Air quality for a sustainable California, U.S.-Baja California, Mexico border region

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Abstract

Air pollutants move freely across political borders. Because of physical conditions such as topography, geomorphology and weather, border communities share common air sheds or air basins that are characterized by changing wind patterns depending on the season. Wind is the means of transport of air pollutants, and thus any human activity that generates pollutants on one side of the border will have an impact on the other side. Many border residents are currently exposed to health-threatening levels of air pollution by the presence of substances such as particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). This situation has created concerns on both sides of the border, and the U.S Environmental Protection Agency (EPA) and the Mexico's National Institute of Ecology (Instituto Nacional de Ecologia-INE) have developed regional strategies to improve air quality based on separate but similar national ambient air quality standards. The objectives of this paper are to describe the current state of binational air quality and to analyze what is needed to be done to make the environment of the CA-BC border region sustainable.
Keywords: air quality, sustainability, CA-BC border region, common airshed, air pollutants, environment.

1 Introduction

Air pollution can be a serious threat to public health. Maintaining good air quality is a serious challenge to almost all nations. Complex systems of regulations and administration have been established to address this challenge,

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which becomes even greater when neighboring countries, each with its own legal system, literally share the causes and effects of particular cases of air pollution because of split airsheds.

Regions adjacent to international boundaries are likely asymmetrical in one or more of the following areas: geography, demography, economy, political system and culture.

Geographic and economic asymmetries can generate transboundary commerce in the form of formal and informal networks for exploiting potentially profitable business opportunities. Political and cultural asymmetries, by contrast, can serve as obstacles to transboundary collaboration. The economies of neighboring regions are frequently complementary in the structure and cost of both inputs (characteristics of the labor force, natural resources, capital, and entrepreneurship) and outputs (final goods and services).

This paper examines how these phenomena are played out in the CA-BC border region. It also analyzes how air quality is managed in that context and what strategies have served or could serve to improve air quality in this region.

2 Characteristics of the U.S.-Mexican border region

2.1 Overview of the border region

The border that divides Mexico and the United States has a length of 3,100 km (the part that corresponds to the CA-BC border is 252 km long, shown in Fig. 1

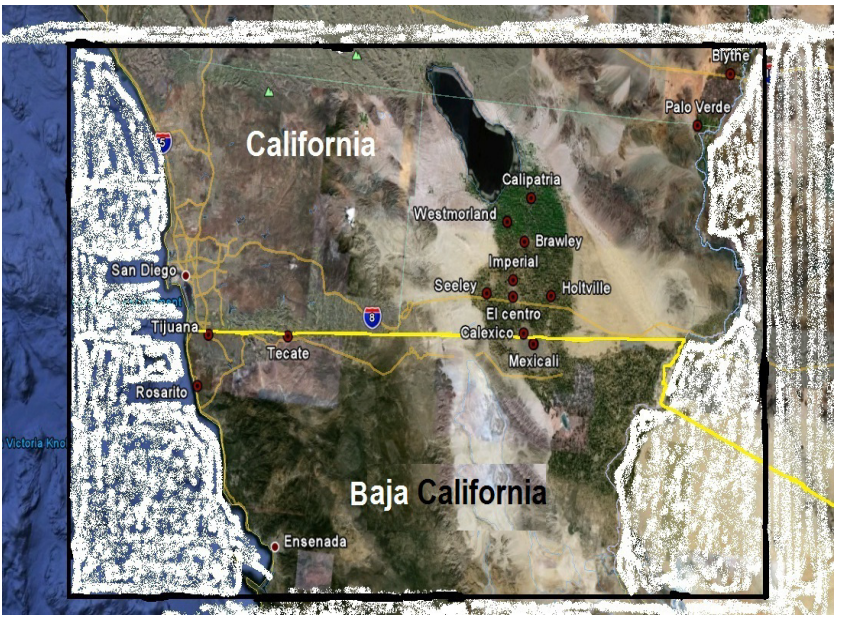

Figure 1: The California-Baja California border region defined by the La Paz agreement.

and includes 5 cities on both sides of the border). From both countries' perspectives, the main objective for the border is to be selective with respect to the transit of people as well as trade. This selectivity, however, does not apply to transboundary air, water, and land pollutants at any point on its entire length, extending from the Pacific Ocean to the Gulf of Mexico. Pursuant to the 1983 La Paz Agreement, the U.S.-Mexico border region is defined as following the border between the two countries from the Pacific Ocean to the Gulf of Mexico and extending 100 km (62 miles) into each country from both sides of the border.

2.1.1 Socioeconomic aspects of the border region

In 1983, the La Paz Agreement was signed by Mexico and the United States to address the need for cooperation on the protection and improvement of the border region's environment. There were growing concerns over the increasing environmental degradation in the metropolitan zones in the border region, which was a direct result of accelerated population growth in the absence of well-planned development, and the pressure of an increasing demand for services, more traffic, and greater generation of waste.

Although population growth occurs on both sides of the border, annual rates have been higher on the Mexican side. The border population has particular demographic dynamics that are very much influenced by internal migration in Mexico. Mexicans have migrated to the northern border because they have perceived it as prosperous, or because they have considered themselves to be temporarily in the area and on their way to the United States. According to the 2010 Census of Population and Housing in Mexico, the BC border region population was 3,155,070 inhabitants; this figure represented 16% of the total population in the six border states, and nearly 2.8% of the national total population.

The perceived prosperity in the Mexican border region was based largely on industrial development, which increased even more with the implementation of the North American Free Trade Agreement (NAFTA) beginning in 1994. In Mexico, the border region has had the lowest unemployment rate and the highest salaries. Economic growth clearly has generated jobs, but such growth has not been accompanied by a complementary increase in infrastructure (such as water-related facilities and roads) and pollution control. This unbalanced development has led to an unsustainable use of natural resources, with the result that environment and public health are being affected on both sides of the border.

Currently, 6 million people inhabit the CA-BC border region, and it is estimated that this number will double by 2025. Therefore, it is a priority to guarantee the well-being of inhabitants and their environment alike. This would require that all future development not only be economically viable, but also be accompanied by social and environmental perspectives that consider the sustainable use of natural resources. There are some key aspects to be considered in that perspective which are described next.

2.1.1.1 Maquiladora industry

Two historical factors were associated with the initial development of the maquiladora (assembly factories) industry in the Mexican border region: the cities' locations and their status as duty-free zones. The combined effect of being far away from the rest of the Mexican Republic and the existence of a duty-free zone in the region since the 1930s had discouraged the establishment of Mexican companies for many years.

2.1.1.2 Infrastructure at the border

As mentioned previously, development of infrastructure has generally not kept pace with population growth, and this has negatively affected the environment. There have been some improvements, however, related to street paving and ports of entry.

2.1.1.3 Street paving

High PM concentrations represent one of the main environmental problems in the border region. A significant source of PM is unpaved roads on the Mexican side. Baja California has addressed this problem in a successful effort to obtain financing for street paving from several national and binational institutions.

2.1.1.4 Ports of entry

Ports of entry at the border itself, where drivers of all passenger vehicles and commercial trucks must stop and present appropriate documents, are often congested. The idling of the vehicles is a source of air pollution.

3 Air quality: management and current status

Pollutants degrade air quality. Air pollutants are substances that, in high enough concentrations, harm human health and sometimes also damage other parts of the ecosystem or materials. These pollutants are quite diverse, but can be classified or characterized in several ways, including by physical or chemical characteristics, by source, by environmental fate, and by effect.

Given the ample range of air pollutants and their sources, nature, and effects, adopting efficient regulatory and management systems of air quality is of fundamental importance [1]. Typical management approaches in the United States and Mexico involve several sets of activities. The first set of activities normally undertaken is the identification of the effects of various pollutants and a determination of which of the pollutants are most threatening and therefore in need of management and control. The next set of activities is the establishment of ambient standards for those pollutants considered to be current or imminent threats.

A subsequent activity focuses on monitoring the ambient concentrations in any geographical area where there is a suspicion that concentrations of one or more pollutants may be threatening. After determining which areas are suffering from violations of one or more standards, another series of activities is carried

out to address the problem in each of those areas. These activities include the development of emission inventories, identification of possible control strategies, modeling to determine which strategy or combination of strategies will most effectively address the problem, and then implementation of the selected strategies. The strategic plans in the United States are called State Implementation Plans, or SIPs. In Mexico, these plans are called *Programas de Gestión de la calidad del aire o Proaires (Air quality Management Programs)* [2–4].

How the United States and Mexico are carrying out these activities, and what is known about the current status of air quality in the border region, are explained in more detail in the following sections.

3.1 Criteria Pollutants and national Ambient air quality standards

Of the myriad of air substances known to be harmful to human health and welfare, some have been identified as being sufficiently hazardous and present in the air in sufficient quantities to merit enforceable standards. The United States and Mexico have independently developed and adopted such standards in the form of the National Ambient Air Quality Standards (NAAQS) and the Mexican Official Norms (Normas Oficiales Mexicanas–NOMs), respectively. In addition, through programs such as Border 2012 the countries have cooperatively developed specific objectives and indicators of progress for the border region.

Acting under the framework established by the federal Clean Air Act in the United States, during the 1980s and 1990s the EPA set standards for six categories of pollutants: ozone, carbon monoxide, total suspended particulates (more recently labeled particulate matter), sulfur dioxide, lead, and nitrogen oxide. Because of the particular criteria used to identify these pollutants – principally based on health effects – these are called the criteria pollutants.

Mexico has also identified the same criteria pollutants and established its own ambient air quality standards (the NOM). Over the past 20 years, both countries have on several occasions increased the strictness of these standards in response to continuing research on the effects of pollutants on public health and on ecosystems. The most recent AAQS for both countries are shown in Table 2.

Before comparing the AAQS values shown is Table 2, two aspects related to the U.S. standards should be explained further. The first is that values for U.S. NAAQS depicted in Table 1 correspond to primary standards that are set to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly.

The second aspect of the U.S. NAAQS that merits explanation is the "attainment" concept. When the measured concentrations of a pollutant do not exceed a standard for that pollutant in a geographical area (such as a city or metropolitan area), then that area is considered to be in a status of attainment. When the concentrations measured by any monitor in a geographical area exceed a standard, then the area is designated to be in nonattainment status for the particular standard. An area may be in attainment status for one pollutant standard and in nonattainment status for another. In addition, the extent to which a particular standard is violated (meaning the severity of the violation) can lead

to an additional level of designation, using the terms marginal, moderate, serious, severe, and extreme. States must design and implement a set of control measures (including some specific measures that are required under federal law depending upon this severity classification) in order to bring the area back to a status of attainment.

Table 1: Comparison of Ambient Air Quality Standards (AAQS) in the United States and Mexico, as of August 2011.

Pollutant	Averaging Time	U.S. NAAQS	Mexico NOM
Carbon monoxide (CO)	8-hour	9 ppm (10 mg/m^3)	11 ppm (12.6 mg/m^3)
	1-hour	35 ppm (40 mg/m^3)	
Lead	3-Month Average	0.15 µg/m^3 (October 15, 2008)	1.5 µg/-m^3
	Quarterly Average	1.5 µg/m^3	
Nitrogen dioxide (NO_2)	Annual (Arithmetic Mean)	0.053 ppm (100 µg/m^3)	
	1-hour	0.100 ppm	0.21 ppm (395 µg/m^3)
Particulate Matter (PM_{10})	24-hour	150 µg/m^3	120 µg/m^3
	Annual	50 µg/m^3	50 µg/m^3
Particulate Matter ($PM_{2.5}$)	Annual (Arithmetic Mean)	15.0 µg/m^3	15.0 µg/m^3
	24-hour	35 µg/m^3	65 µg/m^3
Total suspended particulates (TSP)	24-hour		210 µg/m^3
Ozone (O_3)	8-hour	0.075 ppm (2008 std)	0.08 ppm (1993 std)
		0.08 ppm (1997 std)	
	1-hour	0.12 ppm	0.11 ppm
Sulfur dioxide (SO_2)	Annual (Arithmetic Mean)	0.03 ppm	0.03 ppm (79 µg/m^3)
	24-hour	0.14 ppm	0.13 ppm (341 µg/m^3)

Note: Units of measurement for the standards are parts per million (ppm) by volume, milligrams per cubic meter of air (mg/m^3), and micrograms per cubic meter of air (µg/m^3).
Sources: EPA, SEMARNAT, and Mexico's Ministry of Health.

Table 2 demonstrates that the AAQS for the two countries are quite similar in most of the cases. This similarity between the two regulatory systems makes cross-border collaboration easier in the border region. But this convergence has not been the result of a one-time phenomenon. As has been mentioned, standards in each country have become stricter over the past 20 years. Modifications in

Table 2: Airsheds in Nonattainment status in the border region.

Airshed	O_3	CO	PM
San Diego-Tijuana	8 hrs		
Imperial Valley-Mexicali	Marginal (1 & 8 hrs)		Moderate

Source: The Green Book Nonattainment Areas for Criteria Pollutants, EPA: http://www.epa.gov/oar/oaqps/greenbk/.

U.S. NAAQS have usually come first, followed over time by modifications to the Mexican NOMs. The relatively recent development of $PM_{2.5}$ standards is a good example of this sequence.

The following section looks more closely at one aspect of that cross-border collaboration – the regional air quality indicators that have been developed cooperatively. A subsequent section will then discuss the application of the standards just summarized, identifying the geographical areas that have been in nonattainment status

3.2 Other related indicators of air quality for the border region

The current U.S.-Mexico binational, multimedia environmental program is called Border 2012 (Semarnat and USEPA, 2006). One of the six goals of Border 2012 is to reduce air pollution through implementation of specific projects in the four U.S. and six Mexican border states.

Border 2012 has established indicators to track general environmental conditions and trends and to evaluate the effect of the implementation of programs and projects. In the "State of the Border Region Indicators Report 2005" [5], the Border Indicators Task Force (BITF) presented the following air quality indicators, which were updated in 2008:

1. Number of days exceeding air quality standards in border monitoring areas.
2. Ozone concentrations in the border region.
3. Particulate matter (PM_{10}) concentrations in the border region.
4. Existence of emission-reduction strategies, greenhouse gas emissions, and results of specific emission-reduction projects.

The first three indicators are closely related to the measurements that are used to determine violations in the two countries and therefore attainment designations in the United States.

Three of the indicators of border air quality are based on direct measurements of ambient concentrations by monitoring stations in five geographic areas where there have been monitors on one side or both sides of the border since at least 1997. Here are presented just two of them: (1) Tijuana-San Diego, (2) Mexicali-Calexico. Nine years of measurements, reflecting the data behind the U.S. nonattainment designations, show that the most persistent and pervasive pollutants found in the border region have been ozone and particulate matter (PM_{10}), as seen in Figures 2 and 3.

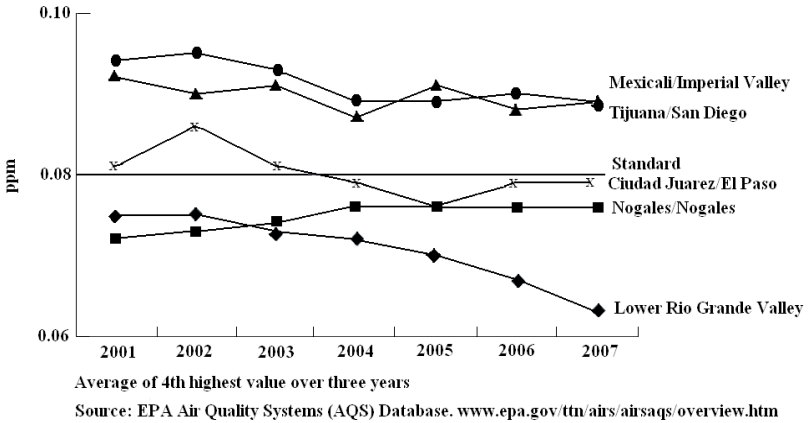

Figure 2: Averaged ozone concentrations in Tijuana and Mexicali.

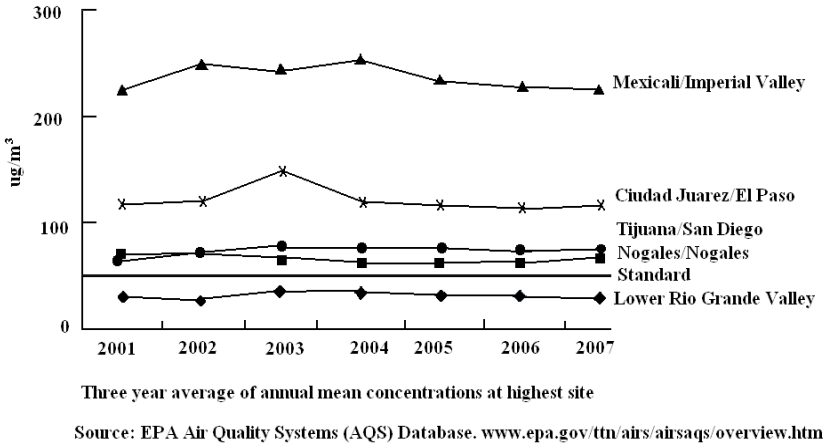

Figure 3: Averaged PM_{10} concentrations in Tijuana and Mexicali.

3.3 Air quality management in the border region

Once the standards have been established, air quality management in the United States and Mexico involves five sets of activities: ambient monitoring, determination of geographical areas that have air quality problems; development of emissions inventories; modeling; and selection and implementation of control strategies. EPA and SEMARNAT have, to varying degrees, made use of all five approaches.

3.4 Monitoring

According to Mexico's National Air Quality Information System (Sistema Nacional de Información de la Calidad del Aire–SINAICA), there are monitoring stations in two Mexican border states, one of which is Baja California (one in Rosarito, four in Tijuana, one in Tecate, and six in Mexicali).

In contrast, the EPA's ambient air quality monitoring program is delegated to the states; in many cases, the states have, in turn, delegated some of this authority to local governments. There are three major categories of U.S. monitoring stations that measure the criteria pollutants: state and local air monitoring stations (SLAMS); national air monitoring stations (NAMS); and special purpose monitoring stations (SPMS). Stations on the U.S. side of the border are principally SLAMS. One example of the latter is Imperial Valley, Ca. with 8 air quality monitoring stations and 14 at San Diego, Ca.

3.5 Determination of Attainment status

The monitoring of the various criteria pollutants has enabled the United States and Mexico to determine the geographical areas that are not able to meet the standards that have been established.

Because of the nature of airsheds, residents on both sides of the border in twin cities in Baja California share the same air quality. Measurements taken on either side can generally serve as a proxy for conditions on the other side, and U.S. designation of attainment or nonattainment status can be interpreted from this perspective. Figures 3 and 4 show how air quality in selected border airsheds has compared to the standards.

Measurements show that the severity of violations of ozone and PM_{10} standards has varied geographically. Thus, the two areas in Baja California-California – Tijuana-San Diego and Mexicali-Imperial Valley – were most severely in violation of the ozone standard and Mexicali-Imperial Valley has had the most severe problem with PM_{10} (Figures 2 and 3).

Table 3 uses the U.S. designations of the severity of violations to characterize these airsheds, reflecting the relative numerical values shown in Figures 3 and 4.

As discussed, the designation of an area as nonattainment in the United States triggers a series of measures to identify sources of pollution and develop control strategies. These topics are described in more detail in subsequent sections.

3.6 Inventories and modeling

In order to have the data that allow for development of the most effective control strategies for areas that violate one or more federal standards, agencies determine the sources of each pollutant or class of pollutants and develop emission inventories. The inventories typically use four categories of sources:

1. Point sources.
2. Area sources
3. Mobile sources
4. Biogenic sources

3.6.1 Inventories of the Mexican- American border states

The Border 2012 program was established by the U.S. Environmental Protection Agency (EPA), Mexico's Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), and other U.S. and Mexican environmental agencies as a successor to the Border XXI program. Border 2012 is designed to address various environmental issues that exist in the U.S.-Mexico border region.

A baseline emissions inventory for 1999 was developed to increase the understanding of emissions sources located within the U.S.-Mexico border region [6]. The baseline emissions inventory combines existing criteria air pollutant emission inventories from the U.S. National Emissions Inventory (NEI) and the Mexico NEI using geographical information system (GIS) techniques for point, area, on road motor vehicle and nonroad mobile emissions for the year 1999.

3.6.1.1 Inventories of the Mexican border states

In 2004, the National Institute of Ecology (Instituto Nacional de Ecología–INE) unveiled the first air emissions inventory for the six Mexican northern border states (inventario de emisiones de los estados de la frontera norte [IEEFN]), using a base year of 1999. This baseline emissions inventory was developed to improve the understanding of emissions sources located in northern Mexico and to support air quality assessments. The IEEFN is a product of binational government partnerships completed through collaborative efforts between the United States and Mexico.

The IEEFN considered all the criteria pollutants, as well as volatile organic compounds (VOC) and ammonia (NH_3) arising from both natural and anthropogenic point and area sources. Estimations showed that CO was the air pollutant most abundantly emitted in the Baja California with up to 171,227 tons annually. VOC emissions totaled 90,969 annual tonnes; PM emissions, including $PM_{2.5}$ and PM_{10}, totaled 154,182 annual tonnes. PM_{10} sources were identified as fugitive dust, and the sources of $PM_{2.5}$ were power plant and industrial activities. These estimations were made for portions of counties/municipalities that lie within the 100 km border zone. U.S. and Mexican emissions may not be entirely comparable due to differences in data and methods used to compile the U.S. and Mexican NEIs for the Border 2012 baseline emissions inventory.

3.6.1.2 Inventories of the U.S. border states

Farms and use of fertilizers in California were the main source of ammonia emissions (19,038 annual tonnes). Mobile sources in the region generated the most CO (932, 816.9 annual tonnes) and PM emissions (120,468 annual tones); CO emissions totaled 135, 586 annual tonnes; PM emissions, including $PM_{2.5}$ and PM_{10}, totaled 120, 468 annual tonnes.

3.7 Control strategies

Under the Mexican General Law of Ecological Equilibrium and Environmental Protection (Ley General del Equilibrio Ecológico y la Protección al Ambiente–

LGEEPA), each level of government has jurisdiction over different categories of emission sources. The LGEEPA requires the federal government to work with state and local governments to develop control strategies for municipalities with serious air quality problems. The set of measures for each area to improve air quality is called a Proaire, and it addresses all the pollutants considered problems in that area.

Historically, Mexico has developed Proaires for three municipalities in the border region: Tijuana and Mexicali in Baja California, and Ciudad Juárez in Chihuahua. Using the most recent emissions inventory, it identifies sources of the offending pollutants that could be reduced and establishes 24 "actions" to be implemented related to transportation and mobility, industry, commerce and services, health protection, environmental education, institutional strengthening, and binational coordination. An updated Proaire 2011-2020 is being developed for Mexicali and Tijuana-Rosarito in 2011.

In the United States, the federal Clean Air Act states that, after the EPA has designated a geographical area as being in nonattainment under a particular pollutant standard, the EPA must set a deadline for the affected state to submit a plan for control strategies that will bring the area into attainment for that pollutant by a certain date. Thus, for each of the U.S. cities or counties listed in Table 3, the relevant U.S. state has submitted a SIP to EPA for each standard that is being violated.

In both countries, the area-specific control strategies are selected and implemented in the larger context of the development of federal laws or regulations that are, in effect, control strategies for the whole country. For instance, both countries have developed emission standards for heavy-duty diesel engines. The U.S. regulations on this topic went into effect with new engines sold in 2007; the Mexican regulations were developed more recently and are not yet in effect.

4 What has been done with regard to binational collaboration

Because sister cities along the Mexican-U.S. border share their airsheds, the resolution of air quality problems calls for maximum cooperation efforts between the United States and Mexican federal governments, among the 10 border states (six in Mexico and four in the United States), and between the sister cities themselves. This presents a number of challenges because of the two different legal and political systems and different languages.

Generally, the people of the two countries have not considered the situation to be adversarial. Collaboration that began with baby steps in the 1980s has increased dramatically since that time. Most of the collaborative activities have taken place under the framework of the La Paz Agreement, signed in 1983 by the presidents of the two countries, but other binational arrangements running in parallel have also facilitated cross-border accomplishments.

5 Observations and recommendations

The border region is experiencing rapid economic and population growth that results in increasing environmental stress. Although much has been done to address air quality problems and progress can be accurately claimed, increased and aggressive action is necessary to assure a sustainable future, especially with regard to ozone and particulate matter.

Each of those elements of air quality management can be pursued by the individual countries and states. But because the problems exist in airsheds that are binational, the situation also requires binational solutions. Officials on both sides of the border have increasingly come to recognize this and are attempting to develop a response. This requires an enhanced binational dialog that involves federal, state, and local officials, nongovernmental organizations (NGOs), and the private sector.

Air pollution cannot be sufficiently mitigated unless policymakers recognize the existence of binational common airsheds and collaborate across the border [7].

People in the different levels of government, in academia, and in the private sector in both countries are capable of overcoming jurisdictional issues and boldly establishing patterns of cooperation that assure a sustainable future for the citizens of this dynamic region.

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