUALITY STANDARDS

The Air Pollution Prevention and Control Regulation, included in the “General Law of Ecological Balance and Environmental Protection”, points out in article 7, fraction IV that it is SEMARNAPs responsibility to set the standards “to be certified by the competent authority, for the concentration of the different pollutants generated by particular sources.” To that effect, SEMARNAP has issued the following standards for environmental monitoring, fixed source emissions, fuel characteristics, and mobile source emissions:

Fixed sources

Official Mexican Standard	**Maximum permissible levels for atmospheric emissions**
NOM-039-ECOL-1993	Sulfur dioxide and trioxide, and sulfuric acid mist in sulfuric acid production plants.
NOM-040-ECOL-1993	Solid particles and control of fugitive emissions generated by cement plants.
NOM-043-ECOL-1993	Solid particles.
NOM-046-ECOL-1993	Sulfur dioxide, sulfur trioxide mist, and sulfuric acid, in dodecylbenzenesulfonic acid production plants.
NOM-051-ECOL-1993	Industrial oil used in fixed sources in the Mexico City Metropolitan Area (ZMCM).
NOM-075-ECOL-1995	Volatile organic compounds from the process of oil-water separators in oil refineries.
NOM-085-ECOL-1994	Smoke, total suspended particles, sulfur oxides, nitrogen oxides and fixed sources that utilize fossil fuels.
NOM-092-ECOL-1995	Gasoline vapor recovery system requirements for service and self-serve stations located in the Valley of Mexico.
NOM-093-ECOL-1995	Laboratory efficiency for gasoline vapor recovery systems in service stations and self –serve stations.
NOM-097-ECOL-1995	Particulate matter and nitrogen oxides from glass manufacturing processes across the country.
NOM-105-ECOL-1996	Total suspended particles and total reduced sulfur compounds generated by the manufacture of cellulose.
NOM-121-ECOL-1997	Volatile organic compounds (VOCs) generated by paint operations in the automobile industry as well as the method to calculate their emissions.
NOM-123-ECOL-1997	Maximum permissible limits for volatile organic compounds (VOCs) in the manufacture of air-dried solvent-based paints and for domestic use, and the procedures for determining their content in paints and recoating solvents.

Fuel Characteristics

Official Mexican Standard	Specifications for:
NOM-086-ECOL-1994	Liquid and gaseous fossil fuels used in fixed and mobile sources.

Mobile Sources

Official Mexican Standard	Maximum permissible levels for pollutant emissions
NOM-041-ECOL-1999	Emission of polluting gases generated by the exhaust of gasoline-fueled vehicles in circulation.
NOM-042-ECOL-1999	Unburned hydrocarbons, carbon monoxide, nitrogen oxides, evaporative hydrocarbons generated by the exhaust of gasoline and gas fueled vehicles in plant.
NOM-044-ECOL-1993	Hydrocarbons, carbon monoxide, nitrogen oxides, total suspended particles and smoke opacity generated by diesel vehicles in plant.
NOM-045-ECOL-1996	Smoke opacity in diesel-fueled vehicles in circulation.
NOM-047-ECOL-1993	Equipment characteristics and measuring procedures for testing the pollutants generated by gasoline, LP gas, and natural gas fueled vehicles.
NOM-048-ECOL-1993	Hydrocarbons, carbon monoxide and smoke generated by gasoline or gasoline-oil powered motorcycles.
NOM-049-ECOL-1993	Equipment characteristics and measuring procedure for testing pollutants in gasoline and gasoline-oil fueled motorcycles.
NOM-050-ECOL-1993	Polluting gas emissions generated by vehicles that use LP gas or natural gas.
NOM-076-ECOL-1995	Polluting gas emissions generated by new vehicles with gross weight greater than 3,857 kilograms.
NOM-077-ECOL-1995	Equipment characteristics and measuring procedures for testing opacity levels in diesel-fueled motor vehicles.
NOM-EM-132-ECOL-1998	Equipment characteristics and measuring procedures for testing the emissions limits of motor vehicles that use gasoline, liquefied oil, natural gas or other alternate fuels (Suspends the legal effects of NOM-047-ECOL1993)

Environmental monitoring

Official Mexican Standard	Measurement and equipment calibration method for determining concentrations
NOM-034-ECOL-1993	Carbon monoxide.
NOM-035-ECOL-1993	Total suspended particles.
NOM-036-ECOL-1993	Ozone.
NOM-037-ECOL-1993	Nitrogen dioxide.
NOM-038-ECOL-1993	Sulfur dioxide.

Furthermore, in 1994 the Health Ministry (Secretaría de Salud), in coordination with SEMARNAP, issued the following health based air quality standards:

Air quality

Official Mexican Standard	Pollutant
NOM-020-SSA1-1993	Ozone
NOM-021-SSA1-1993	Carbon monoxide
NOM-022-SSA1-1993	Sulfur dioxide
NOM-023-SSA1-1993	Nitrogen dioxide
NOM-024-SSA1-1993	Total suspended particles
NOM-025-SSA1-1993	Particulate matter less than 10 microns
NOM-026-SSA1-1993	Lead

ANNEX G. 1983 LA PAZ AGREEMENT AND ANNEX V

A formal joint effort between The United States and Mexico to protect and improve the environment along the border area began in 1983. That year, both countries signed the *Agreement between the United States of America and the United Mexican States on Cooperation Regarding the Protection and Improvement of the Environment in the Border Area*, also known as “La Paz Agreement”.

This agreement outlines the main objectives regarding border environmental cooperation, establishes a mechanism to draft further agreements, annexes, technical actions, as well as hold high level meetings and special technical meetings to promote and foster cooperation between the two countries. Likewise, it established formal communication procedures between the two countries and ordered the appointment of National Coordinators to direct and supervise the implementation of this Agreement.

The La Paz Agreement regulates a framework of cooperation between US and Mexican authorities to prevent, reduce and eliminate air, water and soil pollution sources along a 100-kilometer wide border zone on either side of the international border. This Agreement sets the general guidelines that must be applied in the specific projects mentioned in its five technical annexes. Air quality issues are addressed by Annex IV, which is known as the *"Agreement between the United States of America and the United Mexican States on Cooperation Regarding Transboundary Air Pollution caused by Copper Smelters Along their Common Border";* and Annex V, known as the *"Agreement between the United States of America and the United Mexican States on Cooperation Regarding International Transport of Urban Air Pollution".*

Due to the lack of smelters along the border area between Mexicali and Calexico, only the La Paz Agreement and Annex V are reproduced in the following pages.

AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE UNITED MEXICAN STATES ON COOPERATION REGARDING THE PROTECTION AND IMPROVEMENT OF THE ENVIRONMENT IN THE BORDER AREA

The United States of America and the United Mexican States,

RECOGNIZING the importance of a healthful environment to the long-term economic and social well being of present and future generations of each country as well as of the global community;

RECALLING that the Declaration of the United Nations Conference on the Human Environment, proclaimed in Stockholm in 1972, called upon all nations to collaborate to resolve environmental problems of common concern;

NOTING previous agreements and programs providing for environmental cooperation between the two countries;

BELIEVING that such cooperation is of mutual benefit in coping with similar environmental problems in each country;

ACKNOWLEDGING the important work of the International Boundary and Water Commission and the contribution of the agreements concluded between the two countries relating to environmental affairs;

REAFFIRMING their political will to further strengthen and demonstrate the importance attached by both Governments to cooperation on environmental protection and in furtherance of the principle of good neighborliness;

Have agreed as follows:

Article 1

The United States of America and the United Mexican States, here in after referred to as the Parties, agree to cooperate in the field of environmental protection in the border area on the basis of equality, reciprocity and mutual benefit. The objectives of the present Agreement are to establish the basis for cooperation between the Parties for the protection, improvement and conservation of the environment and the problems which affect it, as well as to agree on necessary measures to prevent and control pollution in the border area, and to provide the framework for development of a system of notification for emergency situations. Such objectives shall be pursued without prejudice to the cooperation, which the Parties may agree to undertake outside the border area.

Article 2

The Parties undertake, to the fullest extent practical, to adopt the appropriate measures to prevent, reduce and eliminate sources of pollution in their respective territory which affect the border area of the other. Furthermore, the Parties shall cooperate in the solution of the environmental problems of mutual concern in the border area, in accordance with the provisions of this Agreement.

Article 3

Pursuant to this Agreement, the Parties may conclude specific arrangements for the solution of common problems in the border area, which may be annexed thereto. Similarly, the Parties may also agree upon annexes to this Agreement on technical matters.

Article 4

For the purposes of this Agreement, it shall be understood that the "border area" refers to the area situated 100 kilometers on either side of the inland and maritime boundaries between the Parties.

Article 5

The Parties agree to coordinate their efforts, in conformity with their own national legislation and existing bilateral agreements to Address problems of air, land and water pollution in the border area.

Article 6

To implement this Agreement, the Parties shall consider and, as appropriate, pursue in a coordinated manner practical, legal, institutional and technical measures for protecting the quality of the environment in the border area. Forms of cooperation may include: coordination of national programs; scientific and educational exchanges; environmental monitoring; environmental impact assessment; and periodic exchanges of information and data on likely sources of pollution in their respective territory which may produce environmentally polluting incidents, as defined in an annex to this Agreement.

Article 7

The Parties shall assess, as appropriate in accordance with their respective national laws, regulations and policies, projects that have significant impacts on the environment of the border area, that appropriate measures may be considered to avoid or mitigate adverse environmental effects.

Article 8

Each Party designates a national coordinator whose principal functions will be to coordinate and monitor implementation of this Agreement, make recommendations to the Parties, and organize the annual meetings referred to in Article 10, and the meetings of the experts referred to in Article 11. Additional responsibilities of the national coordinators may be agreed to in an annex to this Agreement. In the case of the United States of America the national coordinator shall be the Environmental Protection Agency, and in the case of Mexico it shall be the Secretaría de Desarrollo Urbano y Ecología, through the Subsecretaría de Ecología.

Article 9

Taking into account the subjects to be examined jointly, the national coordinators may invite, as appropriate, representatives of federal, state and municipal governments to participate in the meetings provided for in this Agreement. By mutual agreement they may also invite representatives of international governmental or non-governmental organizations who may be able to contribute some element of expertise on problems to be solved.

The national coordinators will determine by mutual agreement the form and manner of participation of non-governmental entities.

Article 10

The Parties shall hold at a minimum an annual high level meeting to review the manner in which this Agreement is being implemented. These meetings shall take place alternately in the border area of Mexico and the United States of America. The composition of the delegations which represent each Party, both in these annual meetings as well as in the meetings of experts referred to in Article 11, will be communicated to the other Party through diplomatic channels.

Article 11

The Parties may, as they deem necessary, convoke meetings of experts for the purposes of coordinating their national programs referred to in Article 6, and of preparing the drafts of the specific arrangements and technical annexes referred to in Article 3.

These meetings of experts may review technical subjects. The opinions of the experts in such meetings shall be communicated by them to on the national coordinators, and will serve to advise the Parties technical matters.

Article 12

Each Party shall ensure that its national coordinator is informed of the activities of its cooperating agencies that are carried out under this Agreement. Each Party shall also ensure that its national coordinator is informed of the implementation of other agreements concluded between the two Governments concerning matters related to this Agreement. The national coordinators of both Parties will present to the annual meetings a report on the environmental aspects of all joint work conducted under this Agreement and on implementation of other relevant agreements between the Parties, both bilateral and multilateral.

Nothing in this Agreement shall prejudice or otherwise affect the functions entrusted to the International Boundary and Water Commission, in accordance with the Water Treaty of 1944.

Article 13

Each Party shall be responsible for informing its Border States and for consulting them in accordance with their respective constitutional systems, in relation to matters covered by this Agreement.

Article 14

Unless otherwise agreed, each Party shall bear the cost of its participation in the implementation of this Agreement, including the expenses of personnel who participate in any activity undertaken on the basis of it. For the training of personnel, the transfer of equipment and the construction of installations related to the implementation of this Agreement, the Parties may agree on a special modality of financing, taking into account the objectives defined in this Agreement.

Article 15

The Parties shall facilitate the entry of equipment and personnel related to this Agreement, subject to the laws and regulations of the receiving country. In order to undertake the monitoring of polluting activities in the border area, the Parties shall undertake consultations relating to the measurement and analysis of polluting elements in the border area.

Article 16

All technical information obtained through the implementation of this Agreement will be available to both Parties. Such information may be made available to third parties by the mutual agreement of the Parties to this Agreement.

Article 17

ARTICLE 17Nothing in this Agreement shall be construed to prejudice other existing or future agreements concluded between the two Parties, or to affect the rights and obligations of the Parties under international agreements to which they are a party.

Article 18

Activities under this Agreement shall be subject to the availability of funds and other resources to each Party and to the applicable laws and regulations in each country.

Article 19

The present Agreement shall enter into force upon an exchange of Notes stating that each Party has completed its necessary internal procedures.

Article 20

The present Agreement shall remain in force indefinitely unless one of the Parties notifies the other, through diplomatic channels, of its desire to denounce it, in which case the Agreement will terminate six months after the date of such written notification. Unless otherwise agreed, such termination shall not affect the validity of any arrangements made under this Agreement.

Article 21

This Agreement may be amended by mutual agreement between the two Parties.

Article 22

The adoption of the annexes and of the specific arrangements provided for in Article 3, and the amendments thereto, will be effected by an exchange of Notes.

Article 23

This Agreement supersedes the exchange of Notes, concluded on June 19, 1978 with the attached Memorandum of Understanding between the Environmental Protection Agency of the United States and the Subsecretariat for Environmental Improvement of Mexico for Cooperation on Environmental Programs and Transboundary Problems.

DONE in duplicate, in the city of La Paz, Baja California, Mexico, on the 14th of August of 1983, in the English and Spanish languages, both texts being equally authentic.

ANNEX V. TO THE AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE UNITED MEXICAN STATES ON COOPERATION REGARDING THE PROTECTION AND IMPROVEMENT OF THE ENVIRONMENT IN THE BORDER AREA.

AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE UNITED MEXICAN STATES ON COOPERATION REGARDING INTERNATIONAL TRANSPORT OF URBAN AIR POLLUTION.

The Government of the United States of America ("the United States") and the Government of the United Mexican States ("Mexico") ("the Parties"),

Recognizing that health and environmental damage may result from emissions of air pollutants in urban areas;

Realizing that the transport of air pollutants occurs from border cities of the United States to border cities of Mexico and from border cities of Mexico to border cities of the United States;

Seeking to ascertain the magnitude of such air pollutant transport and the physical mechanisms facilitating this transport;

Realizing that certain adjacent areas in the United States and in Mexico fail to meet their countries' respective ambient air quality standards for various pollutants;

Seeking to ensure a reduction in air pollution concentrations for the benefit of their citizens living in urban areas along the United States-Mexico border;

Reaffirming Principle 21 of the 1972 Declaration of the United Nations Conference on the Human Environment, adopted at Stockholm, which provides that States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or areas beyond the limits of national jurisdiction;

Recognizing that Article 3 of the Agreement between the Parties on Cooperation for the Protection and Improvement of the Environment in the Border Area of 1983 ("the 1983 Agreement") provides that the Parties may conclude specific arrangements for the solution of common problems in the border areas as annexes to that Agreement,

Have agreed as follows:

Article I
Definitions

1. "Study area" means each specific geographic area of urban air pollution concern, which the Parties agree to subject to the requirements of this Annex, as listed in the appendices to this Annex.
2. "Selected pollutants" means those air contaminants chosen by the Parties for each "study area", as listed in the appendices to this Annex.
3. "Major stationary source" means any stationary source with emissions greater than 97 metric tons (100 tons) per year for which there is a specific air pollution control standard in force, any other source with emissions greater than 243 metric tons (250 tons) per year, and any other stationary source which the Parties mutually so designate for the purposes of this Annex.
4. "Air pollution control standards" means technologically achievable limits for controls on air pollution emissions from stationary sources (e.g., New Source Performance Standards and Límites de Emisión para Fuentes Nuevas).
5. "Ambient air quality standards" means critical ambient levels of air pollutants (e.g., the National Ambient Air Quality Standards and la Norma Mexicana de Calidad del Aire).
6. "Mobile sources" means automotive, bus or truck vehicles, off-road vehicles, waterborne vessels, and aircraft.
7. "Area sources" means all emitters of air contaminants other than major stationary sources and mobile sources.
8. "Industrial classification" means a system of classifying various industrial activities by organizing them into comparable types (e.g., the Standard Industrial Classification (SIC) Code and the Sistema Nacional de Información de Fuentes Fijas (SNIFF)).

9. "Emission point type" means the small-scale source of pollutant release, namely stack, fugitive, volume, or line.

Article II
General Obligations

1. For each study area, the Parties shall detail in their respective territory the magnitude of emissions of selected pollutants and the name, type, and location of each source of pollution, if it is a major stationary source.
2. For each study area, the Parties shall identify in their respective territory the nature and magnitude of control requirements, if any, for each major stationary source needed to conform to the air pollution control standards applicable to that source type and shall identify relatively simple and quickly initiated controls and/or changes in management practice to reduce air pollution from each major stationary source not meeting applicable air pollution control standards.
3. For each study area, the Parties shall estimate in their respective territory the emissions of the selected pollutants due to the activities of all mobile and area sources.
4. The Parties shall issue a joint report incorporating their findings under (1), (2), and (3) above within six months of making such findings.
5. Each Party shall, in its territory, perform ambient monitoring of common selected pollutants and meteorological parameters in each study area in such a way as to ascertain the pollution concentrations arising from each separate urban area and those concentrations due to the interaction of pollutants originating from both urban areas.
6. Each Party shall issue reports at agreed-upon intervals of time, but not longer than yearly intervals, detailing the results of monitoring carried out under (5) above.
7. Each Party shall, in its territory, perform monitoring to the extent necessary to successfully support the use of a state-of-the-art mathematical air modeling analysis. The Parties shall perform the modeling analysis in order to assess accurately the effect of changes in emission levels from each source type within the study area on the ambient concentrations of the related pollutants within the study area.
8. Monitoring in each study area will continue for a period of two years from the commencement Of each study, at which Point the Parties will decide whether further monitoring is desired.

Article III
Compiling air pollution emissions inventories and information about sources as outlined in Article II

1. For the Purposes Of Article II, each Party shall compile air Pollution emission inventories and source information with respect to its territory.
2. The emission inventories shall be based upon emission factors that are mutually acceptable to both Parties.
3. Each Party shall list the emissions of each major stationary source in its territory in mutually agreed-upon conventional units of measure with the source's address and industrial classification; for each separate emission point in the major stationary source, each Party shall list the emissions, latitude and longitude, emission point type, stack diameter, stack height, stack gas exit velocity, stack gas exit temperature, width, length, and height, where applicable.
4. Utilizing the information obtained under (2) and (3) above, each Party shall identify those major stationary sources in its territory that do not meet applicable air Pollution control standards for each selected pollutant. For all such sources, the Parties shall, based upon site visits and/or good engineering practice: (a) identify the type and extent of Pollution control equipment which would be required to bring each such source into conformity with applicable air pollution control standards for each selected pollutant; and (b) identify relatively simple and quickly initiated controls and/or changes in management practice to reduce air pollution from each such source. The Parties shall also identify the approximate percentage of emissions reduction of each selected pollutant that would result from such controls and/or changes in management practice. Participants designated by one Party for agreed site visits in the territory of the other Party shall have the status of observers.

Article IV
Performance of monitoring and modeling as outlined in Article II

1. For the purposes of Article II, each Party shall perform the tasks related to monitoring and modeling with respect to its territory.
2. Each Party shall, in its territory, locate and operate monitors in each study area in numbers sufficient to fulfill the goals of this Annex to as-

sess ambient concentrations of the selected pollutants.

3. Each Party shall, in its territory, locate and operate meteorological stations in numbers sufficient to fulfill the goals of this Annex; these stations shall monitor for the following parameters on a continuous basis: wind speed, wind direction, and temperature.
4. All details relating to the nature, number and placement of the monitoring devices used in (2) and the Parties shall, mutually agree upon (3) above.
5. Analysis associated with monitoring and quality assurance shall be conducted in a manner mutually agreed upon by the Parties.
6. The state-of-the-art mathematical modeling analysis shall be either a dispersion modeling analysis or a receptor modeling analysis or both, as mutually agreed upon by the Parties; supplementary analyses may be authorized by mutual consent of the Parties.

Article V
Harmonization of standards

In order to make more effective the implementation of this Annex, the Parties shall jointly explore ways to harmonize, as appropriate, their air pollution control standards and ambient air quality standards in accordance with their respective legal procedures.

Article VI
Protection of confidential information

The Parties shall adopt procedures to protect the confidentiality of proprietary or sensitive information conveyed pursuant to this Annex, when such procedures do not already exist..

Article VII
Effect on other instruments

Nothing in this Annex or its appendices shall be construed to prejudice other existing or future agreements concluded between the Parties, or affect the rights or obligations of the Parties under international agreements to which they are party.

Article VIII
Implementation

Implementation of this Annex is dependent upon the availability of sufficient funding.

Article IX
Appendices

Appendices to this Annex may be added through an exchange of diplomatic notes and shall form an integral part of this Annex.

Article X
Amendments

This Annex, and any appendices added hereto, may be amended by mutual agreement of the Parties through an exchange of diplomatic notes.

Article XI
Review

The National Coordinators under the 1983 Agreement or their designees shall meet at least every year from the date of entry into force of this Annex, at a time and place to be mutually agreed upon, in order to review the effectiveness of its implementation and to agree on whatever individual and joint measures are necessary to improve such effectiveness.

Article XII
Entry into force

This Annex shall enter into force after signature when each Party has informed the other through diplomatic note that it has completed the internal procedures necessary for the Annex to enter into force.

Article XIII
Termination

This Annex shall remain in force indefinitely, unless one of the Parties notifies the other in writing through diplomatic channels of its desire to terminate it, in which case the Annex shall terminate six months after the date of such written notification.

IN WITNESS WHEREOF the undersigned, being duly authorized by their respective Governments, have signed this Annex.

Done in the City of Washington DC, in duplicate, this third day of October, 1989 in the English and Spanish languages, both texts being equally authentic.

By the Government of the United Mexican States	By the Government of the United States of America

APPENDIX

ANNEX V. TO THE AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE UNITED MEXICAN STATES ON COOPERATION REGARDING THE PROTECTION AND IMPROVEMENT OF THE ENVIRONMENT IN THE BORDER AREA.

AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE UNITED MEXICAN STATES ON COOPERATION REGARDING INTERNATIONAL TRANSPORT OF URBAN AIR POLLUTION.

For the purposes of Annex V, the Parties agree to define Study Area "A" as:

El Paso County, Texas; that part of the State of New Mexico that is both south of latitude 32 degrees 00 minutes North and east of longitude 106 degrees 40 minutes West; and that part of the State of Chihuahua that is both north of latitude 31 degrees 20 minutes North and east of longitude 106 degrees 40 minutes West.

For Study Area "A', the Parties agree to define as selected pollutants the following: ozone, nitrogen oxides, non-methane hydrocarbons, carbon monoxide, sulfur dioxide, particulate matter, and lead.

The Mexican Foreign Ministry salutes the United States Embassy and makes reference to Diplomatic Note # 0521 of May 7, 1996, containing several proposals related to the appendices to Annex V of the Agreement between the United States of America and the United Mexican States on Cooperation regarding the Protection and Improvement of the Environment in the Border Area, signed in La Paz, B.C., August 14, 1983 ("La Paz Agreement"). These proposals were the result of negotiations on the subject between the two federal governments, and are mentioned in the Note from the Embassy.

The Ministry agrees with the revision of the text in paragraph 3 and 5, Article I, Annex V, so it reads as presented in Annex A of the note.

Concerning the additional proposals from the United StatesEmbassy, the Foreign Ministry agrees to eliminate Annex V as it exists in its current form, replacing it with six new appendices included here as Annex "B". Thus the Foreign Ministry agrees to the formation of a Air Quality Improvement Joint Advisory Committee for the Ciudad Juárez, Chihuahua / El Paso, Texas/ Doña Ana County, New Mexico airshed; and that Appendices 2 to 6 define the geographic areas of the study, to be identified with the letters "A" through "E".

In accordance with Article IX of Annex V, the Mexican Foreign Ministry states that the Note proposed by the United States Embassy on May 7, 1996, and the current Note of response, constitute an agreement between the two governments that will take effect on this date.

The Mexican Foreign Ministry thanks the United States Embassy for its timely attention to this matter.

Mexico, D.F., May 7, 1996.

To the Embassy of the United States of America

Annex "A"

Article I
Definitions

3. "Major stationary source" refers to any stationary source whose emissions exceed 91 metric tonnes (100 tons) per year and for which there is a specific air pollution control measure in place, and any other stationary source mutually agreed upon by the Parties, to fulfill this agreement.

5. "Ambient air quality concentrations" refer to the critical concentrations of pollutants in the air (e.g., Normas Oficiales Mexicanas de Calidad del Aire and the National Ambient Air Quality Standards").

Annex "B"

APPENDIX 1

ANNEX TO THE AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE UNITED MEXICAN STATES ON COOPERATION REGARDING THE PROTECTION AND IMPROVEMENT OF THE ENVIRONMENT IN THE BORDER AREA.

AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE UNITED MEXICAN STATES ON COOPERATION REGARDING INTERNATIONAL TRANSPORT OF URBAN AIR POLLUTION.

Recalling that in the preamble to Annex V the Parties affirm their intention to ensure a reduction in air pollution concentrations for the benefit of their citizens living in the urban areas along the United States-Mexico border; and

Recognizing the importance of the participation of the local communities in carrying out the efforts to achieve this objective;

The Parties, having decided to establish a Joint Advisory Committee for the Improvement of Air Quality (hereinafter "The Committee") in the Ciudad Juarez, Chihuahua/El Paso, Texas/Doña Ana County, New Mexico Air Basin (hereinafter "air basin");

Have agreed as follows:

Definition

The air basin is defined as the geographic area that includes El Paso County, Texas, and those parts of Doña Ana County, New Mexico and the metropolitan are of Ciudad Juarez, Chihuahua that are within 100km of the border.

Objective

The Committee is established for the purpose of developing and presenting recommendations to the Air Work Group established under the La Paz Agreement regarding strategies for the prevention and control of air pollution in the air basin;

Scope of Activities

The Committee may develop recommendations for the Air Work Group on:

a) The joint development of studies and analyses on air quality monitoring and modeling, and air pollution prevention and abatement strategies in the air basin;
b) Exchanges of information on air quality matters such as air quality data, air emissions data, and data on compliance with each Party's air standards;
c) Technical assistance programs, technology exchanges, and training in areas relevant to preventing and reducing air pollution in the air basin;
d) Environmental education and outreach programs for the general public relevant to preventing and reducing air pollution in the air basin;
e) Exploring strategies to prevent and reduce air pollution in the air basin, including recommendations on emissions trading and other economic incentives as well as improving the compatibility of air quality programs in the air basin; and
f) Such other air quality improvement issues as the Committee may deem to be pertinent to the air basin and as may be recommended by the Parties.

The Parties will provide a guidance document to the Committee detailing more specific subject areas, which the Committee should consider. This guidance document may be updated periodically by the Parties.

The recommendations may include analyses of the estimated costs, and possible financial sources, to implement the recommendations. The recommendations may also address the availability of technology and training necessary for their implementation.

Structure and Organization

The Committee will consist of 20 individuals, ten of whom are to be selected by each Party, in close consultation with state and local governmental officials and the public in the air basin.

The ten U.S. representatives invited to serve on the Committee will include (i) one representative of the federal government; (ii) one representative from each of the governments of the States of Texas and New Mexico; (iii) one representative from local government in El Paso, Texas; (iv) one representative from local government in Doña Ana County, New Mexico; and (v) five persons, residing in the air basin, who are not employed by federal or any state or local government. At least one of these five persons will be a representative of the business community and at least one will be a representative of a non-governmental organization, a major portion of whose activities concerns air pollution.

The ten Mexican representatives invited to serve on the Committee will include (i) one representative of the National Institute of Ecology (INE-SEMARNAP) ; (ii) one representative of the Federal Attorney for Environmental Protection (PROFEPA); (iii) one representative of the federal health and welfare agency (SSA) ; (iv) one representative of the environmental authorities of the State of Chihuahua ; (v) one representative of the environmental authorities of the Municipality of Ciudad Juarez; and (vi) five Mexican citizens, residing in Ciudad Juarez, who are not employed by federal, state, or local government. At least one of these five persons will be a representative of the private sector, at least one will be a representative of a non governmental organization, a major portion of whose activities concerns air pollution, at least one will be a representative of the academic institutions of Ciudad Juarez, and at least one will be a representative of the Consulting Council for Sustainable Development in the Northern Region.

One federal representative from each side will preside over the Committee. The Committee will make decisions by consensus.

The Committee will establish it own rules of procedure, subject to approval by the Parties. Meeting of the Committee will generally be open to the public.

The Air Work Group will consider the recommendations of the Committee and inform the Committee of any action taken pursuant to such recommendations.

The recommendations of the Committee will not be binding on the Air Work Group or the Parties.

Review and Termination

The Parties will periodically review the implementation of this Appendix.

This Appendix will remain in force indefinitely, unless one of the Parties notifies the other in writing through diplomatic channels of its intention to terminate it or Annex V, in which case the Appendix shall terminate six months after the date of such notification.

ANNEX H. MEXICAN VEHICLE EMISSIONS STANDARDS

Vehicle emissions testing in Mexico is covered by two Official Mexican Standards. The first one, NOM-041-ECOL-1999, published in the Federal Official Newspaper on June 24, specifies the maximum permissible limits for exhaust gases. The second one, NOM-047-ECOL-1993, published in the Federal official newspaper on October 22, establishes the characteristics of the vehicle emissions test procedure. These two standards are reprinted in the following pages.

NOM-041-ECOL-1999

JULIA CARABIAS LILLO, Minister of the Environment, Natural Resources and Fisheries, based on article 32 Bis fractions I, II, IV and V of the Federal Public Administration Law; Article 5 fractions V, and XIX; Article 6; Article 7 fractions III and XIII; Article 8 fractions III and XII; Article 9; Article 36; Article 37 Bis; Article 111 fraction IX; Article 112, fractions V, VII, X and XII; Article 113; Article 160; and, Article 171 of the General Law of Ecological Equilibrium and Environmental Protection; Article 7 fractions II and IV; Article 46; and Article 49 of its Air Pollution Prevention and Control Regulation; Article 38 fraction II; Article 40 fraction X; Article 41; Article 45; Article 46; and, Article 47 of the Federal Law of Meteorology and Standardization, and

Considering

That in compliance with Fraction I, Article 47 of the Federal Law of Meteorology and Standardization, NOM-041-ECOL-1999 was published on March 8, 1999 in the Federal Official newspaper, as a Project. That standard establishes the maximum permissible limits for exhaust emissions from gasoline-powered vehicles. It allows 60 days for the interested parties to submit their comments to the National Advisory Committee on Standardization for Environmental Protection, located on Avenida Revolución 1425, Mezzanine planta alta, Colonia Tlacopac San Ángel, C.P. 01040, Delegación Álvaro Obregón, in Mexico City.

That during the term referred to in the previous paragraph, the Regulatory Impact Statement conducted under the terms in Article 45 of the aforementioned legal order, was available to the public at the Committee's headquarters.

That according to Fractions I and II of Article 47 of the Federal Law on Meteorology and Standardization, the comments submitted by the interested parties regarding the project in question, were analyzed at the Committee's headquarters, making all the necessary changes. A response to those comments, as well as the changes, were published in the Official Federal Newspaper on June 23, 1999.

That having complied with the protocol established by the Federal Law on Meteorology and Standardization for the development of Official Mexican Standards, the National Advisory Committee for Environmental Protection, in session on May 28, 1999, approved the current Official Mexican Standard, NOM-041-ECOL-1999. This standard establishes the maximum permissible limits for gases emitted from the tailpipe of gasoline-powered vehicles in circulation. This new standard replaces NOM-041-ECOL-1996, published in the Official Federal Newspaper on February 25, 1997. Taking into consideration all of the above, I issue the following

Official Mexican Standard NOM-041-ECOL-1999, establishing the maximum permissible limits for the emission of polluting gases generated by the exhaust of gasoline-fueled motor vehicles.

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5. Level of conformity with international standards and lineaments, and with Mexican standards taken as the basis for its development.
6. Bibliography
7. Observance of this standard.

1. Objective and field of application

This Official Mexican Standard establishes the maximum permissible limits for the emission of hydrocarbons, carbon monoxide and oxygen. It also establishes minimum and maximum dilution levels, procedures for measuring nitrogen oxides, and must be observed by all gasoline-powered motor vehicle operators around the country, as well as those in charge of operating all authorized emissions testing centers. An exception to this are those vehicles with gross vehicular weight less than 400 kilograms, motorcycles, tractors for agricultural use, and machinery used in the construction and mining industries.

2. References

Mexican Standard NMX-AA-23-1986, Environmental Protection-Air Pollution Terminology, published in the Official Federal Newspaper on July 15, 1986.

Official Mexican Standard NOM-047-ECOL-1993, establishing the equipment characteristics and measurement procedures for the testing of pollutant emissions generated by all motor vehicles in circulation that run on gasoline, liquefied petroleum gas, natural gas, or other alternate fuels. This standard, published in the Official Federal Newspaper on October 22, 1993, contains the nomenclature in terms of the Agreement through which 58 Official Mexican Standards were updated. This agreement was published on November 29, 1994.

3. Definitions

3.1. Model year

The period from the start of production of certain type of motor vehicle and the 31st of December of the calendar year when the manufacturer designs the model in question.

3.2. For the purpose of this standard motor vehicles are defined and classified in the following manner:

3.2.1. Passenger vehicle (VP)

An automobile, or similar vehicle, with the exception multiple use or utility vehicles and trailers, designed for transporting up to 10 people.

3.2.2. Light-duty trucks (CL1)

Light-duty trucks (group 1) with gross vehicular weight of up to 2,722 kg and test weight (PP) of up to 1,701 kg.

3.2.3. Light-duty trucks (CL2)

Light-duty trucks (group 2) with gross vehicular weight of up to 2,722 kg and test weight (PP) greater than 1,701 and up to 2,608 kg.

3.2.4. Light-duty trucks (CL3)

Light-duty trucks (group 3) with gross vehicular weight greater than 2,722 and up to 3,856 kg and test weight (PP1) of up to 2,608 kg.

3.2.5. Light-duty trucks (CL4)

Light-duty trucks (group 4) with gross vehicular weight greater than 2,722 and up to 3,856 kg and test weight (PP1) greater than 2,608 and up to 3,856 kg.

3.2.6. Medium-duty truck

A motor vehicle with gross vehicular weight greater than 3,856 and up to 8,864 kg.

3.2.7. Heavy-duty truck

A motor vehicle with gross vehicular weight greater than 8,864 kg.

3.2.8. Motor vehicle

Ground transportation, self-propelled freight or passenger vehicle, that uses the public roadways.

3.2.9. Multiple use or utility vehicle

A motor vehicle designed for the transportation of persons and/or products, with or without a chassis, or having special equipment for occasional off-road use. For testing purposes, these will be classified in the same manner as light-duty trucks.

3.2.10. Vehicle in circulation

A motor vehicle circulating in public roadways.

3.3. Testing center

The facility or location established or authorized by the competent authorities for measuring pollutant emissions generated by motor vehicles in circulation.

3.4. Gases, listed as follows:

3.4.1. Total hydrocarbons (HC).
3.4.2. Carbon monoxide (CO).
3.4.3. Oxygen (O_2).
3.4.4. Carbon dioxide (CO_2).
3.4.5. Nitrogen oxides (NOx).

3.5. Engine

A group of mechanical components that convert fuel into kinetic energy to self-propel a motor vehicle. A specific engine is set apart from others based on its disposition, distance between the center of its cylinders, type of fuel, as well as the number of pistons and displacement volume.

3.6 Gross vehicular weight (PBV)

The maximum weight in kilograms specified by the manufacturer for a particular vehicle. It is equivalent to the nominal vehicle weight added to its maximum load capacity, when the fuel tank is filled to its nominal capacity.

3.7. Mexico Valley Metropolitan Zone (ZMVM)

The area including the 16 political delegations of the Federal District, and the following 18 municipalities of the State of Mexico: Atizapán de Zaragoza, Coacalco, Cuautitlán Izcalli, Cuautitlán de Romero Rubio, Chalco de Covarrubias, Chimalhuacán, Ecatepec de Morelos, Huixquilucan, Ixtapaluca, La Paz, Naucalpan de Juárez, Nezahualcoyotl, San Vicente Chicoloapan, Nicolás Romero, Tecámac, Tlanepantla de Baz, Tultitlán and Valle de Chalco Solidaridad.

4. Specifications

4.1 The specification of the maximum permissible levels of vehicular exhaust emissions for all gasoline-fueled vehicles circulating across the country, with the exception of item 4.2 of this Official Mexican Standard.

4.1.1. The maximum permissible levels for the emission of exhaust gases from passenger vehicles in circulation, as a function of the year-model, are presented in Table 1 of this Official Mexican Standard.

Table 1

Model-Year of the Vehicle	**Hydrocarbons**	**Carbon monoxide**	**Oxygen (Max.)***	**Dilution**	
				Min.	**Max.**
	(HC) (ppm)	**(CO) (% Vol.)**	**(O_2) (% Vol.)**	**($CO + CO_2$) (% Vol.)**	
1986 and earlier	500	4.0	6.0	7.0	18.0
1987-1993	400	3.0	6.0	7.0	18.0
1994 and later	200	2.0	6.0	7.0	18.0

* Vehicles of any model-year with an air pump as part of the original equipment have a maximum oxygen limit of 15% by volume.

4.1.2. The maximum permissible levels for the emission of exhaust gases from multiple use or utility vehicles, light-duty trucks CL.1, CL.2, CL.3 and CL.4, medium and heavy-duty trucks in circulation, as a function of the year-model, are presented in Table 2 of this Official Mexican Standard.

Table 2

Model-Year of the vehicle	**Hydrocarbons**	**Carbon monoxide**	**Oxygen (Max.)***	**Dilution**	
				Min.	**Max.**
	(HC) (ppm)	**(CO) (%Vol.)**	**(O_2) (%Vol.)**	**($CO + CO_2$) (% Vol.)**	
1985 and earlier	600	5.0	6.0	7.0	18.0
1986-1991	500	4.0	6.0	7.0	18.0
1992-1993	400	3.0	6.0	7.0	18.0
1994 and later	200	2.0	6.0	7.0	18.0

* Vehicles of any model-year with an air pump as part of the original equipment have a maximum oxygen limit of 15% by volume.

4.2. The specification of the maximum permissible levels of vehicular exhaust emissions for vehicles that circulate in the Mexico Valley Metropolitan Zone (ZMVM).

4.2.1. The maximum permissible limits for the emission of hydrocarbons, carbon monoxide, oxygen, and the minimum and maximum dilution limits for the exhaust of gasoline-fueled passenger vehicles, as a function of the year-model, are established in Table 3 of the Official Mexican Standard.

Table 3

Model-Year of the Vehicle	**Hydrocarbons**	**Carbon Monoxide**	**Oxygen (Max.)***	**Dilution**	
				Min.	**Max.**
	(HC) (ppm)	(CO) (% Vol.)	(O_2) (% Vol.)	($CO + CO_2$) (% Vol.)	
1990 and earlier	300	3.0	6.0	7.0	18.0
1991 and later	200	2.0	6.0	7.0	18.0

* Vehicles of any model-year with an air pump as part of the original equipment have a maximum oxygen limit of 15% by volume.

4.2.2. Table 4 of this Official Mexican Standard establishes the maximum permissible limits for the emission of hydrocarbons, carbon monoxide, oxygen, and the minimum and maximum dilution limits for the exhaust of gasoline-fueled passenger vehicles, light-duty trucks CL1, CL2, CL3 and CL4, multiple use or utility vehicles, medium and heavy-duty trucks in circulation, regardless of their model-year, which are used as taxi cabs, collective transportation vehicles, mini-buses, and all types of public transportation, with local, federal and/or metropolitan plates.

Table 4

Type of Vehicle	**Hydrocarbons**	**Carbon monoxide**	**Oxygen * (Max.)**	**Dilution**	
				Min.	**Max.**
	(HC) (ppm)	(CO) (% Vol.)	(O_2) (% Vol.)	($CO + CO_2$) (% Vol.)	
Taxis, Collective, Mini-buses and all types of passenger public transportation	100	1.0	6.0	7.0	18.0

- Vehicles of any model-year with an air pump as part of the original equipment have a maximum oxygen limit of 15% by volume.

4.2.3. The maximum permissible limits for the emission of hydrocarbons, carbon monoxide, oxygen, and the minimum and maximum dilution limits for the exhaust of gasoline-fueled passenger vehicles, light-duty trucks CL1, CL2, CL3 and CL4, multiple use or utility vehicles, medium and heavy-duty trucks in circulation, as a function of the year-model, with local and/or federal plates, except those covered under item 4.2.2, referred to earlier, are established in Table 4 of this Official Mexican Standard.

Table 5

Model-Year of the Vehicle	**Hydrocarbons**	**Carbon monoxide**	**Oxygen (Max.)***	**Dilution**	
				Min.	**Max.**

	(HC) (ppm)	(CO) (% Vol.)	(0_2) (% Vol.)	($CO + CO_2$) (% Vol.)	
1993 and earlier	350	3.0	6.0	7.0	18.0
1994 and later	200	2.0	6.0	7.0	18.0

* Vehicles of any model-year with an air pump as part of the original equipment have a maximum oxygen limit of 15% by volume.

4.3. The State Governments, in coordination with the Municipalities and in accordance with the applicable legal dispositions, when deemed necessary, will have the ability to apply the maximum permissible limits for emissions, established in Tables 3, 4 and 5 of this Official Mexican Standard.

4.4. 1999 and 2000 year-model vehicles that comply with the maximum permissible limits in the factory, as established in Table 3 of the current Official Mexican Standard NOM-042-ECOL-1999, can be exempted from emissions testing for a period of up to two years after their acquisition, and in accordance with the legal dispositions issued by the respective federal and local authorities. Starting with year-model 2001, vehicles can obtain this and other benefits as determined by the aforementioned authorities.

4.5. Testing protocol

4.5.1. The testing protocol for measuring gasoline-fueled motor vehicle exhaust emissions is established by Official Mexican Standard NOM-047-ECOL-1993, referred to in item 2 of this Official Mexican Standard.

4.5.2. In the Mexico Valley Metropolitan Zone, the dynamic test referred to in the Official Mexican Standard that was cited in the previous paragraph must be used to quantify emissions. An exception to this are those vehicles described by their manufacturer as inoperable in the dynamometer. Nitrogen oxides should also be measured as reference only.

4.5.3. A vehicle is considered to have passed the emissions test when it has complied with the prior inspection (visual inspection) and the smoke test, and none of the readings recorded during the slow-speed (Ralenti) test and the cruise-speed test exceed the limits established in this Official Mexican Standard.

5. Degree of conformity with international standards and lineaments, and with the Mexican standards that were taken as the basis for its development

5.1 There are no equivalent standards. The provisions of domestic character that exist in other countries do not contain the technical and legal elements and precepts included in this Official Mexican Standard. Furthermore, no other Mexican standards were used in its development.

6. Bibliography

6.1. Code of Federal Regulations 40, Parts 86 to 99, revised July 1994, USA.

6.2. Code of Regulations for the State of California, United States of America, (Title 16, Ch. 33).

7. Observance of this standard

7.1. Oversight of compliance with the Official Mexican Standard in question corresponds to the Ministry of the Environment, Natural Resources and Fisheries (SEMARNAP), through the Federal Attorney's Office for the Protection of the Environment (PROFEPA), and the Federal District, State and Municipal governments, within the scope of their corresponding jurisdiction.

7.2. Any violations to this standard will be penalized under the terms outlined by the General Law of Ecological Balance and Environmental Protection, under its Air Pollution Prevention and Control Regulation and other applicable legal requirements.

7.3. The current Official Mexican Standard must be displayed in a visible location at all the authorized emissions testing centers.

7.4. The current Official Mexican Standard will enter into effect 60 days after its publication in the Official Federal Newspaper.

7.5. The current Official Mexican Standard cancels out the Emergency Official Mexican Standard NOM-EM-127-ECOL-1998, published in the Official Federal Newspaper on December 28, 1998 and its extension notice. It also repeals NOM-041-ECOL-1996, which establishes the maximum permissible limits of polluting gas emissions generated by the exhaust of gasoline-powered motor vehicles in circulation. That standard was published in the Official Federal Newspaper on February 25, 1997.

Federal District of Mexico, July 9, 1999.

THE SECRETARY OF THE ENVIRONMENT, NATURAL RESOURCES AND FISHERIES

JULIA CARABIAS LILLO

....

NOM-047-ECOL-1993

Official Mexican Standard NOM-047-ECOL-1993, establishing the equipment characteristics and the measurement procedure for testing the level of pollutant emissions generated by motor vehicles in circulation that use gasoline, liquefied petroleum gas, natural gas, or other alternate fuels.

SERGIO REYES LUJAN, Chairman of the National Institute of Ecology, based on article 32 fraction XXV of the Federal Public Administration Law; Article 5 fraction VIII, Article 6 last paragraph, Article 8 fractions II and VII, Article 9 part A fraction II, Article 36, Article 43, Article 111 fraction IV, Article 160, and Article 171 of the General Law of Ecological Balance and Environmental Protection on the subject of Air Pollution Prevention and Control; Article 38 fraction II, Article 40 fraction X, Article 41, Article 43, Article 46, Article 47, Article 52, Article 62, Article 63 and Article 64 of the Federal Law on Meteorology and Standardization; First and Second Articles of the Agreement through which authority is delegated to the Assistant Secretary of Housing and Real Estate, and to the Chairman of the National Institute of Ecology to issue Official Mexican Standards in the subject of housing and ecology, respectively, and

Considering

That motor vehicles in circulation that run on gasoline, liquefied petroleum gas, natural gas, or other alternate fuels, generate air emissions that adversely affect air quality, make it necessary to establish a protocol for measuring these pollutants, as well as the required equipment characteristics to conduct these measurements, with the objective of preserving the ecological balance and protecting the environment.

That having complied with the protocol established by the Federal Law on Meteorology and Standardization for the development of Official Mexican Standards, the

Chairman of the National Advisory Committee on Standardization for Environmental Protection ordered the publication of the Official Mexican Standard NOM-PA-CCAT-010/93, that establishes the equipment characteristics and measurement procedures for testing the levels of pollutant emissions generated by gasoline-fueled motor vehicles in circulation. This standard was published in the Official Federal Newspaper on June 23, 1993, with the object of giving the opportunity to the interested parties to submit their comments to the Advisory Committee.

That the National Commission on Standardization determined during its July 1, 1993 session that this standard, which was originally identified as NOM-PA-CCAT-010/93, will be identified as NOM-047-ECOL-1993, from now on.

That during the ninety-day term starting on the date of publication of that Official Mexican Standard, the analyses referred to in Article 45 of the legal order were available to the public for review.

That within the same term, the interested parties submitted their comments regarding the proposed standard. The National Advisory Committee on Standardization reviewed these comments, and the appropriate changes were incorporated. The Ministry of Social Development, through the National Institute of Ecology, published the answers to the public comments in "Gaceta Ecológica", Volume V, October 1993 Special Edition.

That the Ministry of Commerce and Industrial Development and the Ministry of Energy, Mines and Quasi-State Industry, expressed their conformity with the contents and issuance of the current Official Mexican Standard.

That upon prior approval from the National Advisory Committee on Standardization for Environmental Protection, in session on September 23, 1993, I have considered of benefit to issue the following:

Official Mexican Standard NOM-047-ECOL-1993, that establishes the equipment characteristics and the measurement procedures for testing the levels of pollutant emissions generated by motor vehicles in circulation that use gasoline, liquefied petroleum gas, natural gas, and other alternate fuels.

Preface

The following entities were involved in the development of this Official Mexican Standard:

MINISTRY OF SOCIAL DEVELOPMENT
- National Institute of Ecology (INE)

- Federal Attorney's Office for the Protection of the Environment (PROFEPA)

MINISTRY OF ENERGY, MINES AND QUASI-STATE INDUSTRY
- Subministry of Energy

MINISTRY OF COMMUNICATION AND TRANSPORTATION

MINISTRY OF HEALTH
- General Bureau of Environmental Health

MINISTRY OF COMMERCE AND INDUSTRIAL DEVELOPMENT

GOVERNMENT OF THE STATE OF MEXICO
- Ministry of Ecology

NATIONAL CHAMBER OF THE TRANSFORMATION INDUSTRY (CANACINTRA)

PATRONAL CONFEDERATION OF THE MEXICAN REPUBLIC

FEDERAL DISTRICT DEPARTMENT

- General Bureau of Environmental Projects

NATIONAL POLYTECHNICAL INSTITUTE

MEXICAN PETROLEUM (PEMEX)
- Industrial Safety, Environmental Protection and Energy Savings Audit
- Environmental Protection and Energy Savings Administration
- Pemex-Gas and Petroquímica Básica
- Environmental Protection and Safety Administration

ASOCIACION NACIONAL DE PRODUCTORES DE AUTOBUSES, CAMIONES Y TRACTOCAMIONES, A.C. (NATIONAL ASSOCIATION OF BUS, TRUCK AND TRACTOR TRAILER MANUFACTURERS)

ASOCIACION NACIONAL DE PRODUCTORES DE AGUAS ENVASADAS, S.A. DE C.V. (NATIONAL ASSOCIATION OF BOTTLED WATER PRODUCERS)

ASOCIACION NACIONAL DE LA INDUSTRIA AUTOMOTRIZ, A.C. (NATIONAL ASSOCIATION OF THE AUTOMOBILE INDUSTRY)

KENWORTH OF MEXICO, S.A. DE C.V.

MERCEDES BENZ OF MEXICO

1. Objective

This Official Mexican Standard establishes the equipment characteristics and measurement methods for the testing of pollutant emissions generated by motor vehicles in circulation, equipped with engines that run on gasoline, liquefied petroleum gas, natural gas, or other alternate fuels. The maximum permissible levels for these pollutants are determined by the corresponding Official Mexican Standard.

2. Field of Application

This Official Mexican Standard must be complied with when establishing and operating vehicular emissions testing centers.

3. References

NMX-AA-23 Terminology.

4. Definitions

4.1. Automobile

A motor vehicle designed for transporting up to 10 people.

4.2. Light-duty truck

A motor vehicle with or without chassis, designed for transporting goods or more than 10 people, and having a gross vehicular weight ranging between 2,727 and 7,272 kilograms.

4.3. Testing Center

A facility or premise that has been established or authorized by the competent authorities to measure the emissions of vehicles in circulation.

4.4. Standard gas

The gas or mixture of gases of known concentration (certified by the manufacturer) used for the calibration of air pollutant measuring equipment and to certify its calibration.

4.5. Cruise speed

The operating condition of a vehicle when its transmission is set to neutral, the engine is running and undergoing acceleration, and no external load is being applied.

4.6. Slow speed idle

The operating condition of a vehicle when the engine is running, there is no acceleration, and the number of revolutions per minute falls within the range specified by the manufacturer.

4.7. Otto cycle engine

A set of mechanical components that transform heat energy into kinetic energy through the discontinuous combustion of a fuel-air mixture in one or more chambers whose volumes have been modified for the movement of pistons or rotors. The combustion process is initiated by an external source of ignition.

4.8. Gross vehicular weight

The real weight of the motor vehicle expressed in kilograms, added to the weight of its maximum load capacity, as specified by the manufacturer, and to the weight of its full tank.

4.9. Static test

The test conditions for a vehicle, consisting of slow-speed idle and cruise speed as specified by this standard.

4.10. Dynamic test

The test conditions for a vehicle, consisting of slow-speed idle and cruise speed, as specified by this standard.

4.11. Normal operating temperature

The temperature reached by the engine and the drive train of the vehicle after it has been in operation for at least 10 minutes, or when the engine oil temperature has reached 60 degrees centigrade.

4.12. Commercial vehicle

A motor vehicle with or without a chassis, used for transporting goods or more than 10 people, and having a gross vehicular weight of up to 2,727 kilograms.

4.13. Multiple use or utility vehicle

A motor vehicle used for transporting goods or up to 10 people, and having a gross vehicular weight of more than 2,727 kg.

4.14. Motor vehicle

A land transportation vehicle used in public roadways, for freight or passengers, which is self-propelled.

4.15. Vehicle in circulation

A motor vehicle used in public roadways.

4.16. Intensive use vehicle

4.16.1. A motor vehicle for public use, used for transporting passengers or freight;

4.16.2. Motor vehicles that provide services to federal public administration entities and agencies, and to the governments of the Federal District, federal entities, and municipalities;

4.16.3. Motor vehicles assigned for commercial use, used for commercial transactions or as a work instrument;

4.16.4. Motor vehicles that provide service to employees and for school use; and

4.16.5. Motor vehicles that have been converted to use liquefied petroleum gas, natural gas, or other alternate fuels, used to provide any type of service.

4.17. Mexico City Metropolitan Zone

The area comprised by the 16 Political Delegations within the Federal District, and the following 17 municipalities of the State of Mexico: Atizapán de Zaragoza, Coacalco, Cuautitlán de Romero Rubio, Cuautitlán Izcalli, Chalco de Covarrubias, Chimalhuacán, Ecatepec, Huixquilucan, Ixtapaluca, La Paz, Naucalpan de Juárez, Nezahualcóyotl, San Vicente Chicoloapan, Nicolás Romero, Tecámac, Tlalnepantla and Tultitlán.

5. Specifications

5.1. The methods used for measuring the emissions generated by motor vehicles in circulation that use gasoline, liquefied petroleum gas, natural gas, or other alternate fuels, are specified below:

5.1.1. Tailpipe emissions

The static test must be used, except in the Mexico City Metropolitan Zone, where the dynamic test must be used for automobiles, commercial vehicles and light vehicles, classified as intensive-use vehicles.

5.1.2. Evaporative emissions

In the Mexico City Metropolitan Zone, the method that must be applied for motor vehicles that use gasoline or other alternate liquid fuels and have a threaded gasoline tank cap, is the fuel tank cap test.

A cap seal test must be conducted to measure the pressure drop in inches of water, according to the limits set by the corresponding standard.

5.1.3. Dates when the above tests will enter into effect

The dates when the aforementioned tests will enter into effect in the Mexico City Metropolitan Zone, are shown in Table 1.

Table 1

Type of test	Used to measure	Year of application in vehicle for:	
		Intensive use	Non-intensive use
Static test	HC, CO, O_2 and Dilution	N/A	Immediate
Dynamic test using Dynamometer with constant load	HC, CO, O_2 and Dilution	Immediate	1997
Fuel tank cap seal	Leaks	1995	1995
Dynamic test using Dynamometer with variable load	HC, CO, O_2, NOx and Dilution	1999	N/A

5.2. Test equipment preparation.

The equipment must be prepared before proceeding with the measurements.

The technician must do the following:

5.2.1. Operate the equipment according to the manufacturer's specifications.

5.2.2. Operate the equipment according to the manufacturer's specifications and in accordance with this standard.

5.2.3. Remove any foreign matter and/or water or moisture accumulated in the filters and the probe.

5.3. Visual Inspection of the vehicle prior to the test.

5.4. The vehicle must meet the following requirements in order undergo the testing procedure specified by this standard:

5.4.1. The technician must check to make sure that the manufacturer installed emissions components and other design elements that have been installed in the vehicle to comply with the applicable emissions control standards have not been:

5.4.1.1. Removed from the emissions control system.

5.4.1.2. Tampered with to keep the emissions control system from working properly.

5.4.1.3. Replaced with a component that was not sold by its manufacturer for that kind of use.

5.4.1.4. Replaced with a component that cannot be connected to other emissions control components.

Disconnected, even though the component is still present and mounted correctly in the vehicle.

5.4.2. The technician must ensure that the exhaust pipe of the vehicle is in perfect operating condition and that it does not have any additional exits to those in its original design, which my cause the dilution or leak of exhaust gases.

5.4.3. The following devices must be in good condition and working properly:

Air filter, oil tank cap, fuel tank cap, crankcase oil level, crankcase ventilation system, activated carbon filter, and engine and tank connecting hoses.

5.5. Test preparation of the vehicle

The vehicle must be prepared before starting the test. The technician must:

5.5.1. Make sure that the choke's manual control is not on.

5.5.2. Make sure that the vehicle's accessories are turned off. These include the lights and A/C.

5.5.3. Make sure that the engine runs at its normal operating temperature.

5.5.4. For automatic transmission vehicles, make sure that the vehicle is set to Park or Neutral. For semiautomatic or manual transmission, make sure that the vehicle is set to neutral and the clutch is not being pressed.

6. Measurement procedures

6.1. Static test method

The static test method is a procedure for measuring hydrocarbons, carbon monoxide, carbon dioxide and oxygen emissions as they exit the tailpipe of a motor vehicle that runs on gasoline, liquefied petroleum gas, natural gas, or other alternate fuel.

The static test procedure consists of three phases: visual smoke inspection, cruise speed test, and slow speed idle test.

6.1.1. Visual smoke inspection test

6.1.1.1. The tachometer of the testing equipment must be connected to the ignition system of the vehicle. The vehicle is run at 2,500 ± 250 revolutions per minute for at least 30 seconds. If black or blue smoke is emitted continuously for more than ten seconds, the test must be stopped and the maximum permissible limits are considered exceeded. This test should not last more than one minute.

6.1.1.2. Blue smoke emissions indicate the presence of oil in the combustion system and black smoke emissions indicate an excess of unburned fuel. Therefore, any of the two indicate high emission levels of hydrocarbons and other pollutants.

6.1.2. Cruise speed test

The testing probe must be inserted into the tailpipe according to the manufacturer's specifications, making sure that the probe is perfectly in place. The engine is run at 2,500 ± 250 revolutions per minute for at least 30 seconds. After 25 consecutive seconds under these operating conditions, the technician must record the average readings that appear in the display of the analyzer during the next five seconds. This test cannot last more than one minute.

6.1.3. Slow-speed idle test

The engine of the vehicle is decelerated to the idle speed specified by the manufacturer, which will not be greater than 1100 revolutions per minute. This rate must be maintained for at least 30 seconds. After 25 consecutive seconds under these operating conditions, the technician must determine the average readings that appear in the display of the analyzer during the next five seconds, and record those values. This test cannot last more than one minute.

6.1.4. Analysis of Results

A vehicle passes this test when none of the values registered in the readings for the slow-speed idle test and the cruise-speed test exceed the maximum permissible levels specified by the applicable standard.

For vehicles equipped with a double exhaust system, the test must be conducted for each system, using the average of the readings recorded in each system as the emissions value for each of the pollutants.

6.2. Method for dynamic test with constant load

The dynamic test with constant load is another procedure for measuring the emissions of hydrocarbons, carbon monoxide, carbon dioxide and oxygen as they exit the exhaust pipe of motor vehicles in circulation that run on gasoline, liquefied petroleum gas, natural gas, or other alternate fuels.

The dynamic test method with constant load consists of three stages. A visual smoke inspection, a dynamic test with load, and a slow-speed idle test.

6.2.1. Visual smoke test

6.2.1.1. This test must be conducted with the engine running at 2,500 ± 250 revolutions per minute for at least 30 seconds. If black or blue smoke is emitted continuously for more than ten seconds, testing must be stopped, and the maximum permissible limits are considered exceeded. This test should not last more than one minute.

Blue smoke emissions indicate the presence of oil in the combustion system and black smoke emissions indicate an excess of unburned fuel. Therefore, any of the two indicate high emission levels of hydrocarbons and other pollutants.

6.2.2. Preparation for the dynamic test:

6.2.2.1. The motorized wheels of the vehicle must be placed over the dynamometer's rollers, securing the vehicle to prevent its movement, in accordance to the to the instructions for the dynamometer.

6.2.2.2. The testing probe must be inserted into the tailpipe, in accordance with the equipment instructions, making sure that the probe is securely placed.

6.2.2.3. The technician must determine the load and speed to be applied to the vehicle in accordance with Table 2.

Table 2

Number of Cylinders, Speed and Load to be Applied

No. of cylinders	Roller Speed (km/h)	Applied load (bhp)
4 or less	40	2.8 - 4.1
5 – 6	40	6.8 - 8.4
7 or more	40	8.4 - 10.8

6.2.3. Dynamic test

With the vehicle running, it is accelerated in second or third gear (choosing the gear that allows for stable operating conditions of the vehicle, without forcing the engine), until the vehicle reaches the specified roller speed. If the vehicle is equipped with automatic transmission the test will be done in second gear.

The load of the dynamometer is adjusted according to the values stipulated in Table 2 and the vehicle is run under normal operating conditions for a minimum of 30 seconds. After 25 consecutive seconds under these operating conditions, the technician must determine the average readings that appear in the display of the analyzer during the next five seconds, and record those values. This test must not last more than one minute.

If a vehicle cannot reach the specified speed or maintain the load specified in Table 2, or if the vehicle design does not allow the use of a dynamometer, the static test procedure must be applied.

6.2.4. Slow-speed idle test

The engine of the vehicle is decelerated to the idle speed specified by the manufacturer, which will not exceed 1100 revolutions per minute, with the transmission placed in neutral. This speed must be maintained for a minimum of 30 seconds. After 25 consecutive seconds under these operating conditions, the technician must determine the average readings that appear in the display of the analyzer during the next five seconds, and record those values. This test must not last more than one minute.

6.2.5. Analysis of results

A vehicle passes this test when none of the values registered in the readings for the slow-speed idle test and the dynamic test exceed the maximum permissible levels specified by the applicable Official Mexican Standard.

For vehicles equipped with a double exhaust system, the test must be conducted for each system, using the average of the readings recorded in each system as the emissions value for each of the pollutants.

6.3. Fuel tank cap test

6.3.1. The measurement procedure consists of a seal test for the cap mounted onto a testing device, using the appropriate size collar. The device is pressurized to the pressure specified in Table 3 and, once the specified pressure is reached, the pressure drop in inches of water during the period specified in the same Table, is measured.

6.3.2. Analysis of Results

A vehicle passes the test whenever there is not a leak that results in a pressure drop greater than the established limit.

The permissible limits for maximum pressure drop for motor vehicles in circulation that run on gasoline or other alternate liquid fuels, are established in Table 3.

Table 3. Limits as a function of the Test Procedure

Model-year of the vehicle	Type of test	Initial pressure (pulg. H_2O)	Maximum pressure drop	
			(inch H_2O)	in seconds
All	Fuel tank cap seal	14 ± 0.5	2.0	20

7. Data recording

The testing center must record the test results in a magnetic medium so these can be sent to the authorities whenever requested.

The minimum data required are:

7.1. Information about the center

Description	Format	Characters
Certificate Number	N	8
Center number	N	3
Test Date	F	6
Test time	A	5
Type of verification	A	1

7.2. Information about the owner of the vehicle

Description	Format	Characters
Name	A	25
Address	A	25
Colonia	A	15
Zip Code	N	5
Delegation or municipality	N	3
State	N	2

7.3. Information about the Vehicle

Description	Format	Characters
Odometer reading	N	7
Model year of the vehicle	N	2
City where it was registered	A	10
License plates	A	7
Class	N	2
Type of fuel	N	1
Brand	N	3
Sub-brand	A	8
Type of service	N	2
Number of cylinders	N	1
Fuel feed	N	1

7.4. Information about the Test

Description	Format	Characters
Test Sequence	A	1

Description	Format	Characters
HC slow-speed idle	N	4
CO slow-speed idle	N	4
CO_2 slow-speed idle	N	4
O_2 slow-speed idle	N	4
RPM slow-speed idle	N	4
HC cruise-speed or dynamic test	N	4
CO Cruise-speed or dynamic test	N	4
CO_2 Cruise-speed or dynamic test	N	4
O_2 Cruise-speed or dynamic test	N	4
NO Cruise-speed or dynamic test	N	4
RPM Cruise-speed or dynamic test	N	4

7.5. Results of the verification

Description	Format	Characters
Test sequence	A	1
HC slow-speed idle	N	4
CO slow-speed idle	N	4
CO_2 slow-speed idle	N	4
O_2 slow-speed idle	N	4
RPM slow-speed idle	N	4
HC Cruise-speed or dynamic test	N	4
CO Cruise-speed or dynamic test	N	4
CO_2 Cruise-speed or dynamic test	N	4
O_2 Cruise-speed or dynamic test	N	4
NO Cruise-speed or dynamic test	N	4
RPM Cruise-speed or dynamic test	N	4
Exhaust emissions	A	1
(Approved, Not approved)		
Cap seal	A	1
(Approved, Not approved)		

Format key: N = Numeric A = Alphanumeric F = Date

8. Equipment specifications

The devices used for the measuring vehicular emissions must comply with the following specifications:

8.1. Gases to be analyzed

8.1.1. The analyzer used during the dynamic test must determine the concentration of hydrocarbons, carbon monoxide, carbon dioxide, nitrogen oxides and oxygen in the exhaust of the vehicle.

8.1.2. The analyzer used during the static test must determine the concentration of hydrocarbons, carbon monoxide, carbon dioxide, and oxygen in the exhaust of the vehicle.

8.2. Measurement scale

8.2.1. The total measurement scale must be between 0 and 10% by volume, for the case of carbon monoxide; 0 to 2000 ppm, for hydrocarbons; 0 to 4000 ppm for nitrogen oxides; 0 to 16% by volume for carbon dioxide; and, 0 to 22% by volume, for oxygen.

8.2.2. The resolution of the scale must be 1 ppm for HC and NO; 0.01% for CO, and 0.1% for CO_2 and O_2.

8.3. Precision, Noise and Replication

8.3.1. The analyzer must comply with the following requirements of accuracy in its readings:

Gas	Range	Precision	Noise	Replication
HC (ppm)	0- 400	±12	6	8
	401-1000	±30	10	15
	1001-2000	±80	20	30
CO (%)	0-2.00	±0.06	0.02	0.03
	2.01-5.00	±0.15	0.06	0.08
	5.01-9.99	±0.40	0.10	0.15
CO_2 (%)	0- 4.0	±0.60	0.20	0.30
	4.1-14.0	±0.50	0.20	0.30
	14.1-16.0	±0.60	0.20	0.30
NO (ppm)	0-1000	±32	16	20
	1001-2000	±60	25	30
	2001-4000	±120	50	60
O_2 (%)	0-10.0	±0.5	0.3	0.4
	10.1-22.0	±1.3	0.6	1.0

Noise is defined as the average difference obtained between peaks from a lone source for a period of 20 seconds.

Replication is determined during 5 successive measurements from the same source.

8.3.2. Response time must not be greater than 8 seconds in order to achieve 90% of the final stabilized reading and must not be greater than 12 seconds in order to achieve 95% of the final stabilized reading.

8.3.3. During the entire work time stability must be less than ± 3%.

8.3.4. The period of stability must be less than 10 minutes after start-up.

8.3.5. The tachometer must have the capability of measuring the number of revolutions per minute (RPM) with a precision of ± 3% .

8.4. Build

8.4.1. The analyzer must be designed to support continuous heavy use for a minimum of eight hours per day.

8.4.2. The analyzer must have a ID plate attached to its outer surface, including: model, serial number, manufacturer's name and address, electric power requirements, and voltage limits during operation.

8.4.3. Must be airtight in all its connections.

8.4.4. Its controls must be accessible to the operators.

8.4.5. The analyzer readings must not be affected by nominal voltage variations of ± 10%.

8.4.6. The internal attachments that are in contact with the test gas must be corrosion resistant and have devices or traps for eliminating or reducing particulate matter and water, with the purpose of avoiding modifications that may affect the analysis of gases. The container used for water removal must be made of clear material, have the ability of being drained and easily dismounted for cleaning.

8.4.7. The external attachments consist of a probe, with a length greater than 3 meters and less than 9 meters, flexible enough to allow its handling.

8.4.8. The local authorities may establish additional specifications for the analyzer, with the object of improving the reliability of results and safety in the handling of certificates and stickers, when applicable.

8.5. Routine Calibration

The calibration of the analyzers must be done with standard gas every third day or according to the manufacturer's specifications. The standard gas must have a guaranteed precision in the mixtures of ± 2% of the indicated concentration.

8.6. Calibration Check

Calibration of the analyzers must be done in a calibration laboratory that is accredited by the Ministry of Commerce and Industrial Development, under the terms specified by the federal Law on Meteorology and Standardization. The analyzers must be calibrated every three months, under normal operating conditions, independent from the calibrations that are done every time one of its parts is replaced, or it undergoes maintenance or repairs.

8.6.1. In order to determine whether the analyzer is perfectly calibrated, measurements must be collected using three different standard gases of known concentration (with a precision of 1%). These gases must be introduced into the device using a normal testing probe.

8.6.2. Three measurements must be collected with each standard gas. The average values of the three readings obtained for each of the pollutants are recorded in the record sheet. A calibration curve is traced in the graphing sheet (Annex 1) using these values, and then it is compared with the representative curve that is shown in the same sheet. The deviation between these two curves must be less than 10% .

8.7. Dynamometer Specifications

As far as the dynamometer is concerned, it must have the appropriate rollers to support the motorized wheels of vehicles being tested, allowing for their continuous rotation. The power generated by the engine of the vehicle that passes from the tires to the rollers, must be transmitted to an energy-absorbing device. The load can be established by the physical characteristics of the design of the energy absorption unit or by an automatic control. The frame and the sets of rollers must be placed in such a way that they allow any make of vehicle to be easily placed on the rollers, in order to test them in a leveled position. A platform between the rollers and the roller brakes will allow quick access and exit to and from the dynamometer. The dynamometer design must allow for the safe testing of front-wheel drive vehicles.

8.7.1. Dynamometer capabilities

8.7.1.1. Test repetitiveness must fall within a 2% tolerance for a given vehicle and a given speed.

8.7.1.2. Short stability periods at a constant speed must not have a power variation that is greater than 0.5 H.P. during the test.

8.7.1.3. The load capacity of the rollers must handle a weight of at least 3500 kilograms.

8.7.1.4. Each roller must have a minimum diameter of 20.32 cm. (8"). The rollers must be spaced in such a way that the radius of the tire, which is 33.02 cm. (13"), must have a contact of at least 50° and not greater than 63°, measured from the center of the axis of the tire to the center of the axis of the rollers. The rollers must not provide a contact surface that is less than 243.84 cm. (96") wide.

8.7.1.5. The speed indicators must be in kilometers or their functional equivalent, using a single scale with a length that is not less than 19 cm. (7.5"), and they must show from 0 to 95 km/h.

8.7.1.6. The dynamometer must have its own calibration unit.

The current Official Mexican Standard must be displayed in a visible location in the public and authorized private emissions testing centers.

9. Oversight

9.1. The Federal, state, and municipal governments (when applicable), are the authorities in charge of enforcing compliance with the current Official Mexican Standard.

10. Penalties

10.1. Non-compliance with the current Official Mexican Standard will be penalized according to the Air Pollution Prevention and Control Regulation included in the General Law of Ecological Balance, and all other legal orders.

11. Bibliography

11.1. Code of Federal Regulations, Vol. 40, 1991, USA.

11.2. California Code of Regulations, United States of America. Title 16 Chapter 33

12. Conformity with international standards

12.1 This official Mexican standard does not conform to any international standard.

13. Effect

13.1. The current Official Mexican Standard will come into effect the day after it is published in the Official Federal Newspaper, with the exception of the requirement of calibration testing included under item 10.6, which will come into effect on January 3, 1994.

13.2 The Agreement overseeing the issuance of Ecological Technical Standard NTE-CCAT-013/89 published in the Official Federal Newspaper on June 7, 1989, is repealed.

Issued in Mexico City, Federal District, on October 18, 1993. Sergio Reyes Luján, Chairman of the National Institute of Ecology.

ANNEX 1

Record sheet to verify the quality of measurement form the analyzers

Testing Center ____________________ No. ______________________________
Address_________________________ Col.________________________________
Pol. Del. or Munic. _____ Tel.______________ RFC _______________________
Equipment Brand_______________________ Serial No.____________________
Place of certification ____

Measurement	**Recorded readings**					
	High			**Low**		
	CO	**HC**	**CO_2**	**CO**	**HC**	**CO_2**
First						
Second						
Third						
Average value						
Concentration of standard gas						

Calibration curves

Hydrocarbons (HC, PPM)				

Standard gas

Carbon monoxide (CO, % Vol)				

Standard gas

Test Date ____

Next Test Date ____

Name and signature of the technician _____________________________

ANNEX I. GLOSSARY OF TERMS

North American Environmental Cooperation Agreement. This agreement, signed in 1993, sets forth the commitment between the governments of Mexico, the United States, and Canada, to improve environmental conditions. It was derived from the North American Free Trade Agreement.

La Paz Agreement. Pact signed in 1993 between Mexico and the United States regarding cooperation for the protection and improvement of the environment along the border region.

Aerobiological. Microorganism that lives suspended in the air.

Aerosol. Colloidal suspension of liquid or solid particles in the atmosphere. This name has also been given to some products that are applied through aspersion and are used as propellants. For example, chlorinated hydrocarbons, such as freon. It is also defined as the mixture of particles less than 3 micrometers in diameter suspended in the atmosphere.

Tune-up. Set of actions necessary to maintain in optimal operating condition the combustion system of vehicles that use internal combustion.

Traffic Count. Record of the number and type of vehicles passing through a particular location on a given road, during a set period of time.

Ambient Air. Open space atmosphere.

Alkanes. Saturated hydrocarbons formed exclusively by carbon and hydrogen.

Allergens. Substance that is usually foreign to the body which, upon entering the body, is capable of inducing harm to the immune system or causing changes in the biochemical synthesis of the nutrients or introduce a new substance that is capable of negating or interfering with its chemical characteristics.

Alkenes. Unsaturated organic compounds with one or more double links.

Alkynes. Unsaturated organic compounds with one or more triple links.

Environment. Set of physical, chemical and biological elements, (natural or artificial, induced by humans), favoring the existence, transformation and development of organisms.

Anaerobic. Environmental condition referring to life or the vital process that occurs in the absence of oxygen, or under low partial pressure of this element.

Annex IV of the La Paz Agreement. Cooperation agreement between Mexico and the United States regarding transboundary air pollution caused by copper smelters throughout the border region.

Annex V of the La Paz Agreement. Cooperation agreement between Mexico and the United States regarding international transport of urban air pollution throughout the border region.

Anthropogenic. Relative to humans; of human origin. It can be applied to ideas that are excessively centered on human problems, putting aside the effects, problems and harm that humans cause to the environment.

Metropolitan Area. Land mass including the political-administrative unit of the central city and other surrounding communities that share certain urban characteristics with the central city, such as job sites, residential areas, space for agricultural and industrial activities, and which maintain a direct, continuous, intense, and reciprocal socioeconomic relationship with the central city.

Aromatic Compounds. Family of cyclic hydrocarbons with the following general formula: $C_6H_{6-n}X_n$. They are characterized by a closed cyclic chain of hexagonal shape, known as the benzenic ring, as well as three double links in their structure. These compounds, like some paraffinic hydrocarbons, are considered toxic compounds due to their insolubility in water, their long presence in the environment and difficult biodegradation.

Atmosphere. Air layer surrounding the earth and extending about 100 km above the earth crust. This physical structure consists of a mixture of 78% nitrogen, 21% oxygen and 1% various gases, including argon, neon, carbon dioxide and water vapor, among other inorganic compounds.

Self-regulation. Setting voluntary measures with the purpose of achieving better environmental performance in the industrial sector, where lower environmental compliance standards than those written in rule are achieved or accepted.

Energy Balance. The amount of energy distributed or consumed by the various production, service and transport sectors.

Benzene. The simplest olefinic hydrocarbon consisting of a closed cyclic chain.

Sulfur Dioxide (SO_2). Pollutant produced during the combustion process of fuels containing sulfur. Emissions from this pollutant originate mainly from industry.

Carbon Dioxide (CO_2). Inorganic gas consisting of two molecules of oxygen and one molecule of carbon. This gas is colorless, odorless and has no flavor; it is produced by human respiration and by the burning of fossil fuels.

Nitrogen Dioxide (NO_2). Pollutant generated when nitrogen contained in fuels and in the air is oxidized through a combustion process.

Butane. Saturated paraffinic hydrocarbon composed of four carbon atoms and ten hydrogen atoms.

Boiler. Pressurized industrial equipment used to generate vapor.

Environmental Quality. Set of unaltered physical, chemical and biological conditions, natural to the environment.

Fuel Quality. Technical specifications of the physical and chemical characteristics of fuels, that define the potential for polluting.

Air Quality. Pollutant concentration in ambient air.

Carcinogen. Chemical, physical, or biological agent capable of causing abnormal, disorderly, and potentially unlimited growth of cells in a tissue or an organ.

Cephalea. Headache.

Cyclone. Device that works through inertial and gravitational force used for the control of particulate matter.

Climate. The set of meteorological phenomena characterizing the average atmospheric conditions of a given point on earth during a minimum period of ten years. The main climatic elements are temperature, rainfall, seasonality, and other factors such as prevailing winds, relative humidity, sunlight, atmospheric pressure, and cloudiness.

Clorofluorocarbons (CFCs). Gases used as propellants in aerosols. Once released they can reach the stratosphere, where the chlorine they contain reacts with ozone, reducing the volume of the protective layer of the latter

Fossil Fuels. Inorganic compounds such as mineral carbon, oil ad gas, thus known because they are derived from the remains of plants and animals that inhabited the earth before humans appeared in our planet.

Clean Fuels. Inorganic compounds used as fuels and containing less than 2% sulfur by weight, or generating pollutant emissions that are negligible. (For example: compressed natural gas, methanol, ethanol, liquefied oil gas, etc.).

Combustion. Fast oxidation process of inorganic materials accompanied by energy release in the form of heat and light.

Incomplete Combustion. Insufficient oxidation occurring when oxygen or time available in the process are less than necessary, producing carbon monoxide (CO), which is a gas known for its toxicity in living organisms.

Volatile Organic Compounds. These include a wide group of individual substances such as hydrocarbons (alkanes, alkenes and aromatics), halogenated compounds (e.g trichloroethylene) and oxygenated compounds (alcohols, aldehydes and ketones). All these are organic compounds of carbon and have enough volatility to occur as vapors in the atmosphere.

Concentration. Relative amount of a specific substance mixed with another substance that is usually larger. For example: 5 parts per million of carbon monoxide in the air. It can also be expressed as the weight of the material in minor proportion found within a volume of air or gas; this is expressed in micrograms of the pollutant per cubic meter of air.

Contamination/Pollution. The presence of matter or energy whose nature, location, or quantity, produce undesirable environmental effects. In other terms, it is the alteration made or induced by humans to the physical, biological, chemical, and radiological integrity of the environment.

Contaminant/Pollutant. Substance or element that, when incorporated and set in motion in the atmosphere, water, soil, plants, animals, or any other element of the environment, alters or modifies its composition, affects health, or hinders its use as a resource.

Air Contaminant/Air Pollutant. Substance in the air that, in high concentrations, can cause damage to humans, animals, plants or materials. It can include almost any natural or artificial compound that is susceptible to being transported through the air. These pollutants are found in the form of solid, liquid, gaseous, or combined particles. They are generally classified in the compounds that are emitted directly from the pollutant source or primary pollutants, and compounds that are produced in the air by the reaction of two or more primary pollutants or by their reaction with natural compounds that are found in the atmosphere.

Criteria Pollutants. Concentration conditions for certain air pollutants known to be hazardous to human health and constituting the main air quality parameters. In the international arena there are seven criteria pollutants: ozone, carbon monoxide, total suspended particles, PM10, sulfur dioxide, nitrogen oxide and lead.

Environmental Contingency. Condition of risk characterized by the presence of high concentrations of criteria pollutants in the air, derived from human activities or natural phenomena. These concentration may be harmful to human health, as well as affect the ecosystems.

Emission Controls. A set of measures that tend to cause a reduction in air pollutant emissions.

Catalytic Converter. Device used to lower air pollution by removing certain pollutants such as hydrocarbons, carbon monoxide and nitrogen oxides from vehicle exhaust pipes, either converting them to carbon dioxide by oxidation or reducing them to nitrogen or oxygen.

Environmental Criteria. The descriptive factors considered in establishing environmental standards for various pollutants. These factors are used to determine the maximum permissible limits for concentration levels, and to limit the number of annual exceedances.

Environmental Health Criteria. Critical summaries of existing knowledge regarding the immediate and long-term effects on human health and human well being, that can be expected from the presence of different substances in the air, water, soil, food, consumer products, and work environment; or by other factors such as noise, ionizing and non-ionizing radiation, radiant heat, and luminosity. These effects are expressed in quantitative terms.

Airshed. A specified physical space containing the layer of the atmosphere that is closest to its internal surface, and limited by uniform meteorological trends of small and medium scale.

Binational Airshed. A physical space containing regions from both the United States and Mexico.

Distillation. Separation of a mixture, using the different boiling points of its components.

Environmental Deterioration. The alteration suffered by one or more elements in an ecosystem, caused by the presence of an element that is foreign to the characteristics and the dynamics of the ecosystem.

Dysphonia. Difficulty in hearing.

Dyspnea. Difficulty in breathing.

Dispersion. Phenomenon that determines the magnitude of the resulting concentration and the area of impact, in which pollutants will disperse and dilute according to the meteorological and geographical conditions of the place in which they were released or generated.

Dose. Amount of substance administered to an organism that may produce an effect.

Ecosystem. Unit of functional structure and basic organization for the interaction of organisms with each other and with the environment, in a specified space.

Synergetic Effect. Combined result of two substances that act on a living organism, which is greater than the effect produced by the sum of the individual effects when applied separately.

Systematic Effect. The result of the interaction between a pollutant and an organism, having generalized nature, and occurring at a place distant from the point of entry of the substance. A systemic effect requires absorption and distribution of the substance throughout the body.

Thermal Efficiency. The ability of combustion equipment to utilize fuel energy, expressed in terms of heat.

Emission. Release of pollutants originating from chimneys and other escape ducts from industrial, commercial and residential areas, as well as motor vehicles, locomotives or exhaust from airplanes and ships.

Energy. The ability of a system to generate work.

Epidemiology. The study of the distribution of diseases or other health conditions and events in human populations related to age, gender, occupation, ethnicity, and economic status, with the purpose of identifying and combating health problems and promoting good health.

Measuring Equipment. Set of devices or instruments needed to measure the concentration of a specific pollutant present in a gas flux.

Erosion. The destruction and elimination of certain physical, chemical and biological characteristics present in the soil. The factors that increase ground erosion are: climate, precipitation (rain, snow, etc.), wind velocity, topography, degree and length of the slope, physical and chemical characteristics of the original soil, ground cover, its nature and the amount of ground cover, natural phenomena such as earthquakes and human factors, for example uncontrolled felling, subsequent burns, excessive grazing, the removal of important organic layers, etc.

Monitoring Station. Set of technical elements designed to measure simultaneously the concentration of pollutants in the air, with the purpose of evaluating air quality in a specific area.

Atmospheric Stability. Meteorological condition directly influenced by wind velocity and by its upward and downward movement, showing convective and advective air movements.

Service Stations. Establishments where gasoline, lubricants and other motor vehicle fuels are sold to the public.

Standards. Technical specifications, usually prepared in a format that is available to the public, developed with the consensus of receiving approval from all the affected parties. They are based on solid scientific data, technology and experience, with the object of promoting the optimal benefits to the community. These specifications must be approved by an appointed group of individuals at the national, regional or international level.

Stomas. Structures in the leaves of plants used for the exchange of gases and liquid substances.

Urban Structure. Roadways, access routes, different uses given to the terrain with the purpose of making cities more functional.

Exposure. The process through which a substance with toxic properties enters or is absorbed by an organism through any route.

Emissions Factor. The relation between the amount of contamination that is produced and the amount of raw material processed or the amount of energy consumed. For example: an emissions factor for a factory that uses boilers to produce iron could be the number of kilograms of particles emitted per ton of raw material processed.

Physiography. The branch of geology that studies the formation and evolution of the earth's relief, as well as the processes and results that determine its transformation.

Photochemicals. Pollutants that are produced by the reaction of two or more compounds in the presence of sunlight.

Photoreactivity. Trait of certain air pollutants that experience or undergo changes in their composition when reacting with each other or with other air constituents in the presence of sunlight.

Breathable Fraction. Particles less than 10 micrometers in diameter that can enter the pulmonary system without obstacle all the way to the alveoli.

Freon. Gas used for refrigeration which, when released in the atmosphere, reacts with ozone in the stratosphere, reducing the volume of the ozone protective layer.

Major Stationary Source. Any stationary source producing emissions greater than 91 metric tons (100 English tons), per year, for which there is a specific air pollution control in effect; or, any other stationary source that is designated by the Parties for purposes of the La Paz Agreement.

Fixed Source. In air pollution terms, it is defined as a fixed point of large quantities of pollutant emissions, generally of industrial nature.

Mobile Source. Any machine, apparatus, or device that emits pollutants into the atmosphere, water and soil, not having a fixed location. All vehicles, such as cars, ships, and airplanes are considered mobile sources.

Natural Gas. Gas mixture used as fuel. It is obtained from certain underground geologic formations. Natural gas is the mixture of hydrocarbons of low molecular weight, such as propane, methane, butane, and others.

Environmental Management. Administration procedures carried out through the setting of goals, planning, resource allocation, application of judicial mechanisms, etc., on human activities that influence the environment.

Temperature Gradient. Profile in the difference of magnitude for values that are higher or lower than a given temperature with respect to a reference temperature or a distance that is described vertically.

Binational Air Quality Workgroup. Workgroup formed as a result of the La Paz Agreement, charged with analyzing and solving air quality problems in the border region between Mexico and the United States.

Hydrocarbons. Organic compounds containing carbon and hydrogen in varied amounts. They are found especially in fossil fuels. Some of these compounds are hazardous air pollutants because of their carcinogenic nature; some others are important due to the role they play in ozone formation at the urban air level.

Aliphatic Hydrocarbons. Open chain hydrocarbons such as fats.

Aromatic Hydrocarbons. Compounds derived from benzene, which is a ring of 6 carbons with three double links.

Polycyclic Aromatic Hydrocarbons. A group of organic compounds having two or more benzenic rings. One of the better known compounds of this kind is benzo[μ]pyrene, do to its presence in urban air. These compounds are formed during the combustion process of fuels such as diesel. They may cause skin and pulmonary cancer.

Hydrolysis. Phenomenon consisting of the release of water through the breakdown of molecules.

Environmental Impact. Any change caused by a proposed project on human health and safety, plants, animals, soil, air, water, climate, the actual ground use, and resources for the traditional use of Indian populations, or physical structures, places or objects of historical, archeological, paleontological, or architectural relevance, or the integration of these factors. It also includes impacts on the cultural heritage or socioeconomic conditions resulting from those factors. "Impact" includes direct, indirect, or cumulative impacts.

Economic Incentives. Financial support instruments applied in environmental policy with the purpose of changing the predominant behaviors of production and consumption for the benefit of the environment.

Incineration. Process of vigorous and controlled oxidation through which solid, liquid and gaseous wastes are burned and turned into inert compounds such as ashes, carbon dioxide and water.

Incinerator. Device especially designed for the combustion of solid, liquid, or gaseous waste, through the proper manipulation of temperature, retention time, turbulence, and combustion air.

Air Quality Metropolitan Index (IMECA). An non-dimensional unit that allows us to compare the magnitudes of the different pollutants using a homogeneous scale ranging from 0 to 500, where 100 corresponds to the value of the Official Mexican Standard established for each pollutant.

Industry. A set of material operations performed to obtain one or more products starting with the transformation of natural resources.

Traffic Engineering. Planning activities for urban roadways, traffic lights and traffic signals, among others, geared toward attaining the optimal performance of the road service structure of a city.

Emissions Inventory. A listing, by source, of the amount of pollutants released to the air in a community; it is used to establish standards or emissions levels.

Desegregated Inventory. A system of database and mathematical calculations used for identifying and quantifying atmospheric emissions generated by the different sectors and polluting sources, such as industry, commerce, vehicles, ground and vegetation, among others.

Thermal Inversion. Atmospheric condition in which a layer of cold air is trapped underneath a layer of hot air, in such way that it hinders the natural convection movement of air. This event causes the pollutants that are present within the trapped layer to be diffused horizontally instead of vertically, and their concentration rises to a very high level when they encounter a reduced dilution capacity and the continuous emissions input.

Kilocalories. Unit of measure that represents the amount of heat required to rise the temperature of one liter of water by one degree Celsius or centigrade.

Urban Physical Environment. A set of natural physical elements (land and climate) and the entire set of works and structures performed by the society that male-up the geographic space of an urban environment, considering the quantitative and qualitative aspects of such elements.

Metabolism. Energy attainment and cell structure formation through the degradation of food.

Heavy Metals. All metals with elemental density greater than 4.5 kilograms per liter and which are deficiently metabolized and eliminated by the body, causing diverse toxic impacts.

Methane. Gaseous, flammable and colorless hydrocarbon. This gas is found in its natural state in deep caverns and mines. It is also emitted by the anaerobic decomposition processes of organic matter, and in swamps.

Meteorology. The study of the physical and energy phenomena produced in the atmosphere.

Metropolis. The main city in a country, state, or region. It comes from the Greek words “mater” which means mother, and “polis” which means city; thus, mother city. It is also generally used to refer to a large city.

Monitoring. Periodical or continuous supervision or proofing, to determine the degree of compliance with the established requirements for pollution levels in several biotic environments.

Microenvironmental Monitoring. Monitoring of the pollution levels in a limited area of the environment that reflects the environmental conditions that are particular to that area.

Carbon Monoxide (CO). Poisonous, colorless, and odorless gas, produced by the incomplete oxidation of fossil fuels.

Morbidity. Any deviation, subjective or objective, from a physiological or psychological state of well being. In this sense, the illness, disease and condition of morbidity are defined in similar manner, and, according to the World Health Organization, it can be measured in three terms: sick people, disease, and duration.

Mutagenic. An agent capable of causing changes in the genetic structure of an organism.

Fog. A cloud that is in contact with the ground. At a regional level, fog is formed by different processes. During the winter, by irradiation (i.e., the cooling of layers near the earth's surface and their resulting condensation.) During the summer, due to the displacement of cloud nuclei from the Gulf of Mexico.

Maximum Permissible Level. The maximum concentration of a pollutant that must not be exceeded; (for example, standards that allow the exceedance of the maximum level only once a year).

Ambient Air Quality Levels. Critical environmental levels of air pollutants (for example, Normas Oficiales Mexicanas de Calidad del Aire and The National Ambient Air Quality Standards).

NOM-ECOL-086-94. The Official Mexican Standard that establishes environmental specifications for fossil, liquid and gaseous fuels used in fixed as well as mobile sources.

Environmental Quality Standard. Numerical data adopted to be used as the frame of reference for comparing environmental measurements with the purpose of interpreting them.

Environmental Health Standards. Technical specifications or other available documents to the public, formulated by a recognized authority at the national, regional or international level, with the cooperation of the affected parties, and based on a review of scientific and technological results, as well as experience, with the object of safeguarding human health or the environment, while considering other social objectives. These standards are enforceable by law and are made to be complied with.

Olefines. Hydrocarbons, also known as alkenes, with a double link between two carbon atoms and having a low molecular weight. They are characterized by having certain physical properties such as volatility and atmospheric reactivity.

Ecological Arrangement. Planning process aimed at evaluating and programming land use and natural resource management in the national territory and other zones over which the country has sovereignty and jurisdictional rights to preserve and restore the ecological balance and protect the environment.

Oxidant. A compound that accepts electrons and raises the valence of another compound when reacting with it.

Photochemical Oxidants. Pollutants that are formed by the action of sunlight on nitrogen oxides and reactive hydrocarbons in the air.

Ozone. Photochemical oxidant produced by the reaction between reactive hydrocarbons, nitrogen oxides and the intensity of solar radiation.

Parameter. The amount measured or pondered over an environmental indicator.

Vehicular Fleet. The number of motorized vehicles that circulate in a human settlement.

Particulates. A pollutant generated by the processes of combustion, heating, production, transport, and handling of pulverized materials. It consists of ashes, smoke, metals, etc. The main emissions source are industries where ovens, boilers, incinerators, etc. are used, as well as motor vehicles that run on diesel. Some natural sources include eroded areas, unpaved roads, volcanic emissions, etc. Particles in the air can be measured as TSP or PM10.

Breathable Fraction Particles (PM10). Standard used for measuring the concentration of solid and liquid particles suspended in the atmosphere, with a diameter equal to, or less than 10 micrometers, which dictates the behavior of particles in the lungs: PM10 penetrate the deepest parts of the lungs and, through clinical and epidemiological studies, have been found to cause health problems in the most sensitive groups of the population, such as children and people with respiratory illnesses.

Primary Particles. Those that are emitted directly to the air.

Secondary Particles. Those that are formed in the atmosphere through the transformation of gases such as (SOx, NOx, and VOCs) in solids or liquids.

Calorific Power. The ability of an energy producing substance to produce heat, expressed in calories per unit of weight or volume. For example, in metric units, it can be expressed as kilocalories per liter or in English units, as BTU/barrel.

Acid Precipitation. A type of harmful rain that occurs when certain pollutants such as sulfur dioxide and nitrogen oxides react with moisture in the atmosphere to form their respective acids dissolved in precipitated water in the form of rain. It can also be acid snow, acid dew, etc.

Total Suspended Particles (TSP). Any material that exist in the solid or liquid state in the atmosphere, with aerodynamic diameter greater than the individual molecules but smaller than 100 μm.

Electrostatic Precipitator. A device to control particles that works through processes of electrostatic charge and electrical attraction.

Vapor Pressure. A trait of chemical compounds that tend to become volatile, which in the vapor phase exercise pressure on their surroundings.

Medium-life Consumer Product. These include industrial items related with the manufacture of electronic products for home and business use.

Long-life Consumer Products. These include industrial items related with the manufacture of heavy-duty machinery and equipment.

Border XXI Program. Bilateral cooperation program assumed by the federal governments of Mexico and the United States to generate environmental alternatives that promote the transition to sustainable development for border communities in both countries.

Environmental Protection. A set of policies and measures applied to preserve and improve the environment, and to prevent and control its deterioration.

Radiation. Energy propagation through matter and space, in the form of fast particles or waves.

Ultraviolet Radiation. Electromagnetic radiation with wavelengths smaller than those of visible light, but greater than those of X-rays.

Infrared Radiation. Electromagnetic radiation with wavelengths greater than those of visible light.

Reactivity. The ability of an element or substance to chemically interact with other substances, releasing energy and other products.

Vapor Recovery. Device used in service stations to control evaporative emissions generated when gasoline and other fuels are loaded and unloaded.

Natural Resource. Natural element of ecosystems susceptible or not to being utilized to the benefit of man.

Catalytic Reduction. Chemical reaction between substances favored by the promoting action from a substance know as a catalyzer.

Reforestation. The act of planting trees in barren areas where there used to be vegetation.

Environmental Regulation. Legal instruments that establish the conditions under which people must conduct themselves to comply with environmental legislation.

Environmental Health. The part of public health administration engaged in the ways of life, substances, forces and conditions surrounding people, which can have an influence on their health and well being.

Environmental Risk. The possibility (or probability) that a particular exposure, or series of exposures, may cause harm to the health of those individuals that are subjected to those exposures.

Public Health. The condition of total physical, mental and social well being of the population.

Synergism. An interaction of two or more chemicals that results in an effect greater than the sum of their separate effects.

Monitoring System. A set of stations or instruments for automated air quality surveillance.

Extratropical Systems. Meteorological systems generated in high latitudes and normally related with high temperatures and strong winds. The typical extratropical systems are cold fronts, polar air masses, jet streams, etc. Also, during the winter season it is typical to find anticyclonic systems, which affect a country after the occurrence of a cold air system; they are atmospheric systems whose nucleus is characterized by high pressure and mild winds that move clockwise in the northern hemisphere. This type of system causes poor pollutant dispersion in their zone of influence.

Immune System. The ability of organisms to respond in the presence of infectious agents. This system protects the body from microbial diseases.

Tropical Systems. Meteorological systems formed in the intertropical convergence zone (the zone where winds from the northern and southern hemisphere flow together), which are formed by different atmospheric conditions (winds, air masses, temperature, etc.) And manifest themselves in the form of tropical hurricanes, storms, depressions, disturbances, or waves. Normally, when these systems approach a country, they generate conditions that are favorable for the dispersion of pollutants.

Smog. A term derived form the combination of the English words “smoke” and “fog”, commonly used to refer to air pollution caused by the gases generated from vehicular exhaust and factories.

Sublimation. Direct transformation of a substance from the solid to the gaseous state.

Soil. A complex mixture of small particles of rocks, minerals, organisms, air, and water. A dynamic body that changes continuously in response to climatic conditions, vegetation, local topography, material of origin, age, use, and human abuse.

Sustainability. The condition of managing natural resources with the purpose of assuring sustainable and environmentally rational decisions; those which, when put into practice, allow for the continuation of the social and economic development process in benefit of current and future generations.

Toxicity. The inherent ability of a chemical agent to produce a harmful effect on living organisms.

Toxic. Chemical agent that, when entering the body, depending on its quantity rather than quality, is capable of causing alterations in biological systems.

North American Free Trade Agreement (NAFTA). Pact signed in 1993 between Mexico, the United States of America and Canada, with the purpose of reducing tariffs and non-tariff related barriers in trade between these three countries; it includes a Parallel Agreement regarding the Environment.

Threshold. The level of intensity of a stimulus below which no effect is perceived on the exposed medium.

Urbanization. Provision of basic services to a community that lacks them, or to an area in which a human settlement is to be built.

Ground Use. Term used in urban planning to refer to the specific purpose assigned for the use of a piece of land.

Viability. The set of roadways or geographic spaces used for circulation and displacement of vehicles and pedestrians.

Northern Border Zone. The area extending 100 kilometers to the north and 100 kilometers to the south of the border between Mexico and the United States.

I. INDUSTRY, COMMERCE AND SERVICES

Actions	Responsible Parties	Progress and development						Projected impact of emissions in tons by 2005				
		2000	2001	2002	2003	2004	2005	NOx	HC	SO_2	CO	PM10
1. Reduce emissions generated by the worst polluting industries through the installation of control equipment and process re-engineering	CANACINTRA, Industry							757	NE	1,707	NE	1,392
2. Implement a vapor recovery program at storage terminals and gas stations	SEMARNAP, PEMEX, Owners							NA	1,436	NA	NA	NA
3. Reinforce the inspection and oversight of industrial, commercial and service establishments	SEMARNAP, State Gov., Mpal. Gov.							NE	NE	NE	NE	NE
4. Come to an agreement with industry on the implementation of a program to reduce Volatile Organic Compounds (VOCs)	SEMARNAP, Maquiladora Association							NA	1,177	NA	NA	NA
5. Request that the Federal Electric Power Commission (CFE) conduct a study to assess the impact from emissions generated by the geothermal power plant in Cerro Prieto and, if necessary, implement a program to reduce those emissions within a year	CFE							NA	NA	NA	NA	NA
6. Conduct environmental audits and self-regulatory actions in the industrial sector	SEMARNAP, State Gov., Mpal. Gov., CANACINTRA, Maquiladora Association							NE	NE	NE	NE	NE
7. Develop an integrated Registry of Emissions and Transfer of Contaminants (RETC) for Mexicali	SEMARNAP, State Gov., Mpal. Gov., CANACINTRA, Maquiladora Association							NE	NE	NE	NE	NE

Abbreviations:

NA = Does Not Apply

NE = Not Estimated

	NOx	HC	SO_2	CO	PM10
Emissions reduction (ton/year)	757	2,613	1,707	NE	1,392
Reduction compared to the sector (%)	34	16	59	NE	3
Reduction compared to the total (%)	4	5	45	NE	2

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II. VEHICLES

Actions	Responsible Parties	Progress and development						Projected impact of emissions in tons by 2005				
		2000	2001	2002	2003	2004	2005	NOx	HC	SO_2	CO	PM10
8. PEMEX will evaluate the possibility of supplying low Reid vapor pressure(RVP) oxygenated gasoline	PEMEX							NE	NE	NE	NE	NE
9. Design the model, come to a consensus, and implement the Vehicle Emissions Program	Mpal. Gov., SCT							3,580	9,868	NA	58,230	123
10. Require all imported vehicles to pass vehicle emissions testing in their country of origin	SHCP, SECOFI							NE	NE	NE	NE	NE
11. Promote the use of LP gas and natural gas in public transportation	Private parties							NE	NE	NE	NE	NE
12. Design and implement a program to stop and penalize visibly polluting vehicles	Mpal. Gov., SCT							NE	NE	NE	NE	NE

Abbreviations:
NA = Does Not Apply
NE = Not Estimated

	NOx	HC	SO_2	CO	PM10
Emissions reduction (ton/year)	3,580	9,868	NE	58,230	123
Reduction compared to the sector (%)	24	32	0	24	24
Reduction compared to the total (%)	19	19	0	22	0.1

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III. URBAN MANAGEMENT AND TRANSPORTATION

Actions	Responsible parties	Progress and devilment						Projected impact of emissions in tons by 2005				
		2000	2001	2002	2003	2004	2005	NOx	HC	SO_2	CO	PM10
13. Apply soil stabilizers for the control of PM10 emissions on streets, unpaved and heavily traveled areas	SEMARNAP, State Gov., Mpal. Gov.							NA	NA	NA	NA	14,496
14. Intensify a paving program for streets and roads	State Gov., Mpal. Gov.							NA	NA	NA	NA	7,839
15. PEMEX involvement in providing preferential prices for fuel and asphalt to be used in paving projects	PEMEX											
16. Come to an agreement on the transfer, operation and funding of the air quality monitoring network	Mpal. Gov.							NA	NA	NA	NA	NA
17. Develop an integrated study and carry out improvements in public transportation	Mpal. Gov.							NE	NE	NE	NE	NE
18. Promote public involvement and environmental education programs	State Gov., Mpal. Gov.							NE	NE	NE	NE	NE
19. Consolidate an epidemiological program to monitor diseases associated with air pollution, as well as implement preventive and corrective measures	SSA							NA	NA	NA	NA	NA
20. Develop a program of financial incentives for individuals, institutions and organizations that develop programs that prevent and control air pollution	SHCP							NE	NE	NE	NE	NE
21. Integrate COPLADEMMs Municipal Ecology Commission in the follow-up of the program	Mpal. Gov.							NA	NA	NA	NA	NA

Abbreviations:

NA = Does Not Apply

NE = Not Estimated

	NOx	HC	SO_2	CO	PM10
Emissions reduction (ton/year)	NE	NE	NE	NE	22,335
Reduction compared to the sector (%)	NE	NE	NE	NE	36
Reduction compared to the total (%)	NE	NE	NE	NE	26

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IV. ECOLOGICAL RECOVERY

Actions	Responsible parties	Progress and development						Projected impact of emissions in tons by 2005				
		2000	2001	2002	2003	2004	2005	NOx	HC	SO_2	CO	PM10
22. Study and set emissions factors and control measures for agricultural burns and practices	SEMARNAP, SAGAR, State Gov.							NE	NE	NE	NE	NE
23. Design a reforestation and preservation program for wooded areas	State Gov., Mpal. Gov., SEMARNAP, SEDENA							NA	NA	NA	NA	6,178

Abbreviations:

NA = Does Not Apply

NE = Not Estimated

	NOx	HC	SO_2	CO	PM10
Emissions reduction (ton/year)	NE	NE	NE	NE	6,178
Reduction compared to the sector (%)	NE	NE	NE	NE	30
Reduction compared to the total (%)	NE	NE	NE	NE	7

V. RESEARCH AND INTERNATIONAL AGREEMENTS

Actions	Responsible parties	Progress and development						Projected impact of emissions in tons by 2005				
		2000	2001	2002	2003	2004	2005	NOx	HC	SO_2	CO	PM10
24. Review and update periodically the emissions inventory and PROAIRE	SEMARNAP, State Gov., Mpal. Gov.							NA	NA	NA	NA	NA
25. Reach agreements with institutions of higher education to conduct air pollution studies	State Gov., Mpal. Gov., SEMARNAP							NA	NA	NA	NA	NA
26. Reach agreements with international institutions to conduct training activities and air pollution related studies	State Gov., Mpal. Gov., SEMARNAP							NA	NA	NA	NA	NA
27. Reinforce the actions of the Border XXI Program and subsequent binational programs	SEMARNAP, State Gov., Mpal. Gov.							NE	NE	NE	NE	NE

Abbreviations:

NA = Does Not Apply

NE = Not Estimated

	NOx	HC	SO_2	CO	PM10
Emissions reduction (tons/year)	NE	NE	NE	NE	NE
Reduction compared to the sector (%)	NE	NE	NE	NE	NE
Reduction compared to the total (%)	NE	NE	NE	NE	NE

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Lic. Alejandro González Alcocer
Gobernador Constitucional del Estado
de Baja California

Arq. Victor Hermosillo Celada
Presidente del XVI Ayuntamiento
de Mexicali

M. en C. Julia Carabias Lillo
Secretaria de Medio Ambiente,
Recursos Naturales y Pesca

Lic. José Antonio González Fernández
Secretario de Salud

Lic. Enrique Provencio
Presidente del Instituto Nacional
de Ecología

First Edition: December 1999

Gobierno del Estado de Baja California
Dirección General de Ecología
Vía Oriente No. 1
Zona del Río
Centro de Gobierno
22320 Tijuana, B.C.

Gobierno Municipal de Mexicali
Dirección de Ecología
Casa Municipal, 2° Piso
Calz. Independencia y Paseo de los Héroes
Centro Cívico
21000 Mexicali, B.C.

Secretaría de Medio Ambiente,
Recursos Naturales y Pesca
Instituto Nacional de Ecología
Av. Revolución 1425
Col. Tlacopac San Ángel
Delegación Álvaro Obregón
01040 México, D.F.

Secretaría de Salud
Lieja 7
Col. Juárez
Delegación Cuauhtémoc
06696 México, D.F.

Delegación Federal Semarnap
Baja California
Av. Madero No. 537
Zona Centro
21000 Mexicali, B.C.

Printed and Made in Mexico

The following individuals were involved in the developing this document:

Hugo Abel Castro Bojorquez
Jesús Contreras Franco
María Guadalupe De la Luz González
Adrián Fernández Bremauntz
Adolfo González Calvillo
José Manuel González Osorio
Rodolfo Iniestra Gómez
Fernando Mares Cossío
Jorge Martínez Castillejos
Roberto Martínez Verde
Antonio Mendez Ocampo
Francisco Montaño Fong
Mariano Montes González
Sergio Eduardo Montes Montoya
Alma Delia Muñoz Capetillo
María de la Luz Ocaña Rodríguez
Gustavo Olaiz Fernández
Cristina Ortuño Mojica
Víctor Hugo Páramo Figueroa
Guadalupe Ramírez Rosas
Hugo Riemann González
Saúl Rodríguez Rivera
Rosalba Rojas Martínez
María Cristina Ruiz Ramírez
Jorge Sarmiento Rentería
Francisco Soto Delgadillo
Julián Torres Ruiz
Guadalupe Tzintzun Cervantes
Enrique Villegas Ibarra
José Zaragoza Ávila