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Vulnerability to Air Pollution in Latin America and the Caribbean Region

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Environmentally and Socially Sustainable Development Department (LCSES)

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Abbreviations and Acronyms

CO	Carbon Monoxide
mg\m^3	milligrams per cubic meter
ug/m^3	micrograms per cubic meter
NMHC:	Non-Methane Hydrocarbons
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
O_3	Ozone
$PM_{2.5}$	Particulate Matter with aerodynamic diameter smaller than 2.5 micrometers
PM_{10}	Particulate Matter with aerodynamic diameter smaller than 10 micrometers
Ppb	parts per billion
Ppm	parts per million
SO_2	Sulfur Dioxide
TSP	Total Suspended Particles
US EPA	United States Environmental Protection Agency
US NAAQS	United States National Air Quality Standards
VOC	Volatile Organic Compounds
WHO	World Health Organization

Foreword

Air pollution creates high costs for society. Each year, air pollution causes an estimated 500,000 to 1 million premature deaths worldwide, with costs equivalent to about 2 percent of GDP. Recent Bank studies in Colombia, Peru, Guatemala, and El Salvador estimated that the cost of outdoor air pollution is equivalent to approximately 1 percent of national GDP. A relatively recent World Bank study of six cities in developing countries found that the social costs of all environmental impacts amount to a total of US$3.8 billion, of which health impacts account for 68 percent.[1] Recent estimates by the Pan American Health Organization (PAHO) concluded that more than 100 million people in Latin American cities are exposed to levels of air pollution that exceed the recommended standards. Moreover, according to the WHO Global Burden of Disease Report (2002) the impact of outdoor air pollution in Latin America is 35,000 annual premature deaths and 276,000 years of life lost (adjusted by disability).

In Latin America's growing urban centers, the factors that contribute to relatively high health risks associated with air pollution include inadequate land-use and transport planning, poor fuel quality, energy-intensive productive activities, and weak air quality management capacity. Exposure to air pollutants is higher around congested areas where informal and formal economic activities take place during the day. The most affected are the most vulnerable: the elderly, the poor, the children, the sick.

Energy efficiency, proper land-use planning, and sustainable transport are some of the responses promoted by the World Bank. Examples of these responses include the following: (a) In 1998, the Bank launched the Clean Air Initiative for Latin America and the Caribbean (CAI-LAC), a partnership among governments, private sector, nongovernmental organizations, and international development agencies. The Bank was at the helm of the CAI-LAC Technical Secretariat until June 2006, when a new nonprofit autonomous organization—the Clean Air Institute (CAI)—was created to manage CAI-LAC and broaden its reach. CAI-LAC's mission is focused on reversing the deterioration of urban air quality in the cities of the region, mitigating climate change, and addressing problems stemming from rapid urbanization, increased vehicular transport, energy use, and industrial production. (b) GEF resources have been blended with Bank funding to develop sustainable transport activities and mitigate climate change in cities such as Mexico, Lima–Callao, Santiago, São Paulo, and Bogotá, and more recently in medium-sized cities of Brazil and Colombia. (c) Development Policy Lending operations are also targeting air pollution as one of the main environmental hazards in the region; ongoing environmental policy planning work in Colombia, Brazil, and Peru is now placing strong emphasis on air pollution control.

[1] Lvovsky, K. et al. (2000). *Environmental Costs of Fossil Fuels: A Rapid Assessment Method with Application to Six Cities*, Environment Department Papers–Pollution Management Series, Paper No. 78, The World Bank.

However, there is limited capacity to assess, monitor, and manage air quality in the region. This study is the first comprehensive attempt to present a general overview of the region's air quality and the availability of resources that characterize the strength of air quality management programs (such as monitoring capability, emissions inventories, and ambient air quality standards). We have compiled and analyzed standards, information on emission inventories and on air quality monitoring networks, and data on ambient concentrations from 100 cities in the region. In general, we have found a weak foundation for air quality management. We have identified cities with potential vulnerability to air pollution. These cities may require special attention as part of our growing sustainable development portfolio. Therefore, these findings will help us reinforce our commitment to achieve the millennium goals and attain a better quality of life in Latin America.

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Executive Summary

In recent decades air quality has worsened in most urban centers as the result of population growth, industrialization, and increased vehicle use. Recognizing the role of transportation in air degradation, the Environmentally and Socially Sustainable Development Unit of the World Bank's Latin America and the Caribbean Region (ESSD LAC) is preparing a project under the sponsorship of the GEF to promote the concept of sustainable transport, energy, and air quality aimed at meeting the needs of many of the region's vulnerable urban conglomerations. This project continues the track of activities undertaken in previous years by the Bank and aimed at assessing and improving air quality. It includes the work carried out by the Clean Air Initiative for Latin American Cities (CAI-LAC), the broader sustainable transport projects agenda, as well as the development of country-level estimates of the cost of environmental degradation aimed at setting priorities for mainstreaming environment in the policy decision-making process in those countries.

CAI-LAC is a partnership among governments, private sector, nongovernmental organizations, and international development agencies, launched by the Bank in 1998. After the Bank's seven years at the helm of the Technical Secretariat, a new nonprofit autonomous organization—the Clean Air Institute—was created in June 2006 to manage CAI-LAC and broaden its reach. CAI-LAC's mission focuses on reversing the deterioration of urban air quality in the cities of the region, mitigating climate change, and addressing problems from rapid urbanization, increased vehicular transport, energy use, and industrial production. CAI-LAC's efforts are currently focused on developing and implementing a regional clean air strategic framework, with the broad participation of key stakeholders.

Several country-level studies in Colombia, Peru, Guatemala, and El Salvador have estimated the cost of environmental degradation (Ecuador and Honduras are also in the pipeline). In these, the cost of outdoor air pollution has been estimated to be equivalent to approximately 1 percent of GDP, which indicates the relevance of air quality degradation in the region.

In view of the urban development characteristics in the region, the Bank is promoting an integrated project approach to address issues of urban sprawl, energy use, land use, and transport planning. This approach is aimed at promoting the use of nonmotorized means of transport and of public transportation, by mainstreaming the environment, specifically sound and sustainable transport programs coordinated with land-use and transport planning, in the policy decision-making process and by providing the necessary resources and tools (e.g., investment in infrastructure, technology transfer, and capacity building). Sustainable integrated transport projects in the agenda and pipeline include Chile, Colombia, Mexico, Peru, and Brazil. These projects will be effective in improving outdoor air quality, especially by decreasing concentrations of $PM_{2.5}$, the form of particulate matter that is most dangerous to human health, and lowering emissions of greenhouse gases through the use of more efficient public transportation fleets, more efficient and less polluting technologies, and changes in public behavior that translate into reduced use of private transport and increased use of nonmotorized modes of transport; all of which translate into a better quality of life.

This study is a supporting document for the GEF Regional Project on Sustainable Transportation. It is the first published document that compiles and synthesizes air quality information and is the first attempt to identify vulnerability to air pollution in 100 selected main urban centers in the Latin America and Caribbean Region.

The objectives of this study are to: (i) provide a quick overview of the capacity to monitor the air quality of the region's main urban centers, and (ii) identify vulnerability to air pollution in the more than 100 urban centers selected throughout the region. These objectives are pursued by identifying the availability of some of the basic resources required for air quality management, and by providing insight about air quality based on historical monitoring data. The study is not aimed at comparing air quality across the region.

The data collected and synthesized concern the availability of four distinct types of information that characterize the strength of air quality management programs: air quality legislation on ambient air quality standards; emission inventories; ambient air quality monitoring capability; and measured concentrations of certain air pollutants over a given time period for selected urban centers.

The study proposes an "air quality map" to synthesize this information. Using a methodology elaborated in Section 9, this map combines information on ambient air quality standards, air quality monitoring capability, and actual monitoring data to provide insight on the state of air pollution. Together with information on availability of resources to manage air quality, this map provides a tool to help identify the vulnerability of selected cities to air pollution.

The study is structured in ten sections. The first three sections provide an introduction and background information, and describe the objectives of this study. Section 4 describes the methodology used. Section 5 provides a regional summary and analysis of ambient air quality standards. Section 6 provides a summary and analysis of emission inventories throughout the region. Section 7 presents a regional summary and analysis of the capacity to monitor ambient concentrations by identifying the availability of monitoring networks and describing their characteristics. Section 8 presents a summary of available historical data across the region. Section 9 presents the methodology used to develop the air quality map[2] and provides an analysis of findings. The final section offers conclusions and recommendations.

Methodology

The study selected a sample of 100 main urban centers among the most populated urban areas located in the Bank's member countries in the Latin America and the Caribbean Region. This sample of urban centers is not necessarily representative of the entire region, but it comprises 34% of the total population living in the region, i.e., a sample population consisting of 187.5 million of the estimated 546 million inhabitants of the entire region,[3] and 46% of the urban population of the region.[4]

Pollutants for which data were collected include the criteria pollutants which the US EPA tracks in its National Ambient Air Quality Standards, with two exceptions. Lead has not been included, because information is not widely available. Total Suspended Particulates have been included if available, in instances where information about PM_{10} or $PM_{2.5}$ is not.

Data were collected from official government sources where possible. This process involved, among other things, personal communications with relevant professionals (Bank staff, experts at relevant governmental institutions such as Ministries of Environment, NGOs, etc.) and Internet searches, in order to determine appropriate local officials and sources to contact directly. If no contact could be established,

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[2] The air quality map combines the information presented in the previous sections on ambient air quality standards, characteristics of monitoring networks, and air quality data. The air quality map is a tool that visually depicts the category in which each urban center is classified based on its capability to monitor ambient concentrations, and the pollutants suspected to be critical.

[3] According to the United Nations' 2003 Demographic Yearbook, the total population of the Latin America and the Caribbean Region in the year 2003 is estimated at 546 million. The total population of selected urban centers, estimated at 187,465,558, was obtained from a different source: Thomas Brinkhoff: City Population, http://www.citypopulation.de, which provided population data aggregated by urban centers as selected by the study.

[4] An estimated 75% of all populations live in urban areas.

information was obtained either from Web pages or relevant publications. Regional Table 2 provides a list of institutions linked to air quality monitoring throughout the region.

Once collected, all information was summarized in regional tables on ambient air quality standards, emission inventories, characteristics of monitoring networks, and historical data by pollutant. Each of these tables is presented and discussed in the appropriate section below. Monitoring and air quality data are synthesized spatially on an air quality map, which, together with information on availability of resources to manage air quality helps identify vulnerability of selected urban centers to air pollution. The map, the methodology and findings of the map, as well as an analysis of vulnerability are presented in this document's section on the air quality map.

Ambient Air Quality Standards[5]

Air quality concentration standards are commonly dictated by national or city regulations. In the absence of regulations, some urban centers use international standards as a benchmark. In Latin America, international references tend to be either the US NAAQS or the WHO guidelines, rather than those of the European Union. Ideally, localized standards are based on empirically derived health-related impacts; in practice, however, because most countries in the region lack sufficient resources or research capabilities to develop local regulations based on scientific evidence, they often base their own standards on international benchmarks such as those of the NAAQS or WHO guidelines.

It is a policy issue and a sovereign decision to determine which specific at-risk groups should be protected by the standards and what degree of risk is considered to be acceptable. Therefore, changes in international guidelines such as those of the WHO may not have any direct impact on local standards, but implicitly affect the level of risk each nation is willing to accept.

Ambient air quality standards should be used as instruments to establish legally enforceable air quality objectives. They identify which pollutants should be monitored, what levels are deemed to be acceptable for some scientifically based objectives, and help determine what types of government intervention might be necessary to ensure compliance.

Most selected countries in the region (14 out of the 19 selected)[6] have set standards for ambient air quality concentrations. Four Central American countries—Guatemala, Honduras, Nicaragua, and Panama—are exceptions, and instead have used a combination of the WHO guidelines and US NAAQS as reference values instead. In addition, some urban centers, such as the Province and City of Buenos Aires and Mendoza in Argentina, also set their own standards defined by local legislation.[7]

When cities and countries specify PM_{10} or $PM_{2.5}$ standards, they tend to be similar to those of the US NAAQS. However, standards for gases tend to differ—both in average concentrations and averaging times—by country and sometimes even by urban centers within the same country. Normally, the local standard tends to be more stringent than the national standard.

A small number of countries and urban centers have current standards that stand out within the region and in comparison to international benchmarks. The most stringent standards are found in Uruguay, while the most permissive were, until very recently, found in Colombia. The most outdated standards, and probably the reason why they are not commonly used, are the standards set by the national law in Argentina.

[5] Regional Table 3 summarizes ambient air quality standards across selected countries in the region.
[6] Standards representing Uruguay, which has no national ambient air quality standards, are those for the city of Montevideo. No information regarding availability of standards is available for Paraguay.
[7] Until very recently, Bogotá also set locally defined standards, but these have been replaced by a national standard.

Emission Inventories[8]

Emission inventories are a key part of a sound air quality management program. They identify the sources of emissions and thus help allocate responsibility for observed pollution concentrations to different sectors. In so doing, they provide insight and guidance on how to control specific pollutants of concern.

Differences among methodologies used to estimate the various inventories—not only among different cities, but often even among inventories carried out in the same city by different groups or at different times—make direct comparison of emissions sources difficult.

Just by identifying the availability of emission inventories among selected urban centers, and not even evaluating their qualitative characteristics (e.g., source completeness, pollutant completeness or frequency), the situation can be described as inadequate.

Emissions inventories were found in only 39 of the 100 selected urban centers,[9] representing about 54% of 187.5 million people who live in all selected urban centers. These 39 cities are located in Argentina, Brazil, Chile, Colombia, the Dominican Republic, Ecuador, Mexico, and Peru. Mexico stands out as the only country for which emission inventories were found for all selected urban centers, since it has developed a national emission inventory which can be disaggregated to the municipal level. Very few urban centers, all of which are also located in Mexico, reported more than one emission inventory study.

Mobile sources are mainly accountable for direct emissions of CO, $NO_{x,}$, and hydrocarbons, while sulfur oxides tend to be emitted directly by fixed sources, as Regional Table 5 shows. While most emission inventories report particulate matter as mainly originating from fixed and especially natural sources, particularly when measured as TSP, this tends to overemphasize large particles that have less impact on human health than the particles emitted by combustion processes, such as those used in the transport sector.

In addition to playing a significant role in direct emissions of PM_{10} and $PM_{2.5}$, mobile sources play a significant role in the formation of secondary particulates and ozone because they account for an important share of emissions of NOx, VOCs, and sulfates.

Monitoring Capability[10]

Air quality monitoring among selected urban centers is generally weak, with only few exceptions, and the circumstances in which that monitoring occurs varies substantially, resulting in different standards of geographic density of monitoring stations, types of analyzers available at those stations, and the number of pollutants monitored, among other differences. Given the volume of data for the region, this report cannot evaluate the quality of the monitoring networks or their implementation, nor compare them on objective criteria such as completeness,[11] representativeness,[12] reliability,[13] or transparency.[14]

[8] Emission inventories found in selected urban centers of the region are summarized in Regional Tables 4 and 5.

[9] That more urban areas do not undertake emissions inventories is probably a result of the high costs of implementation. Recife Metropolitan Region, Belo Horizonte Metropolitan Region, Arequipa, and Trujillo are supposed to have undertaken emission inventory studies, but because no confirmation of this was received, they were not included in this estimated number. In addition, urban centers with partial or incomplete inventories (Cochabamba, San José, and Guayaquil) were also not included in this number.

[10] Characteristics of monitoring capability for all selected urban centers are summarized in Regional Table 6.

[11] Refers to capability to monitor all criteria pollutants and relevant meteorological parameters.

[12] Refers to coverage in space, time, sources, population, and land use.

[13] Refers to quality assurance, audits, and assessment of equipment.

[14] Refers to availability of periodic air quality reports and real-time public Internet accessibility, among others.

Information on monitoring capacity was collected for 98 of the selected 100 urban centers,[15] of which only 59, representing 79% of the population living in all selected urban centers, have some type of permanent monitoring consisting of at least a single station.[16] All other urban centers either had a network or at least one station in the past that is no longer in operation,[17] have undertaken temporal studies,[18] or have no monitoring at all. Figure 7 summarizes the availability of monitoring capability across the region.

Focusing on the 59 urban centers with permanent monitoring, some deficiencies can be observed when one looks at the methods used and the capability to monitor selected pollutants. First, of the 59 urban centers with permanent monitoring, 18 are only equipped with manual analyzers. With regard to gaseous pollutants, in particular O_3 and CO, where the standards are defined for periods of one or several hours only, it is important to have automatic analyzers that can provide real-time data comparable to the standards.

Second, there is a significant difference in capability to monitor selected pollutants, especially with particulate matter. Although nearly all 59 urban centers with permanent monitoring capability monitor some form of particulates,[19] only 10, representing 36% of the population living in all selected urban centers, monitor $PM_{2.5}$.[20] [21] By contrast, each selected gaseous pollutants can be monitored in almost three-quarters of urban centers with monitoring capability,[22] but the capability to monitor each specific pollutant varies by urban center. For gases, not only is the number of urban centers that monitor gases important, but so is the method available to monitor them, as discussed above.

Distribution of resources to monitor air quality among selected countries is not clearly correlated with development indicators such as GDP, as one might otherwise expect. While advanced monitoring networks are indeed found in Brazil, Chile, and Mexico—countries with relatively high GDP per capita—this capability tends to be limited to a few cities, particularly in Brazil and Chile.[23] In addition, in certain relatively wealthy countries where one would expect to find advanced monitoring capability—namely Argentina and Costa Rica—air quality monitoring networks are rudimentary or nonexistent. Elsewhere in

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[15] The two urban centers for which no information was found are Mar del Plata in Argentina and Asunción in Paraguay.

[16] Fifty-one urban centers—representing 77% of the sample population—have a monitoring network defined, for the purpose of this report, as at least two stations that monitor air quality on a regular basis. Eight other urban centers, representing 2% of the sample population, have one station.

[17] Six urban centers fall in this category: Córdoba in Argentina; Cartagena and Cúcuta in Colombia; Managua in Nicaragua; and Chihuahua and Hermosillo in Mexico.

[18] Temporal studies to monitor air quality were found in seven of the urban centers with no permanent monitoring capability, and are briefly described in Regional Table 7.

[19] Among all 59 urban centers with monitoring capability, PM_{10} is monitored in 49. Among those that do not monitor PM_{10}, with the exception of Santos, Brazil, all have TSP analyzers.

[20] In addition, another two urban centers have monitored $PM_{2.5}$ as part of temporal studies: Santo Domingo in the Dominican Republic and Trujillo in Peru.

[21] While 49 of the 59 urban centers with monitoring capability do monitor PM_{10} in some fashion, there is no way to extrapolate PM_{10} data to likely $PM_{2.5}$ concentrations, because the latter depends on unique atmospheric and emissions characteristics of the region.

[22] Among all 59 urban centers with monitoring capability, there are only two whose networks are not equipped to monitor gases. These two networks are the four-station network in Matamoros, Mexico, which only monitors PM_{10}; and the three-station network in Goiânia, Brazil, which only monitors TSP.

[23] Although the operation and administration of the monitoring networks in Mexico is under the responsibility of the local governments, monitoring capability is distributed throughout the country. An important element that contributed to the distribution of monitoring capability throughout the country, are the incentives provided by the air quality monitoring component of the World Bank–financed *Programa Ambiental de Mexico* project at the end of the 1980s and the beginning of the 1990s, which included the donation of monitoring equipment, technical assistance, and capacity building to the entire country.

Central America and the Caribbean, air quality monitoring networks are also generally poor, in line with what one might expect when looking at GDP.

The most technically advanced monitoring networks in the region are found in Mexico, Brazil, and Chile. The Mexico City, São Paulo and Santiago Metropolitan Regions have allocated substantial resources to identify the origins and impacts of air quality degradation and, as a result, have developed highly advanced monitoring networks capable of delivering real-time data. Elsewhere in Mexico, 12 of the selected urban centers, distributed throughout the country, have a monitoring network. Most of these belong to Mexico's national air quality information system, SINAICA.[24] Among other selected urban centers in Brazil, only half have a monitoring network. In Chile, even if all selected urban centers do have a monitoring network, Santiago Metropolitan Region has the most sophisticated one, consisting of seven stations providing real-time data since 1997.

The relatively poor availability of air quality monitoring capacity in Argentina is somewhat of an anomaly. Of eight urban centers for which information is available, only two have monitoring networks (Buenos Aires and Mendoza), while a third, Bahia Blanca, has a single monitoring station. Given the size of Buenos Aires[25] and its status as the capital and business center of one of the region's largest countries, it is surprising that it has only two stations, only one of which is equipped with automatic analyzers and monitors (PM_{10} and $PM_{2.5}$) and began operating only in August 2005.

Central American and Caribbean countries are generally at an early stage of monitoring. Many have relied on resources from various initiatives, including the SwissContact Foundation [26] as well as the work of the Central American Commission for Environment and Development (CCAD)[27] to promote the development of air quality management throughout this subregion. The former initiative has also contributed to the development of monitoring networks in Bolivia's urban centers (Red MoniCA).[28] Only three cities in Central America have full monitoring networks (San Salvador, Tegucigalpa, and Panama City), and only one of these has any form of automation (Panama City has an automatic analyzer for carbon monoxide). Managua's monitoring network is no longer operational. Several other cities in

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[24] SINAICA is a federal government initiative and serves as a national air quality information system. It is a software program that brings together and disseminates data generated by the principal automatic air quality monitoring networks through the Web site of the National Institute of Ecology (INE). Its purpose is to describe the current and historical state of air quality in the country's various urban centers. The operation and administration of the monitoring networks is the responsibility of local governments. Currently, SINAICA includes the monitoring networks of the Metropolitan Area of the Valley of Mexico, Guadalajara, Toluca, and Puebla, as well as those of Salamanca, León, Celaya, Irapuato, Monterrey, Ciudad Juárez, Tijuana–Rosarito–Tecate, and Mexicali.

[25] The City of Buenos Aires is a federal district composed of 48 neighborhoods (*barrios*). Greater Buenos Aires includes both the City of Buenos Aires and its 24 suburbs, known as *partidos* (municipalities). In 2001, 2.8 million people lived in the City of Buenos Aires. In 2003, 13 million people—about one-third of Argentina's population—lived within Greater Buenos Aires.

[26] The SwissContact Foundation executed the "Aire Puro" project for a period of 10 years since 1993 with funding from the Swiss Agency COSUDE. Although the project focused on vehicular emissions, it also performed air quality monitoring in all capitals of the countries involved (Costa Rica, Panama, Nicaragua, Honduras, El Salvador, and Guatemala), providing real data to raise awareness among the population and authorities of the problem of air pollution, and demonstrating the need for the creation of air quality monitoring networks.

[27] Following the abovementioned SwissContact Foundation project, CCAD (the Central American Commission for Environment and Development) is currently working on the initial stages of a long-term project to develop a Central American policy and strategy for air quality management. Under a more strategic perspective, the objective of this project for the next 10 years is to undertake a series of more integrated activities focusing on (a) strengthening coordination among institutions (environment, health, transport, etc.) and (b) harmonizing the implementation of regulations across the region (ambient concentration, quality of fuels, import of vehicles, emissions from fixed and mobile sources, monitoring and enforcement).

[28] La Paz, El Alto, and Santa Cruz are equipped with manual (both passive and active) analyzers, while the network in Cochabamba is equipped with both manual and automatic equipment.

Central America have had some temporal studies (San José, Guatemala City, and San Pedro Sula), but no ongoing monitoring is available. Therefore, Central America lags behind other parts of the Latin America region in terms of air quality monitoring.

The situation in the Caribbean is even worse. While the two selected urban centers do not necessarily represent the reality of this region, they are at an even earlier stage of monitoring air quality compared to the selected urban centers in Central America. The only temporal air quality monitoring study undertaken in Santo Domingo was part of a broader project financed by the World Bank, while Kingston has only one manual station measuring TSP and PM_{10}.

Among other selected countries, Colombia has almost the opposite situation as Argentina: all urban centers of at least half a million inhabitants have a monitoring network, although two, those of Cartagena and Cúcuta, are no longer in operation.

The little information collected for selected urban centers in Venezuela indicated the existence of a national monitoring network and some independent stations operated by INTEDEP of PDVSA. These groups of monitoring stations do not work as a network. Monitoring capacity, as part of the national network, is available in the selected urban centers of Caracas, Maracaibo, Barcelona, and Valencia; of these, the latter two only monitor TSP. PDVSA has several additional monitoring stations in Caracas and Maracaibo.

Initiatives among other selected urban centers in the region include the development of the *Plan Integral de Saneamiento Atmosférico en Lima–Callao* (PISA) as part of which the five existing monitoring stations will integrate a future network that should be ready by 2010. Moreover, Quito has created an institution devoted to improving the city's air quality (*Corporación para el Mejoramiento del Aire de Quito*, CORPAIRE). This institution operates and processes monitoring data of the existing network (*Red Metropolitana de Monitoreo Atmosférico de Quito*, REMMAQ) composed of 9 stations with both automatic and manual analyzers that monitor all pollutants considered in this study.

Disparity in availability of monitoring capability, albeit on a smaller scale, can still be seen among the most populated urban centers in each selected country. With the exception of Santa Cruz in Bolivia, São Paulo in Brazil, and Guayaquil in Ecuador, the most populated urban center in each country always coincides with its capital. Nearly three-fourths of these 19 urban centers have monitoring capability; of these, all monitor particulate matter. In terms of gaseous pollutants, ozone is monitored in fewer than half of all urban centers, and in nearly half of these cases it is monitored with manual analyzers only.

Air Quality Data Availability

As a means to provide some insight into each selected urban center, the study focused on collecting historical ambient air quality data. To do so, we constructed an indicator from commonly available information instead of relying on self-reported data regarding compliance with an air quality standard. Even when the latter data were available, the format in which the information is presented is often either inconclusive (for example, violations of standard reflect numbers of monitoring stations rather than a real reflection of air quality) or not particularly relevant (averaging times that bear no relation to the standard).

The indicator developed is the maximum registered ambient concentration of all selected pollutants for all relevant averaging times. This is supplemented with an indicator of the number of violations of locally defined standards since the year 2000, where available. Non-numerical data were also taken into consideration for some urban centers, that is, where numerical data are not available but information presented in graphs or brief statements in study papers provide some insight into the state of air quality. These data were obtained from permanent monitoring networks and single stations, or from temporal monitoring studies.

Historical data of maximum registered ambient concentrations for relevant averaging times or violations of the locally defined standards since the year 2000, for a time horizon of several months up to 6 years, were gathered for 51 urban centers. In addition, no numerical data were found for 9 urban centers, but textual or graphical information presented in reports and papers reviewed for the present study have provided some insight into air quality (denoted as non-numerical data). No information was available for the remaining urban centers.

Eighty-two percent of collected numerical data was obtained from monitoring networks (42 of the 51 urban centers where numerical data were available), 10% from single stations, 6% from studies, and 2% from previous existing monitoring capability. In 6 urban centers with monitoring networks, numerical data could not be obtained (representing 12% of monitoring networks): Mendoza, Goiânia, Pereira, Mexicali and Tijuana–Rosarito, and Maracaibo.

A breakdown of data availability by pollutant indicates, for example, that in the case of PM_{10} data are available for 46 urban centers, of which 5 have non-numerical data only. Twenty-nine of these 46 urban centers provide data for at least 2 years. In addition, although 10 urban centers have the capacity to monitor $PM_{2.5}$, data were found for only 8, of which 2 correspond to the results of temporal studies (Santo Domingo in the Dominican Republic and Trujillo in Peru).

A breakdown of data availability by country indicates that numerical or a combination of both numerical and non-numerical data were obtained for all selected urban centers in Bolivia, Chile, Central America, the Caribbean, Ecuador, Peru, and Uruguay. A comparison of the geographical distribution of data availability and monitoring capability indicates that some of the data obtained for Central America, the Caribbean, Ecuador, and Peru came from temporal studies.

Air Quality Map

The air quality map is a visual tool whose objective is to provide a rough guide to air quality for each urban center by indicating one of the twelve bins under which each urban center is categorized based on a list of *suspect critical pollutants* (SCP), monitoring capability, and availability of monitoring data. The aim of the last two criteria is to capture to some degree the capability to generate more or less reliable and representative data.

SCP is defined as a pollutant whose highest recorded concentrations, among the latest available, exceeded the value of either the applicable short-exposure (e.g., 24 hours for PM_{10}, $PM_{2.5}$, NO_2, and SO_2, and 1 hour for O_3 and CO) or long-exposure standards (e.g., 1 year for PM_{10}, 8 hours for O_3 and CO). They were identified using the latest information, collected since the year 2000, on the data described in the previous section. The approach to identify SCP is a second-best means of identifying those pollutants that exceed international benchmarks with enough regularity as to create a risk to human health—that is, identifying which pollutants have critical exceedances, which required some other type of information that was not available under the present study (e.g., distribution of ambient concentrations of pollutants with respect to a benchmark).

Applicable standards refer to those used for comparing ambient air quality data. Where local or national standards are available, and are at least as strict as international benchmarks, the local standard has been used. Otherwise, the international benchmarks (US NAAQS and WHO guidelines) have been used.

For the purpose of binning the cities, SCPs are classified in two groups: particulate matter and ozone in one, and the remaining gases in the other. This division introduces a rough, binary distinction between air pollution problems that tend to be more chronic and widespread, and those that tend to be more localized in space and time.

Analysis

Several important conclusions may be drawn from the list of *suspect critical pollutants* presented in Regional Table 8:

- Overall, particulate matter has been identified as a *suspect critical pollutant* in 45 of the 53 urban areas for which information is available,[29] representing 66% of the population represented in the data. However, it is important to note that fully 96% of the population in areas where data about PM is available, live in areas where the pollutant is classified as suspect critical. This points to the urgency of expanding the monitoring of this pollutant.
- Although not widely monitored, $PM_{2.5}$ was identified as a *suspect critical pollutant* in all urban centers where there are data on this pollutant. Urban centers in this group include the São Paulo and Santiago Metropolitan Regions, Greater Concepción, Santo Domingo, Quito, the Metropolitan Zone of the Valley of Mexico, Lima–Callao, and Trujillo, covering 29% of the population living in all selected urban areas. These results suggest the need for more widespread standard-setting and monitoring of this pollutant. Note that three of the urban centers monitoring $PM_{2.5}$ did not even provide data for PM_{10}.
- There are only 8 urban centers, whose populations account for 4% of all people living in all selected urban centers, where PM_{10} was not identified as a *suspect critical pollutant*: Belo Horizonte, Campinas, São José dos Campos, Ribeirão Preto, and Sorocaba in Brazil, Tampico and Villahermosa in Mexico, and Montevideo in Uruguay. As will be discussed below, however, we should be cautious about how we interpret these 8 urban centers.
- O_3 was identified as a *suspect critical pollutant* in 19 of the 31 urban centers for which data on this pollutant are available. 16 of these were identified as suspect critical for some form of PM as well. These 19 urban areas account for 79% of the population living in cities for which ozone information is available, and 43% of the overall population represented by the database. Nevertheless, a larger proportion of monitored cities are classified as nonsuspect critical for ozone than for particulate matter (39% vs. 15%). This suggests that as a critical pollutant, ozone is more variable than particulate matter.
- In nearly all urban centers with data for SO_2, it was not identified as a *suspect critical pollutant*. The only exception was Arequipa, Peru.
- In fewer than half of all urban centers for which data were available, CO and NO_2 were the pollutants identified as suspect critical.

The classification, whose methodology places particular weight on particulate matter—the most widely monitored pollutant and the one associated with the highest risk to human health—and on the availability of resources allocated to managing air quality presented and discussed throughout this document, allows the analysis of *suspect critical pollutants* to be expanded by differentiating among urban centers based on their capacity to generate monitoring data as well as the number of years for which data are available.[30] Better monitoring capability and more years of data could represent more reliable and representative data; therefore, findings on *suspect critical pollutants* could be considered less uncertain. By similar logic, less reliable and representative data could raise concerns about the reliability of results.

[29] It only considered the four cases where TSP was identified as a suspect critical pollutant as a means to identify possible vulnerability when data on PM_{10} or $PM_{2.5}$ were not available. Concentrations of TSP are not always correlated with concentrations of smaller particles. Thus, leaving the cases where TSP was identified as a nonsuspect critical pollutant was a conservative decision to signal vulnerability to particulate matter.

[30] The results of the classification are presented in Regional Table 9.

Nearly half of all selected urban center either do not monitor air quality or do not provide enough data to classify them. Among the remaining half, particulate matter, with only some exceptions, was always identified as a *suspect critical pollutant*, regardless of whether the data were considered more or less reliable. All urban centers where particulate matter was identified as a *nonsuspect critical pollutant* are among those assumed to provide less reliable data. A closer look at several basic characteristics of this subset of urban centers (e.g., number of stations monitoring PM_{10}, availability of emission inventory, and availability of data) isolates Belo Horizonte as an urban area that appears less vulnerable to air pollution.

According to the criteria used, 22 and 31 of the 100 selected urban centers provide more and less reliable, representative data, respectively. Twenty-two urban centers, inhabited by 93 million people (representing 50% of the population living in all selected urban centers), were classified in the first six categories, while 31, with 37 million people (representing 19% of the population living in all selected urban centers), were classified in categories 7 to 10. The first six categories include those urban centers with monitoring capability consisting of at least two stations that provide data on a regular basis and where data were available for at least two years; while categories 7 to 10 include those with less monitoring capability if any at all (in some cases the only data available came from temporal studies), and those where data were available for less than two years. Of the remaining urban centers, 22 are classified in category 11 (inhabited by 35 million people, 19% of the population living in all selected urban centers); in other words, the information necessary to classify them was not available. Twenty-five urban centers (which account for 22 million people, 11% of the population living in all selected urban centers) are classified in category 12.[31]

With respect to identifying those urban centers that are most vulnerable to air pollution, it is important to understand that the reliability of results plays a lesser role because the assessment of vulnerability to air pollution relied on the identification of suspect rather than actual critical pollutants. In this regard, the 45 urban centers where particulate matter, especially $PM_{2.5}$, was identified as a *suspect critical pollutant*, can be considered the most vulnerable to air pollution. Among these centers, those with limited availability of resources to manage urban air quality can be considered particularly at risk.

Based on the above and on the availability of resources to manage air quality, the most vulnerable urban centers among all those selected appear to be those located in Central America, the Caribbean, Argentina, Venezuela, and Bolivia, but further analysis incorporating other variables into the vulnerability analysis is required to confirm this hypothesis. In Brazil, air quality is an issue in many urban centers, but vulnerability varies, mainly because of differences in available resources to manage air quality. In Mexico, air quality also remains an issue in many urban centers, but resources to manage air quality are more widely available and better distributed throughout the country, thus making it relatively less vulnerable. Nevertheless, 48% of Mexico's urban centers lack data indicating the state of air quality.

Various other urban centers, although well endowed with resources, remain vulnerable to air pollution. Most of the pollutants monitored in the Rio de Janeiro Metropolitan Region and the Guadalajara Metropolitan Zone (PM_{10}, O_3, CO, and NO_2) were identified as suspect critical.

Santiago de Chile, the São Paulo Metropolitan Region, and Mexico City (ZMVM) also fall in this group. After experiencing the most serious problems with air pollution in the entire region, and despite undertaking solid plans to manage air degradation and being well endowed with resources to manage air quality, these three metropolitan areas are still vulnerable to air pollution. Their air quality, although improved, is still deficient. These three urban centers were classified in category 1, in which at least PM_{10}, $PM_{2.5}$, and O_3 are identified as *suspect critical pollutants*. Quito, the only other urban center classified in category 1, is the only one of these centers that lacks years of experience in dealing with air quality

[31] Corresponds to 21 urban centers where no permanent or temporal monitoring has taken place since 2000, and 4 other urban centers that had some type of monitoring capacity in the past (either a network or a single station), but no data were obtained: Cartagena in Colombia, and Chihuahua, Hermosillo, and San Luis Potosí in Mexico.

issues. Its network began operating in 2003 and the only information on sources of emissions comes from a preliminary inventory undertaken in the same year, making it the most vulnerable city in this category.

An analysis of the vulnerability of the most populated urban centers in each selected country shows that Montevideo appears to be the least vulnerable to air pollution: it is the only one, among those with information,[32] where no particulate matter and/or ozone were identified as *suspect critical pollutants*. On the other hand, the most vulnerable and most populated urban centers by country appear to be those of all selected Central American and Caribbean countries (Panama City, Managua, Tegucigalpa, Guatemala City, San Salvador, San José, Kingston, and Santo Domingo), in addition to Santa Cruz in Bolivia and Guayaquil in Ecuador. First, particulate matter was identified as a *suspect critical pollutant* in all of them. Second, none, with the exception of Santo Domingo, has carried out emission inventories. Third, monitoring capability is very limited because five of them lack permanent monitoring (Managua had some monitoring capacity in the past but not any longer, while Guatemala City, Santo Domingo, San José, and Guayaquil have only undertaken temporal studies), and the rest have only manual capacity, with the exception of Panama City which monitors CO with automatic analyzers.

Conclusions

Improved air quality is a common goal for most urban areas with large populations because air quality degradation has been a by-product of their rapid growth. However, differences in both the quality of air in metropolitan areas and the resources available to manage air quality have meant that urban residents' vulnerability to air pollution varies substantially across the region.[33]

The study assessed the existence of certain key resources to manage air quality and evaluated the state of air quality by identifying *suspect critical pollutants* based on a methodology that examined the highest ambient air quality concentration registered in any single station. In doing so, it was able to provide clues about the vulnerability of selected urban centers to air pollution.

A large number of these centers appear highly vulnerable to air pollution. Particulate matter was identified as a *suspect critical pollutant* in 45 of the 100 selected urban centers, but this figure would likely be higher if more ambient air quality information were actually available. The 123 million people who inhabit these 45 cities represent 96% of people living in cities where this pollutant is monitored and information available. The data also suggest that the more reliable and sophisticated the monitoring network is, the more likely fine particulates are to be suspect critical—that is, with maximum readings that exceed international benchmarks. Although not monitored in many places, ultrafine particulate matter ($PM_{2.5}$) was always identified as a *suspect critical pollutant* when it was monitored.

Ambient air quality standards are found in most selected countries (14 out of 19), but in many cases particulate matter and ozone standards need to be updated. Although the highest risk to human health is associated with fine and ultrafine particles, in some countries the only available particulate standard is TSP, and only a few actually set standards for ultrafine particulates. For ozone, several countries need to evaluate whether to revise their 1-hour standard or at least set a new standard for an 8-hour period, following the US EPA which, based on scientific information, replaced the NAAQS's 1-hour standard with an 8-hour standard.

Although an important part of the air quality management process, emission inventories are practically nonexistent throughout the region, perhaps because of their cost. Furthermore, they are not undertaken

[32] Asunción, Caracas, and Buenos Aires lack sufficient data for classification. However, in Caracas data indicate that TSP is not identified as a suspect critical pollutant.

[33] Differences in resource allocations result from differences in political will and availability of financial resources, while differences in the status of air quality depend on a combination of factors including physical characteristics of the area under consideration (e.g., topography and weather patterns), characteristics of economic activity, and availability of emission reduction technology.

with a frequency that reflects changes in population and economic activity. Mexico is the only country that has developed a national emission inventory aimed at initiating and improving air quality management plans, and the only country where several selected urban centers reported more than one emission inventory.

No clear pattern emerges in the overall picture about which urban centers have monitoring capabilities and what type. One might have speculated that the most polluted urban areas have the best monitoring capabilities, as is the case for Santiago de Chile, Mexico City, and São Paulo, but there are plenty of other cities where evidence suggests that they might be polluted although they have very limited monitoring capability (such as those classified in category 7 including, for example, Córdoba, La Paz, Recife, Santo Domingo, and Arequipa).

Air quality monitoring is particularly weak in Central America, the Caribbean, and Argentina, where less than half of the selected urban areas have any kind of ongoing monitoring capability. Even where there is such capability, capacity and sophistication to monitor specific pollutants differs substantially. PM_{10} is monitored in less than half of all selected urban centers, while $PM_{2.5}$ is monitored in only 10%. A number of urban centers monitor CO and O_3 using manual rather than automated methods, and thus lack the capacity to generate the real-time data necessary for compliance verification with episodic standards.

Two other common deficiencies identified in the present report are the absence of a standardized methodology to collect and process data, and the poor state of data reporting practices. Even within individual countries, let alone for the entire region, there is often no common methodology to ensure that data collected in one place is comparable with that collected in another, and data quality assurance is minimal. Reports analyzing air quality data are rarely available, and when they are, they tend to be produced intermittently and without updates; in many cases, the most current reports are already outdated. Furthermore, processed data are sometimes presented without proper description or in formats that do not provide complete or relevant information necessary to draw a conclusion about whether a standard has been violated.

Recommendations

Recommendations focus on highlighting areas that, according to the initial findings presented in this document, need improvement, especially with regard to the availability of emission inventories and monitoring capacity.

Recommendations also focus on providing guidance about work that is complimentary to this study. Because this study is the first attempt to identify the vulnerability of main urban centers at such a scale, there are many ways to improve its content.

Additional work should incorporate several key factors in the analysis of vulnerability to air pollution, including a more comprehensive analysis of air quality management, and differences in characteristics such as the topography, weather patterns, and economic activity of selected urban centers. These factors indicate the population's level of exposure to polluted air and provide a more detailed analysis of the characteristics of monitoring capability.

Several topics presented in this document should be explored further in order to provide answers to questions resulting from the analysis. This is particularly true for topics related to air quality regulation, monitoring capability, and the analysis of vulnerability.

1. INTRODUCTION

This report constitutes the first published document that compiles and synthesizes air quality information for more than 100 main urban centers in the Latin America and Caribbean Region. It was developed to support the GEF Regional Project on Sustainable Transportation at the request of the Environmentally and Socially Sustainable Development Department of the World Bank's Latin America and Caribbean Region (LAC).

It is an initial attempt to identify vulnerability to air pollution in selected urban centers by analyzing air quality-related information collected over a one-year period from direct communication with experts at relevant institutions, as well as from Internet searches and reviews of relevant publications. Because data collection has been and continues to be an ongoing process, this study is limited to documenting what has been collected to date. The content of this study should continue to be improved and updated.

The data collected and synthesized concern the availability of four distinct types of information that characterize the strength of air quality management programs: air quality legislation on ambient air quality standards; emission inventories; ambient air quality monitoring capability; and measured concentrations of certain air pollutants over a given time period for selected urban centers. This study does not assess the quality of the information provided; it merely identifies where such information exists. The pollutants for which ambient concentration data are presented include three categories of particulate matter (TSP, PM_{10}, and $PM_{2.5}$), ozone, nitrogen oxide, sulfur dioxide, and carbon monoxide. More information about the characteristics of these pollutants is presented in Annex 1.

The information presented is synthesized in an "air quality map." This map combines information on monitoring capability, ambient air quality standards, and air quality data to provide an insight into the state of air pollution. These data, together with information on the availability of resources to manage air quality, are used to indicate the vulnerability of selected cities to air pollution.

2. BACKGROUND

In recent decades, population growth, industrialization, and increased vehicle use resulting from rapid urban growth in Latin America have led to worsening air quality in most urban centers in the region. The deterioration in air quality has been aggravated by the absence of integrated air quality management programs.

Recognizing the role of transportation in air degradation, the Environmentally and Socially Sustainable Development Department of the World Bank's Latin America and the Caribbean Region (ESSD-LAC) is preparing a GEF–sponsored project to promote the concept of sustainable transport, energy, and air quality in the entire region.[34] This new project is aimed at addressing the needs of many of the region's vulnerable urban centers and at assisting local institutions to engage as early as possible in sound and sustainable transport programs and coordinated land use and transport planning.

This regional project continues the track of activities undertaken in previous years by the Bank and aimed at assessing and improving air quality. It includes the work carried out by the Clean Air Initiative for Latin American Cities (CAI-LAC), the broader sustainable transport projects agenda, as well as the development of

[34] This project is motivated by the fact that significant local benefits can be obtained by reducing GHG emissions from ground transportation as a result of better air quality, transportation systems, and efficient energy use. The project uses a comprehensive, multisectoral, multiyear approach to promote a long-term modal shift to less energy-intensive modes of transport; and to achieve land-use planning by taking into account the demand for transportation. The coordination of urban development and transportation planning produces the best and most sustainable results in terms of reducing fuel consumption and related gas emissions. This approach is also integrated into improvements in the quality of life as related to improved mobility, reduced costs, increased opportunities for leisure, study, and work, better air quality, and better urban space.

country-level estimates of the cost of environmental degradation aimed at setting priorities for mainstreaming environment in the policy decision-making process in those countries.

CAI-LAC is a partnership among governments, private sector, nongovernmental organizations, and international development agencies, launched by the Bank in 1998. After the Bank's seven years at the helm of the Technical Secretariat, a new nonprofit autonomous organization—the Clean Air Institute—was created in June 2006 to manage CAI-LAC and broaden its reach. CAI-LAC's mission focuses on reversing the deterioration of urban air quality in the region's cities, mitigating climate change, and addressing problems from rapid urbanization, increased vehicular transport, energy use, and industrial production. CAI-LAC's efforts are currently focused on developing and implementing a regional clean air strategic framework, with the broad participation of key stakeholders.

Several country-level studies in Colombia, Peru, Guatemala, and El Salvador have estimated the cost of environmental degradation (Ecuador and Honduras are also in the pipeline). In these, the cost of outdoor air pollution has been estimated to be equivalent to approximately 1 percent of GDP, which indicates the relevance of air quality degradation in the region.

In view of the urban development characteristics in the region, the Bank is promoting an integrated project approach to address issues of urban sprawl, energy use, land use, and transport planning. This approach is aimed at promoting the use of nonmotorized means of transport and of public transportation, by mainstreaming the environment, specifically sound and sustainable transport programs coordinated with land-use and transport planning, in the policy decision-making process and by providing the necessary resources and tools (e.g., investment in infrastructure, technology transfer, and capacity building). Sustainable integrated transport projects in the agenda and pipeline include Chile, Colombia, Mexico, Peru, and Brazil. These projects will be effective in improving outdoor air quality, especially by decreasing concentrations of $PM_{2.5}$, the form of particulate matter that is most dangerous to human health, and lowering emissions of greenhouse gases through the use of more efficient public transportation fleets, more efficient and less polluting technologies, and changes in public behavior that translate into reduced use of private transport and increased use of nonmotorized modes of transport; all of which translate into a better quality of life.

In order to provide a solid basis for the preparation of the regional project on sustainable transportation, understanding the region's vulnerability to air pollution is essential. Unfortunately, the information required for this analysis is not readily available: it is not compiled anywhere, and, in many urban centers, if air quality information exists at all, it is not always consistent. Similarly, at the regional level, there is a gap in knowledge about the availability of resources allocated to air quality management, which entities are responsible for air quality management tasks in different cities and countries, and the state of air quality in each urban center.

3. OBJECTIVES AND SCOPE

The objectives of this study are to: (i) provide a quick overview of the capacity of the region's main urban centers to monitor air quality, and (ii) indicate vulnerability to air pollution among the more than 100 urban centers selected throughout Latin America and the Caribbean. These objectives are pursued by identifying the availability of several basic resources required for air quality management, and by providing some insight into the state of air quality based on historical air quality data. The study is not aimed at comparing air quality across the region.

The study is intended to serve as a reference tool for project managers. It first provides summarized information on air quality for all selected urban centers, and then attempts to highlight vulnerability to air quality by synthesizing information related to ambient concentrations in an air quality map.

The study is structured in seven sections. Section 1 describes the methodology of the study. Section 2 provides a regional summary and analysis of ambient air quality standards. Section 3 provides a summary and analysis of emission inventories throughout the region. Section 4 presents a regional summary and analysis of the capacity to monitor ambient air quality by identifying the availability of monitoring networks and describing their characteristics. Section 5 presents a summary of available historical data across the region. Section 6 presents the methodology to develop the air quality map and provides an analysis of findings. The last section presents conclusions and recommendations.

4. METHODOLOGY

The study's implementation included seven steps:

- selection of urban centers;
- selection of pollutants;
- definition of information to be collected;
- identification of potential sources of information;
- gathering of data on air quality regulation, air quality monitoring capability, emission inventories, and historical data on ambient concentrations;
- compilation of data in regional tables on ambient air quality standards, emission inventories, characteristics of monitoring networks, and historical data by pollutant; and
- translation of data into an air quality map, to provide a quick overview of the region's vulnerabilities to air quality.

The first step was to select urban centers for which information would be gathered. The study selected a sample of 100 main urban centers among the most populated urban areas located in the Bank's member countries in the Latin America and the Caribbean Region. This sample of urban centers is not necessarily representative of the entire region, but it comprises 34% of the total population living in the region, i.e., a sample population consisting of 187.5 million of the estimated 546 million inhabitants of the entire region,[35] and 46% of the urban population of the region.[36] Population numbers by urban center are presented in Regional Table 1 and the distribution of selected urban centers among countries is shown in Figure 1.

In a number of cases, metropolitan growth around a central city has swallowed up older, formerly distinct, cities and towns. In 14 such cases,[37] information has been gathered for the individual municipality which is part of a larger metropolitan area, and is included in the accompanying regional tables in order to provide potential for more disaggregated analysis; nevertheless, in the analysis used in this report, to ensure comparability only the metropolitan scale data has been used.

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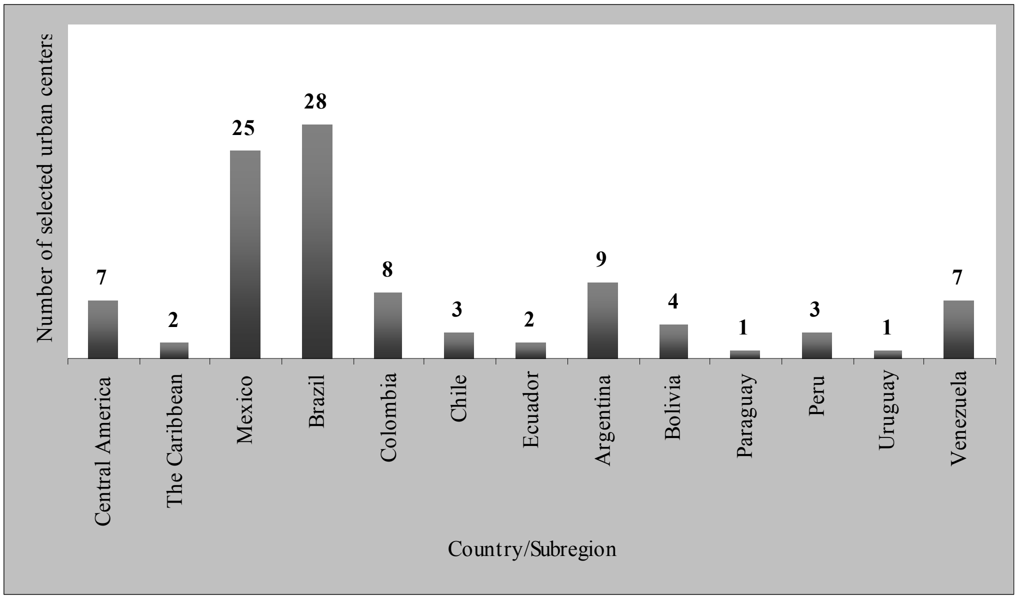
[35] According to the United Nations 2003 Demographic Yearbook, the total population for the Latin America and the Caribbean Region in the year 2003 is estimated at 546 million. The total population of selected urban centers is estimated at 187,465,558 and was obtained from a different source: Thomas Brinkhoff: *City Population,* http://www.citypopulation.de, which provided population data aggregated by urban centers as selected by the study.

[36] It is estimated that 75% of all populations live in urban areas.

[37] These include Guarulhos, São Bernardo dos Campos, Osasco, and Santo André which belong to the São Paulo Metropolitan Region, Nova Iguaçu, São Gonçalo, and Duque de Caxias which belong to the Rio de Janeiro Metropolitan Region, Jaboatão which belongs to the Recife Metropolitan Region, Ecatepec, Naucalpán, Nezahualcóyotl, and Tlalnepantla which belong to Mexico City (ZMVM), Guadalupe which belongs to the Monterrey Metropolitan Area, and Zapopán which belongs to the Guadalajara Metropolitan Area.

Figure 1: Number of Selected Urban Centers in the Region by Country



Pollutants for which data were collected include the criteria pollutants which the US EPA tracks in its National Ambient Air Quality Standards, with two exceptions. Lead has not been included, because information is not widely available. Total Suspended Particulates have been included if available, in instances where information about PM_{10} or $PM_{2.5}$ is not.

The data collected addressed four topics: ambient air quality standards, air quality monitoring capability (availability of networks, pollutants monitored, monitoring methods, etc.), emission inventories (availability of studies estimating emissions by type of source: mobile, fixed, and biogenic), and availability of air quality monitoring data (historical data and episodes of high levels of ambient concentrations of pollutants). When no monitoring network was in place, the study looked into any temporal studies that could provide a view of the situation.

Data were collected from official government sources where possible. This process involved, among other things, personal communications with relevant professionals (Bank staff, experts at relevant governmental institutions such as Ministries of Environment, NGOs, etc.) and Internet searches, in order to determine appropriate local officials and sources to contact directly. If no contact could be established, information was obtained either from Web pages or relevant publications. Regional Table 2 provides a list of institutions linked to air quality monitoring throughout the region.

Once collected, all information was summarized in regional tables on ambient air quality standards, emission inventories, characteristics of monitoring networks, and historical data by pollutant. Each of these tables is presented and discussed in the appropriate section below. Monitoring and air quality data are synthesized spatially in an air quality map, which, together with information on availability of resources to manage air quality helps identify vulnerability of selected urban centers to air pollution. The map, the methodology and findings of the map, as well as an analysis of vulnerability are presented in this document's section on the air quality map.

5. AMBIENT AIR QUALITY STANDARDS

An essential component of an air quality management program is the legal framework that establishes local ambient air quality standards of various types of local pollutants, such as particulate matter (often of different size categories), ozone precursors (such as non-methane hydrocarbons or oxides of nitrogen), air toxics (such as ammonia or 1,3 butadiene), and other pollutants such as lead or carbon monoxide. Such standards are often used as instruments to establish legally enforceable air quality objectives. They identify which pollutants should be monitored and what levels are deemed to be acceptable for some scientifically based objectives, and help determine what types of government intervention might be necessary to ensure compliance.

Regional Table 3 summarizes the ambient air quality standards defined by air quality management legislation in each country, as well as international benchmarks provided by the standards of the US EPA, EU, the State of California, and WHO reference values for selected pollutants.[38]

Air quality concentration standards are commonly dictated by national or city regulations. In the absence of regulations, some urban centers use international standards as a benchmark. In Latin America, international references tend to be either the US NAAQS or the WHO guidelines, rather than those of the European Union. Ideally, localized standards are based on empirically derived health-related impacts; in practice, however, because most countries in the region lack sufficient resources or research capabilities to develop local regulations based on scientific evidence, they often base their own standards on international benchmarks such as those of the NAAQS or WHO guidelines.

It is a policy issue and a sovereign decision to determine which specific groups at risk should be protected by the standards and what degree of risk is considered to be acceptable. Therefore, changes in international guidelines such as those of the WHO might not have any direct impact on local standards, but implicitly affect the level of risk each nation is willing to accept.

WHO is expected to revise its guidelines for four criteria pollutants in the summer of 2006. These revised guidelines will set reference values for particulate matter for the first time.[39] These ambient concentration reference values will be substantially more stringent than current standards under the NAAQS, for both PM_{10} and $PM_{2.5}$. They will also tighten recommended ambient concentrations for ozone and SO_2.[40] In the present analysis, WHO guidelines do not refer to these expected revisions.

Regional Table 3 provides a summary of primary[41] [42] air quality concentration standards for conventional[43] pollutants. It also includes the standards used by the US EPA, California, EU, and the WHO reference values

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[38] A detailed comparison of international legislation regulating air quality management was recently carried out by IDEAM (Instituto de Hidrología, Meteorología y Estudios Ambientales–Colombia), and it is available on its Web page. This document, entitled "*Documento Soporte Norma de Calidad del Aire,*" compares standards of pollutants, air quality indexes, air quality emergency planning, etc. For more details refer to: http://www.ideam.gov.co/biblio/paginaabierta/discusion.htm.

[39] No threshold value for harmful effects has yet been determined. However, WHO has chosen to set as guidelines, values which, if achieved, would be expected to result in significantly reduced rates of adverse health effects. WHO still stresses that there is a need to reduce exposure to non-threshold pollutants even where current concentrations are close to or below the proposed guidelines.

[40] The new air quality guideline (AQG) values are summarized in the following table:

Pollutant	Averaging Time	AQG Value (μg/m³)
PM_{10}	1 year	20
	24 hours (99th percentile)	50
$PM_{2.5}$	1 year	10
	24 hours (99th percentile)	25
O_3	8 hours, daily maximum	100
SO_2	24 hours	20

[41] To avoid confusion, the definition of primary and secondary standards used in this study is that of the US EPA (impact on human health versus impact on the environment). Some countries use a different definition for primary and secondary standards, where both standards are related to effects on human health, but the difference lies in the period of exposure: short-term exposure (primary standard) and chronic exposure (secondary standard). Regional Table 4 provides a summary of primary standards based on the US EPA's definition. If any standards fall under the second definition of secondary standard, these are included in the same table under the appropriate period. For additional information refer to footnote 36.

which serve as a benchmark for international comparison. Note that WHO reference values for all pollutants are always more stringent than the NAAQS.

Most selected countries in the region (14 of the 19 selected)[44] have set standards for ambient air quality concentrations. Four Central American countries—Guatemala, Honduras, Nicaragua, and Panama—are exceptions, and instead have used a combination of the WHO guidelines and US NAAQS as reference values instead. In addition, some urban centers, such as the Province and City of Buenos Aires and Mendoza in Argentina, also set their own standards defined by local legislation.[45]

When cities and countries specify PM_{10} or $PM_{2.5}$ standards, they tend to be similar to those of the US NAAQS. However, standards for gases tend to differ—both in average concentrations and averaging times—by country and sometimes even by urban centers within the same country. Normally, the local standard tends to be more stringent than the national standard.

A small number of countries and urban centers have current standards that stand out within the region and in comparison to international benchmarks. The most stringent standards are found in Uruguay,[46] while the most permissive were, until very recently, found in Colombia.[47] The most outdated standards, and probably the reason why they are not commonly used, are those set by the national law in Argentina.[48]

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[42] Few countries have set primary and secondary standards. One example is Brazil, where primary standards refer to effects on human health and secondary standards refer to effects on the environment (flora, fauna, etc.).

[43] There are standards for nonconventional pollutants, but these beyond the scope of this study and therefore are not reported.

[44] Standards representing Uruguay, which has no national ambient air quality standards, are those for the city of Montevideo. No information regarding availability of standards is available for Paraguay.

[45] Until very recently, Bogotá also set locally defined standards, but these have been replaced by a national standard.

[46] Uruguay has no national standards but Montevideo has a decree that sets the standards to be used. These standards tend to be more stringent than those of the US NAAQS and are very similar to the guidelines of the WHO. Because Montevideo's standards for most pollutants are closer to WHO reference values, which are stricter than those of the US NAAQS, it could be considered one of the most aggressive urban centers in terms of standards, especially for SO_2, NO_2, O_3, and TSP. The exception is the annual standard for PM_{10} (60 $\mu g/m^3$) which is generally set at 50 $\mu g/m^3$ in the entire region, except for Bogotá (80 $\mu g/m^3$) and Mendoza (100 $\mu g/m^3$).

[47] Until recently Colombia's standards were generally more permissive compared to the entire region. Colombia's national law set standards for gases and TSP which were different, and generally less strict (CO, SO_2 and TSP), than all international reference values. This legislation did not provide for standards for PM_{10}. The DAMA resolution that set the standards used in Bogotá, although stricter than the national law for CO and SO_2, was still less strict than international benchmarks and other countries' standards for CO, NO_2, PM_{10}, and TSP. By contrast, the new resolution provides a daily standard for PM_{10} equal to that of the US NAAQS, and an annual standard which by 2011 will also be equal to that of the US NAAQS (beginning at 70 $\mu g/m^3$, decreasing to 60 $\mu g/m^3$ by 2009, and ending at 50 $\mu g/m^3$ by 2011). With respect to gases, the new legislation introduced an 8-hour standard that, together with the new 1-hour ozone standard, became the strictest ozone standards in the entire region. This legislation also introduces stricter standards for all other gases (SO_2 and NO_2).

[48] Argentina's national law sets country standards but none of the urban centers for which data were gathered (Buenos Aires, Bahia Blanca, Mendoza, and Córdoba) uses them; instead they use local regulations (e.g., Bahia Blanca uses the standards established by the Province of Buenos Aires). National legislation does not provide standards for PM_{10} and defines less stringent standards for CO and NO_2 and more stringent standards for SO_2, O_3, and TSP than those of the US NAAQS. By contrast, local legislation generally provides standards for PM_{10} (equal to those of the US NAAQS) and very closely follows the standards of the US NAAQS for gases, thus providing less stringent standards for CO and NO_2 and more stringent standards for SO_2 and O_3 when compared to the National Law. The main exception is the legislation of the City of Buenos Aires (Ordinance 39.025). The latter sets the daily standard for PM_{10} at the US NAAQS's level but sets standards for gases using averaging times not seen in any other country included in the study (i.e., 20-minute standards for CO, SO_2, NO_2, and O_3). Law 1356 of 2004 of the City of Buenos Aires, which includes updated standards for gases very similar if not equal to those of the US NAAQS, will revoke the standards of Ordinance 39.025 once it becomes regulated. In addition, the new law includes an annual standard for PM_{10} and daily and annual standards for $PM_{2.5}$ at the same levels as those of the US NAAQS.

Some standards have changed over time for different reasons. In some cases the standards were no longer considered pertinent (e.g., the TSP standard was removed from the NAAQS), or became obsolete (episodic averaging time of O_3 in the NAAQS was increased from one to eight hours). In other cases, standards are tightened as air quality improves in response to policies to reduce air pollution, especially in cases where the standards are tied to legally enforceable policies. Mexico has recently adopted stricter standards for PM_{10} and total suspended particles. In Chile, modifications to the most current standards have already been proposed and are currently under review by the National Commission for Environment (CONAMA); they are expected to take effect in 2006.[49] In April 2006 Colombia published a resolution that establishes new and more stringent standards than those they replace.[50]

Analysis by Pollutant

Figures 2 to 5 depict the availability of standards across the region and compare them to international benchmarks (US NAAQS and WHO guidelines). The estimated percentages are based on the information presented in Regional Table 3.[51]

Particulate Matter (PM_{10}, $PM_{2.5}$, TSP)

In terms of mortality, particulate matter is the pollutant with the highest risk to human health. The risk seems to come both from the composition of the particle and its size. Various studies show that smaller particle sizes are associated with higher levels of toxicity,[52] probably related to the inability of the human body to flush away these particles. As a result, as PM regulation has progressed, efforts have focused on more and more regulation of smaller particle size. Thus, in the US, for example, a general TSP standard was replaced in 1987 with standards for PM10, and supplemented with standards for PM2.5 in 1997.

Within Latin America, 12 of 14 countries that set PM standards do so for PM_{10}. Two (Argentina and Venezuela) set standards only for TSP, while four—the Dominican Republic, Ecuador, El Salvador, and Mexico—also set standards for $PM_{2.5}$. The fact that many more do not have $PM_{2.5}$ standards, and several countries do not even have PM_{10} standards, is cause for concern because it suggests that the standards they have in place may not be based on associated health–based risks. Four countries (Guatemala, Honduras, Nicaragua, and Panama) have no particulate standards at all. This information is summarized in Figure 2.

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[49] In order to counter deteriorating air pollution trends, cities such as Santiago and Mexico City, usually ranked among the most polluted cities in the region in recent decades, have been forced to undertake integrated air quality management plans. Besides their relative improvement to air quality, integrated plans have resulted in stronger institutional and policy frameworks to ensure economic growth while steering ambient concentration, although still high, toward acceptable thresholds.

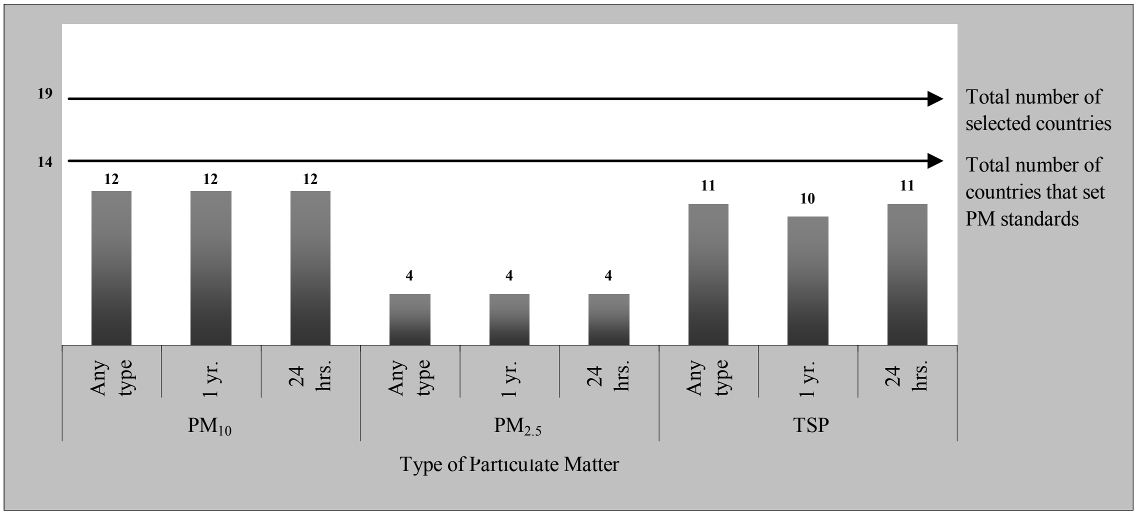
[50] Ministry of Health Decree 02/1982 and DAMA Resolution 1208/2003.

[51] Only national standards are considered; locally established standards are not included with the exception of Uruguay's. For Chile, the 2004 standard is used.

[52] Ostro, Bart. 2004. Outdoor Air Pollution: Assessing the Environmental Burden of Disease at National and Local Levels. Environment Disease Series, N 5. WHO, Geneva 2004.

Cohen, A.J., Anderson, H.R., Ostro, B., Pandey, K.D., Krzyzanowski, M., Kuenzli, N., Gutschmidt, K., Pope, C.A., Romieu, I., Samet, J.M., and Smith, K.R. 2004. Mortality Impacts of Urban Air Pollution. In Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors, eds. M. Ezzati, A.D. López, A. Rodgers, and C.U.J.L. Murray, vol. 2, pp. Geneva: World Health Organization.

Figure 2: Availability of Ambient Air Quality Standards for Particulate Matter across the Region (number of selected countries)



Notes:

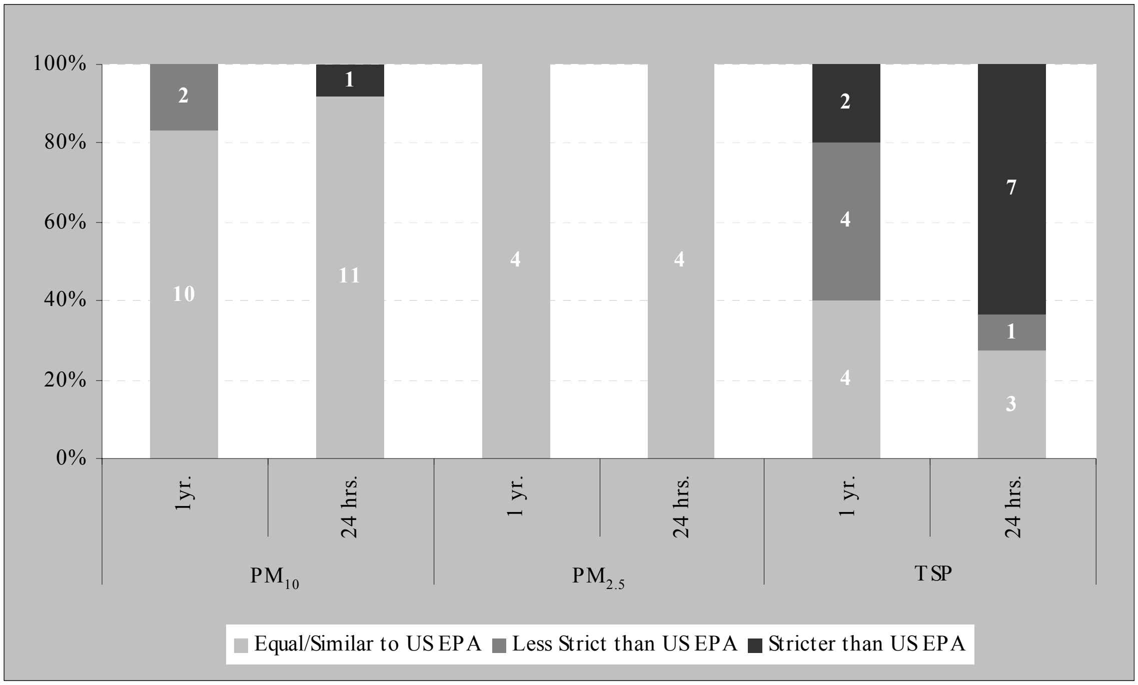
1. Estimated values are based on the information presented in Regional Table 3: Monitoring Standards across Countries (including WHO, EU, and US EPA standards), and only consider Argentina's National Law and Chile's current legislation.
2. Category *Any Type* refers to availability of standards for any averaging time.
3. With respect to PM_{10}: Local legislation in Argentina, specifically that of the Province and City of Buenos Aires (new legislation), sets annual and 24-hour standards for PM_{10}. Legislation in Bogotá also includes annual and 24-hour standards for PM_{10}. This information is not included in the graph.
4. $PM_{2.5}$: In addition to what is presented in the graph, the City of Buenos Aires' new legislation, which will revoke the current standards once it is regulated, sets standards for $PM_{2.5}$

Figure 3 compares local particulate matter standards to those of the US NAAQS. It shows that PM_{10} standards across the region are similar to those established by US EPA. Among those countries with PM_{10} standards, most have daily and annual PM_{10} standards nearly identical to those of the US NAAQS. The exceptions are Colombia (70 µg/m³ for 1 year) and Montevideo (60 µg/m³ for 1 year) which have less stringent values, and Mexico which has stricter standards. In September 2005 Mexico adopted changes to its 24-hour PM_{10} and TSP standards by lowering their values to 120 µg/m³ and 210 µg/m³, respectively, from the previous values of 150 µg/m³ and 260 µg/m³. Mendoza also has less stringent standards (100 µg/m³ for 1 year) than the US NAAQS.

Although TSP standards are no longer specified in the US NAAQS, daily and annual TSP standards are still used by more than half of selected countries, respectively (Figure 2), as a means of keeping historical track and assessing the impacts of erosion, unpaved roads, and other sources of gross particulate matter. In two cases, TSP is the only category of particulate monitored and therefore has been used as the second-best and only alternative[53] to monitoring PM_{10} and $PM_{2.5}$. The latter is the case of Venezuela and Argentina's National Law, which provide standards only for TSP; Venezuela sets TSP standards equal to those of the US EPA, while Argentina only sets a daily standard which is stricter than that of the US EPA.

[53] WHO considers it misleading to offer guidelines on air quality for particles in suspension based on TSP. Therefore, since 1987 it has recommended monitoring particles smaller than 10 micrometers.

Figure 3: Comparison of Particulate Matter Standards to those of US NAAQS (relative to the number of urban centers with air quality standards for each specific pollutant)



Notes:

1. The numbers inside the bars indicate the number of urban centers with standards compared to those of the US EPA; the vertical axis shows the relative weight.
2. Estimated percentages are based on the information presented in Regional Table 3: Monitoring Standards across Countries (including WHO, EU, and EPA standards)[2, 3] and only consider Argentina's National Law, and Chile's current legislation.
3. With respect to PM_{10}:
   - The graph does not include the daily and annual standards set by local legislation in Argentina (Province and City of Buenos Aires) which are identical in value to those of the US EPA.
4. The graph does not include the daily and annual standards of $PM_{2.5}$ considered in the City of Buenos Aires' new legislation which, once regulated, will replace the current law that does not provide standards for fine particles. $PM_{2.5}$ standards are equal in value to those of the US EPA.

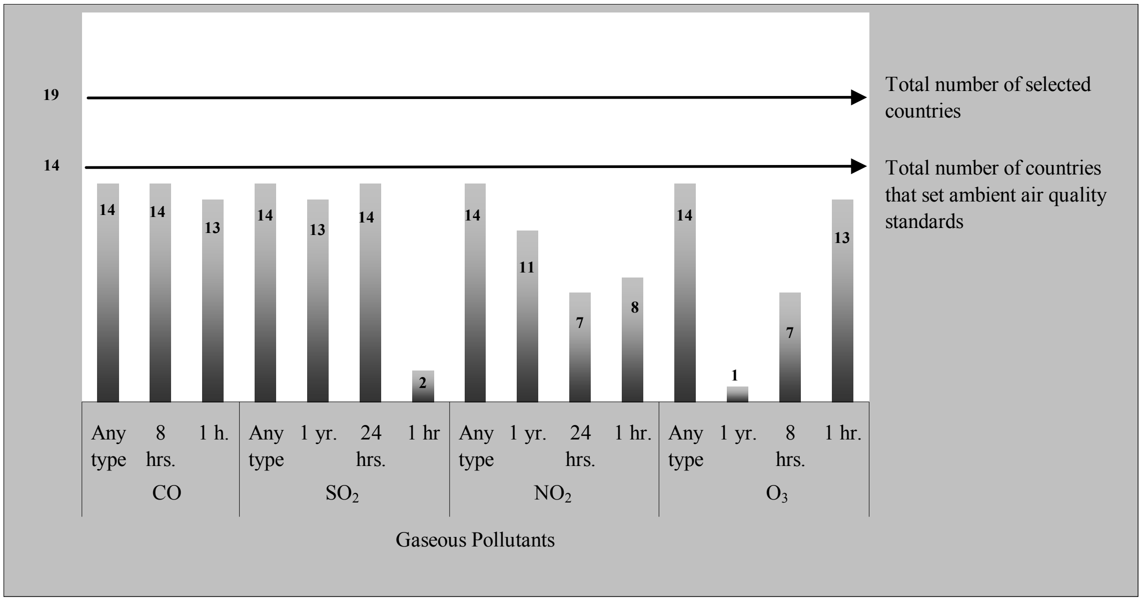
Figure 3 shows that 3 countries set daily TSP standards at a level similar level to that of the US NAAQS, while 7 countries have a more stringent daily standard compared to the same benchmark. Colombia is the only country whose National Law sets a less strict daily TSP standard; however, this value is not very relevant because Colombian legislation provides for PM_{10} standards. With respect to the US EPA's annual TSP reference standard (75 $\mu g/m^3$), this value is generally stricter than local annual standards with the exception of those of Jamaica and Uruguay, both of which have an annual standard of 60 $\mu g/m^3$.

Gaseous pollutants (CO, SO_2, NO_2, O_3)

Among countries whose legislation provides ambient air quality standards (14 of 19 countries), all set some type of standards for gases. Averaging times for CO and SO_2 are noticeably consistent across countries, while those for NO_2 and O_3 are quite variable (fewer than half have daily and hourly standards for NO_2, or an 8-hour standard for O_3).

Figure 4 depicts the availability of standards for gases across the region and Figure 5 compares local standards to those of the US NAAQS and WHO guidelines (for NO_2 and O_3).

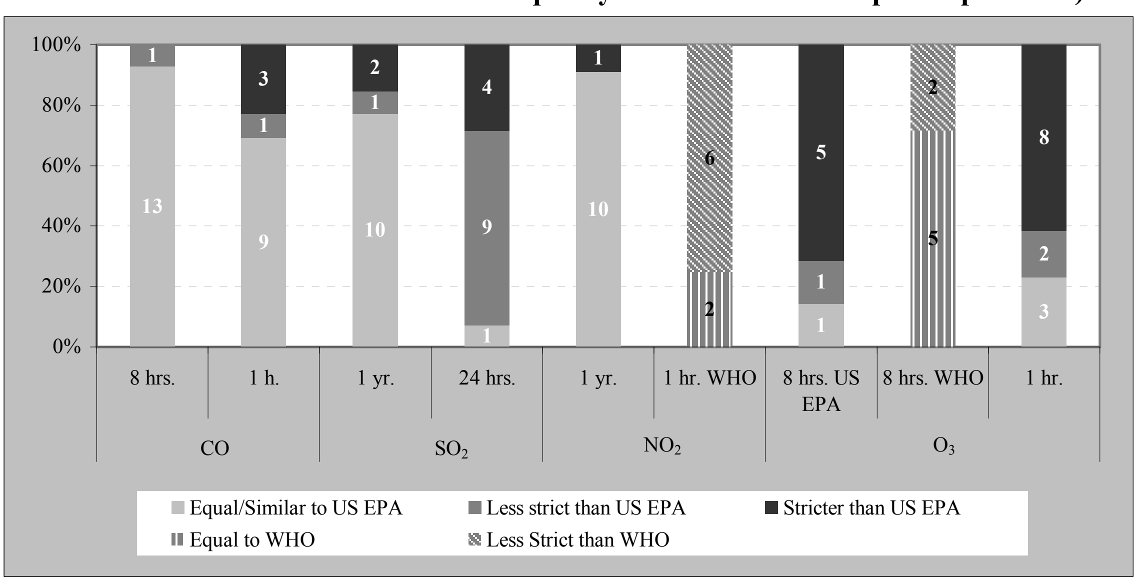
Figure 4: Availability of Ambient Air Quality Standards for gGses across the Region (number of selected countries)



Notes:

1. Estimated values are based on the information presented in Regional Table 3: Monitoring standards across countries (including WHO, EU, and EPA standards)[2, 3] and only consider Argentina's National Law and Chile's current legislation.
2. Category *Any Type* refers to availability of standards for any averaging time.
3. In addition to what is presented in the graph:
   - With respect to NO_2:
     - Local legislation in Argentina (Province and City of Buenos Aires) sets an annual standard for NO_2. The local legislation in the Province of Buenos Aires and Bogotá also considers a 1-hour standard.
     - A modification to the current legislation in Chile, which will come into effect in 2006, includes an additional 1-hour standard.
   - With respect to CO, local legislation in Argentina (Province and City of Buenos Aires) sets 1- and 8-hour standards.
   - With respect to SO_2, local legislation in Argentina (Province and City of Buenos Aires) sets annual, daily and 3-hour standards for SO_2.
   - With respect to O_3:
     - Local legislation in Argentina (City of Buenos Aires) considers an 8-hour standard.
     - Local legislation in Argentina (Province and City of Buenos Aires) considers a 1-hour standard.
     - The modifications to the current Chilean law, which will come into effect in 2006, replace the 1-hour standard with an 8-hour standard.

Figure 5: Comparison of Ambient Air Quality Standards to US NAAQS and WHO Guidelines (relative to the number of urban centers with air quality standards for each specific pollutant)



Notes:
1. The numbers inside the bars indicate the number of urban centers with standards compared to those of the US EPA or WHO; the relative weight can be observed in the vertical axis.
2. The 1-hour standard for NO_2 is compared to WHO reference values, because there is no US EPA standard for this pollutant for a 1-hour averaging time. The 8-hour standard for O_3 is also compared to that of the WHO because several countries follow this reference value.
3. Estimated percentages are based on the information presented in Regional Table 3: Monitoring Standards across Countries (including WHO, EU, and EPA Standards)[2, 3] and only consider Argentina's national laws and Chile's current legislation.
4. In addition to what is presented in the graph:
   - With respect to NO_2:
     - Local legislation in Argentina (Province and City of Buenos Aires) considers an annual NO_2 standard that is equal to that of the US EPA.
     - Chile's current legislation will be modified and become effective in 2006. It includes an additional 1-hour standard, less strict than that of the WHO.
   - With respect to CO:
     - Local legislation in Argentina (Province and City of Buenos Aires) sets stricter 1- and 8-hour values for CO than those in the national laws; these values are identical in value to those of the US EPA and less strict than those of the WHO.
     - Modifications to Chile's current standard, which will become effective in 2006, set stricter 1- and 8-hour values for CO, identical in value to those of the WHO.
   - With respect to SO_2:
     - Local legislation in Argentina (Province and City of Buenos Aires) sets annual and daily standards for SO_2, similar to and slightly less strict in value than those of the US EPA, respectively.
     - There are no international benchmarks for 3-hour standards.
     - Modifications to Chile's current law set stricter 24-hour standards, even stricter in value than those of the US EPA.
   - With respect to O_3:
     - Local legislation in Argentina (City of Buenos Aires) considers an 8-hour standard equal in value to that of the US EPA in the first case and stricter in the second.
     - Local legislation in Argentina (Province and City of Buenos Aires) considers a 1-hour standard equal in value to that of the US EPA in the first case and stricter in the second.
     - Modifications to Chile's current law, which will become effective in 2006, change the 1-hour standard to an 8-hour standard, which is stricter than that of the US EPA.

Each of these gaseous pollutants is discussed in more detail in Annex 2.

6. EMISSION INVENTORIES

Emission inventories are a key part of a sound air quality management program. They identify the sources of emissions and thus help allocate responsibility for observed pollution concentrations to different sectors. In so doing, they provide insight and guidance on how to control specific pollutants of concern.

Just by identifying the availability of emission inventories among selected urban centers, and not even evaluating their qualitative characteristics (e.g., source completeness, pollutant completeness or frequency), the situation can be described as inadequate. Regional Tables 4 and 5 summarize the results of the different emission inventory studies undertaken in the selected urban centers; Regional Table 4 presents the results in absolute values while Regional Table 5 presents the results in percentages by pollutant (i.e., how much of a specific pollutant is generated by fixed, mobile, or natural sources).[54] [55]

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[54] Population numbers were not included in these tables because in most cases emission inventories did not provide data on population inhabiting the area under study. Population numbers for the selected urban areas are available in Regional Table 1.

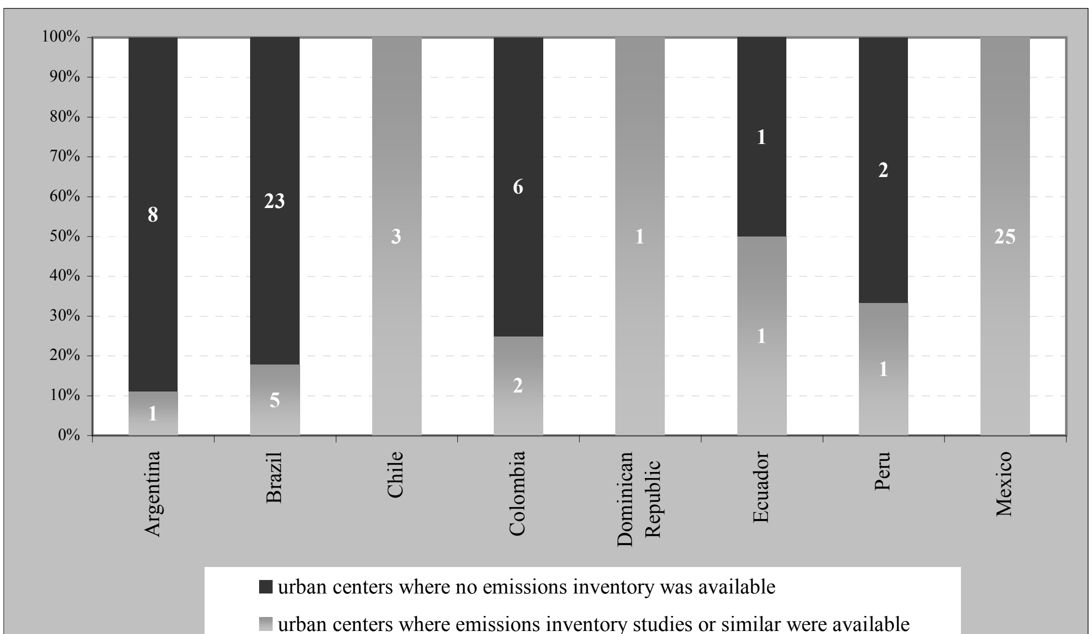
[55] No comparisons of the relative weight of pollutants by source are made because the impact of each on human health is influenced by several factors for which there is limited information. These factors include toxicity, reactivity in the atmosphere, as well as the dispersion conditions that affect the level and location of concentrations and ultimately exposure to pollutants.

Emissions inventories were found in only 39 of the 100 selected urban centers,[56] representing about 54% of 187.5 million people who live in all selected urban centers. These 39 cities are located in Argentina, Brazil, Chile, Colombia, the Dominican Republic, Ecuador, Mexico, and Peru. Mexico stands out as the only country for which emission inventories were found for all selected urban centers, since it has developed a national emission inventory which can be disaggregated to the municipal level. Some urban centers, including the ZMVM, the Puebla Metropolitan Area, Guadalajara, Monterrey, Ciudad Juárez, Mexicali, Tijuana–Rosarito, and Toluca, had previously carried out independent emission inventories studies as well. A profile of available emissions inventories by country is presented in Figure 6 below.

Differences among methodologies used to estimate the various inventories—not only among different cities, but often even among inventories carried out in the same city by different groups or at different times—make direct comparison of emissions sources difficult.

Mobile sources are mainly accountable for direct emissions of CO, NO_{x},, and hydrocarbons, while sulfur oxides tend to be emitted directly by fixed sources, as Regional Table 5 shows. While most emission inventories report particulate matter as mainly originating from fixed and especially natural sources, particularly when measured as TSP, this tends to overemphasize large particles that have less impact on human health than the particles emitted by combustion processes, such as those used in the transport sector.

Figure 6: Availability of Emission Inventories (relative to the number of selected urban centers by country)



- Information presented in the graph was extracted from Regional Table 4: Summarized emission inventory data.
- The values reflect the number of urban centers where emission inventory studies were found, rather than the number of emission inventories.

[56] The fact that more urban areas do not undertake emissions inventories is probably a result of the high costs of implementation. Recife Metropolitan Region, Belo Horizonte Metropolitan Region, Arequipa, and Trujillo are supposed to have undertaken emission inventory studies, but because no confirmation of this was received, they were not included in this estimated number. In addition, urban centers with partial or incomplete inventories (Cochabamba, San José, and Guayaquil) were not included in this number.

In addition to playing a significant role in direct emissions of PM_{10} and $PM_{2.5}$, mobile sources play a significant role in the formation of secondary particulates and ozone because they account for an important share of emissions of NOx, VOCs, and sulfates.

7. MONITORING CAPABILITY

As part of a sound air quality management program, monitoring of ambient concentrations of certain pollutants helps to identify which pollutants are reaching concentration levels that are dangerous to the population, and where those populations are at risk of exposure to those pollutants. Annex 3 describes the characteristics of a monitoring network and the methods utilized for sampling air quality concentrations.

Air quality monitoring among selected urban centers is generally weak, with only a few exceptions, and the circumstances in which that monitoring occurs vary substantially, resulting in different standards of geographic density of monitoring stations, types of analyzers available at those stations, and the number of pollutants monitored, among other differences.

In some urban centers, monitoring data are generated by only one station; in others, no ongoing air quality monitoring is in place, and only information from single or occasional studies is available. Even among those urban centers where some type of permanent monitoring is carried out, resources to monitor air quality, the methods and instruments utilized for monitoring, the precision of the monitoring equipment used, the know-how to maintain, calibrate, and operate monitoring equipment, the characteristics of the laboratories where data are analyzed, and the quality assurance criteria and methods used—including criteria to determine representativeness of the data and fulfillment of monitoring conditions required by the instruments utilized—can vary drastically from place to place, and can affect the quality of the air quality monitoring data. Given the volume of data for the region, this report cannot evaluate the quality of the monitoring networks or their implementation, nor compare them on objective criteria such as completeness,[57] representativeness,[58] reliability,[59] or transparency.[60]

Regional Table 6 summarizes the characteristics of air quality monitoring resources available in each urban area. It provides information on monitoring network availability,[61] size of the network, pollutants monitored, methods of monitoring, and any observation that helps in understanding the information presented.

Ambient air quality monitoring among selected urban centers is generally weak. Information on monitoring capacity was collected for 98 of the 100 selected urban centers,[62] of which only 59, representing 79% of the population living in all selected urban centers, have some type of permanent monitoring consisting of at least a single station.[63] All other urban centers either had a network or at least one station in the past that is no longer in operation,[64] have undertaken temporal studies,[65] or have no monitoring at all. Figure 7 summarizes the availability of monitoring capability across the region.

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[57] Refers to capability to monitor all criteria pollutants and relevant meteorological parameters.

[58] Refers to coverage in space, time, sources, population, and land use.

[59] Refers to quality assurance, audits, and assessment of equipment.

[60] Refers to availability of periodic air quality reports and real-time public Internet accessibility, among others.

[61] It is difficult to determine whether a group of stations form a monitoring network because such a determination depends on the network's design requirements. In order to facilitate the analysis for this study, however, we have defined a monitoring network as a group of at least two stations that monitor ambient concentrations on a regular basis.

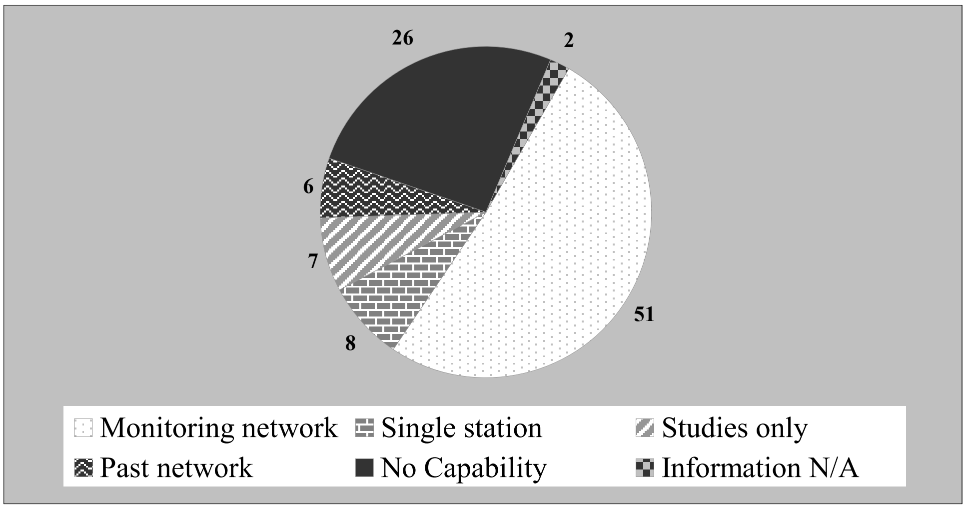
[62] The two urban centers for which no information was found are Mar del Plata in Argentina and Asunción in Paraguay.

[63] Fifty-one urban centers—representing 77% of the sample population—have a monitoring network defined, for the purpose of this report, as at least two stations that monitor air quality on a regular basis. Another 8 urban centers, representing 2% of the sample population, have one station.

[64] Six urban centers fall in this category: Córdoba in Argentina; Cartagena and Cúcuta in Colombia; Managua in Nicaragua; and Chihuahua and Hermosillo in Mexico.

Focusing on the 59 urban centers with permanent monitoring, one can observe some deficiencies when looking at the methods used and the capability to monitor selected pollutants. First, of the 59 urban centers with permanent monitoring, only 40 are equipped with automatic or both automatic and manual analyzers, while 18 are only equipped with manual analyzers (Figure 8). With regard to gaseous pollutants, in particular O_3 and CO, where the standards are defined for periods of one or several hours only, it is important to have automatic analyzers that can provide real-time data comparable to the standards. The only alternative to obtain similar data is to routinely collect and analyze manual samples, which is often difficult due to the time and resources involved. For example, in all selected urban centers where gases are monitored with manual methods, the exposure time of analyzers was not less that one week for O_3 and CO and 24 hours for SO_2 and NO_2. Therefore, the data obtained with this method are not comparable to the hourly or several-hour standards, and compliance with these standards cannot be verified.[66]

Figure 7: Monitoring Capability across Selected Urban Centers in the Region



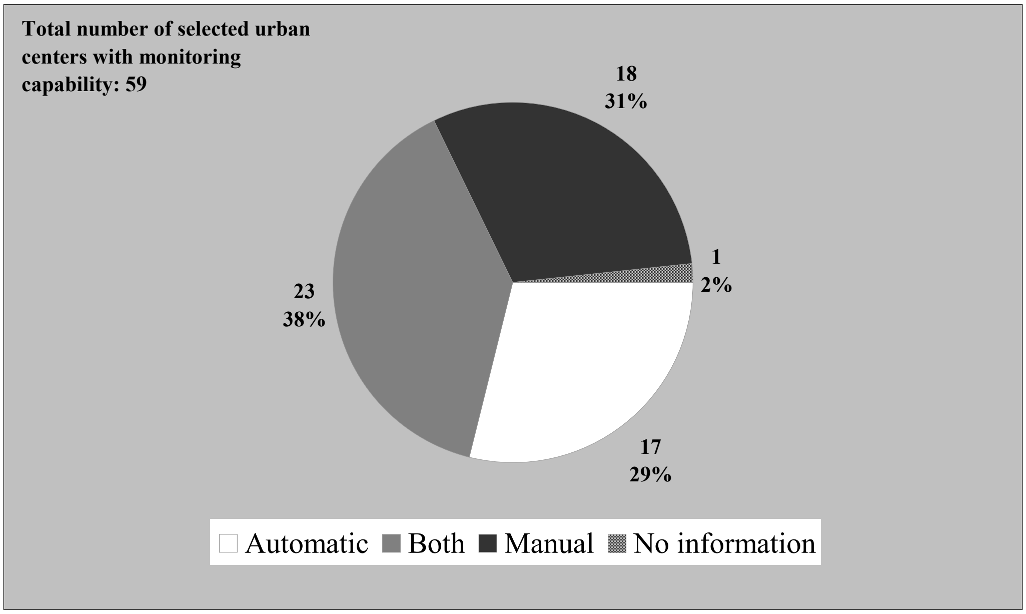
Notes:

- Information extracted from Regional Table 6: Characteristics of Monitoring Capability across the Region.
- Although Maracaibo in Venezuela has a monitoring network, there is no available information on methods utilized.
- For the purpose of the study, Monitoring Network is defined as at least two stations providing data on a regular basis.

[65] Temporal studies to monitor air quality were found in seven of the urban centers with no permanent monitoring capability, and are briefly described in Regional Table 7.

[66] Among the 51 urban centers with a monitoring network, nearly three-quarters are equipped with automatic analyzers, and more than half of these also have manual analyzers, while among the 8 single-station urban centers, automatic analyzers are less available: only three are equipped with this type of analyzer.

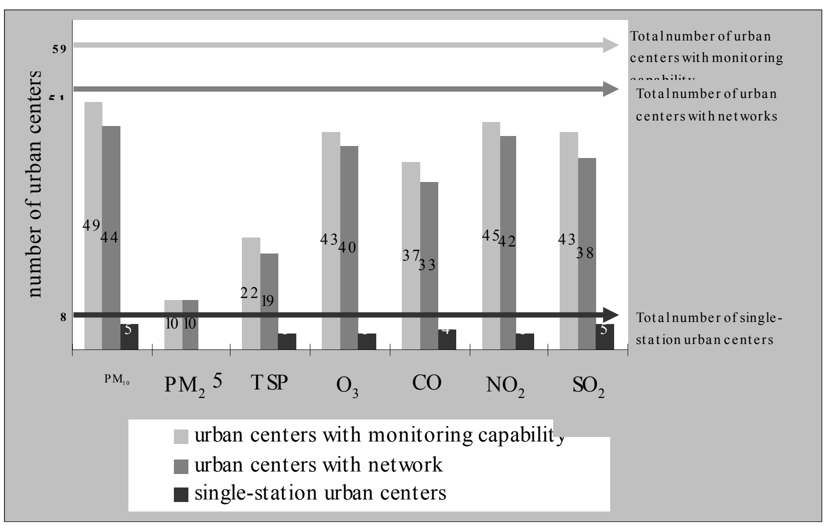
Figure 8: Monitoring Methods Used in Selected Urban Centers with Monitoring Capability (number and percentage)



Notes:

- Information for the chart is extracted from Regional Table 6: Characteristics of Monitoring Capability across the Region.
- Category *No information* includes the city of Maracaibo in Venezuela which has a network; no detailed information about the methods used for monitoring was found.

Figure 9: Monitoring Capability by Pollutant across Selected Urban Centers with Monitoring Capability



Note: Information extracted from Regional Table 6: Characteristics of Monitoring Capability across the Region.

Distribution of resources to monitor air quality among selected countries is not clearly correlated with development indicators such as GDP, as one might otherwise expect. While advanced monitoring networks are indeed found in Brazil, Chile, and Mexico—countries with relatively high GDP per capita—this capability tends to be limited to a few cities, particularly in Brazil and Chile. In addition, in certain relatively wealthy countries where one would expect to find advanced monitoring capability—namely Argentina and Costa Rica—air quality monitoring networks are rudimentary or nonexistent. Elsewhere in Central America and the Caribbean, air quality monitoring networks are also generally poor, in line with what one might expect when looking at GDP. Distribution of monitoring capability across selected countries is shown in Figure 10.

The most technically advanced monitoring networks in the region are found in Mexico, Brazil, and Chile. The Mexico City, São Paulo, and Santiago Metropolitan Regions have allocated substantial resources to identify the origins and impacts of air quality degradation and, as a result, have developed highly advanced monitoring networks capable of delivering real-time data.

Elsewhere in Mexico, 12 of the selected urban centers, distributed throughout the country, have a monitoring network (representing 52% of selected urban centers in Mexico, as shown in Figure 10, and inhabited by 81% of the population living in selected Mexican urban centers). Eleven of them, including Mexico City's network, are equipped with automatic or a combination of automatic and manual analyzers and most of them belong to Mexico's national air quality information system, SINAICA.[67] Of the remaining 12 urban centers, 3 were identified as having a single station, of which 2 are equipped with automatic analyzers. Nine selected urban centers in Mexico do not currently have any monitoring capability, although two—Chihuahua and Hermosillo—have had such capacity in the past.[68]

In Brazil, half of the 28 selected urban centers (accounting for 77% of the population living in all selected Brazilian urban centers) have a monitoring network. Of these, 10 are equipped with both automatic and manual analyzers. Another urban center, Santos, has a single, manual monitoring station.

In Chile, all three selected urban centers have monitoring capability (Figure 10); that of the Santiago Metropolitan Region is the most sophisticated and consists of seven stations providing real-time data since 1997 with advanced technology (MACAM-2). The six stations located within the urban area of Greater Valparaiso were not designed as a network, but instead were the result of local environmental regulation. These six stations belong to three different networks, two of which are private and were constructed as requirements of environmental impact assessments of specific projects implemented within the geographical area of Greater Valparaiso.[69] [70]

The relatively poor availability of air quality monitoring capacity in Argentina is somewhat of an anomaly. Of eight urban centers for which information is available, only two have monitoring networks (Buenos Aires and Mendoza), while a third, Bahia Blanca, has a single monitoring station. Córdoba has analyzers to monitor several pollutants, but this equipment is not operational because of lack of funds. In addition, two somewhat

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[67] SINAICA is a federal government initiative and serves as a national air quality information system. It is a software program that brings together and disseminates data generated by the principal automatic air quality monitoring networks through the Web site of the National Institute of Ecology (INE). Its purpose is to describe the current and historical status of air quality in the country's various urban centers. The operation and administration of the monitoring networks is the responsibility of local governments. Currently, SINAICA includes the monitoring networks of the Metropolitan Area of the Valley of Mexico, Guadalajara, Toluca, and Puebla, as well as those of Salamanca, León, Celaya, Irapuato, Monterrey, Ciudad Juárez, Tijuana–Rosarito–Tecate, and Mexicali.

[68] Although the operation and administration of the monitoring networks in Mexico is under the responsibility of the local governments, monitoring capability is distributed throughout the country. An important element that contributed to the distribution of monitoring capability throughout the country, are the incentives provided by the air quality monitoring component of the World Bank–financed *Programa Ambiental de Mexico* project at the end of the 1980s and the beginning of the 1990s, which included the donation of monitoring equipment, technical assistance, and capacity building to the entire country.

[69] In order to verify that specific projects would not affect the air quality of the geographical area where they have been developed, the environmental impact assessment of each of these projects has required the construction of a monitoring network.

[70] The Valparaiso Region has a total of nine networks (eight private and one public), but the study refers to those located within the territory of Greater Valparaiso only.

outdated temporal studies were found for Rosario. Given the size of Buenos Aires[71] and its status as the capital and business center of one of the region's largest countries, it is surprising that it has merely two stations, only one of which is equipped with automatic analyzers and monitors (PM_{10} and $PM_{2.5}$) and began operating only in August 2005.

Central American and Caribbean countries are generally at an early stage of monitoring. Many have relied on resources from various initiatives, including the SwissContact Foundation [72] as well as the work of the Central American Commission for Environment and Development (CCAD)[73] to promote the development of air quality management throughout this subregion. The former initiative has also contributed to the development of monitoring networks in Bolivia's urban centers (Red MoniCA).[74] Only three cities in Central America have full monitoring networks (San Salvador, Tegucigalpa, and Panama City), and only one of these has any form of automation (Panama City has an automatic analyzer for carbon monoxide). Managua's monitoring network is no longer operational. Several other cities in Central America have had some temporal studies (San José, Guatemala City and San Pedro Sula), but no ongoing monitoring is available. Therefore, Central America lags behind other parts of the Latin America region in terms of air quality monitoring.

The situation in the Caribbean is even worse. While the two selected urban centers do not necessarily represent the reality of this region, they are at an even earlier stage of monitoring air quality compared to the selected urban centers in Central America. The only temporal air quality monitoring study undertaken in Santo Domingo was part of a broader project financed by the World Bank, while Kingston has only one manual station measuring TSP and PM_{10}.

Among other selected countries, Colombia has almost the opposite situation as Argentina: all urban centers of at least half a million inhabitants have a monitoring network, although two, those of Cartagena and Cúcuta, are no longer in operation. Four of the six currently operational networks are fully automated.

The little information collected for selected urban centers in Venezuela indicated the existence of a national monitoring network and some independent stations operated by INTEDEP of PDVSA. These groups of monitoring stations do not work as a network. Monitoring capacity, as part of the national network, is available in the selected urban centers of Caracas, Maracaibo, Barcelona, and Valencia. Of these, the latter two only monitor TSP. PDVSA has several additional monitoring stations in Caracas and Maracaibo.

Initiatives among other selected urban centers in the region include the development of the *Plan Integral de Saneamiento Atmosférico en Lima–Callao* (PISA) as part of which the five existing monitoring stations will integrate a future network that should be ready by 2010. Moreover, Quito has created an institution devoted to

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[71] The City of Buenos Aires is a federal district composed of 48 neighborhoods (*barrios*). Greater Buenos Aires includes both the City of Buenos Aires and its 24 suburbs, known as *partidos* (municipalities). In 2001, 2.8 million people lived in the City of Buenos Aires. In 2003, 13 million people—about one-third of Argentina's population—lived within Greater Buenos Aires.

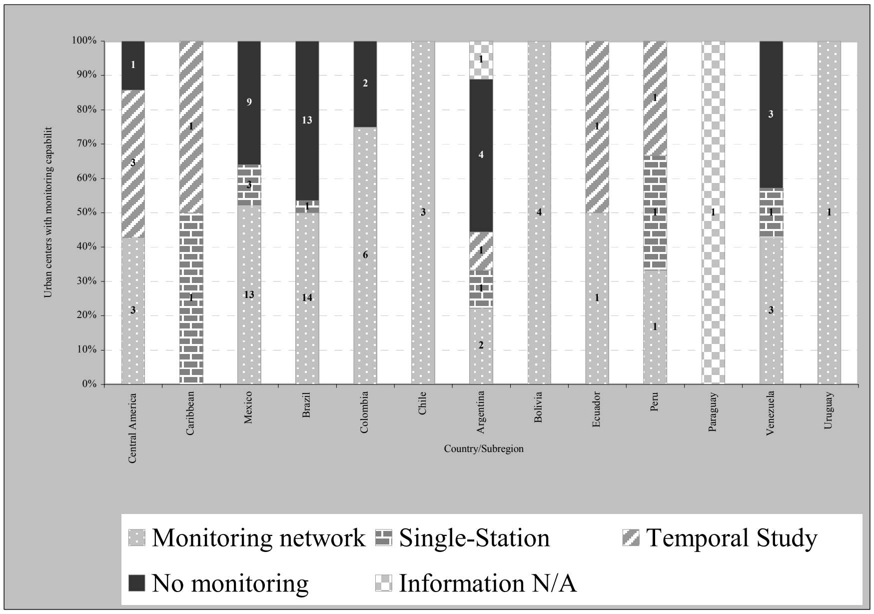
[72] The SwissContact Foundation executed the "Aire Puro" project for a period of 10 years since 1993 with funding from the Swiss Agency COSUDE. Although the project focused on vehicular emissions, it also performed air quality monitoring in all capitals of the countries involved (Costa Rica, Panama, Nicaragua, Honduras, El Salvador, and Guatemala), providing real data to raise awareness among the population and authorities of the problem of air pollution, and demonstrating the need for the creation of air quality monitoring networks.

[73] Following the abovementioned SwissContact Foundation project, CCAD (the Central American Commission for Environment and Development) is currently working on the initial stages of a long-term project to develop a Central American policy and strategy for air quality management. Under a more strategic perspective, the objective of this project for the next 10 years is to undertake a series of more integrated activities focusing on (a) strengthening coordination among institutions (environment, health, transport, etc.) and (b) harmonizing the implementation of regulations across the region (ambient concentration, quality of fuels, import of vehicles, emissions from fixed and mobile sources, monitoring and enforcement).

[74] La Paz, El Alto, and Santa Cruz are equipped with manual (both passive and active) analyzers, while the network in Cochabamba is equipped with both manual and automatic equipment.

improving the city's air quality (*Corporación para el Mejoramiento del Aire de Quito*, CORPAIRE). This institution operates and processes monitoring data of the existing network (*Red Metropolitana de Monitoreo Atmosférico de Quito*, REMMAQ) composed of 9 stations with both automatic and manual analyzers that monitor all pollutants considered in this study.

Figure 10: Geographical Distribution of Monitoring Capability across Selected Urban cCnters in the Region (relative to the number of urban centers selected by country/subregion)



Notes:

- Information extracted from Regional Table 6: Characteristics of Monitoring Capability across the Region.
- Paraguay was not included in the graph.

Disparity in availability of monitoring capability, albeit on a smaller scale, can still be seen among the most populated urban centers in each selected country.[75] With the exception of Santa Cruz in Bolivia, São Paulo in Brazil, and Guayaquil in Ecuador, the most populated urban center in each country always coincides with its capital. Nearly three-fourths of these 19 urban centers have monitoring capability; of these, more than half are equipped with automatic analyzers. Particulate matter is monitored in all urban centers with monitoring capability. In terms of gases, ozone is monitored in fewer than half of all urban centers (47%). In nearly half of these cases, it is monitored with manual analyzers only. Of the six urban centers with no monitoring capability, all—with the exceptions of Asunción, for which there is no information, and Guayaquil—are located in Central America and the Caribbean (San José, Santo Domingo, Guatemala City, and Managua).

8. AIR QUALITY DATA AVAILABILITY

While air quality is monitored in a large number of urban centers across the region as documented in the previous section, consistency of that data among different urban centers cannot be ensured because monitoring practices are not standardized. Therefore, the study focused on collecting historical ambient air quality data, where available, as a means to assess the state of air quality in each urban center.

[75] The list of most populated urban centers in each selected country includes Buenos Aires, Santa Cruz, São Paulo, Santiago, Bogotá, San José, Santo Domingo, Guayaquil, San Salvador, Guatemala City, Tegucigalpa, Kingston, Mexico City, Managua, Panama City, Asunción, Lima–Callao, Montevideo, and Caracas.

To do so, we constructed an indicator from commonly available information rather than relying on self-reported data regarding compliance with an air quality standard. Even when the latter data were available, the format in which the information is presented is often either inconclusive (for example, violations of standards reflect numbers of monitoring stations rather than a real reflection of air quality) or not particularly relevant (averaging times that bear no relation to the standard).

The indicator developed is the maximum registered ambient concentration of all selected pollutants for all relevant averaging times. This is supplemented with an indicator of the number of violations of locally defined standards since the year 2000, where available. Non-numerical data were also taken into consideration for some urban centers, that is, where numerical data are not available but information presented in graphs or brief statements in study papers provide some insight into the state of air quality. These data were obtained from permanent monitoring networks and single stations, or temporal monitoring studies.

Historical data of maximum registered ambient concentrations for relevant averaging times or violations of the locally defined standards since the year 2000, for a time horizon of several months up to 6 years, were gathered for 51 urban centers as shown in Figure 11.[76] In three cases the only data available are on TSP. In addition, no numerical data were found for 9 urban centers, but textual or graphical information presented in reports and papers reviewed for the present study have provided some insight into air quality (denoted as non-numerical data). No information was available for the remaining urban centers.

Figure 11: Data Availability (2000–2005)

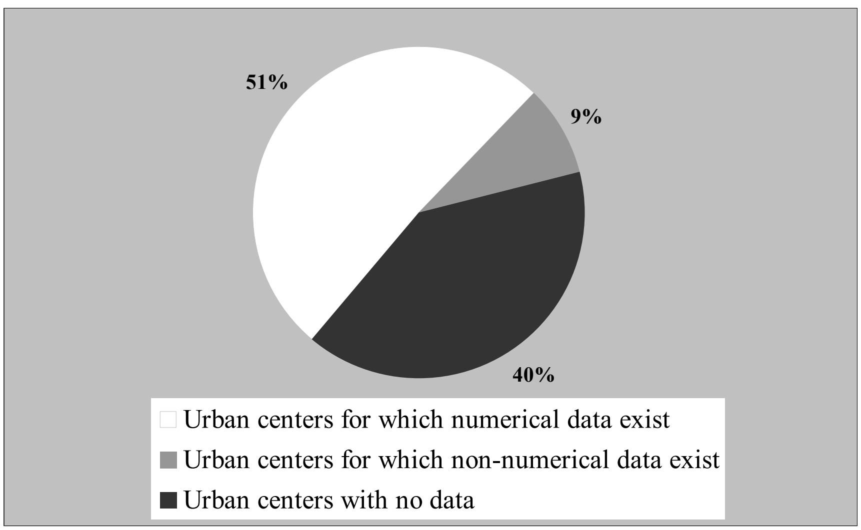


Table 1 shows a matrix of data availability compared with monitoring capability. Eighty-two percent of collected numerical data were obtained from monitoring networks (42 of the 51 urban centers where numerical data were available), 10% from single stations, 6% from studies, and 2% from previous existing monitoring capability. In 6 urban centers with monitoring networks, numerical data could not be obtained (representing 12% of monitoring networks): Mendoza in Argentina, Goiânia in Brazil, Pereira in Colombia, Mexicali and Tijuana–Rosarito in Mexico, and Maracaibo in Venezuela.

[76] In Mexicali, although O_3 historical data exist for the period 1997–1999, they were not considered in the calculation of this number because the data correspond to a period before 2000.

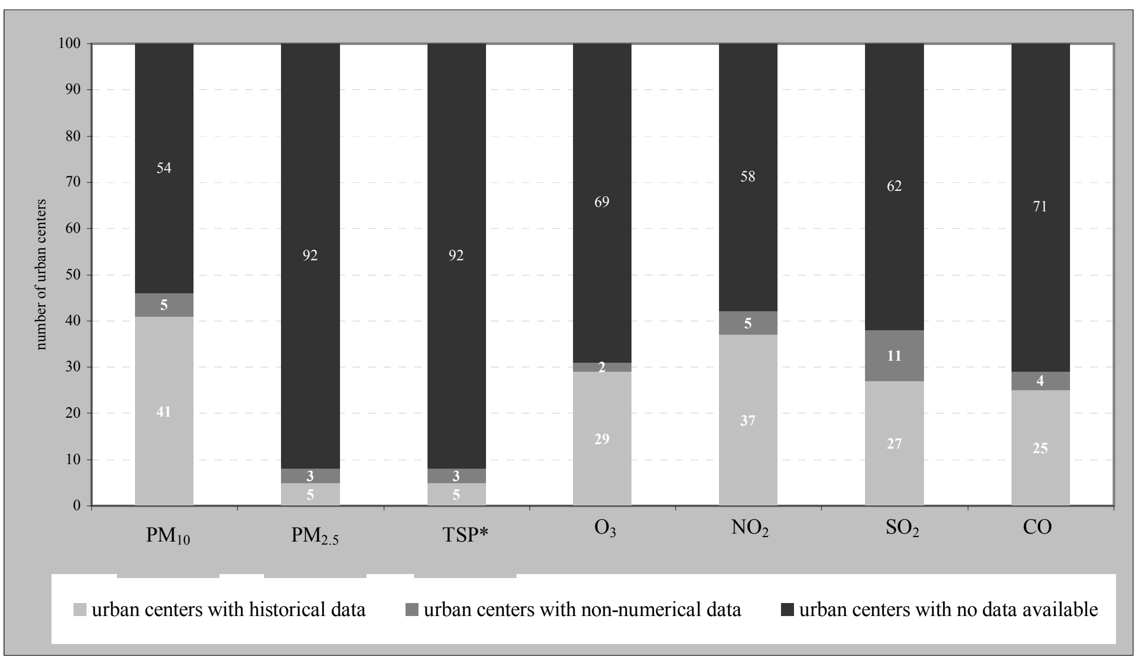
Table 1: Data Availability/Monitoring Capability

		Monitoring Capability						
		Monitoring Network	**Single station**	**Study**	**Previous Monitoring Capability**	**No Capability**	**N/A Information**	**Total Data Availability**
Data Availability	Numerical Historical Data	42	5	3	1			51
	Non-Numerical Data	3	2	3	1			9
	No Data	6	1	1*	4	24	4	40
Total Monitoring Capability		51	8	7	6	24	4	

* The studies available for the city of Rosario, Argentina, provided data prior to the year 2000. Therefore, it was classified in the category *No Data*. For further details refer to Regional Table 7: Countries with Air Quality Studies.

A breakdown of data availability by pollutant is shown in Figure 12. In the case of PM_{10}, for example, data are available for 46 urban centers, of which 5 have non-numerical data only. PM_{10} data were obtained from 38 urban centers with a monitoring network, 3 with a single station, 3 with temporal studies, and 2 from urban centers that had some type of monitoring capability in the past but none at present (Córdoba in Argentina, and Managua in Nicaragua).

Figure 12: Availability of Data by Pollutant



* TSP only includes those urban centers where data for other forms of particulate matter, PM_{10} or $PM_{2.5}$, were not available. Therefore, the "no data" value in this case is overestimated.

Only 4 urban centers had data on all selected pollutants (PM_{10}, $PM_{2.5}$, O_3, NO_2, SO_2, and CO)—São Paulo, Mexico, Quito, and Santiago—although another 16 had data on fine particulates as well. Although 10 urban centers have the capacity to monitor $PM_{2.5}$, data were found for only 8, of which 2 correspond to the results of temporal studies (Santo Domingo in the Dominican Republic and Trujillo in Peru). A summary of the length of data availability is shown in Table 2.

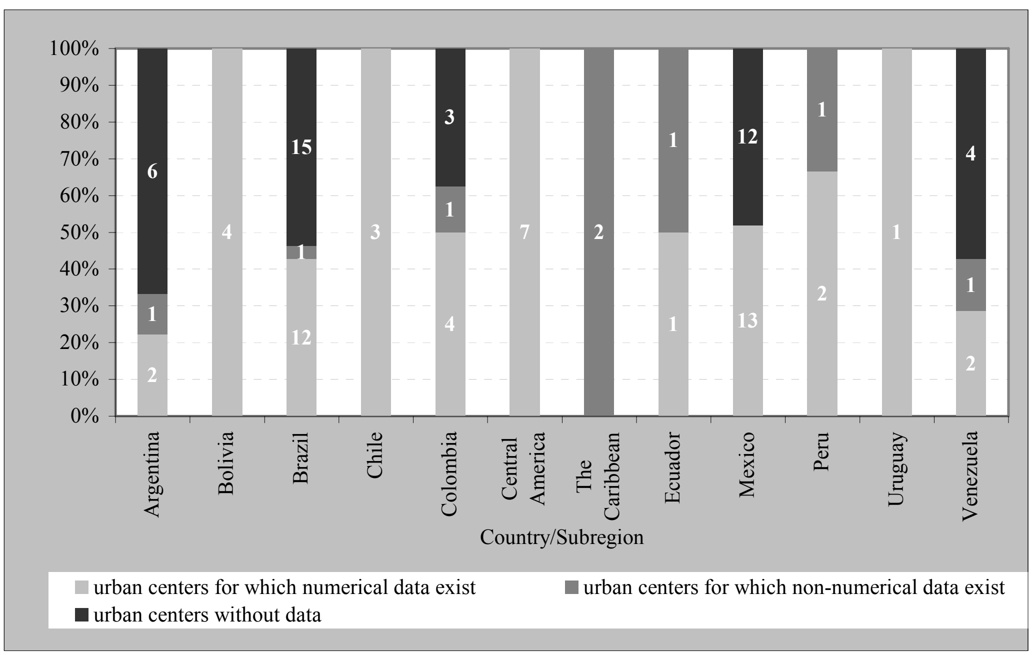
Table 2: Length of Data Availability

	Length of Data Availability (numerical data only)*						Total Numerical Data Available
	≤1 year	2 years	3 years	4 years	5 years	≥ 6 years	
PM_{10}	12	6	4	2	7	10	41
$PM_{2.5}$	1		1		3		5
O_3	8	5	3	1	4	8	29
NO_2	12	8	6	3	5	3	37
SO_2	5	3	8	2	7	2	27
CO	5	2	5	5	8		25

* Refers to the maximum number of years for which data (either maximum values and/or number of violations) were found.

A breakdown of data availability by country is shown in Figure 13. It shows that numerical or a combination of both numerical and non-numerical data were obtained for all selected urban centers in Bolivia, Chile, Central America, the Caribbean, Ecuador, Peru, and Uruguay. A comparison of the geographical distribution of data availability and monitoring capability (Figure 10) shows that some of the data obtained for Central America, the Caribbean, Ecuador, and Peru came from temporal studies.

Figure 13: Availability of Data by Country/Subregion



Note: Value inside of bard refers to the number of urban centers.

9. AIR QUALITY MAP

A metropolitan area's vulnerability to air pollution depends both on air quality and the availability of resources to manage it. Previous chapters have addressed the latter; this chapter focuses on the former—the quality of air in metropolitan regions as revealed by the data gathered. Ideally, a picture of the state of air quality in a city would be built up by looking at concentrations of different pollutants, human activity in the vicinity of those concentrations, air quality standards for those pollutants, and meteorological and topographical conditions of the different areas under consideration. Under the present study, this type of information was not available, so the nature of what we mean by "state" of air quality must be, by definition, substantially more limited. Ideally, we want to know which pollutants exceed international benchmarks with enough regularity as to create a risk to human health, that is, to identify which pollutants have critical exceedances. In practice, however, the common denominator of the data collected here only allow for identification of *maximum values* of measured concentrations, meaning, at best, single exceedances of international benchmark values. As a result, we can only identify pollutants *suspected* of critical exceedances that may create a risk to human health.

Therefore, the indicator developed is called *suspect critical pollutants* (SCP), which will be elaborated upon below. All urban areas are then categorized into 12 bins, based on SCP, monitoring capability, and availability of monitoring data. These bins are then mapped onto a regional *air quality map,* a visual tool whose objective is to provide a rough guide to air quality for each urban center. We caution that the air quality map does not provide a comparison, since data have not been harmonized, quality controlled, or classified according to uniformly applicable criteria.

The map identifies each urban center's vulnerability to air pollution, where vulnerability means not only whether the urban area has exceeded international benchmarks, but also whether the region has resources to measure air quality and whether those resources have produced air quality information. Thus, the map combines visually much of the information presented thus far.

This section first presents a description of the methodology utilized to classify urban centers, and is then followed by the results of the classification and an analysis of findings.

Methodology

Urban centers have been classified into 12 air quality bins, as defined in Table 3. Binning classifications were based on three criteria: air quality monitoring capability (existence of a network of at least two stations capable of providing data on a regular basis), availability of air quality data (data available to the authors for at least two years), and the types of *suspect critical pollutants* (SCPs) as defined below.

For bin classification purposes, the most recently available data point after the year 2000 for all collected data were used. Because of the scope of the analysis, data were used in the methodology as directly provided by local authorities or as taken from relevant studies; they were neither checked nor reworked for reliability or representativeness. The air quality monitoring capability and availability of air quality data criteria capture data quality issues to some degree.

A *suspect critical pollutant* is defined as a pollutant whose highest recorded concentration, among the latest ones available, exceeded the value of either the applicable short-exposure (e.g., 24 hours for PM_{10}, $PM_{2.5}$, NO_2, and SO_2, and 1 hour for O_3 and CO) or long-exposure standards (e.g., 1 year for PM_{10}, 8 hours for O_3 and CO). In some cases, where no numerical data were available, insights into likely concentrations have been gleaned from graphs or text in relevant studies and reports, and *suspect critical pollutants* were inferred from these likely concentrations.

Applicable standards refer to those used for comparing ambient air quality data. Where local or national standards are available, and are at least as strict as international benchmarks, the local standard has been used. Otherwise, the international benchmarks (US NAAQS and WHO guidelines) have been used.

To determine an SCP, the maximum registered ambient concentration value of each pollutant for each averaging time is compared against the threshold of the applicable standard. If the value exceeds that threshold, the pollutant is considered suspect. We use the term "suspect" because the information available in this database is insufficient to determine whether the applicable standard has actually been violated, since violations usually entail some mechanism to track exceedances over time (e.g., 98^{th} percentile, second maximum, or the average of the last three years exceeds the standards), and also because in most cases information is insufficient to figure out whether violations to the standard were a pattern or only represented some exceptions.

For the purpose of binning the cities, SCPs are grouped into two groups: particulate matter and ozone in one, and the remaining gases in the other. This division introduces a rough, binary distinction between air pollution problems that tend to be more chronic and widespread, and those that tend to be more localized in space and time.

The following table summarizes the criteria.

Table 3: Criteria to Classify Urban Centers on the Map

Existence of Air Quality Monitoring Capability		Availability of Data	Which pollutants exceeded the value of the applicable standards?[2, 3]	Category
Existence of a network (of at least two stations) that provided data on a regular basis	AND	Data for at least two years	At least PM_{10}[1] and O_3 and $PM_{2.5}$	1
			At least $PM_{2.5}$ AND [PM_{10}[1] or O_3]	2
			At least PM_{10}[1] and O_3	3
			At least $PM_{2.5}$ or PM_{10}[1] or O_3	4
			NO_2 and/or CO and/or SO_2	5
			None	6
Existence of only one station, or Existence of a network not providing data on a regular basis (due to technical and/or financial difficulties), or Only temporal studies	OR	Data for less than two years	At least $PM_{2.5}$ and/or PM_{10}[1]	7
			At least O_3	8
			NO_2 and/or CO and/or SO_2	9
			None	10
No information or insufficient information				11
No monitoring [4]				12

1. TSP was considered only when (a) there were no data for PM_{10} or $PM_{2.5}$, either due to lack of monitoring or unavailability of data, and (b) the maximum registered concentrations exceeded the value of the relevant TSP standard (see note 2).
2. Applicable standards refer to those used for comparing ambient air quality data. Where local or national standards are available, and are at least as strict as international benchmarks, the local standard has been used. Otherwise, the international benchmarks (US NAAQS or WHO guidelines, in that order) have been used.
3. For each pollutant, the maximum registered value in any given station is compared with the *value* of the applicable standard and not the standard itself, because the standard usually specifies not just the value but all other conditions under which it is considered a violation (e.g., when the 98^{th} percentile exceeds the standard, when the average of the three last years exceeds the standard, etc.).
4. Refers to absence of permanent or temporal monitoring, and where no data could be obtained from previous monitoring, if it ever existed.

ANALYSIS

Suspect critical pollutants

Regional Table 8 uses a color code to identify *suspect critical pollutants* by urban center. Red indicates that a pollutant is suspect for that urban area, while green indicates that it is probably not suspect. Yellow and pink indicate that the pollutant is not monitored, or information was not available, respectively. Regional Table 8 also contains information on the overall bin for the city, as described above, as well as information about whether an emissions inventory exists for the city.

A summary of the number of areas for which each pollutant has been identified as an SCP is shown in Figure 14. Several important conclusions may be drawn from this figure:

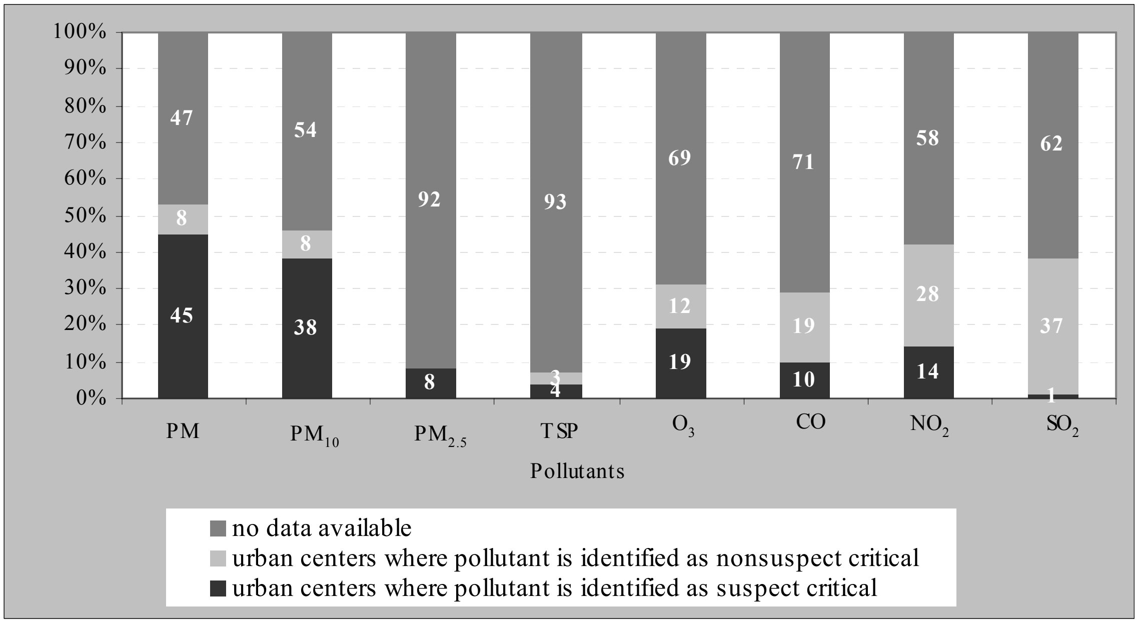
- PM_{10} was identified as a *suspect critical pollutant* in 38 of the 46 urban centers for which data on the pollutant are available (representing 83% of urban centers for which there are data). These 38 urban centers are inhabited by 107 million people, equivalent to 57% of the population living in all selected urban centers or 94% of people living in urban areas for which there is information about this pollutant. In contrast, there are only 8 urban centers where PM_{10} was not identified as a *suspect critical pollutant*: Belo Horizonte, Campinas, São José dos Campos, Ribeirão Preto, and Sorocaba in Brazil, Tampico and Villahermosa in Mexico, and Montevideo in Uruguay. As will be discussed below, however, we should be cautious about how we interpret these 8 urban centers.

- Although not widely monitored, $PM_{2.5}$ was identified as a *suspect critical pollutant* in all urban centers where there are data on this pollutant. Urban centers in this group include the São Paulo and Santiago Metropolitan Regions, Greater Concepción, Santo Domingo, Quito, the Metropolitan Zone of the Valley of Mexico, Lima–Callao, and Trujillo, covering 29% of the population living in all selected urban areas. These results suggest the need for more widespread standard-setting and monitoring of this pollutant. Note that three of the urban centers monitoring $PM_{2.5}$ did not even provide data for PM_{10}.
- In the seven urban centers where PM_{10} or $PM_{2.5}$ data were not available, and TSP was used as the indicator for particulate concentrations instead, this pollutant was identified as suspect critical in four.[77] These results also point to the need for more widespread standard setting and monitoring of fine and ultrafine particulates.
- Overall, particulate matter has been identified as a *suspect critical pollutant* in 45 of the 53 urban areas for which information is available,[78] representing 66% of the population represented in the data. It is important to note, however, that fully 96% of population residing in areas where data about PM are available live in areas where the pollutant is classified as suspect critical. Again, this points to the urgency of expanding the monitoring of this pollutant.
- O_3 was identified as a *suspect critical pollutant* in 19 of the 31 urban centers for which data on this pollutant are available. 16 of these were also identified as suspect critical for some form of PM as well. These 19 urban areas account for 79% of the population living in cities for which ozone information is available, and 43% of the overall population represented by the database. More monitored cities are classified as nonsuspect critical for ozone than for particulate matter (39% versus 15%). This suggests that as a critical pollutant, ozone is more variable than particulate matter.
- In nearly all urban centers with data for SO_2, it was not identified as a *suspect critical pollutant*. The only exception was Arequipa, Peru.
- In fewer than half of all urban centers for which data were available, CO and NO_2 were the pollutants identified as suspect critical.

[77] TSP is monitored in several urban centers, but for the purpose of the study TSP data were only collected for those cities where no information for either PM_{10} or $PM_{2.5}$ was available.

[78] It only considered the four cases where TSP was identified as a suspect critical pollutant as a means to identify possible vulnerability when data on PM_{10} or $PM_{2.5}$ were not available. Concentrations of TSP are not always correlated with concentrations of smaller particles. Thus, leaving the cases where TSP was identified as a nonsuspect critical pollutant was a conservative decision to signal vulnerability to particulate matter.

Figure 14: Number and Percentage of Urban Centers where Pollutants are Identified as Suspect and Nonsuspect Critical



Notes: Value inside of bard refers to the number of urban centers.

- Information extracted from Regional Table 8.
- TSP data were only collected for those cities where no information for either PM_{10} or $PM_{2.5}$ was available.
- With respect to PM:
  - It combines the results of PM_{10}, $PM_{2.5}$, and TSP.
  - It only considered the four cases where TSP was identified as a *suspect critical pollutant* as a means to identify possible vulnerability when data on PM_{10} or $PM_{2.5}$ were not available.
  - To identify PM as a *suspect critical pollutant*, it is sufficient that either PM_{10} or $PM_{2.5}$ (or TSP if there are no data for PM_{10} or $PM_{2.5}$) was identified as a critical pollutant, regardless if the other was identified as a *nonsuspect critical pollutant*.

Results of the Classification

The results of the binning classification, according to the criteria shown in Table 3, are presented in Regional Table 9. As discussed above, this classification methodology places particular weight on particulate matter—the most widely monitored pollutant and the one associated with the highest risk to human health—and on the availability of resources allocated to managing air quality presented and discussed throughout this document. The classification allows the analysis of *suspect critical pollutants* to be expanded by differentiating among urban centers based on their capacity to generate monitoring data as well as the number of years for which data are available. Better monitoring capability and more years of data could represent more reliable and representative data; therefore, findings on *suspect critical pollutants* could be considered less uncertain. Likewise, less reliable and representative data could raise concerns about the reliability of results. For example, if a pollutant was monitored at only one station, there is no certainty that that station captured the worst-case scenario concentrations. Therefore, even if the pollutant were not identified as suspect critical, if it had been monitored elsewhere or more comprehensively it might have been so identified.

As a result, different urban centers might end up in the same bin for very different reasons. Therefore, the binning outcomes should not be interpreted without close reference to the observations in the rightmost column of Regional Table 9 and a clear understanding of the methodology utilized. As an example, both Córdoba and Cali are classified in category 7, but the mechanisms by which they are so classified are not the same: Córdoba has high concentrations of PM_{10} and low concentrations of O_3, while Cali has high concentrations of both pollutants.

Nearly half of all selected urban center either do not monitor air quality or do not provide enough data to classify them. Among the remaining half, particulate matter, with only some exceptions, was always identified as a *suspect critical pollutant*, regardless of whether the data were considered more or less reliable.

Figure 15 provides a summary of the classification by showing the distribution of urban centers by category, and the distribution of urban centers relative to their capacity to generate more or less reliable and representative data. According to the criteria used, 22 and 31 of the 100 selected urban centers provide more and less reliable, representative data, respectively. Twenty-two urban centers, inhabited by 93 million people (representing 50% of the population living in all selected urban centers), were classified in the first six categories, while 31, with 37 million people (representing 19% of the population living in all selected urban centers), were classified in categories 7 to 10. The first six categories include those urban centers with monitoring capability consisting of at least two stations that provide data on a regular basis and where data were available for at least two years; while categories 7 to 10 include those with less monitoring capability if any at all (in some cases the only data available came from temporal studies), and those where data were available for less than two years. Of the remaining urban centers, 22 are classified in category 11 (inhabited by 35 million people, 19% of the population living in all selected urban centers). In other words, the information necessary to classify them was not available. Twenty-five urban centers (which account for 22 million people, 11% of the population living in all selected urban centers) are classified in category 12.[79]

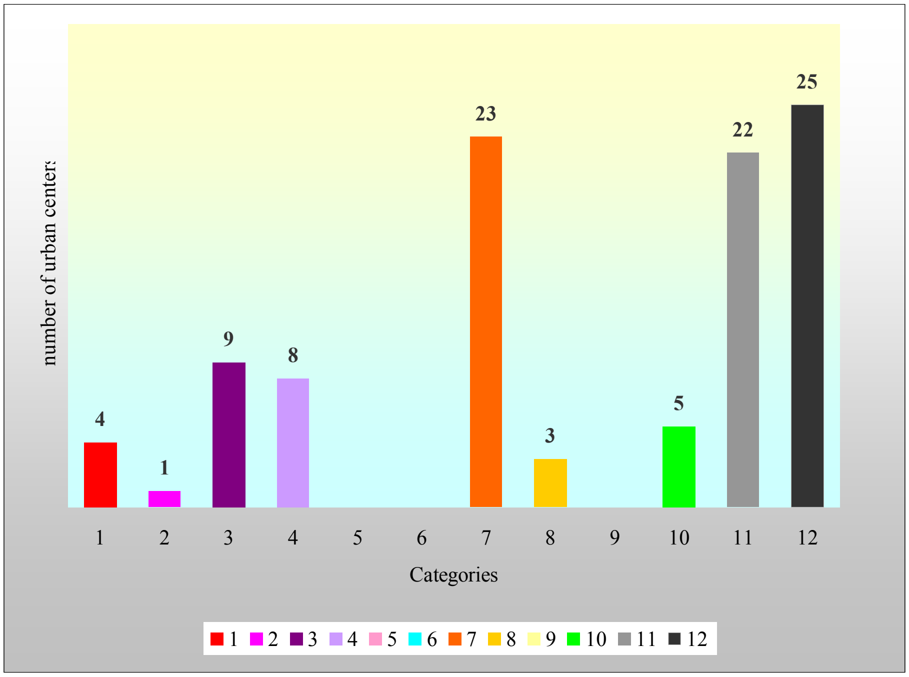
In all urban centers with more reliable monitoring infrastructure (i.e., those with a network of at least 2 monitoring stations in continuous operation for at least 2 years), fine particulate matter was *always* identified as a *suspect critical pollutant*, as shown in Figure 16.[80] Furthermore, wherever data on ultrafine particulate matter were available, those data *always* identified $PM_{2.5}$ as a *suspect critical pollutant* as well. The same relationship does not hold for ozone, however; in the group of 22 urban centers with networks of at least 2 monitoring stations in continuous operation for at least 2 years, ozone was identified as suspect critical only in 14 of them.[81]

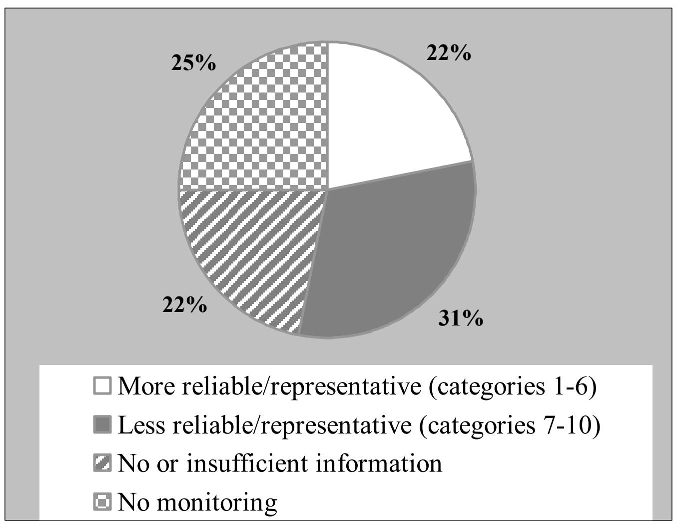
[79] Corresponds to 21 urban centers where no permanent or temporal monitoring has taken place since 2000, and 4 other urban centers that had some type of monitoring capacity in the past (either a network or a single station), but no data were obtained: Cartagena in Colombia, and Chihuahua, Hermosillo, and San Luis Potosí in Mexico.

[80] Urban centers were only classified in the first four of the six categories corresponding to those providing more reliable data. The first three categories always refer to particulate matter (either PM_{10}, $PM_{2.5}$, or a combination of both) being identified as a suspect critical pollutant. The fourth category refers to PM_{10} or ozone being identified as a suspect critical pollutant, but in this case $PM_{10}$was always the reason why urban centers were classified in this category.

[81] Ozone was identified as a nonsuspect critical pollutant in 5 of the 22 urban centers.

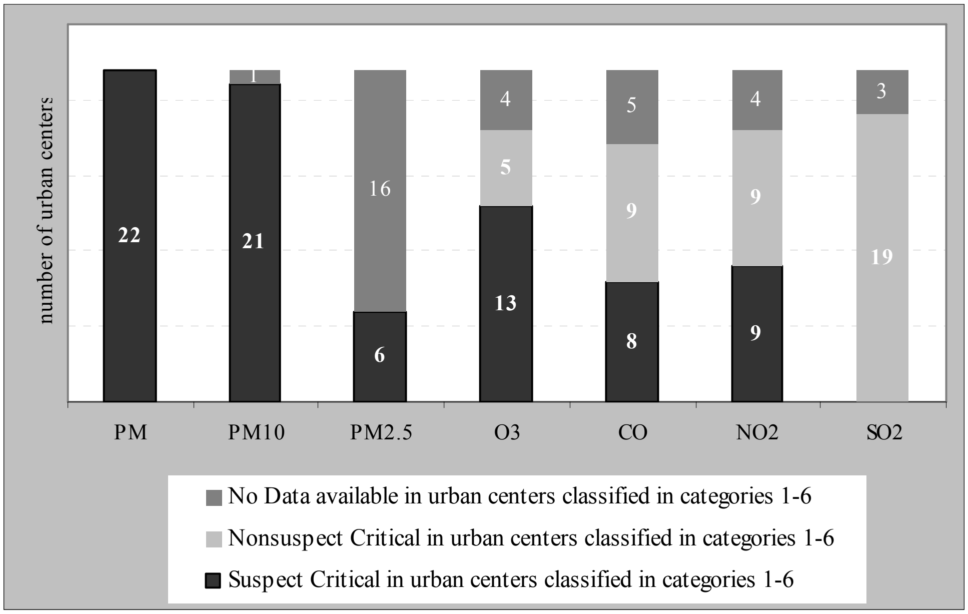
Figure 15: Summary of Classification





Information extracted from Regional Table 9.
Reports the result of the classification for the 100 selected urban centers.

Figure 16: Number of Selected Urban Centers where Pollutants are Identified as Suspect and Nonsuspect Critical (among those assumed to generate more reliable and representative data)



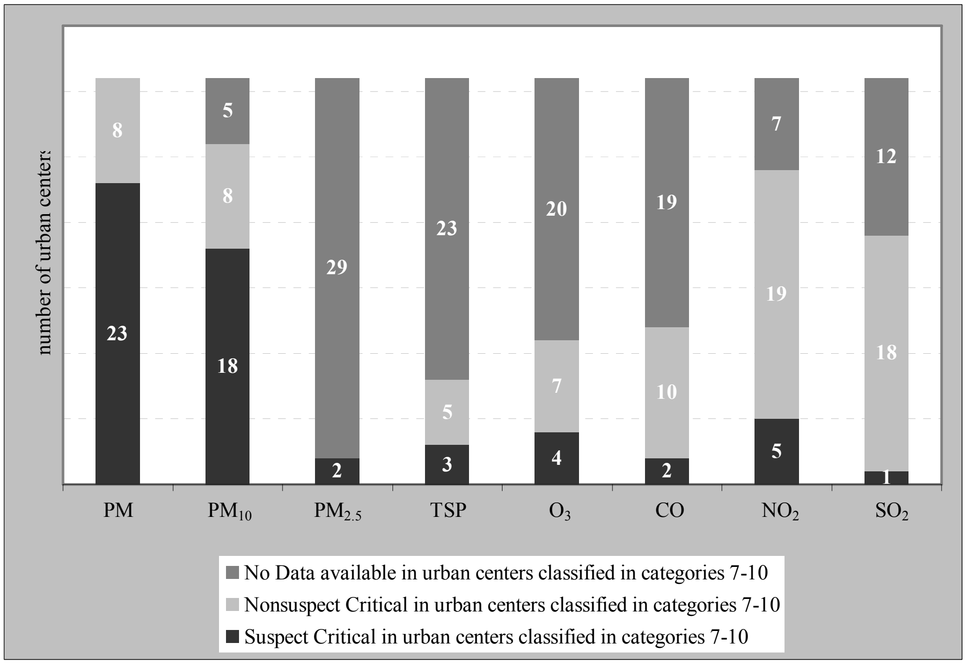
Notes:

- Information extracted from Regional Table 8.
- With respect to PM:
  - It combines the results of PM_{10} and $PM_{2.5}$.
  - To identify PM as a *suspect critical pollutant*, it is sufficient that either PM_{10} or $PM_{2.5}$ was identified as a critical pollutant, regardless if the other was identified as a *nonsuspect critical pollutant*.

The results obtained for the 31 urban centers classified in categories 7 to 10 (summarized in Figure 17), that is, those assumed to generate less reliable/representative data, indicate that particulate matter was in most cases identified as a critical pollutant. Particulate matter in the form of PM_{10}, $PM_{2.5}$, or TSP[82] was considered a *suspect critical pollutant* in 23 of the 31 urban centers in this group, inhabited by 30 million people (16% of the overall population represented in the database). It was considered a *nonsuspect critical pollutant* in the remaining 8 urban centers, representing 26% of urban centers in this group. Moreover, wherever monitored and data were available, $PM_{2.5}$ was always identified as a *suspect critical pollutant*.

[82] TSP was the only type of particulate matter for which there was information in three cases. The Recife Metropolitan Region in Brazil and Barcelona in Venezuela only monitor TSP, while Torreón in Mexico also monitors PM_{10}, but no data were available.

Figure 17: Number of Urban Centers where Pollutants are Identified as Suspect and Nonsuspect Critical (among those assumed to generate less reliable and representative data)



Notes:

- Information extracted from Regional Table 8.
- TSP data were only collected for those cities where no information for either PM_{10} or $PM_{2.5}$ was available.
- With respect to PM:
  - It combines the results of PM_{10}, $PM_{2.5}$, and TSP.
  - It only considered the three cases in which TSP was identified as a *suspect critical pollutant* as a means to identify possible vulnerability when data on PM_{10} or $PM_{2.5}$ were not available.
  - To identify PM as a *suspect critical pollutant*, it is sufficient that either PM_{10} or $PM_{2.5}$ (or TSP if there are no data for coarse and fine particles) was identified as a critical pollutant, regardless if the other was identified as a *nonsuspect critical pollutant*.

A more detailed look at the results for PM_{10} in all urban centers where it was identified as a *nonsuspect critical pollutant* (Table 4) helps to determine whether any of these urban centers may be considered less vulnerable to air pollution.

- Of the five urban centers where no particulate matter or gas monitored was identified as suspect critical (all classified in category 10), most monitor PM_{10} in only one station; therefore, results may not be representative: Campinas, Belo Horizonte, Tampico, and Montevideo. In addition, information for Villahermosa came from partial data for the years 2001 and 2002 so it too may not be representative. The only results that are not questioned are those of Belo Horizonte. The reason for classifying it among those that provide less reliable and representative data was that by time the report was written data were available for less than two years.
- The remaining three urban centers only had issues with ozone: São José dos Campos, Ribeirão Preto, and Sorocaba in the State of São Paulo in Brazil. However, in these cases particulate matter is monitored in only one station; therefore, results may not be representative.
- All but two urban centers have undertaken emission inventories: Ribeirão Preto and Montevideo.

Table 4: Characteristics of Urban Centers where Particulate Matter was Identified as a Nonsuspect Critical Pollutant

Urban Center	Classification	Nonsuspect Critical Pollutants	Suspect Critical Pollutants	Number of Stations Monitoring PM_{10}	Availability of Emission Inventory
São José dos Campos	8	PM_{10}, SO_2	O_3	1	Yes
Ribeirão Preto	8	PM_{10}, CO, NO_2, SO_2	O_3	1	No
Sorocaba	8	PM_{10}, NO_2, SO_2	O_3	1	Yes
Belo Horizonte	10	PM_{10}, O_3, CO, NO_2, SO_2		3	Yes
Campinas	10	PM_{10}, CO, NO_2, SO_2		1	Yes
Tampico	10	PM_{10}		1	Yes
Villahermosa	10	PM_{10}, O_3, NO_2, SO_2		3	Yes
Montevideo	10	PM_{10}, O_3, NO_2, SO_2		1	No

Because the assessment of vulnerability to air pollution relied on the identification of suspect rather than actual critical pollutants, reliability of data played a lesser role in identifying the most vulnerable urban centers, and therefore all data can be combined for this analysis.

The 45 urban centers where particulate matter and especially $PM_{2.5}$ were identified as *suspect critical pollutants*, can be considered the most vulnerable to air pollution. Among these centers, those with limited availability of resources to manage urban air quality can be considered particularly at risk:

- Monitoring capability in Bahia Blanca, Kingston, León, Querétaro, and Arequipa is quite limited because each is equipped with only one station to monitor particulate matter (PM_{10}).
- In Santo Domingo and Trujillo, information to identify $PM_{2.5}$ as a *suspect critical pollutant* was obtained from temporal studies because no permanent monitoring is in place. Data from which PM_{10} was identified as a *suspect critical pollutant* in San José, Guayaquil, and Guatemala City also came from temporal monitoring because no permanent monitoring is in place.
- Córdoba and Managua had a monitoring network or at least one station in the past, but these are no longer in operation.
- None of the following urban centers has undertaken emission inventories: Córdoba, La Paz, El Alto, Santa Cruz, the Porto Alegre Metropolitan Region, the Curitiba Metropolitan Region, Grande Vitória, Barranquilla, Cali, San Salvador, Guatemala City, Tegucigalpa, Managua, Panama City, Arequipa, Trujillo, and Barcelona.[83]
- Grande Vitória, the Curitiba Metropolitan Region,[84] Porto Alegre, and Cali had high concentrations of PM_{10} and have not undertaken emission inventory studies. However, all have large monitoring networks with automatic equipment to monitor all pollutants except $PM_{2.5}$.
- Guatemala City, Tegucigalpa, Managua, and Panama City have no legislation setting ambient air quality standards for any pollutant.

[83] Several of these urban centers carried out greenhouse gas emission inventories as part as their commitment to the United Nations Convention on Climate Change, but they provide information at the national level, not at the geographic level required to serve as a tool for air quality management. Therefore, they were not considered in this analysis.
[84] In the Curitiba Metropolitan Region, high levels of PM_{10} and O_3 were recorded in the municipality of Araucária (adjacent to the municipality of Curitiba), where most of the metropolitan region's industrial activity is concentrated.

- In 16 of these urban centers ozone was also identified as a *suspect critical pollutant*.[85] On the other hand, in 9 of these urban centers ozone did not register concentrations high enough to be considered suspect critical: Cochabamba, Grande Vitória, Greater Valparaiso, Bogotá, Aguascalientes, Córdoba, Santo Domingo, San Salvador, and León.
- Regional Table 8 shows that the urban centers where the highest number of *suspect critical pollutants* were identified include the São Paulo Metropolitan region (PM_{10}, $PM_{2.5}$, O_3, CO, and NO_2), the Rio de Janeiro Metropolitan Region (PM_{10}, O_3, CO, and NO_2), the Curitiba Metropolitan Region (PM_{10}, O_3, CO, and NO_2), the Metropolitan Zone of Guadalajara (PM_{10}, O_3, CO, and NO_2), the Santiago Metropolitan Region (PM_{10}, $PM_{2.5}$, O_3, and CO), and the Metropolitan Zone of the Valley of Mexico (PM_{10}, $PM_{2.5}$, O_3, and NO_2).

In addition, two main observations can be drawn from looking at the composition of the four urban centers in category 1, that is, where at least all PM_{10}, $PM_{2.5}$, and O_3 are identified as *suspect critical pollutants*—São Paulo, Santiago, Quito, and Mexico (ZMVM). Despite having undertaken solid plans to manage air degradation and being well endowed with resources to manage air quality after experiencing the most serious problems with air pollution in the entire region, Santiago, São Paulo, and ZMVM are still vulnerable to air pollution because air quality, although improved, is still deficient. Quito is the only one of these urban centers without the years of experience dealing with air quality issues that other four have; its network started operating in 2003 and the only information on sources of emissions comes from a preliminary inventory undertaken in the same year, making it more vulnerable compared to the other four included in this category.

Urban centers classified in categories 11 and 12, those for which there is no information because of lack of monitoring or data unavailability, are also probably vulnerable to air pollution. While they lack resources to monitor air quality, there is no reason to believe that they would not also show pollutant levels exceeding local standards and international benchmarks if they were to engage in monitoring.

Although collected data on different pollutants in the same urban center were not necessarily registered at the same monitoring station, there is some evidence showing the link between ozone and its precursors, namely NOx (NO_2). In 69% of all urban centers with data on NO_2 and O_3 (26 urban centers), both pollutants are identified together either as suspect critical (15%) or nonsuspect critical (54%). In the remaining 31%, one or the other, but not both, is identified as suspect critical.

A larger percentage of urban centers classified in the first six categories compared to those classified in categories 7 to 10 have undertaken emission inventory studies, 86% (19 of 22 urban centers) compared to 42% (13 of 31 urban centers). Such a result is logical; urban centers with emission inventories are more likely to devote more resources to air quality management, and thus have more permanent air quality monitoring systems.

The classification results by country in Figure 18 show the following observations:

- Chile is the only country where all selected urban centers were classified as providing more reliable and representative data (categories 1 to 6).
- Although Mexico has the most resources to manage air quality (emission inventories were found for all Mexican urban centers and more than 60% of selected urban centers have monitoring capability), 12 urban centers (3 classified in category 11 and 9 classified in category 12) are still considered vulnerable because there are no data that could signal the state of air quality.
- Urban centers where no pollutants were identified as *suspect critical pollutants* (category 10) are located in Brazil, Mexico, and Uruguay.

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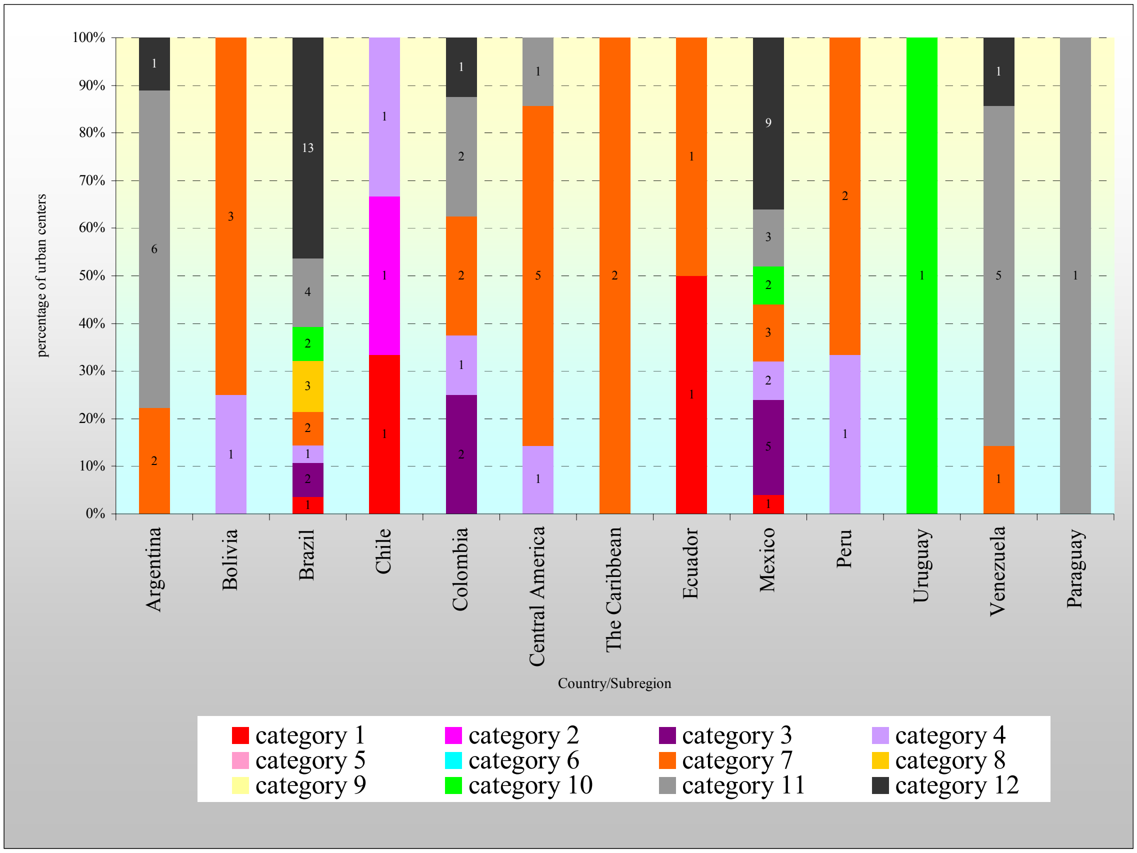
[85] Several places, especially those providing less reliable and representative data, did not generate the necessary data to assess whether ozone could be considered a suspect critical pollutant.

Figure 18: Classification Results relative to the Number of Selected Urban Centers by Country



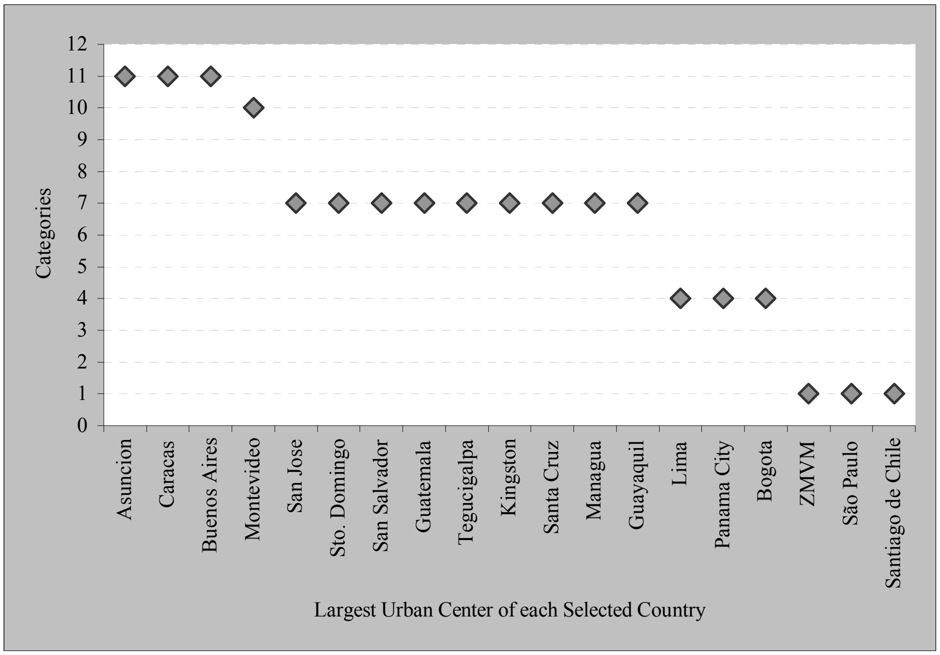
Information extracted from Regional Table 9.
Only reports the result for the Rio de Janeiro Metropolitan Region and not that for the City of Rio de Janeiro which is also available in Regional Table 9.

The classification results for the most populated urban centers of all 19 countries (Figure 19) indicate the following:

- Among the most populated urban centers in each selected country, Montevideo appears to be the least vulnerable to air pollution because it is the only one, among those with information, where neither particulate matter nor ozone was identified as a *suspect critical pollutant*. However, PM_{10} is only monitored in one station.
- Three urban centers (Asunción, Caracas, and Buenos Aires) lack sufficient data for classification. However, Caracas has data on TSP which indicates that it is not identified as a *suspect critical pollutant*.
- According to the defined criteria, only six of the most populated urban centers of all selected countries (Santiago, São Paulo, ZMVM, Bogotá, Panama City, and Lima–Callao) provided more reliable and representative data. These include the capital of one Central American country.
- It seems that the most vulnerable most populated urban centers of all selected countries include those of all selected Central American and Caribbean countries (Panama City, Managua, Tegucigalpa, Guatemala City, San Salvador, San José, Kingston, and Santo Domingo), in addition to Santa Cruz in Bolivia and Guayaquil in Ecuador. Particulate matter was identified as a *suspect critical pollutant* in all of them. With the exception of Santo Domingo, none has carried out emission inventories. Monitoring capability is very limited because five of them lack permanent monitoring (Managua had some monitoring capacity in the past but not any longer, while Guatemala City, Santo Domingo, San José, and Guayaquil have only undertaken temporal studies), and the rest, with the exception of Panama City, have only manual capacity.

- Although Santiago, São Paulo, Mexico City, Bogotá, and Lima at least presented high concentrations of particulate matter, they have more resources to manage air quality, especially Santiago and Mexico City.

Figure 19: Classification Results for Largest Urban Centers of each Selected Country



Category	**Observations**
1	Better monitoring capability and data available for at least two years indicating that all PM_{10}, $PM_{2.5}$, and O_3 were at least identified as *suspect critical pollutants*.
4	Better monitoring capability and data available for at least two years indicating that at least PM_{10}, $PM_{2.5}$, or O_3 was identified as a *suspect critical pollutant*
7	Limited monitoring capability or data for less than two years indicating that at least PM_{10}, $PM_{2.5}$, or O_3 was identified as a *suspect critical pollutant*
10	Limited monitoring capability or data for less that two years indicating that none of all pollutants monitored was identified as a *suspect critical pollutant*
11	No or insufficient information

Information extracted from Regional Table 9.

10. CONCLUSIONS AND RECOMMENDATIONS

Improved air quality is a common goal for most urban areas with large populations because air quality degradation has been a by-product of their rapid growth. However, differences in both the quality of air in metropolitan areas and the resources available to manage air quality have meant that urban residents' vulnerability to air pollution varies substantially across the region.[86]

The study assessed the existence of certain key resources to manage air quality and evaluated the state of air quality by identifying *suspect critical pollutants* based on a methodology that examined the highest ambient air quality concentration registered in any single station. In doing so, it was able to provide clues about the vulnerability of selected urban centers to air pollution.

Many of these centers appear highly vulnerable to air pollution. Particulate matter was identified as a *suspect critical pollutant* in 45 of the 100 selected urban centers, but this figure would likely be higher if more ambient air quality information were actually available. The 123 million people who inhabit these 45 cities represent 96% of people living in cities where this pollutant is monitored and information available. The data also suggest that the more reliable and sophisticated the monitoring network is, the more likely fine particulates are to be suspect critical, with maximum readings that exceed international benchmarks. Although not monitored in many places, ultrafine particulate matter ($PM_{2.5}$) was always identified as a *suspect critical pollutant* when it was monitored.

Ambient air quality standards are found in most selected countries (14 out of 19), but in many cases particulate matter and ozone standards need to be updated. Although the highest risk to human health is associated with fine and ultrafine particles, in some countries the only available particulate standard is TSP, and only a few actually set standards for ultrafine particulates. For ozone, several countries need to evaluate whether to revise their 1-hour standard or at least set a new standard for an 8-hour period, following the US EPA which, based on scientific information, replaced the NAAQS's 1-hour standard with an 8-hour standard.

Although an important part of the air quality management process, emission inventories are practically nonexistent throughout the region, perhaps because of their cost. Furthermore, they are not undertaken with a frequency that reflects changes in population and economic activity. Mexico is the only country that has developed a national emission inventory aimed at initiating and improving air quality management plans, and the only country where several selected urban centers reported more than one emission inventory.

No clear pattern emerges in the overall picture about which urban centers have monitoring capabilities and what type. One might have speculated that the most polluted urban areas have the best monitoring capabilities, as is the case for Santiago de Chile, Mexico City, and São Paulo, but there are plenty of other cities where evidence suggests that they might be polluted although they have very limited monitoring capability (such as those classified in category 7 including, for example, Córdoba, La Paz, Recife, Santo Domingo, and Arequipa).

Air quality monitoring is particularly weak in Central America, the Caribbean, and Argentina, where less than half of the selected urban areas have any kind of ongoing monitoring capability. Even where there is such capability, capacity and sophistication to monitor specific pollutants differ substantially. PM_{10} is monitored in less than half of all selected urban centers, while $PM_{2.5}$ is monitored in only 10%. A number of urban centers monitor CO and O_3 using manual rather than automated methods, and thus lack the capacity to generate real-time data necessary for compliance verification with episodic standards.

Two other common deficiencies identified in the present report are the absence of a standardized methodology to collect and process data, and the poor state of data reporting practices. Even within individual countries, let alone for the entire region, there is often no common methodology to ensure that data collected in one place is

[86] Differences in resource allocations result from differences in political will and availability of financial resources, while differences in the status of air quality depend on a combination of factors including physical characteristics of the area under consideration (e.g., topography and weather patterns), characteristics of economic activity, and availability of emission reduction technology.

comparable with that collected in another, and data quality assurance is minimal. Reports analyzing air quality data are rarely available, and when they are, they tend to be produced intermittently and without updates. In many cases, the most current reports are already outdated. Furthermore, processed data are sometimes presented without proper description or in formats that do not provide complete or relevant information necessary to draw a conclusion about whether a standard has been violated.

Recommendations

Recommendations focus on highlighting areas that, according to the initial findings presented in this document, need improvement, especially with regard to the availability of emission inventories and monitoring capacity.

Recommendations also focus on providing guidance regarding work that is complimentary to this study. Because this study is the first attempt to identify the vulnerability of main urban centers at such a scale, there are many ways to improve its content.

The availability and frequency of emission inventories must be improved. If sources of emissions are not identified, effective, efficient policies aimed at improving air quality cannot be developed and implemented. Unfortunately, information presented in this document indicates that the situation is inadequate because emission inventories are unavailable in most selected urban centers. In addition, the amount of the various pollutants emitted depends on the type of industries existing in the area under study and on the quality of roads (paved or unpaved) and the age of vehicles. Thus, emission inventories should be updated periodically because the emissions generated in a city change constantly as the city develops.

A look at the availability of monitoring capability indicated that, in order to provide the necessary data for policy making, monitoring capacity needs to improve in terms of coverage (availability of networks throughout selected urban centers) and of availability of equipment, especially with respect to analyzers of ultrafine particulate matter, and automatic analyzers for gases. A more in-depth analysis of the characteristics of the monitoring capability in each selected urban center would help to identify the specific needs of individual monitoring networks. In the meantime, health-related data (morbidity and mortality data associated with air pollution) could be used as an indicator of the vulnerability of urban centers for which there are no monitoring data.

Local initiatives such as SINAICA (the National Air Quality Information System in Mexico) support the creation of a common platform to share air quality monitoring data, and therefore could serve as a model for other countries and regional initiatives. However, its benefit could be enhanced if, in addition to sharing air quality data, common criteria to collect data across urban centers are adopted.

All countries should set national or local ambient air quality standards as a means to explicitly indicate the level of risk a country or city considers acceptable for its susceptible population, and should aim to at least standardize the methodology in order to make this decision transparent. Most countries lack sufficient budget to develop local regulations based on local scientific evidence; therefore, based on unknown methodologies, they copy or determine their standards from values defined by international benchmarks such as the US NAAQS or the WHO reference values which are based on health concerns supported by scientific evidence. Nevertheless, some countries, including Guatemala, Honduras, Nicaragua, and Panama, still have not regulated maximum tolerable concentrations of ambient air quality.

Similarly, countries should consider setting standards for at least those selected pollutants associated with the highest health-related effects, and revise standard values based on new scientific evidence. Because particulate matter, especially PM_{10} and above all $PM_{2.5}$, is the pollutant associated with the highest risks to human health, it is imperative that countries set standards for both PM_{10} and $PM_{2.5}$. This is especially the case in countries such as Argentina and Venezuela which only set standards for TSP. Standards for TSP can still coexist with standards for finer particles, but they should not be the only particulate matter standard available. Several countries within the region could also evaluate whether to revise their ozone standards, following the US EPA, which in 1997 replaced the NAAQS's 1-hour standard with an 8-hour standard based on the results of several studies that assessed the risks of exposure to the pollutant.

Complementary Work

Additional, complementary work can be defined by incorporating several key factors in the analysis of vulnerability to air pollution, including:

1. Evaluation of the capacity of urban centers to manage air quality: Air quality management can imply the following general but not necessarily hierarchical topics:

   - Legal framework, including national law, regulations, and standards;
   - Administrative or institutional capabilities, including dedicated government structures, budget, human resources, etc.;
   - Government plans and programs to improve air quality, deal with air pollution episodes, or promote specific control strategies;
   - Emission inventories and licensing of emission sources;
   - Air quality and meteorological monitoring networks and stations at national, regional, and local levels, including air quality objectives, quality assurance programs, social communication policies, etc.

A more comprehensive analysis of air quality management would improve the reliability of results by expanding the scope of work of the document that is actually focused on examining the availability of emission inventories, monitoring capability, and air quality data.

2. Topographic, meteorological, and economic activity–related differences among selected urban centers that affect their likelihood of vulnerability to air pollution. For example, the analysis should consider the topographic advantages of places that enjoy strong and continuous winds such as the island nations of the Caribbean, in contrast to high altitude or confined cities such as La Paz, Quito, Mexico City, Guadalajara, and Santiago de Chile, whose periods of stagnation increase their vulnerability to air pollution.

3. Factors that capture the population's level of exposure to polluted air: the population's size and its level of exposure to different pollutants; location of economic activity to location of the population; and considerations on whether well-defined residential, commercial, and industrial areas exist. This analysis would only be feasible in urban centers that have allocated resources to monitor ambient air quality concentrations and emission inventories, and that, according to the findings of this study, appear vulnerable to air pollution.

4. Characterization of monitoring networks by looking at several key features such as completeness, representativeness, reliability, and transparency. This would help to evaluate the quality of the data used in the analysis of vulnerability to air pollution.

The study reported on the ambient air quality standards used in each country but did not explore the methodology to determine them. Latin American and Caribbean countries usually lack sufficient budget or research capabilities to develop local regulations based on scientific evidence; thus, it would be expected that ambient air quality standards are copied from international benchmarks such as the US NAAQS, WHO guidelines, or European Union countries' standards, especially considering that health impacts for certain pollutants are equal for all human beings regardless their race, nutrition, environment, etc. Thus, local research in Latin America could be unnecessary. The evidence of more stringent standards in Uruguay and more permissive standards in Colombia (compared with US NAAQS) raised immediate questions: *How are standards defined in the region? Are any of the standards presented based on scientific evidence?*

Air quality monitoring should provide the input for policy making, but if air quality standards are not used as instruments to set air quality objectives, legally enforceable policies cannot be implemented because there are no incentives for compliance. It is perceived that in most Latin American countries and cities, air quality standards are mere guidelines, and compliance is not legally mandatory. However, this needs to be documented.

The document partially examines the topic of ambient air quality standards but overlooks all other matters regulated by national and/or local legal frameworks for air quality. Broadening the analysis to the entire legal framework would provide answers to questions such as: *How do the various standards differ from guidelines in terms of practical consequences? What are the enforcement mechanisms for air quality standards or the consequences of exceeding those standards in different countries (if any)?*

Another important aspect not covered in this study is an examination of the availability of air quality indexes. It is known that several countries including Chile, Mexico, Brazil, and Ecuador disseminate air quality monitoring results as a function of a locally defined index that classifies air quality on any given day as, for example, good, moderate, or poor. Air quality indexes are mainly related to reporting activities, perhaps the most important duty of democratic governments and the most important phase of air quality management to promote people's awareness and participation.

Air quality indexes are particularly relevant during air pollution episodes and are usually linked to action plans, regardless of the lack of international standardization. In this sense, it should be noted that these same countries have also developed criteria to declare critical conditions based on registered levels of ambient concentrations referenced to an air quality index or to a pre-established level of a specific pollutant, which do not necessarily coincide with the value of the regulating standards.[87]

Documenting the availability of air quality indexes and examining them in detail would answer questions such as: How many urban centers in the region have the capability to communicate air quality risks to their citizens? How many urban centers in the region have contingency plans based on air quality indexes?

The analysis of the existence of monitoring capability raises several questions that should also be explored in future work. Because air quality objectives are essential to evaluate a monitoring station or network, how many of the region's monitoring networks have documented air quality objectives? Air quality objectives, or at least air quality or emissions reduction goals, should also be detected and documented. In order to define their performance and compliance with air quality regulations, how many monitoring stations or networks have quality assurance programs? Even if the answer is none, this situation should be documented.

An assessment of the experiences of urban centers where a sound, integrated air quality management plan exists would provide a solid basis for others to learn from it. The best known cases are Santiago, the São Paulo Metropolitan Region, and Mexico City (ZMVM), all of which have engaged in formal programs and permanent surveillance to manage air pollution[88] with good but not fully satisfactory results. A more detailed study of the reasons for success and failure of different policies and instruments would provide answers to questions about the cost-effectiveness of these policies and indicate the conditions required for their proper functioning.

It appears that the assessment of health and environmental effects of air pollution at local levels has not generally been documented, but further collection and analysis of data on this topic would be required for a well-informed opinion.

An important conclusion, but one that requires further documentation, relates to the role of foreign institutions in promoting good practices in air quality management. Foreign institutions such as the SwissContact foundation in Bolivia and Central America, CCAD in Central America, and the World Bank in Mexico and the Dominican Republic appear to have played an important role in promoting good practices in air quality management in

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[87] For example, Chile developed the ICAP index based on concentrations of PM_{10}. Above certain levels of the index, it declares warning, pre-emergency, or emergency conditions with associated policies to be implemented in each case. Specifically, warnings are declared when ICAP is between 201 and 300 (PM_{10} daily averages above 195 μg/m³), pre-emergency for ICAP between 301 to 500 (PM_{10} daily averages above 240 μg/m³), and emergency for ICAP higher than 501 (PM_{10} daily averages above 330 μg/m³). It declares a warning when the concentration of PM_{10} has exceeded 195 μg/m³ (24 hours), but in fact the norm states that the concentration of PM_{10} for an average 24-hour period can only exceed 150 μg/m³ once a year.

[88] Examples include the "*Plan de Descontaminación de la Región Metropolitana 2002–2010*" in Chile and the "*Programa para Mejorar la Calidad del Aire de la Zona Metropolitana del Valle de México 2002–2010*."

several of the urban centers examined. To assess the potential impact of foreign-driven activities, including those of the World Bank, it is essential to learn the extent to which foreign demand and financing have been responsible for the implementation of these good practices, including the implementation of air quality monitoring networks and studies or the development of emission inventories in LAC. This type of analysis could indicate whether this is one reason why a relatively developed country such as Argentina lacks monitoring capability.

11. SOURCES

Urban Center	Source
Bahia Blanca	▪ Direct communication with the Government of Bahia Blanca ▪ Web page of the government of Bahia Blanca www.bahiablanca.gov.ar/cte/monitoreo_aire.html
Buenos Aires	▪ Web page for Air Quality Monitoring in the City of Buenos Aires http://www.buenosaires.gov.ar/areas/gob_control/aire
Córdoba	▪ Córdoba's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005 ▪ *Aspectos destacados del diagnóstico de calidad del aire en la ciudad de Córdoba, Municipalidad de Córdoba*. II Foro Libre del Ambiente–El Aire, July 2000
La Plata	▪ La Plata's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005
Mar del Plata	▪ N/A
Mendoza	▪ Web page of the Dirección de Saneamiento y Control Ambiental in Mendoza www.saneamiento.mendoza.gov.ar/aire.htm
Posadas	▪ Posadas's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005
Rosario	▪ Ing. Daniel A. Andrés, Ing. Eduardo J. Ferrero, Ing. César E. Mackler. *Monitoreo de contaminantes del aire en la ciudad de Rosario*, Universidad Tecnológica Nacional, Facultad Regional Rosario ▪ Rosario's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005
Tucuman	▪ Tucumán's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005
Cochabamba	▪ Direct communication with Universidad Católica Boliviana (Red MoniCA). ▪ Dennis Bascopé et al. *Resultados del Monitoreo de la calidad del aire en la ciudad de Cochabamba*, Departamento de Ciencias Exactas e Ingeniería, Universidad Católica Boliviana, Cochabamba, Bolivia ▪ Direct communication with SwissContact Foundation in Bolivia
La Paz	▪ Direct communication with SwissContact Foundation in Bolivia ▪ La Paz-El Alto's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005
El Alto	▪ Direct communication with SwissContact Foundation in Bolivia ▪ La Paz-El Alto's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005
Santa Cruz	▪ Direct communication with SwissContact Foundation in Bolivia
São Paulo Metropolitan Region	▪ Relatório de Qualidade do Ar 2004 no Estado de São Paulo, CETESB ▪ Direct communication with CETESB (Companhia de Tecnologia e Saneamento Ambiental)
Rio de Janeiro Metropolitan Region	▪ Relatório Anual da Qualidade do Ar 2003, 2002, FEEMA (Fundação Estadual de Engenharia do Meio Ambiente) ▪ FEEMA's Web page: www.feema.rj.gov.br/ ▪ Direct communication with the Municipal Secretary of the Environment of the

Urban Center	Source
	City of Rio de Janeiro
Belo Horizonte	▪ Belo Horizonte's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005 ▪ FEAM's (Fundação Estadual do Meio Ambiente) Web page: www.feam.br/principal/home.asp
Porto Alegre	▪ Relatório da Qualidade do Ar 2001-2002, FEPAM (Fundação Estadual de Proteção Ambiental Henrique Luis Roessler–RS) ▪ Porto Alegre Metropolitan Region's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005
Recife Metropolitan Region	▪ Direct communication with CPRH (Agência Estadual de Meio Ambiente e Recursos Hídricos)
Salvador	▪ External consultant
Fortaleza	▪ Fortaleza's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005 ▪ SEMACE's (Superintendência Estadual do Meio Ambiente, CEARA) Web page: www.semace.ce.gov.br
Curitiba Metropolitan Region	▪ Relatório da Qualidade do Ar na Região Metropolitana de Curitiba 2003, 2002, 2001, 2000
Brasília	▪ SEMARCH's (Secretaria de Estado de Meio Ambiente e Recursos Hídricos) Web page: www.semarh.df.gov.br ▪ External consultant
Belém	▪ External consultant
Goiânia	▪ Web page of the Agência Ambiental do Estado de Goiás: www.agenciaambiental.go.gov.br/monitoramento/index.php#
Santos	▪ Relatório da Qualidade do Ar 2004 no Estado de São Paulo, CETESB ▪ Direct communication with CETESB (Companhia de Tecnologia e Saneamento Ambiental)
Manaus	▪ External consultant
Grande Vitória	▪ Relatório da Qualidade do Ar da Região da Grande Vitória 2004, 2003 ▪ Relatório Anual de Qualidade do Ar, SEAMA (Secretaria de Estado de Meio Ambiente e Recursos Hídricos) 2000–2001
Campinas	▪ Relatório da Qualidade do Ar 2004 ao Estado de São Paulo, CETESB ▪ Direct communication with CETESB (Companhia de Tecnologia e Saneamento Ambiental)
São Luis	▪ External consultant
Natal	▪ External consultant
Maceió	▪ External consultant
Teresina	▪ External consultant
João Pessoa	▪ External consultant
São José dos Campos	▪ Relatório da Qualidade do Ar 2004 no Estado de São Paulo, CETESB ▪ Direct communication with CETESB (Companhia de Tecnologia e Saneamento Ambiental)

Urban Center	Source
Ribeirão Preto	▪ Relatório da Qualidade do Ar 2004 no Estado de São Paulo, CETESB ▪ Direct communication with CETESB (Companhia de Tecnologia e Saneamento Ambiental)
Aracajú	▪ External consultant
Cuiabá	▪ External consultant
Florianópolis	▪ External consultant
Campo Grande	▪ External consultant
Londrina	▪ External consultant
Sorocaba	▪ Relatório da Qualidade do Ar 2004 no Estado de São Paulo, CETESB ▪ Direct communication with CETESB (Companhia de Tecnologia e Saneamento Ambiental)
Greater Concepción	▪ Air program Web page of CONAMA Bío Bío: www.conamabiobio.cl/web_aire_biobio/home_aire.htm
Santiago (Metropolitan Region)	▪ Direct communication with CONAMA RM ▪ *Resumen Calidad Aire en Santiago 1997–2004*, CONAMA RM
Greater Valparaíso	▪ Technical Report (Informe Técnico) No. 2004 of CONAMA Region V and Direct Communication with CONAMA Region V
Barranquilla	▪ Direct communication with DAMAB (Departamento Técnico Administrativo del Medio Ambiente Barranquilla) ▪ *Datos estadísticos de la Red de Monitoreo de Enero a Junio del 2005*. DAMAB, July 2005 ▪ *Documento Soporte Norma de Calidad del Aire*. Subdirección de Estudios Ambientales, IDEAM, November 2005, available at. www.ideam.gov.co/biblio/paginaabierta/discusion.htm
Bogotá	▪ Direct Communication with DAMA ▪ DAMA's Web page: www.dama.gov.co/aire/air.htm ▪ *Informe Anual de la Calidad del Aire de Bogotá 2004*, DAMA ▪ *Documento Soporte Norma de Calidad del Aire*. Subdirección de Estudios Ambientales, IDEAM, November 2005, available at: www.ideam.gov.co/biblio/paginaabierta/discusion.htm
Bucaramanga	▪ CDMB's (Corporación Autónoma Regional para la Defensa de la Meseta de Bucaramanga) Web page: www.cdmb.gov.co/monitoreo/redaire.php ▪ *Documento Soporte Norma de Calidad del Aire*. Subdirección de Estudios Ambientales, IDEAM, November 2005, available at: www.ideam.gov.co/biblio/paginaabierta/discusion.htm
Cali	▪ Julián Bedoya et al., *Urban air quality in Colombia: a 2004 status report.* ▪ Direct communication with relevant professionals ▪ *Documento Soporte Norma de Calidad del Aire*. Subdirección de Estudios Ambientales, IDEAM, November 2005, available at: www.ideam.gov.co/biblio/paginaabierta/discusion.htm
Cartagena	▪ *Documento Soporte Norma de Calidad del Aire*. Subdirección de Estudios Ambientales, IDEAM, November 2005, available at: www.ideam.gov.co/biblio/paginaabierta/discusion.htm

Urban Center	Source
Cúcuta	▪ *Documento Soporte Norma de Calidad del Aire*. Subdirección de Estudios Ambientales, IDEAM, November 2005, available at: www.ideam.gov.co/biblio/paginaabierta/discusion.htm
Medellín	▪ *Documento Soporte Norma de Calidad del Aire*. Subdirección de Estudios Ambientales, IDEAM, November 2005, available at: www.ideam.gov.co/biblio/paginaabierta/discusion.htm ▪ Web page of the Universidad Nacional de Colombia, Medellín Center: www.unalmed.edu.co/redaire
Pereira	▪ *Documento Soporte Norma de Calidad del Aire*. Subdirección de Estudios Ambientales, IDEAM, November 2005, available at: www.ideam.gov.co/biblio/paginaabierta/discusion.htm
San José	▪ Rodríguez, Susana and Herrera, Jorge. *Calidad del Aire en la Capital entre 1993 y 2003*, Revista Semestral de la Escuela de Ciencias Ambientales, Universidad Nacional Costa Rica, number 27, June 2004. ▪ Lucrecia Navarro, *II Informe de la Calidad del Aire en San José (monitoreo realizado entre Agosto 2000 y Agosto 2001*). Ministerio de Salud and Universidad Nacional, June 2002
Santo Domingo	▪ *Diagnóstico Ambiental y Análisis Económico/Fiscal, Capítulo 6: Calidad del aire y Anexo: Resultados Calidad del Aire y Ruido*, Secretaría de Estado de Medio Ambiente y Recursos Naturales. Abt Associates Inc., December 2002
Guayaquil	▪ Direct communication with the Municipality of Guayaquil ▪ Guayaquil's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005 ▪ *Estudio de la Calidad del Aire en la Ciudad de Guayaquil: Diagnóstico e Investigación Referencial*, PETROECUADOR
Quito	▪ Direct communication with CORPAIRE (Corporación para el Mejoramiento del Aire de Quito) ▪ Quito's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005
San Salvador	▪ Web page of the Ministry of the Environment: www.marn.gob.sv/varios/Monitoreo%20aire.htm
Guatemala City	▪ *Monitoreo del aire en la ciudad de Guatemala, Informe Anual 2004*, Universidad de San Carlos de Guatemala
San Pedro Sula	▪ Web page of CESCCO (Centro de Estudios y Control de Contaminantes): www.cescco.gob.hn
Tegucigalpa	▪ *Proyecto de Monitoreo de Contaminantes del Aire en el Distrito Central: Informe Año 2004*, Centro de Estudios y Control de Contaminantes (CESCCO)
Kingston	▪ Direct communication with National Environment and Planning Agency (NEPA) ▪ Ulriksen et al., *Recopilación de Información para estudio de Efectos de Contaminantes atmosféricos para ciudades de Latinoamérica y el Caribe*. Fundación Centro Nacional del Medio Ambiente (CENMA), January 2004
Acapulco	▪ Direct communication with the Instituto Nacional de Ecología (INE)
Aguascalientes	▪ Direct communication with the Secretaría de Desarrollo Social, Gobierno del Estado de Aguascalientes
Chihuahua	▪ Direct communication with the Instituto Nacional de Ecología (INE)

Urban Center	Source
Ciudad Juárez	▪ SINAICA's (Sistema Nacional de la Información de la Calidad del Aire) Web page: http://sinaica.ine.gob.mx
Coatzacoalcos	▪ Direct communication with the Instituto Nacional de Ecología (INE)
Cuernavaca	▪ SINAICA's (Sistema Nacional de la Información de la Calidad del Aire) Web page: http://sinaica.ine.gob.mx/
Culiacán	▪ Direct communication with the Instituto Nacional de Ecología (INE)
Guadalajara (ZMG)	▪ SINAICA's (Sistema Nacional de la Información de la Calidad del Aire) Web page: http://sinaica.ine.gob.mx
Hermosillo	▪ Direct communication with the Instituto Nacional de Ecología (INE)
León	▪ Web page of the Red de Monitoreo de Calidad del Aire del Estado de Guanajuato: http://sinaica.ine.gob.mx/red_guanajuato.html
Matamoros	▪ *Informe de Resultados 2002–2004 de la Red de Monitoreo Atmosférico del Estado de Tamaulipas* available at: www.tamaulipas.gob.mx/gobierno/secretarias/sec_obras/dir_med_amb/dir_recursos_naturales/monitoreo
Mérida	▪ Direct communication with the Instituto Nacional de Ecología (INE)
Mexicali	▪ SINAICA's (Sistema Nacional de la Información de la Calidad del Aire) Web page: http://sinaica.ine.gob.mx
Zona Metropolitana del Valle de México (ZMVM)	▪ SINAICA's (Sistema Nacional de la Información de la Calidad del Aire) Web page: http://sinaica.ine.gob.mx ▪ Direct communication with the Secretaría de Medio Ambiente del Distrito Federal and Web page of the Sistema de Monitoreo Atmosférico de la Ciudad de México: www.sma.df.gob.mx/simat
Monterrey (ZMM)	▪ SINAICA's (Sistema Nacional de la Información de la Calidad del Aire) Web page: http://sinaica.ine.gob.mx
Puebla (ZMP)	▪ SINAICA's (Sistema Nacional de la Información de la Calidad del Aire) Web page: http://sinaica.ine.gob.mx
Querétaro	▪ Web page of the Secretaría de Desarrollo Sustentable del Estado de Querétaro: www.queretaro.gob.mx
Saltillo	▪ Direct communication with the Instituto Nacional de Ecología (INE)
San Luis Potosí	▪ Web page of the Secretaría de Ecología y Gestión Ambiental del Estado de San Luis Potosí: www.segam.gob.mx
Tampico	▪ *Informe de Resultados 2002-2004 de la Red de Monitoreo Atmosférico del Estado de Tamaulipas* available at: www.tamaulipas.gob.mx/gobierno/secretarias/sec_obras/dir_med_amb/dir_recursos_naturales/monitoreo
Toluca	▪ SINAICA's (Sistema Nacional de la Información de la Calidad del Aire) Web page: http://sinaica.ine.gob.mx/
Veracruz	▪ Veracruz's grant proposal "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005
Villahermosa	▪ *Primer Informe de la Calidad del Aire del Estado de Tabasco 2001-2002*, Secretaría de Desarrollo Social y Protección del Medio Ambiente
Tijuana–Rosarito	▪ SINAICA's (Sistema Nacional de la Información de la Calidad del Aire) Web page: http://sinaica.ine.gob.mx

Urban Center	Source
Torreón	▪ Web page of the Dirección General de Medio Ambiente del Estado de Torreón: http://www.torreon.gob.mx/gobierno/dependencias/medioambiente/index.php
Managua	▪ *Monitoreo de Contaminación del Aire en la Ciudad de Managua, Informes Anuales 2000 and 2001, Proyecto Aire Puro,* SwissContact Foundation
Panama City	▪ Direct communication with the University of Panama ▪ Panama City's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005
Asunción	▪ N/A
Arequipa	▪ Arequipa's grant proposal "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005 ▪ Air quality information from the Ministry of Health obtained through the Comité de Gestión de Aire Limpio for the cities of Lima–Callao
Lima–Callao	▪ Direct communication with the Comité de Gestión de Aire Limpio for the cities of Lima–Callao ▪ Web page of the Dirección General de Salud Ambiental (DIGESA) www.digesa.sld.pe
Trujillo	▪ Trujillo's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005
Montevideo	▪ Direct communication with the Laboratorio de Higiene Ambiental, Departamento de Desarrollo Ambiental, Intendencia Municipal de Montevideo
Barcelona	▪ *Primer Informe de la Calidad del Aire en las Principales Ciudades de Venezuela*, October 2003, Ministerio del Ambiente y de los Recursos Naturales
Barquisimeto	▪ Briefing for a World Bank mission to Venezuela to identify an Environmentally Sustainable Development Management Program, January 2005
Caracas	▪ Caracas's grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project," December 2005 ▪ *Primer Informe de la Calidad del Aire en las Principales Ciudades de Venezuela*, October 2003, Ministerio del Ambiente y de los Recursos Naturales
Ciudad Guyana	▪ Briefing for a World Bank mission to Venezuela to identify an Environmentally Sustainable Development Management Program, January 2005
Maracaibo	▪ Direct communication with ICLAM (Instituto para la Conservación del Lago de Maracaibo)
Maracay	▪ Briefing for a World Bank mission to Venezuela to identify an Environmentally Sustainable Development Management Program, January 2005
Valencia	▪ *Primer Informe de la Calidad del Aire en las Principales Ciudades de Venezuela*, October 2003, Ministerio del Ambiente y de los Recursos Naturales

REGIONAL TABLES

Regional Table 1: Population Figures of Selected Urban Centers in the Latin America and Caribbean Region

Country	Urban Centers	Population	Observations
ARGENTINA	Bahía Blanca	274,509	2001 Census
	Buenos Aires	12,046,799	Greater Buenos Aires, 2001 Census
	Córdoba	1,368,301	2001 Census
	La Plata	694,253	Conurbation of La Plata, 2001 Census
	Mar del Plata	541,733	2001 Census
	Mendoza	848,660	Metropolitan Area, 2001 Census
	Posadas	279,961	Metropolitan Area, 2001 Census
	Rosario	1,161,188	Metropolitan Area, 2001 Census
	Tucumán	738,479	Metropolitan Area, 2001 Census
BOLIVIA	Cochabamba	770,137	2001 Census
	La Paz	789,585	2001 Census
	El Alto	647,350	2001 Census
	Santa Cruz	1,116,059	2001 Census
BRAZIL	São Paulo Metropolitan Region (SPMR)	19,037,487	2005 Estimate
	Rio de Janeiro Metropolitan Region (RJMR)	11,570,524	2005 Estimate
	Belo Horizonte	2,375,300	2005 Estimate
	Porto Alegre Metropolitan Region	3,978,263	2005 Estimate
	Recife Metropolitan Region	3,599,181	2005 Estimate
	Salvador	3,350,523	Metropolitan Region, 2005 Estimate
	Fortaleza	3,349,826	Metropolitan Region, 2005 Estimate
	Curitiba Metropolitan Region	3,141,366	2005 Estimate
	Brasília	2,231,100	2005 Estimate
	Belém	1,396,800	2005 Estimate
	Goiânia	1,193,100	2005 Estimate
	Santos	416,100	2005 Estimate
	Manaus	1,634,100	2005 Estimate
	Grande Vitória	1,612,885	2005 Estimate
	Campinas	1,028,300	2005 Estimate
	São Luís [2]	1,227,659	Metropolitan Area, 2005 Estimate
	Natal	1,179,347	Metropolitan Area, 2001 Census
	Maceió	1,116,075	Metropolitan Area, 2005 Estimate
	Teresina	747,000	2005 Estimate

Country	Urban Centers	Population	Observations
	João Pessoa	999,180	Metropolitan Area, 2005 Estimate
	São José dos Campos	600,049	Metropolitan Area, 2005 Estimate
	Ribeirão Preto	551,312	Metropolitan Area, 2005 Estimate
	Aracajú	498,600	2005 Estimate
	Cuiabá	533,800	Metropolitan Area, 2005 Estimate
	Florianópolis	933,560	Metropolitan Area, 2005 Estimate
	Campo Grande	749,768	Metropolitan Area, 2005 Estimate
	Londrina	708,523	Metropolitan Area, 2005 Estimate
	Sorocaba	565,180	Metropolitan Area, 2005 Estimate
CHILE	Greater Concepción	848,023	2002 Census
	Metropolitan Region of Santiago	5,428,590	2002 Census
	Greater Valparaíso	803,683	2002 Census
COLOMBIA	Barranquilla	1,751,684	2003 Projection
	Bogotá	7,448,271	Conurbation of Bogotá, 2003 Projection
	Bucaramanga	979,040	Conurbation of Bucaramanga, 2003 Projection
	Cali	2,401,110	Conurbation of Cali, 2003 Projection
	Cartagena	976,882	Conurbation of Cartagena, 2003 Projection
	Cúcuta	814,079	Conurbation of Cúcuta, 2003 Projection
	Medellín	2,958,240	Conurbation of Medellín, 2003 Projection
	Pereira	649,778	Conurbation of Pereira, 2003 Projection
COSTA RICA	San José	336,829	2004 Estimate
DOMINICAN REPUBLIC	Santo Domingo	1,887,586	2002 Census
ECUADOR	Guayaquil	1,985,379	2001 Census
	Quito	1,399,378	2001 Census
EL SALVADOR	San Salvador	2,232,300	Conurbation of San Salvador, 2005 Projection
GUATEMALA	Guatemala City	942,348	2002 Census (provisional)
HONDURAS	San Pedro Sula	439,086	2001 Census
	Tegucigalpa	769,061	2001 Census
JAMAICA	Kingston	579,137	2001 Census
MEXICO	Acapulco	620,656	2000 Census

Country	Urban Centers	Population	Observations
	Aguascalientes	594,092	Conurbation of Aguascalientes 2000 Census
	Chihuahua	657,876	Conurbation of Chihuahua, 2000 Census
	Ciudad Juárez	1,187,275	Conurbation of Ciudad Juárez, 2000 Census
	Coatzacoalcos	249,879	2000 Census
	Cuernavaca	672,719	Conurbation of Cuernavaca, 2000 Census
	Culiacán	540,823	Conurbation of Culiacán, 2000 Census
	Guadalajara (ZMG)	3,477,401	2000 Census
	Hermosillo	545,928	Conurbation of Hermosillo, 2000 Census
	León	1,020,818	Conurbation of Leon, 2000 Census
	Matamoros	376,279	2000 Census
	Mérida	743,983	Conurbation of Mérida, 2000 Census
	Mexicali	549,873	Conurbation of Mexicali, 2000 Census
	Metropolitan Area of the Valley of Mexico (ZMVM)	17,308,562	Mexico City, 2000 Census
	Monterrey (ZMM)	3,161,509	Metropolitan Zone 2000 Census
	Puebla (ZMP)	2,104,935	Metropolitan Zone, 2000 Census
	Querétaro	554,707	Conurbation of Querétaro, 2000 Census
	Saltillo	593,909	Conurbation of Saltillo, 2000 Census
	San Luis Potosí	798,782	Conurbation of San Luis Potosí, 2000 Census
	Tampico	590,119	Conurbation of Tampico, 2000 Census
	Toluca (ZMVT)	950,198	Conurbation of Toluca, 2000 Census
	Veracruz	535473	Conurbation of Veracruz, 2000 Census
	Villahermosa	357,669	2000 Census
	Tijuana–Rosarito	1,148,681 (Tijuana)	Conurbation of Tijuana, 2000 Census
	Torreón	771,939	Conurbation of Torreón, 2000 Census
NICARAGUA	Managua	973,100	2005 Projection
PANAMA	Panama City	415,964	2000 Census
PARAGUAY	Asunción	1,620,483	Conurbation area, 2002 Census (provisional)
PERU	Arequipa	760,329	2002 Estimate
	Lima–Callao	7,665,536	2002 Estimate

Country	Urban Centers	Population	Observations
	Trujillo	611,007	2002 Estimate
URUGUAY	Montevideo	1,269,648	2004 Census
VENEZUELA	Barcelona	328,000	2001 Census (provisional)
	Barquisimeto	811,000	2001 Census (provisional)
	Caracas	1,836,000	2001 Census (provisional)
	Ciudad Guyana	629,000	2001 Census (provisional)
	Maracaibo	1,609,000	2001 Census (provisional)
	Maracay	394,000	2001 Census (provisional)
	Valencia	1,196,000	2001 Census (provisional)

Source: *Thomas Brinkhoff: City Population, http://www.citypopulation.de*

Regional Table 2: List of Relevant Institutions linked to Air Quality Monitoring

Country	City	Relevant Institutions	Responsibilities	Web pages
Argentina	Bahía Blanca	Gobierno Municipal de Bahía Blanca, Departamento de Saneamiento Ambiental	Operation of monitoring network and data processing	www.bahiablanca.gov.ar/saneamiento
	Buenos Aires	Gobierno de Buenos Aires, Dirección de Política Ambiental	Operation of monitoring network	www.buenosaires.gov.ar/areas/gob_control/aire
	Córdoba	Subsecretaría del Medio Ambiente e Higiene Urbano	Institution in charge of air quality management	www.cordoba.gov.ar
	La Plata	Secretariat of Environmental Policy of the Province of Buenos Aire–Municipalidad de la Ciudad de La Plata	Responsible for air quality monitoring	www.spa.gba.gov.ar
		Centro de Investigación del Medio Ambiente (CIMA) de la Facultad de Ciencias Exactas de la Universidad Nacional de la Plata Laboratorio de Servicios para la Industria y el Sistema Científico (LASEISIC)	Periodic air quality monitoring	
	Mendoza	Dirección de Saneamiento y Control Ambiental	Institution responsible for air quality management and enforcement	www.saneamiento.mendoza.gov.ar/aire.htm
	Mar del Plata			
	Posadas		No air quality monitoring program.	
	Rosario	Secretaría de Servicios Públicos y Medio Ambiente	Institution responsible for air quality management	www.rosario.gov.ar
	Tucumán	Gobierno de Tucumán, Dirección de Medio Ambiente		www.tucuman.gov.ar
Bolivia	Cochabamba	Universidad Católica Boliviana de San Pablo	Management of monitoring network	www.ucbcba.edu.bo
	La Paz	SwissContact Foundation	Promotes air quality monitoring	
	Santa Cruz	SwissContact Foundation	Promotes air quality monitoring	
Brazil	Aracajú [1]	ADEMA (Administração Estadual de Meio Ambiente)	Government institution responsible for environmental issues within the State of Sergipe. No air quality monitoring program.	www.adema.se.gov.br
	Belém[1]	SEMMA (Secretaria Municipal de Meio Ambiente)	Government institution responsible for environmental issues in Belém. No air quality monitoring program.	www.belem.pa.gov.br/semma
	Belo Horizonte	FEAM (Fundação Estadual do Meio Ambiente).	State-level institution responsible for management of air quality	www.feam.br/principal/home.asp
	Brasília	Secretaria de Estado de Meio Ambiente e Recursos Hídricos	Institution responsible for management of air quality	www.semarh.df.gov.br

Country	City	Relevant Institutions	Responsibilities	Web pages
		Centro de Formação de Recursos Humanos em Transportes (CEFTRU), Universidade de Brasília	Manage 2 air quality monitoring stations	
	Campinas	CETESB (Companhia de Tecnologia e Saneamento Ambiental)	State-level institution responsible for management of air quality	www.cetesb.sp.gov.br
	Campo Grande[1]	SEMADES (Secretaria Municipal de Meio Ambiente e Desenvolvimento Sustentável)	Government institution responsible for environmental issues in Campo Grande. No air quality program.	www.campogrande.ms.gov.br/index3.htm?canal_id=394
	Curitiba[2]	SEMA (Secretaria de Estado do Meio Ambiente e Recursos Hídricos)	State-level institution responsible for management of air quality	www.pr.gov.br/meioambiente/sema/index.shtml
	Cuiabá[1]	SMADES (Secretaria Municipal de Meio Ambiente e Desenvolvimento Urbano)	Government institution responsible for environmental issues in Cuiabá. No air quality monitoring program.	www.cuiaba.mt.gov.br/smades/index.jsp
	Florianópolis[1]	FLORAM (Fundação Municipal do Meio Ambiente de Florianópolis)	Government institution responsible for environmental issues in Florianópolis. No air quality monitoring program.	www.pmf.sc.gov.br/floram/index.php
	Fortaleza	SEMACE (Superintendência Estadual do Meio Ambiente, Ceará)	State-level institution responsible for a program to monitor air quality	www.semace.ce.gov.br/
	Goiânia	Agência Ambiental do Estado de Goiás—DMA (Departamento de Monitoramento Ambiental)	State-level institution responsible for management of air quality (including monitoring, laboratory analysis)	www.agenciaambiental.go.gov.br/agencia/index.php
	João Pessoa[1]	SEMAM (Secretaria Municipal de Meio Ambiente)	Government institution responsible for environmental issues in João Pessoa. No air quality monitoring program.	www.joaopessoa.pb.gov.br/secretarias/semam
	Londrina[1]	SEMA (Secretaria Municipal do Ambiente)	Government institution responsible for environmental issues in Londrina. No air quality monitoring program.	www.londrina.pr.gov.br/ambiente
	Maceió[1]	SEMPMA (Secretaria Municipal de Proteção ao Meio Ambiente)	Government institution responsible for environmental issues in Maceió. No air quality monitoring program.	www.maceio.al.gov.br/secretarias%5Fe%5Forgaos%5Fmunicipais/sempma
	Manaus[1]	SEDEMA (Secretaria Municipal de Desenvolvimento e Meio Ambiente)	Government institution responsible for environmental issues in Manaus. No air quality monitoring program.	www.manaus.am.gov.br/secretarias/secretariaMunicipalDeDesenvolvimentoEMeioAmbiente
	Natal[1]	SEMURB (Secretaria Especial de Meio Ambiente e Urbanismo)	Government institution responsible for environmental issues in Natal. No air quality monitoring program.	www.natal.rn.gov.br/semurb/index.php
	Porto Alegre Metropolitan Region	FEPAM (Fundação Estadual de Proteção Ambiental Henrique Luis Roessler–RS)	State-level institution responsible for management of air quality	www.fepam.rs.gov.br/qualidade/boletim_ar_automática.asp

Country	City	Relevant Institutions	Responsibilities	Web pages
	Recife	CPRH (Agência Estadual de Meio Ambiente e Recursos Hídricos)	State-level institution responsible for management of air quality	www.cprh.pe.gov.br/frme-index-secao.asp?idsecao=29
	Ribeirão Preto	CETESB (Companhia de Tecnologia e Saneamento Ambiental)	State-level institution responsible for management of air quality	www.cetesb.sp.gov.br/
	Rio de Janeiro Metropolitan Region	FEEMA (Fundação Estadual de Engenharia do Meio Ambiente)	State-level institution responsible for management of air quality.	www.feema.rj.gov.br/
		SMAC (Secretaria Municipal de Meio Ambiente da Cidade do Rio de Janeiro)	Responsible for air quality management in the City of Rio de Janeiro	www.rio.rj.gov.br/smac/
		SMABR (Secretaria de Meio Ambiente de Belford Roxo)	Responsible for air quality management in the city of Belford Roxo	
	Salvador[1]	SEPLAM (Secretaria Municipal do Planejamento, Urbanismo e Meio Ambiente)	Government institution responsible for environmental issues in Salvador. No air quality monitoring program.	www.seplam.pms.ba.gov.br/
	Santos	CETESB (Companhia de Tecnologia e Saneamento Ambiental)	State-level institution responsible for management of air quality	www.cetesb.sp.gov.br/
	São José dos Campos	CETESB (Companhia de Tecnologia e Saneamento Ambiental)	State-level institution responsible for management of air quality	www.cetesb.sp.gov.br/
	São Luís[1]	SEMA (Secretaria de Estado de Meio Ambiente e Recursos Naturais)	Government institution responsible for environmental issues within the State of Maranhão. No air quality monitoring program.	
	São Paulo	CETESB (Companhia de Tecnologia e Saneamento Ambiental)	State-level institution responsible for management of air quality	www.cetesb.sp.gov.br/
	Sorocaba	CETESB (Companhia de Tecnologia e Saneamento Ambiental)	State-level institution responsible for management of air quality	www.cetesb.sp.gov.br/
	Teresina[1]	SDU (Superintendência de Desenvolvimento Urbano e Meio Ambiente)	Government institution responsible for environmental issues within the State of Maranhão. No air quality monitoring program.	www.teresina.pi.gov.br/novothe/orgao/default.asp
	Vitória	SEAMA (Secretaria de Estado de Meio Ambiente e de Recursos Hídricos)	State-level institution responsible for management of air quality	www.seama.es.gov.br/
Chile	Concepción	Comisión Nacional de Medio Ambiente, Región Bío Bío (CONAMA Bío Bio)	Air quality monitoring	www.conamabiobio.cl/web_aire_biobio/home_aire.htm
	Santiago	Servicio de Salud Metropolitano de Medio Ambiente (SESMA)	Operation of the monitoring network and validation of data	www.asrm.cl/sitio/pag/aire/indexjs3aire.asp

Country	City	Relevant Institutions	Responsibilities	Web pages
	Valparaíso (V Region)	Comisión Nacional de Medio Ambiente (CONAMA)	Coordinating institution	www.conamarm.cl
		Centro Nacional del Medio Ambiente (CENMA)	Validation of monitoring data	www.cenma.cl
		CONAMA V Region	PM_{10} forecast	www.conama.cl
Colombia[4]	Barranquilla	DAMAB (Departamento Técnico Administrativo del Medio Ambiente Barranquilla)	Institution responsible for management of air quality	
	Bogotá	Departamento Técnico Administrativo del Medio Ambiente	Operation of monitoring network; data processing	www.dama.gov.co
	Bucaramanga	CDMB (Corporación Autónoma Regional para la Defensa de la Meseta de Bucaramanga)	Operation of the monitoring network; data processing	www.cdmb.gov.co
	Cali	DAGMA (Departamento Administrativo de Gestión del Medio Ambiente)	Operation of the monitoring network; data processing	www.dagmacali.gov.co
	Cartagena	CARDIQUE (Corporación Autónoma Regional del Canal del Dique)	Institution responsible for air quality management	cardique.gov.co/inicio.html
	Cúcuta	CORPONOR (Corporación Autónoma Regional de la Frontera Nororiental)	Institution responsible for air quality management	www.corponor.gov.co/index.htm
	Medellín	Universidad Nacional de Colombia, Medellín	Operation of monitoring network; data processing of data and air quality evaluation	www.unalmed.edu.co/redaire
	Pereira	CARDER (Corporación Autónoma Regional de Risaralda)	Institution responsible for air quality management	www.carder.gov.co/
Costa Rica	San José	Ministerio de Salud	Proyecto Aire Limpio Programa Vigilancia Calidad del Aire (including Pilot Plan)	www.mopt-gtz.go.cr/airelimpio/contact.html
		Universidad Nacional de Costa Rica	Road emission control Monitoring study (PM_{10}, NO_2)	
Dominican Republic	Santo Domingo	Secretaría de Estado de Medio Ambiente y Recursos Naturales/Dirección de Calidad Ambiental	Air quality monitoring	www.ceiba.gov.do
Ecuador	Guayaquil	Municipalidad de Guayaquil/Departamento de Medio Ambiente	Air quality monitoring; data processing	www.guayaquil.gov.ec
	Quito	Corporación para el Mejoramiento del Aire de Quito (CORPAIRE)	Operation of monitoring network; data processing	www.corpaire.org
El Salvador	San Salvador	Ministerio de Medio Ambiente y Recursos Naturales (MARN)	Operation of monitoring network	www.marn.gob.sv/varios/Monitoreo%20aire.htm

Country	City	Relevant Institutions	Responsibilities	Web pages
Guatemala	Guatemala City	USAC, Facultad de Ciencias Químicas y Farmacia, Laboratorio de Monitoreo de Aire	Operation of monitoring network; analysis of emission inventory	www.usac.edu.gt
		Ministerio de Ambiente y Recursos Naturales (MARN)	Institution in charge of executing and formulating environmental policies	www.marn.gob.gt
Honduras	San Pedro Sula	Municipalidad de San Pedro Sula/División Ambiental	Air quality monitoring	www.alcaldiasanpedrosula.com/dina_1.htm
	Tegucigalpa	Centro de Estudios y Control de Contaminantes de Honduras (CESCCO)	Operation of the monitoring network; analysis	www.cescco.gob.hn
Jamaica	Kingston	National Environment and Planning Agency	Air quality monitoring	www.nrca.org
		Ministry of Health (Environmental Control Unit)	Air quality study in 1997	www.moh.gov.jm
Mexico	Acapulco[1]	Gobierno de Acapulco de Juárez/ Secretaría de Desarrollo Urbano/ Departamento de Ecología	Institution in charge of environmental management. No air quality monitoring program.	www.acapulco.gob.mx/dependencias/desarollo urbano/ecologia/
	Aguascalientes	Gobierno del Estado de Aguascalientes/ Secretaría de Desarrollo Social/ Departamento de Calidad del Aire	Institution in charge of air quality management	www.aguascalientes.gob.mx
	Chihuahua	Gobierno del Estado de Chihuahua/ Departamento de Ecología	Operation of mobile units for air quality monitoring	www.chihuahua.gob.mx
	Ciudad Juárez	Health Department, Ciudad Juárez	Maintenance and operation of monitoring network	www.chihuahua.gob.mx
	Coatzalcoalcos[1]	Gobierno del Estado de Veracruz	Institution in charge of environmental management. No air quality monitoring program.	www.veracruz.gob.mx
	Cuernavaca	Gobierno del Estado de Morelos/Comisión Estatal del Agua y Medio Ambiente	Operation of monitoring station, data processing	www.ceamamorelos.gob.mx/secciones/ambiente/monitoreo_ atmosférico.html
	Culiacán[1]	Gobierno Municipal de Culiacán/Dirección de Desarrollo Urbano y Ecología	Institution in charge of environmental management. No air quality monitoring program.	www.culiacan.gob.mx
	Guadalajara (ZMG)	Secretaría de Medio Ambiente para el Desarrollo Sustentable, Estado de Jalisco	Operation of monitoring network (RAMAG); validation, processing, and dissemination of data	semades.jalisco.gob.mx
	Hermosillo	Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT)	Institution in charge of air quality monitoring	www.sonora.semarnat.gob.mx
	León	Universidad Tecnológica de León	Operation of monitoring network, data processing	www.utleon.edu.mx

Country	City	Relevant Institutions	Responsibilities	Web pages
		Gobierno del Estado de Guanajuato/Institute of Ecology	Institution in charge of air quality management	www.guanajuato.gob.mx/ieeg/
	Matamoros	Gobierno del Estado de Tamaulipas/Unidad de Calidad del Aire	Operation of monitoring network; air quality monitoring	www.tamaulipas.gob.mx
	Mérida [1]	Municipio de Mérida/Dirección de Desarrollo Urbano	Institution in charge of environmental management. No air quality monitoring program.	www.merida.gob.mx
	Mexicali	Gobierno del Estado de Baja California/Dirección General de Ecología	Operation of monitoring network; validation, processing, and dissemination of data	www.bajacalifornia.gob.mx
	Mexico City (ZMVM)	Gobierno del Distrito Federal	Operation of monitoring network (RAMA); validation, processing, and dissemination of data	www.sma.df.gob.mx/simat/
		Instituto Nacional de Ecología (INE)	Preparation of National Emission Inventory	www.ine.gob.mx
		Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT)	Establishes air quality norms and methodology for measurement	www.semarnat.gob.mx
	Monterrey (ZMM)	Gobierno del Estado de Nuevo León	Operation of monitoring network (SIMA); validation, processing, and dissemination of data	www.medioambiente.nl.gob.mx/sima
	Puebla (ZMP)	Secretaría de Desarrollo Urbano, Ecología y Obras Públicas	Operation of monitoring network (REMA), validation, processing, and dissemination of data	www.remapuebla.gob.mx/
	Querétaro	Subsecretaría de Medio Ambiente, Gobierno del Estado de Querétaro	Institution in charge of environmental management	www.queretaro.gob.mx
		Centro de Estudios Académicos sobre la Contaminación Ambiental/Facultad de Ciencias Químicas/Universidad Autónoma de Querétaro	Operation of monitoring network	www.uaq.mx
	Saltillo[1]	Gobierno del Estado de Coahuila/Dirección de Protección Ambiental	Institution in charge of environmental management. No air quality monitoring program.	www.coahuila.gob.mx
	San Luis Potosí	Gobierno del Estado de San Luis Potosí/Secretaría de Ecología y Gestión Ambiental (SEGAM)	Operation of monitoring stations; air quality monitoring	www.segam.gob.mx

Country	City	Relevant Institutions	Responsibilities	Web pages
	Tampico	Gobierno del Estado de Tamaulipas/ Unidad de Calidad del Aire	Operation of monitoring network; air quality monitoring	www.tamaulipas.gob.mx
	Tijuana–Rosario	Gobierno del Estado de Baja California/Dirección General de Ecología	Operation of monitoring network; validation, processing, and dissemination of data	www.bajacalifornia.gob.mx/
	Torreón	Municipio de Torreón/Departamento de Medio Ambiente	Operation of monitoring network; air quality monitoring	www.torreon.gob.mx
	Veracruz [1]	Gobierno del Estado de Veracruz/ Secretaría de Desarrollo Regional/ Coordinación Estatal de Medio Ambiente	Entity in charge of environmental management. No air quality monitoring program.	www.sdmaver.gob.mx
	Villahermosa	Gobierno del Estado de Tabasco/Secretaría de Desarrollo Social y Protección del Medio Ambiente	Institution in charge of air quality management	www.tabasco.gob.mx
Nicaragua	Managua	Ministerio de Ambiente y Recursos Naturales (MARENA)	In charge of operating air monitoring stations	www.marena.gob.ni
		Universidad Nacional de Ingeniería–Centro de Investigación y Estudios Medio Ambiente (CIEMA-UNI)	In charge of operating air monitoring stations	www.ciema.uni.edu.ni
Panama	Panama City	Instituto Especializado de Análisis de la Universidad de Panamá	Operation of monitoring network; analysis	www.up.ac.pa/home.htm
Paraguay	Asunción [3]			
Peru	Trujillo	Dirección General de Salud Ambiental (DIGESA)		www.digesa.sld.pe
	Arequipa	Dirección General de Salud Ambiental (DIGESA)	Air quality monitoring	www.digesa.sld.pe
	Lima–Callao	Dirección General de Salud Ambiental (DIGESA)	Operation of monitoring stations and air quality monitoring	www.digesa.sld.pe
		Secretaría Nacional de Meteorología e Hidrología (SENAMHI)	Operation of monitoring stations	www.senamhi.gob.pe
		Comité de Gestión de la Iniciativa del Aire Limpio para Lima–Callao		www.airelimpio.org.pe
Uruguay	Montevideo	Intendencia Municipal de Montevideo/Departamento de Desarrollo Ambiental/Laboratorio de Higiene Ambiental (LHA-IMM)	Operation of monitoring network; data analysis and processing	www.montevideo.gub.uy/ambiente/aire.htm
Venezuela	Barcelona	Ministerio del Ambiente y Recursos Naturales (MARN)/Dirección de Calidad Ambiental	Institution in charge of air quality management	www.marn.gov.ve

Country	City	Relevant Institutions	Responsibilities	Web pages
	Barquisimeto[3]	Ministerio del Ambiente y Recursos Naturales (MARN)/Dirección de Calidad Ambiental		www.marn.gov.ve
	Caracas	Ministerio del Ambiente y Recursos Naturales (MARN)/Dirección de Calidad Ambiental	Institution in charge of air quality management	www.marn.gov.ve
	Ciudad Guyana[3]	Ministerio del Ambiente y Recursos Naturales (MARN)/Dirección de Calidad Ambiental		www.marn.gov.ve
	Maracaibo	Instituto para la Conservación del Lago de Maracaibo (ICLAM)	Institution involved in air quality management	www.iclam.gov.ve
	Maracay[1]		No air quality monitoring program.	www.marn.gov.ve
	Valencia	Ministerio del Ambiente y Recursos Naturales (MARN)/Dirección de Calidad Ambiental	Institution in charge of air quality management	www.marn.gov.ve

Notes:

1. Because these cities have no air quality program, the institutions listed correspond to those responsible for environmental issues in general. If no local environmental institution was found, the state-level institution is indicated instead.
2. The State Secretariat of the Environment and Water Resources is responsible for air quality management through the Air Quality Management Project. It is anticipated that the project will be executed until December 2007. Several entities coparticipate in the project, including Simepar, FIEP, and various industries and cities of the Metropolitan Region. The Paraná Environmental Institute is in charge of coordination.
3. Because there is no certainty that these cities have an air quality monitoring program, the institution listed corresponds to that responsible for environmental issues in general. In Paraguay, no information is available.
4. The Ministry of Environment, Housing and Territorial Development (MAVDT) is in charge of making national policies which must be followed by the regional authorities as well. However, these regional authorities may prepare stricter norms as long as they are supported by technical studies. The Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) provides technical and scientific support to MAVDT and prepares studies for national norms.

Regional Table 3: Monitoring Ambient Air Quality Standards across Selected Countries[1] (including WHO reference values,* EU and US NAAQS)[3]

Country	CO [mg/m^3 (ppm)][2, 4]		SO_2 (µg/m^3)[2]				NO_2 (µg/m^3)[2]			PM_{10} (µg/m^3)[2]		$PM_{2.5}$ (µg/m^3)[2]		O_3 (µg/m^3)[2]			TSP (µg/m^3)[2]	
	8 hrs.[5]	1 hrs.[5]	1 yr.[5]	24 hrs.[5]	3 hrs.[5]	1 hr.[5]	1 yr.[5]	24 hrs.[5]	1 hr.[5]	1 yr.[5]	24 hrs.[5]	1 yr.[5]	24 hrs.[5]	1 yr.[5]	8 hrs.[5]	1 hr.[5]	1 yr.[5]	24 hrs.[5]
EU[a]	10 (9)			125		350	400		200	30	50	20	40		120			
US NAAQS[b]	10 (9)	40 (35)	79	341			100			50	150	15	65		157	235[6]	75[7]	260[7]
California[c]	10 (9)	23 (20)		105[8]		655			470[8]	20	50	12	65			180[8]		
WHO	10 (9)	30 (26)[9]	50	125			40		200						120			
Argentina[d]	10	50		70[19]					846[8]							196[8]		150[19]
Buenos Aires Province[e, 10]	10 (9)	40 (35)	80	365	1300		100		400	50	150					235		
City of Buenos Aires[f, 11]	10 (9)	40 (35)	80	365	1300		100			50	150	15	65		157	235		
City of Buenos Aires[g, 11]		15 (13)[13]		70		500[13]		100	400[13]		150					100[13]		
Mendoza Province[h]	10	40	125				90			100						125		
Bolivia[i]	10	40	80	365				150	400	50	150					236	75	260
Brazil[12, j]	10 (9)	40 (35)	80	365			100		320	50	150					160	80	240
Chile[k]	10	40	80	365			100			50	150					160		
Chile[14]	10	30	80	250			100		400	50	150				120			
Colombia[w, 15]	10 (8.8)	40 (35)	80	250	750		100	150	200	70[21]	150				80	120	100	300
Colombia[l]	15	50	100	400	1500			100								170	100	400
Colombia (Bogotá)[m]	11 (10)	40 (35)	81[8]	350[8]	1400[8]		100[8]	220[8]	320[8]	80	180				130[8]	170[8]	100	400
Costa Rica[n]	10	40	80	365	1500		100		400	50	150					160	90	240
Dominican Republic[o]	10	40	100	150		450	100	300	400	50	150	15	65		160	250	80	230
Ecuador[p]	10	40	80	350			100	150		50	150	15	65		120	160		
El Salvador[q]	10	40	80	365			100	150		50	150	15	65	60	120	235	75	260
Guatemala[16]																		
Honduras[16]																		
Jamaica[12, r]	10	40	80	365		700	100			50	150					235	60	150
Mexico[s]	13 (11)[17]		78	341					395	50	120	15	65		157[8]	216	75	210
Nicaragua[16]																		
Panama[16]																		
Paraguay[20]																		
Peru[t]	10	30	80	365			100		200	50	150				120			
Uruguay Montevideo[18, u]	10	30	60	125			40	200		60	150				120	125	60	150
Venezuela[v]	10	40	80	365			100	300								240	75	260

Notes:
***** The primary aim of the WHO reference values is to provide a basis for protecting public health from adverse effects of air pollution and to eliminate or reduce exposure to those pollutants that are known or likely to be hazardous to human health and well-being. These guidelines are health-based or based on environmental effects, and are not standards per se. It is a policy issue to decide which specific groups at risk should be protected by the standards and what degree of risk is considered to be acceptable.
1: Air quality legislation also regulates nonconventional pollutants such as lead (Pb), methane (CH4), and ammonia (NH3); for the purpose of this document, these have not been taken into consideration.
2: Units of measurement for the standards are by volume (parts per million [ppm] and parts per billion [ppb]), or by mass (milligrams per cubic meter of air [mg/m³], and micrograms per cubic meter of air [µg/m³]).The difference between both measurements is that the latter are affected by local monitoring conditions (altitude, pressure, etc.). Under certain conditions of temperature and pressure (25º C and 760 torr), volume can be transformed into mass and vice versa using the conversion formula mentioned in note 8 below.
3: This table is a summary of all available information until the day this report was written.
4: The values presented here appear as they are enacted by the law, that is, in mg/m³, ppm, or both.
5: For further details on methods and frequency of measurement set by each legislation, information can be requested from the authors.
6: The EPA has replaced the 1-hour ozone standard with a new 8-hour standard; however, the 1-hour standard is still used as a reference value outside the US. For further details refer to the following link http://www.epa.gov/ttn/oarpg/naaqsfin/o3fact.html.
7: The US EPA TSP standard was replaced in 1987 with the PM_{10} standard; the TSP standard is still being used as a reference value in other countries.
8: This value is a conversion to µg/m³ using the molecular weight of each pollutant. For 25 degrees Celsius and atmospheric pressure of 760 mercury ml, the conversion formula for the 4 pollutants is as follows: ppm x M/0.02447=µg/m³ where M=molecular weight (Molecular weights: CO = 28, NO_2 = 46, SO_2 = 64, O_3 = 48).
9: WHO also has 30-min. (60 mg/m³) and 15-min. (100 mg/m³) reference values for CO.
10: The standards of the Province of Buenos Aires are included in the table because they are used as a reference in the city of Bahia Blanca.
11: Law No. 1356/2004, which establishes air quality standards for the City of Buenos Aires, will abolish the norms set by Ordinance 39.025/1983 once the former is regulated.
12: In addition to primary standards, the legislation in these countries also provide secondary air quality standards. In addition to health effects, secondary standards take into account minimum adverse effects on flora and fauna. The secondary norms in Brazil are for: TSP (µg/m³): 60 (annual) and 150 (24 hrs.); PM_{10} (µg/m³): 50 (annual) and 150 (24 hrs.); SO_2 (µg/m³): 40 (annual) and 100 (24 hrs.); CO (µg/m³): 10,000 (8 hrs.) and 40,000 (1 hr.); O_3 (µg/m³): 160 (1 hr.); NO_2 (µg/m³): 100 (annual) and 190 (1 hr.).
Jamaica's secondary standards for SO_2 are 60 µg/m³ (annual), 280 µg/m³ (24 hrs.).
13: These values correspond to a 20-minute period rather than a 1-hour period standard as established in the legislation for the City of Buenos Aires. In addition, the ordinance provides a standard for CO (24 hrs.) of 3 mg/m³, PM_{10} (20 min.) of 500 µg/m³, and O_3 (24 hrs.) of 30 µg/m³.
14: These are the revised values of the National Commission on the Environment which will modify the existing law. These values will become effective in 2006 (Supreme Decree 112 (O_3)-113 (SO_2)-114 (NO_2)-115 (CO)/2002, D.S.59(PM_{10}) and D.S. N.45/2001 of the General Secretariat of the Office of the President).
15: These standards correspond to new Resolution 601 issued by the Ministry of the Environment on April 4, 2006. These standards replace the standards of the Colombian National Law (Decree 02/1982 of the Ministry of Health) and those of Bogotá (DAMA Resolution 1208/2003). Because the changes are so recent, the table also includes the standards of the National Law and the DAMA Decree.
16: These countries have no national standards. They use a combination of WHO reference values of the WHO and US EPA standards instead.
17: The actual CO 8-hour norm for Mexico is 12,595 µg/m³.
18: No standards are set at the national level; the city of Montevideo has had its own norms since 1993.
19: These values correspond in fact to a monthly period rather than a 24-hour-period standard of SO_2 as established by National Law 20.284.
20: No information is available for this country
21: The PM_{10} annual standard by 2009 will be 60 µg/m³ and will be further reduced to 50 µg/m³ by 2011.

LEGISLATIVE FRAMEWORK:
a: EU standards : http://europa.eu.int/eur-lex/pri/en/oj/dat/1999/l_163/l_16319990629en00410060.pdf
b: US EPA standards: http://epa.gov/air/criteria.html
c: California ambient air quality standards are listed in the Table of Standards in Section 70200 of Title 17 of the California Code of Regulations.
d: National Law 20.284/1973 of the Ministry of Health
e: Decree No. 3395/1996 of Secretariat of Environmental Policies Law 5965
f: Law 1356/2004 of the City of Buenos Aires Environmental Authority
g: Ordinance 39.025/1983 of the City of Buenos Aires Environmental Authority
h: Provincial Law 5961of the Department of Sanitation and Environmental Control; the values mentioned in this case are defined as alert values but without a detailed description of an alert situation.
i: Environmental Law 1333/1992
j: CONAMA Resolution No. 003/1990
k: Resolution 1215 (NO_2, O_3) of the Ministry of Health 1978, D.S. No. 185 (SO_2) Ministry of Mining 1992, and D.S. 59 (PM_{10}) CONAMA 1998
l: Decree No. 02/1982 of the Ministry of Health
m: DAMA Resolution 1208/2003, Bogotá
n: Decree 30221-S/2002 of the Ministry of Health
o: Norm No. NA-AI-001-03/2003, Regulation of Environmental Law 64/2000 of the State Secretariat of the Environment

p: Decree 3516/2003 of the Ministry of Environment
q: Norm No. 13.11.01:01/2003 of the Ministry of Environment and Natural Resources
r: The first national ambient air quality standards for Jamaica were passed in 1996; law number not available (http://www.nrca.org/WSSD/Regulations/AmbientAirQuality.pdf)
s: NOM-020-SSA1, NOM-021-SSA1, NOM-022-SSA1, NOM-023-SSA1, NOM-024-SSA1, NOM-025-SSA1, NOM-026-SSA1 (1993)
t: Decree No. 074-2001-PCM/2001 of DIGESA
u: Decree 16556 of the Intendencia Municipal de Montevideo
v: Decree 638/1995 of the Ministry of Environment and Natural Resources
w: Resolution 601 (April 4, 2006) of the Ministry of the Environment, Housing and Territorial Development.

Regional Table 4: Summary of Emission Inventory Data

Country	City	(Yes/No)	Base year	Source Types	Emissions Estimates (tons/year) CO	SO_2	NO_x [1]	PM	HC	Other [2]	Observations
Argentina	Bahía Blanca[a]	Y	2001	Fixed	2,250	2,850	4350	750	2700	2100	Category *Other* in this case includes, among others, NH_3, Hg, Cl_2, H_2. Mobile sources also include air traffic
				Domestic	240.98	0.0756	202.50	14.49	511.65		
				Mobile	17024	224	3136	224	1792		
				Total	**19,514.98**	**3074**	**7,688.5**	**988.49**	**5003.65**	**2100**	
Bolivia	Cochabamba[j]	N									A study entitled "Modeling of emissions of the automotive park of Cochabamba" was carried out using the EMOD/CMAP program
Brazil	Belo Horizonte Metropolitan Region	N/A									Partial inventory of fixed sources for 2002. Further information was unavailable.
	Campinas Metropolitan Region[b]	Y	2004	Fixed	3,240	22,930	5,590	4,970	2,400		Fixed sources included 41 companies in the Metropolitan Region.
				Mobile	304,260	3,320	62,510	5,470	68,270		
				Total	**307,500**	**26,250**	**68,100**	**10,440**	**70,670**		
	Recife Metropolitan Region	N/A									Recife is supposed to have an emission inventory but data were unavailable
	Rio de Janeiro Metropolitan Region[h]	Y	N/A[4]	Fixed	6300	55800	30300	10600	25900		Fixed sources considered 425 of the 500 most polluting companies. The inventory did not consider natural sources (fires, wind/soil erosion, nonpaved roads) or small sources with low polluting potential
				Mobile	314,700	7,500	60200	7800	53400		
				Total	**321,000**	**63,300**	**90,500**	**18,400**	**79,300**		
	São José dos Campos[c]	Y	2004	Fixed	750	23000 [3]	5350	2810	910		Fixed sources only included 5 companies considered to be responsible for 90% of industrial emissions.
				Mobile	48,420	510 [3]	8730	820	11,160		
				Total	**49,170**	**23,510**	**14,080**	**3,630**	**12,070**		
	São Paulo Metropolitan Area	Y	2004	Fixed	38,600	17,100 [3]	14,000	31,600	12,000		245 companies were taken into consideration for the estimation of emissions of SO_x and 308 for PM_{10}; these companies represent more than 90% of emissions of these pollutants. To estimate emissions of CO, HC and NO_x, 750, 800, and 740 companies were considered, respectively.
				Mobile	1,706,100	20,800 [3]	356,500	31,600	392,500		
				Total	**1,744,700**	**37,900**	**370,500**	**63,200**	**404,500**		
	Sorocaba	Y	2004	Fixed	2180	3750 [3]	5360	2950	740		The inventory also includes the small town of Votorantim which is located only a few km from Sorocaba.
				Mobile	57,190	1000 [3]	11,080	1010	12,870		
				Total	**59,370**	**4,750**	**16,440**	**3,960**	**13,610**		
Chile	Greater Concepción[d]	Y	2000	Point	2,416	15,898	4,491	12,693		1,859	Mobile sources include ground, maritime, and air sources. Category *Other* includes VOC and NH_3.
				Area	48,492	96	661	6,779		18,190	
				Mobile	16,218	293 [3]	5,043	248		2,269	
				Total	**67,126**	**16,287**	**10,195**	**19,720**		**22,318**	

Country	City	(Yes/No)	Base year	Source Types	Emissions Estimates (tons/year) CO	SO_2	NO_x [1]	PM	HC	Other [2]	Observations
	Santiago Metropolitan Region	Y	2000	Fixed	7,392	6,840	6,655	1,371		36,640	Category *Other* includes VOC and NH_3, which are quite significant. Area sources include dry cleaners, paint shops, agricultural burning, and biogenic emissions.
				Area	4,322	16	310	534		47,139	
				Mobile	175,725	335	47,045	2,467		25,662	
				Total	**187,439**	**9,052**	**54,010**	**4,373**		**109,441**	
	Valparaíso--Viña del Mar[o]	Y	1997	Fixed	144	99	217	25		0.4	Category *Other* includes VOC.
				Mobile	93,237	1,897	12,669	1,641		11.8	
				Total	**93,381**	**1,996**	**12,886**	**1,666**		**12**	
	Greater Valparaíso[p, v]	Y	2000	Point	135.71	1396.76	425.42	222.67		366.75	Category *Other* includes VOC and NH_3. Fugitive sources include construction and demolition, resuspended street dust, and preparation of agricultural land.
				Area	2966.11	1399.36	515.48	692.83		5526.34	
				Fugitive				27,917.82			
				Mobile	14,245.72	236.88	3812.38	178.37		2394.5	
				Total	**17,347.54**	**3033**	**4753.28**	**29,011.69**		**8287.59**	
Colombia	Bogotá[i] (urban perimeter)	Y	2002	Point	283.97	3,188.27	619.4	2,036.7		175,904	Category *Other* includes VOC, CO_2 and CH_4 all released from decomposition processes at sanitary landfills which in Bogotá are very large and situated fairly close to the city.
				Area	7,713.9	1,925.7	776.72	905.93		276,958.3	
				Mobile	291,912	2,171	13,004	1,552		1,826,930	
				Total	**299,909.87**	**7,285.01**	**14,400.12**	**4,494.63**		**2,279,792.32**	
	Bogotá[e] (entire perimeter)	Y	2002	Point	11,853.37	604,676.8	7,636.16	2,843.3		1,603,837.7	Covers the urban perimeter plus some areas surrounding Bogotá with the purpose of taking into account the emissions of industries outside the urban perimeter that have an impact on Bogotá's air quality. Category *Other* includes VOC, CO_2, and CH_4 all released from decomposition processes at sanitary landfills which in Bogotá are very large and situated fairly close to the city.
				Area	7713.91	1925.74	776.72	905.93		277,767.92	
				Mobile	455,055	362	20,123	2397		2,630,579	
				Total	**474,622**	**606,962**	**28,536**	**6,146**		**4,512,170**	
	Bucaramanga	N									CDMB is currently preparing the conceptual design for a future inventory.
	Medellín (Valle del Aburra)[q]	Y	1999	Fixed	9282	18,840	5,925	33,731		1,251	Category *Other* includes volatile organic compounds, aldehydes, alkenes, alcans, methane, and aromatic compounds.
				Mobile	52,447	472	8,031	492		12,437	
				Biogenic	0	0	342	0		6004	
				Total	**61,729**	**19,311**	**14,298**	**34,223**		**19,691**	
Costa Rica	San José	N									An incomplete inventory including fixed sources is supposed to be underway; no further information was available.
Dominican Republic	Santo Domingo[f]	Y	2000	Fixed	134,387	32,869 [3]	42,100	4,987		23,936	Mobile sources include private cars, light and heavy vehicles, motorcycles, and agricultural machinery. Fixed sources include industries, open air burning of waste, residential and commercial sources for energy production. Particles include $PM_{2.5}$ only. Category *Other* includes volatile organic compounds.
				Mobile	124,130	3,099 [3]	18,365	3,040		21,675	
				Total	**258,517**	**35,968**	**60,465**	**8,027**		**45,611**	
Ecuador	Guayaquil[w]	N									There is no formal emission inventory to date for the city of Guayaquil; however, several

Country	City	(Yes/No)	Base year	Source Types	Emissions Estimates (tons/year) CO	SO_2	NO_x [1]	PM	HC	Other [2]	Observations
											studies have been carried out with the objective of determining the main sources of air pollutants. No further information was available.
	Quito[u]	Y	2003	Fixed	872	2,284	4,893	57			No formal inventory exists for Quito. These figures are part of a preliminary inventory done in 2003 by the Departamento Metropolitano de Medio Ambiente and CORPAIRE.
				Mobile	74,193	4,810	11,849	791	9,658		
				Total	**75,065**	**7,094**	**16,742**	**848**	**9,658**		
El Salvador	San Salvador	N									Work is supposed to be in progress to prepare a future inventory for El Salvador's main cities.
Mexico	Acapulco de Juárez	Y	1999	**Total**	**51,034.7**	**1,500.2**	**5,934.9**	**4,881.5**		**33,441**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Aguascalientes	Y	1999 [r]	**Total**	**42,980.3**	**5,259.8**	**6,816.6**	**2,833.6**		**24,187**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Chihuahua	Y	1999 [r]	**Total**	**59,731.9**	**10,460.3**	**12,775.60**	**5,800.8**		**21,896**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Ciudad Juárez	Y	1996	Point	861	716 [3]	1,393	210	2,395		
				Area	2,055	1,834 [3]	802	281	19,244		
				Mobile	449,844	1,596 [3]	23,920	1,020	54,493		
				Natural				45,096			
				Total	**452,760**	**4,146**	**26,115**	**46,607**	**76,132**		
		Y	1999 [r]	**Total**	**91,776.5**	**38,745.9**	**27,152.8**	**8083.6**		**45,075.1**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Coatzalcoalcos	Y	1999 [r]	Total	17,775.5	2,529.2	8,694.10	8,919.2		27,127.6	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Cuernavaca	Y	1999 [r]	**Total**	**23,033**	**1,753.8**	**2,976.3**	**803.9**		**9,424.6**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Culiacán	Y	1999 [r]	Total	43,977	1,962.6	7,559.4	5,576.5		26,503.4	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Ecatepec*	Y	1999 [r]	**Total**	**152,593.2**	**5,798.1**	**16,732.5**	**3,542**		**42,975.9**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$

Country	City	(Yes/No)	Base year	Source Types	Emissions Estimates (tons/year)						Observations
					CO	SO_2	NO_x [1]	PM	HC	Other [2]	
	Guadalajara	Y	1995	Point	4,269	5,506 [3]	3,148	1,595	4,269		
				Area	57,248	118	218	40	57,248		
				Mobile	895,991	2461 [3]	33,820	5,845	82,318		
				Natural				294,304			
				Total	**957,508**	**8,085**	**37,186**	**301,784**	**143,835**		
		Y	1999 [r]	**Total**	**220,318.7**	**9,686.7**	**23,562.2**	**5521.1**		**55,858.8**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Guadalupe*	Y	1999 [r]	**Total**	**75,883.6**	**2,492.7**	**10,442.3**	**4,419.7**		**18,976.4**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Hermosillo	Y	1999 [r]	**Total**	**38,141.7**	**14,379.4**	**8,545.6**	**3,725.9**		**20,059.5**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	León	Y	1999 [r]	**Total**	**86,112.2**	**9,850.5**	**11,454.7**	**3,389.5**		**32,255**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Matamoros	Y	1999 [r]	**Total**	**25,897.3**	**1,269.9**	**6,349.9**	**2,936.9**		**13,149**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Mérida	Y	1999 [r]	**Total**	**47,084.6**	**9,700.8**	**9,136.3**	**5,244.6**		**17418.7**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Mexicali	Y	1996	Point	4,721	2,849 [3]	1,537	1,994	1,407		
				Area	18,944	11 [3]	735	61,932	15,379		
				Mobile	243,073	937 [3]	14,927	515	31,184		
				Natural			1,348	20,548	3,441		
				Total	**266,738**	**3,797**	**18,547**	**84,989**	**51,411**		
		Y	1999 [r]	Point							Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
				Area							
				Mobile					8852.9		
				Total	**51,315.5**	**6,739.4**	**10,229.7**	**8852.9**		**27,399.5**	
	Metropolitan Zone of the Valley of Mexico (ZMVM)[k]	Y	1998	Point	9,213	12,442	26,988	3,093	23,980		PM includes PM_{10} only
				Area	25,960	5,354	9,866	1,678	247,599		
				Natural	N/A	N/A	3,193	7,985	15,669		
				Mobile	1,733,663	4,670	165,838	7,133	187,773		
				Total	**1,768,836**	**22,466**	**205,885**	**19,889**	**475,021**		
		Y	1999 [r]	**Total**	**1,481,038**	**40,031.9**	**170,901.9**	**33,124.10**		**444,671.7**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
		Y	2000	Point	10,004	10,288	24,717	2,809	22,010		
				Area	6,633	45	10,636	509	197,803		
				Mobile	2,018,788	4,348 [3]	157,239	5,287	194,517		
				Natural			859	1,736	15,425		

Country	City	(Yes/No)	Base year	Source Types	Emissions Estimates (tons/year) CO	SO_2	NO_x [1]	PM	HC	Other [2]	Observations
				Total	**2,035,425**	**14,681**	**193,451**	**10,341**	**429,755**		
		Y	2002	Fixed	14,122	3620	29,268	19,622		772,545	Preliminary version. Does not include natural sources (soil and vegetation). PM includes PM_{10} and $PM_{2.5}$. Category *Other* includes volatile organic compounds and total organic compounds
				Mobile	1,927,101	4929	156,311	7962		392,877	
				Natural							
				Total	**1,941,223**	**8,549**	**185,579**	**27,584**		**1,165,422**	
	Metropolitan Area of Monterrey (ZMM)[s]	Y	1995	Point	3,281	27,997	18,549	45,946	5,578		
				Area	8		458	16	36,660		
				Mobile	904,473	2,469 [3]	34,268	5,941	83,137		
				Natural				763,725			
				Total	**907,762**	**30,466**	**53,275**	**815,628**	**125,375**		
		Y	1999[r]	**Total**	**298,586.9**	**63,973.6**	**55,625.2**	**21,315.1**		**91,933.6**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Naucalpan*	Y	1999[r]	**Total**	**79,319.4**	**5,958**	**8,940**	**2,427.3**		**28,548**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Nezahualcóyotl*	Y	1999[r]	**Total**	**114,621.2**	**2,040.8**	**11,763.6**	**1,923.4**		**29,700.8**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Metropolitan Area of Puebla[l]	Y	1999[r]	**Total**	**52,950.5**	**8,588.8**	**28,434.1**	**10,051.5**		**54,068.7**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
		Y	2004	Fixed	1058.5	3847.5	7388	3909.8		4788.62	PM includes PM10, $PM_{2.5}$ and TSP. Category *Other* includes lead in mobile sources and CH_4, TOC, VOC in area sources.
				Area	9599.17	11,756.25	2058.91	6095.04		56,222.37	
				Mobile	285,516	832 [3]	17,086		41,152	21	
				Total	**296,173.67**	**16,435.75**	**26,532.91**	**10,004.84**	**41,152**	**61,031.99**	
	Querétaro	Y	1999[r]	**Total**	**41,420**	**4,796.2**	**6,769.6**	**3,228.5**		**19,118.1**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Saltillo	Y	1999[r]	**Total**	**43,717.2**	**2,596.5**	**6,951.9**	**8,229.8**		**17,308.3**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	San Luis Potosí	Y	1999[r]	**Total**	**47,805.1**	**9,638**	**6,826.3**	**3,636**		**19,248**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Metropolitan Area of Tampico[m]	Y	1999[r]	**Total**	**43,967.8**	**131,878.5**	**21,284.7**	**6,639.9**		**40,275**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$

Country	City	(Yes/No)	Base year	Source Types	Emissions Estimates (tons/year)						Observations
					CO	SO_2	NO_x [1]	PM	HC	Other [2]	
	Tlanepantla de Baez*	Y	1999 [r]	**Total**	**67,909.8**	**6021.8**	**8607.3**	**2596.2**		**28,035.9**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Veracruz	Y	1999 [r]	**Total**	**27,330.4**	**1137.5**	**19,352.4**	**1988.4**		**10,401.4**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Villahermosa	Y	1999 [r]	Point	0	159,308.19	18,108.7	0	0	3,751	Extracted from the National Inventory. Point sources include oil activities. Category *Other* includes VOC
				Area	8,730.86	7,753.07	308.80	882.09	191.03		
				Mobile	184,036	3139.50	88,887.7	0	28,718		
				Total	**192,766.86**	**170,200.76**	**107,305.2**	**882.09**	**28,909.03**	**3,751**	
	Tijuana–Rosarito	Y	1998	Fixed	17,774	29,259 [3]	5,150	26,862	39,633		
				Mobile	281,917	949 [3]	23,501	1,214	36,908		
				Natural			145	1,273	1,195		
				Total	**299,691**	**30,208**	**28,796**	**29,349**	**77,736**		
		Y	1999 [r]	**Total**	**91,060.7**	**35,937.5**	**21,785.4**	**7,347.9**		**45,553**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Toluca	Y	1999 [r]	**Total**	**24,517**	**5,261.3**	**3,541.2**	**1,936.3**		**12,143.7**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Torreón [r]	Y	1999	**Total**	**40,223.2**	**4,859.3**	**6,524.8**	**2,053.1**		**16,667.1**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
	Zapopan [n, r,*]	Y	1999	**Total**	**116,269.7**	**4,930.7**	**14,079.1**	**6,700.8**		**67,976.4**	Extracted from the National Inventory. Category *Other* includes NH_3 and VOC. PM includes both PM_{10} and $PM_{2.5}$
Peru	Lima–Callao [g]	Y	2002	Fixed	2.4		12.92	7.4	1.51		Mobile source emissions were calculated based on 871,033 units. Fixed sources include domestic sources as well.
				Mobile	593.87		99.66	16.13	111.96		
				Total	596.27		112.58	23.53	113.47		

Notes:

*: The table also provides information for several urban centers located within the territory of the metropolitan regions of ZMVM, Monterrey, and Guadalajara.

1. All inventories record the values of NO_x which includes all nitrogen oxides such as NO, NO_2, etc.
2. This refers to other pollutants which are included in emission inventories of various countries such as CH_4, SO_4, NH_3 etc.
3. SO_x is reported in this case which includes all sulfur oxides such as SO_2, SO_3, etc.
4. The exact inventory year for the Rio de Janeiro Metropolitan Region was not mentioned in the source. The information was extracted from a FEEMA publication dated May 2004.

Inventory information:

a: Pollutants from fixed sources in Bahía Blanca were calculated based on the "Sworn Statements of Gaseous Effluents" (Declaraciones Juradas de Efluentes Gaseosos"), measurements of pollutants in chimneys and/or estimates according to emissions factors recommended as references by international norms. Regarding mobile sources, the vehicular park of Bahía Blanca at the end of 2001 was composed of 71,535 "live units" and the park was 5 years old. In order to estimate pollutants emitted due to air traffic a LTO (Landing Take-off) factor was used which considers all activities taking place close to the airport at a height lower than 914 meters.

b: The Metropolitan Region of Campinas includes the following municipalities, all considered for this inventory: Americana, Artur Nogueira, Campinas, Cosmópolis, Engenheiro, Coelho, Estiva Gerbi, Holambra, Hortolândia, Indaiatuba, Itapira, Jaguariuna, Limeira, Mogi-Guaçú, Mogi-Mirim, Monte-Mor, Nova Odessa, Paulínia, Pedreira, Santa Barbara do Oeste, Santo Antônio da Posse, Sumare and Valinhos and Vinhedo. Many of these have a high level of industrialization.
c: The municipality of São José dos Campos covers an area of 1,102 km^2 with around 540,000 inhabitants. The industrial park is composed of 900 companies and the vehicular park around 190,000 vehicles.
d: Greater Concepción includes the towns of Tome, Penco, Concepción, Talcahuano, Chiguayante, Halqui, Don Pedro de la Paz, Coronel, and Lota.
e: This inventory uses the same model described in note "i" but the coverage area is larger, including Bogotá, Cundinamarca, and a portion of the department of Boyaca, Meta, Tolima, and Caldas, all comprising an area of 44,944 km^2;the many polluting industries located in this territory have a major impact on the city of Bogotá.
f: A study entitled "Modeling of emissions of the automotive park of Cochabamba" used the EMOD/CMAP program; it also includes the town of Haina due to the existence of polluting electrical power plants and open-air waste burning in this town.
g: The emission inventory was estimated using the model of the International Petroleum Industry Association (IPIECA).
h: The Metropolitan Region of Rio de Janeiro includes the cities of São Gonçalo, Duque de Caixas, and Nova Iguaçú.
i: The emission inventory is calculated using the French software AREMIS; calculation principles are based on the CORINAIR methodology developed by the European Environmental Agency (EEA). These represent figures for the urban perimeter of Bogotá only which comprises an area of 865 km^2.
j: There is no inventory of emissions for Cochabamba. The only study found, entitled "Modelación de las emisiones del parque automotor de Cochabamba," estimates emissions from mobile sources covering an area of 4 km^2.
k: This covers slightly over 3,500 km^2 , including the 16 delegations of the Federal District (1,486 km^2) and 18 neighboring municipalities of the State of Mexico (2,054 km^2); the 16 delegations are the following: Azcapotzalco, Coyoacán, Cuajimalpa de Morelos, Gustavo A. Madero, Iztacalco, Iztapalapa, La Magdalena Contreras, Milpa Alta, Alvaro Obregón, Tláhuac, Tlalpan, Xochimilco, Benito Juárez, Cuauhtémoc, Miguel Hidalgo, Venustiano Carranza; the 18 municipalities are as follows: Atizapán de Zaragoza, Coacalco de Berriozábal, Cuautitlán, Chalco, Chicoloapan, Chimalhuacán, Ecatepec de Morelos, Huixquilucan, Ixtapaluca, Naucalpan de Juárez, Nezahualcóyotl, Nicolás Romero, La Paz, Tecámac, Tlalnepantla de Báez, Tultitlán, Cuautitlán, Izcalli, Valle de Chalco Solidaridad.
l: The Metropolitan Area of Puebla includes the municipalities of Amozoc, Coronango, Cuautlancingo, Puebla, San Andrés Cholula, and San Pedro Cholula.
m: The Metropolitan Area of Tampico includes the municipalities of Tampico, Ciudad Madero, and Altamira.
n: The Metropolitan Area of Zapopan includes the municipalities of Juanacatlán, El Salto, Tlajomulco de Zúñiga, Tlaquepaque, Tonalá, and Zapopan.
o: This inventory is for Valparaíso–Viña del Mar.
p: The Greater Valparaíso area includes the following municipalities: Valparaíso, Concon, Quilpue, Villa Alemana, and Viña del Mar.
q: The MODEMED model was used for this inventory. The inventory covers an area of 400 km^2.
r: This inventory is part of the national emission inventory for Mexico with the base year of 1999.
s: The Metropolitan Area of Monterrey includes the following municipalities: Apodaca, Ciudad Benito Juárez, García, General Escobedo, Monterrey, Santa Catarina, San Nicolás de los Garza, San Pedro Garza García.
u: No formal inventory exists for Quito. These figures are part of a preliminary inventory done in 2003 by DMMA (Departamento Metropolitano de Medio Ambiente) and CORPAIRE with estimates of pollutants from fixed and mobile sources.
v: Mobile sources covered a limited geographical area within the region. This area is defined by the coverage of the transport models utilized in the calculation of emissions from on-road mobile sources. Most area sources have a regional coverage and base information does not allow the disaggregation of emissions at the level used by mobile sources. Ttherefore, it is impossible to identify the relative responsibilities of each source at any geographical level.
w: There is no formal emission inventory to date for the city of Guayaquil. However, several studies have been performed in the city to determine the main sources of air pollutants. One of these studies is entitled "Plan de Prevención y Control de la Contaminación Industrial y de Otras Fuentes."

Inventory sources
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Metropolitan Area of Campinas: "*Relatório da Qualidade do Ar no Estado de São Paulo 2004,*" São Paulo 2005, Companhia de Tecnologia de Saneamento Ambiental (CETESB)
Rio de Janeiro: "*Inventário de Fontes Emissoras de Poluentes Atmosféricos da Região Metropolitana do Rio de Janeiro,*" May 2004, Fundação Estadual de Engenharia do Meio Ambiente (FEEMA)
São José dos Campos: "*Relatório da Qualidade do Ar no Estado de São Paulo 2004,*" São Paulo 2005, Companhia de Tecnologia de Saneamento Ambiental (CETESB).
Metropolitan Area of São Paulo: "*Relatório da Qualidade do Ar no Estado de São Paulo 2004,*" São Paulo 2005, Companhia de Tecnologia de Saneamento Ambiental (CETESB)
Sorocaba: "*Relatório da Qualidade do Ar no Estado de São Paulo 2004,*" São Paulo 2005, Companhia de Tecnologia de Saneamento Ambiental (CETESB)
Greater Concepción: "*Resumen y Rectificación del Inventario de Emisiones Atmosféricas del Gran Concepción Estimación Año 2000,*" August 2005, National Environmetnal Commission (CONAMA-Bío Bío)
Metropolitan Region of Santiago: Ëvolución de la Calidad del Aire en Santiago 1197-2003," National Eenvironmental Commission (CONAMA)
Valparaíso–Viña del Mar: National Commission of the Environment, V Region (CONAMA V REGION)
Greater Valparaíso: National Environmental Commission, Region V (CONAMA REGION V)

Bogotá: "*Diseño e Implementación de un Modelo de Calidad de Aire para Bogotá-Sexto Informe Semestral, Inventario de Emisiones para Bogotá y la Región 2002,*" January 2004, Center for Environmental Engineering Research of the Universidad de los Andes
Medellín: "*Modelo de Emisiones Atmosféricas en el Valle de Aburra-Modemed (Medellín),*" Universidad Pontificia Bolivariana de Medellín
Santo Domingo: "*Diagnóstico Final y Análisis Económico/Fiscal, Calidad del Aire,*" December 2002, Secretaría de Estado de Medio Ambiente y Recursos Naturales, Abt Associates and Engine Fuels Inc. and Emissions Engineering
Quito: "*Distrito Metropolitano de Quito Fuentes Generadoras de Contaminantes (Inventario de Emisiones Preliminar),*" February 2005, Corporation for Air Improvement in Quito (CORPAIRE), Metropolitan Division of Environment (DMMA)
Mexico: "*1999 Mexico National Emission Inventory,*" November 2005, National Institute of Ecology (INE), Secretariat of Environment and Natural Resources (SEMARNAT), prepared the National Emission Inventory (NEI)
Ciudad Juárez: *Programa de Gestión de la Calidad del Aire de Ciudad Juárez,1998-2002*
Mexicali: *Programa para Mejorar la Calidad del Aire de Mexicali, 2000-2005*
Tijuana–Rosarito: *Programa para Mejorar la Calidad del Aire Tijuana–Rosarito, 2000-2005*
ZMVM (1998): *Programa para Mejorar la Calidad del Aire de la Zona Metropolitana del Valle de México, 2002-2010*
ZMVM (2002): Inventario de Emisiones de la ZMVM, 2002. Versión Preliminar, Gobierno del Distrito Federal.
Lima–Callao: "*Plan Integral de Saneamiento Atmosférico para Lima–Callao No. 1, PISA LC 2005–2010,*" Lima, Peru

Regional Table 5: Summary of Emission Inventory (% of total)

Country	Urban Center	Year of inventory	Type of source	Emissions estimates (tons/year)						Observations
				CO	SO_2	NO_x	PM	HC	Other	
Argentina	Bahia Blanca[a]	2001	Fixed	11.52	92.71	56.57	75.87	53.96	100	Category *Other* in this case includes NH_3, Hg, Cl_2, H_2. Mobile sources also include air traffic
			Domestic	1.23	0	2.63	1.46	10.22	0	
			Mobile	87.23	7.28	40.78	22.66	35.81	0	
			Total	**100**	**100**	**100**	**100**	**100**	**100**	
Brazil	Campinas Metropolitan Area[b]	2004	Fixed	1.05	87.35	8.20	47.60	3.39		Fixed sources included 41 companies in the Metropolitan Region.
			Mobile	98.95	12.65	91.80	52.40	96.61		
			Total	**100**	**100**	**100**	**100**	**100**		
	São Paulo Metropolitan Area	2004	Fixed	2.21	45.11	3.77	50	2.96		245 companies were taken into consideration to estimate emissions of SO_x and 308 for PM_{10}; these companies represent more than 90% of emissions of these pollutants. To estimate emissions of CO, HC, and NO_x, 750, 800, and 740 companies were considered, respectively.
			Mobile	97.79	54.89	96.23	50	97.04		
			Total	**100**	**100**	**100**	**100**	**100**		
	Rio de Janeiro Metropolitan Region[h]	N/A[4]	Fixed	1.96	48.10	33.48	57.60	32.66		Fixed sources considered 425 of the 500 most polluting companies. The inventory did not consider natural sources (fires, wind/soil erosion, nonpaved roads) or small sources with low polluting potential
			Mobile	98.04	51.90	66.52	42.40	67.34		
			Total	**100**	**100**	**100**	**100**	**100**		
	São José dos Campos[c]	2004	Fixed	1.52	97.83	37.99	77.41	7.54		Fixed sources only included 5 companies considered to be responsible for 90% of industrial emissions.
			Mobile	98.48	2.17	62.01	22.59	92.46		
			Total	**100**	**100**	**100**	**100**	**100**		
	Sorocaba	2004	Fixed	3.67	78.94	32.60	74.94	5.43		The inventory also includes the small town of Votorantim which is located only a few kms away from Sorocaba.
			Mobile	96.33	21.06	67.40	25.06	94.57		
			Total	**100**	**100**	**100**	**100**	**100**		
Chile	Greater Concepción[d]	2000	Point	3.59	97.61	44.05	64.36		8.32	Mobile sources include ground, maritime, and air sources. Category *Other* includes VOC and NH_3.
			Area	72.24	0.58	6.48	34.37		81.50	
			Mobile	24.16	1.80	49.46	1.25		10.17	
			Total	**100**	**100**	**100**	**100**		**100**	
	Santiago Metropolitan Region	2000	Fixed	3.94	75.56	12.32	31.35		33.47	Category *Other* includes VOC and NH_3, which are quite significant. Area sources include dry cleaners, paint shops, agricultural burning, and biogenic emissions.
			Area	2.30	0.1	0.5	12.21		43.07	
			Mobile	93.75	3.70	87.10	56.14		25.70	
			Total	**100**	**100**	**100**	**100**		**100**	
	Valparaíso–Viña del Mar[o]	1997	Fixed	0.1	4.95	1.68	1.50		0.03	Category *Other* includes VOC.
			Mobile	99.9	95.05	98.32	98.50		99.97	
			Total	**100**	**100**	**100**	**100**		**100**	
	Greater Valparaíso[p], [v]	2000	Point	0.7	46.05	8.95	0.7		4.42	Category *Other* includes VOC and NH_3. Fugitive sources include construction and demolition, resuspended street dust and preparation of agricultural land.
			Area	17.09	46.13	10.84	2.38		66.68	
			Fugitive				96.22			
			Mobile	82.11	7.81	80.20	0.6		28.89	
			Total	**100**	**100**	**100**	**100**		**100**	
Colombia	Bogotá (urban perimeter) [i]	2002	Point	0	43.76	4.30	45.31		7.71	Category *Other* includes VOC, CO_2, and CH_4 all released from decomposition processes at sanitary landfills which in Bogotá are very large and situated fairly close to the city.
			Area	2.57	26.43	5.39	20.15		12.14	
			Mobile	97.33	29.80	90.30	34.53		80.13	
			Total	**100**	**100**	**100**	**100**		**100**	
	Bogotá (entire territory)[e]	2002	Point	2.49	99.62	26.75	46.26		35.54	Covers the urban perimeter plus some areas surrounding Bogotá, taking into account the emissions of industries outside of the urban perimeter that have an impact on Bogotá's air quality. Category *Other* includes VOC, CO_2, and CH_4, all released from decomposition processes at sanitary landfills which in Bogotá are very large and situated fairly close to the city.
			Area	1.62	0.3	2.72	14.74		6.15	
			Mobile	95.87	0	70.52	39		58.29	
			Total	**100**	**100**	**100**	**100**		**100**	
	Medellín (Valle del Aburra)[q]	1999	Fixed	15.03	97.56	41.43	98.56		6.35	Category *Other* includes volatile organic compounds, aldehydes, alkenes, alcans, methane, and aromatic compounds.
			Mobile	84.96	2.44	56.16	1.43		63.16	
			Biogenic			2.39			30.49	
			Total	**100**	**100**	**100**	**100**		**100**	

Country	Urban Center	Year of inventory	Type of source	Emissions estimates (tons/year)						Observations
				CO	SO_2	NO_x	PM	HC	Other	
Dominican Republic	Santo Domingo[f]	2000	Fixed	51.98	91.38	69.62	62.12		52.47	Mobile sources include private cars, light and heavy vehicles, motorcycles, and agricultural machinery. Fixed sources include industries, open-air waste burning, residential and commercial sources for energy production. Particles include $PM_{2.5}$ only. Category *Other* includes volatile organic compounds.
			Mobile	48.01	8.61	30.37	37.87		47.52	
			Total	**100**	**100**	**100**	**100**		**100**	
Ecuador	Quito[u]	2003	Fixed	1.16	32.19	29.22	6.72			No formal inventory exists for Quito. These figures are part of a preliminary inventory performed in 2003 by the Departamento Metropolitano de Medio Ambiente and CORPAIRE.
			Mobile	98.83	67.81	70.78	93.28	100		
			Total	**100**				**100**		
Mexico	Ciudad Juárez	1996	Point	0.2	17.26	5.33	0.45			
			Area	0.45	44.23	3.07	0.06			
			Mobile	99.35	38.49	91.59	2.1	71.57		
			Natural				96.75			
			Total	**100**	**100**	**100**	**100**	**100**		
	Guadalajara	1995	Point	0.4	68.10	8.46	0.5	2.96		
			Area	6.37	1.45	0	0	39.80		
			Mobile	99.77	30.43	90.94	1.93	57.23		
			Natural				97.52			
			Total	**100**	**100**	**100**	**100**	**100**		
	Mexicali	1996	Point	1.76	75.03	8.28	2.34	2.73		
			Area	7.10	0.2	3.96	72.87	29.91		
			Mobile	91.12	24.67	80.48	0.6	60.65		
			Natural			7.26	24.17	6.69		
			Total	**100**	**100**	**100**	**100**	**100**		
	Monterry Metropolitan Area[s]	1995	Point	0.3	91.89	34.81	5.63	4.44		
			Area	0		0.8	0	29.24		
			Mobile	99.63	8.10	45.55	0.7	66.31		
			Natural				93.63			
			Total	**100**	**100**	**100**	**100**	**100**		
	Puebla Metropolitan Area[l]	2004	Fixed	0.35	23.40	27.84	39.07		7.84	PM includes PM10, $PM_{2.5}$ and TSP. Category *Other* includes lead in mobile sources and CH_4, TOC, and VOC in area sources.
			Area	3.24	71.52	7.75	60.92		92.11	
			Mobile	96.40	5.06	64.39		100	0	
			Total	**100**	**100**	**100**	**100**	**100**	**100**	
	Tijuana–Rosarito	1998	Fixed	5.93	96.85	17.88	91.52	50.98		
			Mobile	94.06	3.15	81.61	4.13	47.47		
			Natural			0.5	4.33	1.53		
				100	**100**	**100**	**100**	**100**		
	Villahermosa	1999	Point	0	93.60	16.87	0	0	100	Point sources include oil activities. Category *Other* includes VOC.
			Area	4.52	4.55	0.2	100	0.6	0	
			Mobile	95.47	1.84	82.83	0	99.33	0	
			Total	**100**	**100**	**100**	**100**	**100**	**100**	
	Metropolitan Area of the Valley of Mexico[k]	1998	Point	0.5	55	13	16	5		PM includes PM_{10} only.
			Area	1.5	24	5	8	52		
			Natural	N/A	N/A	2	40	3		
			Mobile	98	21	80	36	40		
			Total	**100**	**100**	**100**	**100**	**100**		
	Metropolitan Area of the Valley of Mexico[k]	2000	Point	0.49	70.07	12.77	27.16	5.12		
			Area	0.32	0.3	5.49	4.92	46.02		
			Mobile	99.18	29.61	81.28	51.12	45.26		
			Natural			0.4	16.78	3.58		
			Total	**100**	**100**	**100**	**100**	**100**		
	Metropolitan Area of the Valley of Mexico[k]	2002	Fixed	0.7	42.35	15.78	71.14		66.2	Preliminary version. Does not include natural sources (soil and vegetation). PM includes PM_{10} and $PM_{2.5}$. Category *Other* includes volatile organic compounds and total organic
			Mobile	99.30	57.65	84.22	28.86		33.71	
			Total	**100**	**100**	**100**	**100**		**100**	

Country	Urban Center	Year of inventory	Type of source	Emissions estimates (tons/year)						Observations
				CO	SO_2	NO_x	PM	HC	Other	
										compounds
Peru	Lima–Callao[g]	2002	Fixed	0.4		11.47	31.44	1.33		Mobile source emissions were calculated based on 871,033 units. Fixed sources also include domestic sources.
			Mobile	99.60		88.53	68.56	98.67		
			Total	**100**		**100**	**100**	**100**		

Inventory information:
a: Pollutants from fixed sources in Bahía Blanca were calculated based on the "Sworn Statements of Gaseous Effluents" (Declaraciones Juradas de Efluentes Gaseosos"), measurements of pollutants in chimneys and/or estimates according to emissions factors recommended as references by international norms. Regarding mobile sources, the vehicular park of Bahía Blanca at the end of 2001 was composed of 71,535 "live units" and the park was 5 years old. In order to estimate pollutants emitted due to air traffic a LTO (Landing Take-off) factor was used which considers all activities taking place close to the airport at a height lower than 914 meters.
b: The Metropolitan Region of Campinas includes the following municipalities, all considered for this inventory: Americana, Artur Nogueira, Campinas, Cosmópolis, Engenheiro, Coelho, Estiva Gerbi, Holambra, Hortolândia, Indaiatuba, Itapira, Jaguariuna, Limeira, Mogi-Guaçú, Mogi-Mirim, Monte-Mor, Nova Odessa, Paulínia, Pedreira, Santa Barbara do Oeste, Santo Antônio da Posse, Sumare and Valinhos and Vinhedo. Many of these have a high level of industrialization.
c: The municipality of São José dos Campos covers an area of 1,102 km^2 with around 540,000 inhabitants. The industrial park is composed of 900 companies and the vehicular park around 190,000 vehicles.
d: Greater Concepción includes the towns of Tome, Penco, Concepción, Talcahuano, Chiguayante, Halqui, Don Pedro de la Paz, Coronel, and Lota.
e: This inventory uses the same model described in note "i" but the coverage area is larger, including Bogotá, Cundinamarca, and a portion of the department of Boyaca, Meta, Tolima, and Caldas, all comprising an area of 44,944 km^2;the many polluting industries located in this territory have a major impact on the city of Bogotá.
f: A study entitled "Modeling of emissions of the automotive park of Cochabamba" used the EMOD/CMAP program; it also includes the town of Haina due to the existence of polluting electrical power plants and open-air waste burning in this town.
g: The emission inventory was estimated using the model of the International Petroleum Industry Association (IPIECA).
h: The Metropolitan Region of Rio de Janeiro includes the cities of São Gonçalo, Duque de Caixas, and Nova Iguaçú.
i: The emission inventory is calculated using the French software AREMIS; calculation principles are based on the CORINAIR methodology developed by the European Environmental Agency (EEA). These represent figures for the urban perimeter of Bogotá only which comprises an area of 865 km^2.
j: There is no inventory of emissions for Cochabamba. The only study found, entitled "Modelación de las emisiones del parque automotor de Cochabamba," estimates emissions from mobile sources covering an area of 4 km^2.
k: This covers slightly over 3,500 km^2 , including the 16 delegations of the Federal District (1,486 km^2) and 18 neighboring municipalities of the State of Mexico (2,054 km^2); the 16 delegations are the following: Azcapotzalco, Coyoacán, Cuajimalpa de Morelos, Gustavo A. Madero, Iztacalco, Iztapalapa, La Magdalena Contreras, Milpa Alta, Alvaro Obregón, Tláhuac, Tlalpan, Xochimilco, Benito Juárez, Cuauhtémoc, Miguel Hidalgo, Venustiano Carranza; the 18 municipalities are as follows: Atizapán de Zaragoza, Coacalco de Berriozábal, Cuautitlán, Chalco, Chicoloapan, Chimalhuacán, Ecatepec de Morelos, Huixquilucan, Ixtapaluca, Naucalpan de Juárez, Nezahualcóyotl, Nicolás Romero, La Paz, Tecámac, Tlalnepantla de Báez, Tultitlán, Cuautitlán, Izcalli, Valle de Chalco Solidaridad.
l: The Metropolitan Area of Puebla includes the municipalities of Amozoc, Coronango, Cuautlancingo, Puebla, San Andrés Cholula, and San Pedro Cholula.
m: The Metropolitan Area of Tampico includes the municipalities of Tampico, Ciudad Madero, and Altamira.
n: The Metropolitan Area of Zapopan includes the municipalities of Juanacatlán, El Salto, Tlajomulco de Zúñiga, Tlaquepaque, Tonalá, and Zapopan.
o: This inventory is for Valparaíso–Viña del Mar.
p: The Greater Valparaíso area includes the following municipalities: Valparaíso, Concon, Quilpue, Villa Alemana, and Viña del Mar.
q: The MODEMED model was used for this inventory. The inventory covers an area of 400 km^2.
r: This inventory is part of the national emission inventory for Mexico with the base year of 1999.
s: The Metropolitan Area of Monterrey includes the following municipalities: Apodaca, Ciudad Benito Juárez, García, General Escobedo, Monterrey, Santa Catarina, San Nicolás de los Garza, San Pedro Garza García.
u: No formal inventory exists for Quito. These figures are part of a preliminary inventory done in 2003 by DMMA (Departamento Metropolitano de Medio Ambiente) and CORPAIRE with estimates of pollutants from fixed and mobile sources.
v: Mobile sources covered a limited geographical area within the region. This area is defined by the coverage of the transport models utilized in the calculation of emissions from on-road mobile sources. Most area sources have a regional coverage and base information does not allow the disaggregation of emissions at the level used by mobile sources. Ttherefore, it is impossible to identify the relative responsibilities of each source at any geographical level.
w: There is no formal emission inventory to date for the city of Guayaquil. However, several studies have been performed in the city to determine the main sources of air pollutants. One of these studies is entitled "Plan de Prevención y Control de la Contaminación Industrial y de Otras Fuentes."

Inventory sources
Bahía Blanca: "*Inventario de emisiones gaseosas-Bahía Blanca Julio de 2003,*" Municipality of Bahía Blanca.
Metropolitan Area of Campinas: "*Relatório da Qualidade do Ar no Estado de São Paulo 2004,*" São Paulo 2005, Companhia de Tecnologia de Saneamento Ambiental (CETESB)
Rio de Janeiro: "*Inventário de Fontes Emissoras de Poluentes Atmosféricos da Região Metropolitana do Rio de Janeiro,*" May 2004, Fundação Estadual de Engenharia do Meio Ambiente (FEEMA)
São José dos Campos: "*Relatório da Qualidade do Ar no Estado de São Paulo 2004,*" São Paulo 2005, Companhia de Tecnologia de Saneamento Ambiental (CETESB).

Metropolitan Area of São Paulo: "*Relatório da Qualidade do Ar no Estado de São Paulo 2004,*" São Paulo 2005, Companhia de Tecnologia de Saneamento Ambiental (CETESB)
Sorocaba: "*Relatório da Qualidade do Ar no Estado de São Paulo 2004,*" São Paulo 2005, Companhia de Tecnologia de Saneamento Ambiental (CETESB)
Greater Concepción: "*Resumen y Rectificación del Inventario de Emisiones Atmosféricas del Gran Concepción Estimación Año 2000,*" August 2005, National Environmetnal Commission (CONAMA-Bío Bío)
Metropolitan Region of Santiago: Ëvolución de la Calidad del Aire en Santiago 1197-2003," National Eenvironmental Commission (CONAMA)
Valparaíso–Viña del Mar: National Commission of the Environment, V Region (CONAMA V REGION)
Greater Valparaíso: National Environmental Commission, Region V (CONAMA REGION V)
Bogotá: "*Diseño e Implementación de un Modelo de Calidad de Aire para Bogotá-Sexto Informe Semestral, Inventario de Emisiones para Bogotá y la Región 2002,*" January 2004, Center for Environmental Engineering Research of the Universidad de los Andes
Medellín: "*Modelo de Emisiones Atmosféricas en el Valle de Aburra-Modemed (Medellín),*" Universidad Pontificia Bolivariana de Medellín
Santo Domingo: "*Diagnóstico Final y Análisis Económico/Fiscal, Calidad del Aire,*" December 2002, Secretaría de Estado de Medio Ambiente y Recursos Naturales, Abt Associates and Engine Fuels Inc. and Emissions Engineering
Quito: "*Distrito Metropolitano de Quito Fuentes Generadoras de Contaminantes (Inventario de Emisiones Preliminar),*" February 2005, Corporation for Air Improvement in Quito (CORPAIRE), Metropolitan Division of Environment (DMMA)
Mexico: "*1999 Mexico National Emission Inventory,*" November 2005, National Institute of Ecology (INE), Secretariat of Environment and Natural Resources (SEMARNAT), prepared the National Emission Inventory (NEI)
Ciudad Juárez: *Programa de Gestión de la Calidad del Aire de Ciudad Juárez,1998-2002*
Mexicali: *Programa para Mejorar la Calidad del Aire de Mexicali, 2000-2005*
Tijuana–Rosarito: *Programa para Mejorar la Calidad del Aire Tijuana–Rosarito, 2000-2005*
ZMVM (1998): *Programa para Mejorar la Calidad del Aire de la Zona Metropolitana del Valle de México, 2002-2010*
ZMVM (2002): Inventario de Emisiones de la ZMVM, 2002. Versión Preliminar, Gobierno del Distrito Federal
Lima–Callao: "*Plan Integral de Saneamiento Atmosférico para Lima–Callao No. 1, PISA LC 2005–2010,*" Lima, Peru

Regional Table 6: Characteristics of Monitoring Capability across the Region

Country	City	Operating Monitoring Network (Yes/No) [2]	Number of Stations[3]	Pollutants monitored	Monitoring Methods[3] (Automatic/ Manual)	Observations[1]
Argentina	Bahía Blanca	N	1	PM_{10}, O_3, CO, NO_x, SO_2, VOC	Automatic	Bahía Blanca has a single automatic mobile station which is kept in any one place for at least a year at the time. Since 2002 it has been located in Campo Scout "E. Pilling".
	Buenos Aires	Y	2	PM_{10}, $PM_{2.5}$, CO, NO, NO_2, NO_x	Automatic	One of the stations started operating in August 2005 and is the only one that monitors PM.
	Córdoba	N				Córdoba had 2 trucks equipped to continuously monitor PM_{10}, TSP, O_3, CO, NO, NO_2, and SO_2, but they are currently not functioning due to lack of funds. Additionally, there would be 2 manual samplers for PM_{10} and TSP, but no additional information and data were available.
	La Plata	N				Periodic monitoring has been carried out by the Centro de Investigación del Medio Ambiente (CIMA) and the Laboratorio de Servicios para la Industria y el Sistema Científico (LASEISIC), but no further information was available.
	Mar del Plata	N/A				
	Mendoza	Y	5	Fixed: SO_2, NO_2, TSP Mobile: TSP, PM10, PM2.5, VOC, SO_2, NO, NO_x, NO_2, CO and O_3	Manual/Automatic	Information was obtained form the Web page that indicates that there are four fixed manual stations located in the most representative locations of the "microcentro" of Mendoza. There is an additional automatic mobile station under the responsibility of the Engineering Department of Universidad Nacional del Cuyo.
	Posadas	N				
	Rosario	N				A temporal study is available. For further details see next table.
	Tucumán	N				Sporadic monitoring was carried out in the late 1990s with the help of 2 fixed stations. No further information available.
Bolivia	Cochabamba	Y	7	Automatic: CO, SO_2, O_3, NO_x Manual: NO_2, O_3, PM_{10}	All 7 have manual equipment (2 of which have high volume samplers) and 3 of them also have automatic equipment	
	La Paz	Y	9	Manual (active): PM_{10} Manual: O_3, NO_2	Manual (4 of which have active samplers)	
	El Alto	Y	12	Manual (active): PM_{10} Manual: O_3, NO_2	Manual (3 of which only have active samplers)	

Country	City	Operating Monitoring Network (Yes/No) [2]	Number of Stations[3]	Pollutants monitored	Monitoring Methods[3] (Automatic/ Manual)	Observations[1]
	Santa Cruz	Y	11	PM_{10}, O_3, NO_2	Manual (3 of which have active samplers)	
Brazil	São Paulo Metropolitan Region (SPMR)	Y	38	Automatic: PM_{10}, SO_2, O_3, CO, NO_x, NO, NO_2, CH_4, NMHC Manual: TSP, $PM_{2.5}$, SO_2, smoke[4]	23 Automatic and 15 Manual	State-level network run by CETESB. CETESB has 3 additional mobile stations which are utilized throughout the state of São Paulo as needed. In addition to the City of São Paulo (14 aut./11 man.), the SPMR also includes the Municipalities of Guarulhos (1), Osasco (1 aut./1 man.), Santo André (2 aut./1 man.), and São Bernardo do Campos (1 aut./1 man.), Diadema (1), Mauá (1), São Caetano do Sul (1 aut./1 man.), and Taboão da Serra (1). Information for some of these municipalities is also presented in this table.
	Rio de Janeiro Metropolitan Region (RJMR)	Y	32	Automatic: SO_2, PM_{10}, CO, O_3, HC, NO_x, CH_4 Manual: PM, TSP, NO_x, O_3, CO, HC,	9 Automatic and 23 Manual	One State- and two Municipal- level networks operate in the RJMR. The largest belongs to FEEMA (23 manual and 4 automatic), the second largest belongs to SMAC (4 automatic), and one automatic station belongs to SMABR. In addition there are 3 mobile stations (2 belonging to FEEMA and one to SMAC). The RJMR also includes the cities of Nova Iguaçú, Duque de Caxias, and São Gonzalo, for which information is also presented in this table.
	Belo Horizonte	Y	3	PM_{10}, SO_2, CO, NO_2, O_3	Automatic	State-level network under the responsibility of FEAM. FEAM has six additional stations within the Metropolitan Region of Belo Horizonte: Contagem (1), Ibirité (2), and Betim (3).
	Porto Alegre Metropolitan Region	Y	15	Automatic: PM_{10}, SO_2, CO, NO_2, O_3 Manual: TSP, PM_{10}, SO_2	8 Automatic and 7 Manual	The network is run by FEPAM. The numbers presented in the table refer to the stations of the automatic network that are located within the metropolitan area and in the municipality of Triunfo; and the manual stations located within the metropolitan area and in the municipalities of Charqueadas, Estância Velha, Triunfo, and Montenegro. In addition, the state network includes an automatic and a manual station in the municipality of Caxias do Sul, and 4 manual stations in the municipality of Rio Grande. There is an additional automatic mobile station, which is utilized throughout the State of Rio Grande do Sul as needed.
	Recife Metropolitan Region	Y	10	TSP, SO_2, NO_2, smoke[5]	Manual	State-level network. The Metropolitan Region includes the municipalities of Jabaotão dos Guararapes (2 stations) Recife (7), and Cabo de Santo Agostinho (1). Only 7 are under operation. The other three and six new ones are expected to be back in operation by the end of 2005. Information for Jabaotão is also presented in this table.

Country	City	Operating Monitoring Network (Yes/No) [2]	Number of Stations[3]	Pollutants monitored	Monitoring Methods[3] (Automatic/ Manual)	Observations[1]
	Salvador	N				
	Fortaleza	Y	4	TSP, SO_2, smoke[4]	Manual (active high and low volume)	State-level network. One of the stations is located in the Maracanaú industrial district.
	Curitiba Metropolitan Region	Y	12	Automatic: PM_{10}, TSP, SO_2, NO_2, O_3, CO, NO (only Araucária) Manual: TSP, SO_2, smoke[4]	8 Automatic and 4 Manual	State-level network. The network includes the stations located in the municipalities of Curitiba (4 automatic and 1 manual station) and Araucária (4 automatic and 3 manual stations).
	Brasília	Y	5	TSP, PM_{10}, SO_2, smoke[4]	Manual	Two separate groups of stations. The first is composed of 3 stations under the responsibility of the DF Government, and the second is composed of two stations under the responsibility of the University of Brasília.
	Belem	N				
	Goiânia	Y	3	TSP	Manual	State-level network.
	Santos	N	1	SO_2, smoke[4]	Manual	State-level network run by CETESB. CETESB has 3 additional mobile stations which are utilized throughout the State of São Paulo as needed. This station is part of the São Paulo Metropolitan Region network.
	Manaus	N				
	Grande Vitória	Y	7	TSP, PM_{10}, SO_2, NO_2, O_3, CO, Hydrocarbons	Automatic	State-level network. An additional station was supposed to have been implemented in 2004–2005 to monitor PM_{10}, TSP, SO_2, CO, NO_x and HC. The network has been in operation since the year 2000.
	Campinas	Y	2	Automatic: PM_{10}, NO, NO_2, O_3 Manual: SO_2, smoke	1 Automatic and 1 Manual	State-level network run by CETESB. CETESB has 3 additional mobile stations which are utilized throughout theSstate of São Paulo as needed.
	São Luís[2]	N				The State has supposedly started studies to install a network; no further information available. There is no information about whether the municipal government has undertaken any air quality monitoring programs.
	Natal	N				
	Guarulhos*	N	1	PM_{10}	Automatic	State-level network run by CETESB. CETESB has 3 additional mobile stations which are utilized throughout the State of São Paulo as needed. This station is part of São Paulo Metropolitan Region network.
	Maceió	N				Nothing at the State level, but there is no information about whether the municipal government has undertaken any air quality monitoring programs.
	Nova Iguaçú*	Y	2	Automatic: PM_{10}, SO_2, O_3, NO_x Manual: PM_{10}	1 Automatic and 1 Manual	State-level network run by FEEMA. This station is part of the Rio de Janeiro Metropolitan Region network.

Country	City	Operating Monitoring Network (Yes/No) [2]	Number of Stations[3]	Pollutants monitored	Monitoring Methods[3] (Automatic/ Manual)	Observations[1]
	Teresina	N				Nothing at the State level, but there is no information about whether the municipal government has undertaken any air quality monitoring programs.
	João Pessoa	N				
	São Gonçalo*	Y	2	Automatic: PM_{10}, SO_2, O_3, NO_x Manual: PM_{10}	1 Automatic and 1 Manual	State-level network run by FEEMA. This station is part of the Rio de Janeiro Metropolitan Region network.
	Duque de Caxias*	N	1	PM_{10}	Manual	State-level network run by FEEMA. This station is part of the network of the Rio de Janeiro Metropolitan Region network.
	São José dos Campos	Y	2	Automatic: PM_{10}, SO_2, O_3 Manual: SO_2, smoke[4]	1 Automatic and 1 Manual	State-level network run by CETESB. CETESB has 3 additional mobile stations which are utilized throughout the State of São Paulo as needed.
	Ribeirão Preto	Y	2	Automatic: PM_{10}, SO_2, CO, NO_2, O_3 Manual: PM_{10}, SO_2, smoke[4]	1 Automatic and 1 Manual	State-level network run by CETESB. CETESB has 3 additional mobile stations which are utilized throughout the State of São Paulo as needed. The automatic station began operating in August 2004.
	Aracajú	N				Nothing at the State level, but there is no information about whether the municipal government has undertaken any air quality monitoring programs.
	Cuiabá	N				
	São Bernardo do Campo*	Y	2	Automatic: PM_{10} Manual: TSP	1 Automatic and 1 Manual	State-level network run by CETESB. CETESB has 3 additional mobile stations which are utilized throughout the State of São Paulo as needed. This station is part of the São Paulo Metropolitan Region network.
	Florianópolis	N				
	Campo Grande	N				
	Osasco*	Y	2	Automatic: PM_{10}, SO_2, CO, NO, NO_2, NO_x, O_3 Manual: TSP	1 Automatic and 1 Manual	State-level network run by CETESB. CETESB has 3 additional mobile stations which are utilized throughout the State of São Paulo as needed. This station is part of the network of the São Paulo Metropolitan Region. Since November 2003, O_3 is no longer monitored.
	Santo André*	Y	3	Automatic: PM_{10}, O_3, CO Manual: TSP	2 Automatic and 1 Manual	State-level network run by CETESB. CETESB has 3 additional mobile stations which are utilized throughout the state of São Paulo as needed. This station is part of the São Paulo Metropolitan Region network.
	Londrina	N				No information about whether the State or municipal government has undertaken any air quality monitoring programs.

Country	City	Operating Monitoring Network (Yes/No) [2]	Number of Stations[3]	Pollutants monitored	Monitoring Methods[3] (Automatic/ Manual)	Observations[1]
	Sorocaba	Y	3	Automatic: PM_{10}, SO_2, NO_2, O_3 Manual: SO_2, smoke[4]	1 Automatic and 2 Manual	State-level network run by CETESB. CETESB has 3 additional mobile stations which are utilized throughout the State of São Paulo as needed.
	Jaboatão*	Y	2	TSP, SO_2, NO_2	Manual	State-level network. This station is part of the Recife Metropolitan Region network.
Chile	Greater Concepción	Y	6	PM_{10}, $PM_{2.5}$, SO_2, CO, NO_2, O_3	Automatic	Greater Concepción includes the municipalities of Tome, Penco, Concepción, Hualpen, Talcahuano, Chiguayante, Hualqui, San Pedro de la Paz, Coronel, and Lota. The six stations are located in the municipalities of Talcahuano and Hualpen. In addition the network is complemented by several passive samplers for SO_2, NO_2, and VOCs.
	Metropolitan Region of Santiago	Y	7	PM_{10}, $PM_{2.5}$, SO_2, CO, NO_2, NOx, O_3	Automatic	In addition to the 7 automatic stations, 2 mobile stations operate in the Metropolitan Region.
	Greater Valparaíso	Y	6	Automatic: PM_{10}, SO_2, O_3, NO_2, CO Manual: PM_{10} and $PM_{2.5}$	PM: 1 automatic and 4 manual (active) Gases: 5 automatic	Greater Valparaíso includes the municipalities of Quilpué, Viña del Mar, Villa Alemana, Concón, and Valparaíso. Region V, where Greater Valparaíso is located, has 9 networks (23 stations), 3 of which are located in the Greater Valparaíso area (4 stations in Concón, 1 in Quilpué, and 1 in Viña del Mar). Quilpué has an additional meteorological station in addition to the meteorological equipment available in all other 6 monitoring stations.
Colombia	Barranquilla	Y	3	PM_{10}, SO_2, CO, NO, NO_2, NO_x, O_3, Total Hydrocarbons	Automatic	The network also has 3 meteorological stations.
	Bogotá	Y	13	TSP, PM_{10}, SO_2, CO, NO_x, O_3	Automatic	Because 2 of the 13 stations are being relocated (Olaya and Mezclas), only 11 are in operation.
	Bucaramanga	Y	5	SO_2, CO, NO_x, O_3, PM_{10}	Automatic	In operation since January 2001. Two additional stations measure weather parameters only.
	Cali	Y	9	NO_x, O_3, CO, PM_{10}, SO_2	Automatic	8 fixed and 1 mobile stations
	Cartagena	N				Cartagena had a network with 4 stations but it is currently not in operation. Moreover, the equipment is unassembled in storage. However, CARDIQUE has manual active equipment to monitor PM_{10} and automatic analyzers for CO and O_3. No further information available.
	Cúcuta	N				Cúcuta had a network with 5 stations but it is currently in not in operation. It operated from 1998 until 2003.
	Medellín	Y	18	SO_2, NO_2, CO, PM_{10}, TSP	Automatic: O_3 and CO Manual Active: PM_{10} and TSP Manual: SO_2 and NO_x	

Country	City	Operating Monitoring Network (Yes/No) [2]	Number of Stations[3]	Pollutants monitored	Monitoring Methods[3] (Automatic/ Manual)	Observations[1]
	Pereira	Y	4	PM_{10}, SO_2, NO_x, CO, O_3	Automatic for CO and O_3, Manual (active) for PM_{10}, and Manual for SO_2 and NO_x	Collected information indicates that the network has operated since 1998, but the selection of the location does not follow EPA and WHO guidelines. In addition, no validation process is in place. Two of the stations are currently being relocated.
Costa Rica	San José	N				A temporal study is available. For further details see next table.
Dominican Republic	Santo Domingo	N				A temporal study is available. For further details see next table.
Ecuador	Guayaquil	N				One mobile station has been used since 2002 for specific monitoring campaigns to measure NO_x, SO_2, PM_{10}, and CO. According to the Municipality of Guayaquil, available data comes from specific studies. The findings presented in the report are those of a specific temporal study described in the next table.
	Quito	Y	9	CO, NO_2, NO, NO_x, O_3, $PM_{2.5}$, TSP, PM_{10}, SO_2	Automatic and Manual (active) (TSP, PM_{10})	The monitoring network has been operating since June 2003. Six of the stations are equipped with both automatic and manual analyzers, and the remaining 3 are automatic. $PM_{2.5}$ has been monitored since September 2004.
El Salvador	San Salvador	Y	4	PM_{10}, TSP, O_3, NO_2	Manual	The monitoring network began operating in 1996. A fully operational network is expected by 2006.
Guatemala	Guatemala City	N				A temporal study is available. For further details see next table.
Honduras	San Pedro Sula	N				A temporal study is available. For further details see next table.
	Tegucigalpa	Y	9	TSP, PM_{10}, NO_2, O_3	Manual (passive and active)	The network was originally composed of 7 stations. However, as of March 2004 there are also 2 samplers for particles located on the roofs of 2 buildings.
Jamaica	Kingston	N	1	PM_{10}, TSP	Manual	Two other stations are expected to start operating in late October and November 2005. No further information available.
Mexico	Acapulco	N				
	Aguascalientes	Y	5	TSP, PM_{10}, NO_2, NO_x, CO, SO_2, O_3	Automatic	
	Chihuahua	N				Chihuahua had a manual network that stopped functioning in 1993. The Department of Ecology of the State Government of Chihuahua in coordination with the Research Center for Advanced Materials operated mobile units in the urban area from 2001–2004 measuring PM_{10}, CO, NO_2, O_3, and SO_2. There are plans for the implementation of a fixed monitoring network in the city.

Country	City	Operating Monitoring Network (Yes/No) [2]	Number of Stations[3]	Pollutants monitored	Monitoring Methods[3] (Automatic/ Manual)	Observations[1]
	Ciudad Juárez	Y	5	Automatic: PM_{10}, O_3 and CO Manual: PM_{10}	3 automatic and 2 manual	Real-time monitoring has been used since December 2002.
	Coatzacoalcos	N				
	Cuernavaca	N	1	O_3, CO, SO_2, NO_2	Automatic	This station is part of the larger monitoring network of the State of Morelos (RAMAMOR) An additional mobile station monitors TSP
	Culiacan	N				
	Ecatepec (ZMVM)*	Y	4	Automatic: O_3, SO_2, NO_2, PM_{10}, $PM_{2.5}$ Manual: PM_{10}, $PM_{2.5}$, TSP	2 Automatic and 2 manual	The automatic stations are part of the larger automatic monitoring network of the ZMVM (RAMA), while the manual stations are part of the larger manual monitoring network of ZMVM (REDMA).
	Guadalajara (ZMG)	Y	8	CO, SO_2, O_3, NO, NO_x, PM_{10}	Automatic	The ZMG also includes the city of Zapopan which was selected as a separate urban center for the purpose of the study. This monitoring network has been operating since 1995.
	Guadalupe (ZMM)*	N	1	O_3, NO_2, NO_x, NO_2, SO_2, CO, PM_{10}, $PM_{2.5}$	Automatic	This station is part of the larger network of the Metropolitan Area of Monterrey which has a total network of 5 stations.
	Hermosillo	N				Hermosillo had a network of 4 stations that monitored PM_{10}, TSP, NO_2 and SO_2, but they are no longer in operation.
	León	N	1	PM_{10}, SO_2, O_3, CO, NO_x	Automatic	
	Matamoros	Y	4	PM_{10}	Manual	These 4 stations are part of the larger State Network for Air Quality Monitoring of the State of Tamaulipas (REMA)
	Mérida	N				
	Mexicali	Y	5	Automatic: O_3, NO_2, SO_2, CO and PM_{10} Manual: PM_{10}	4 automatic stations and 1 manual station	
	Metropolitan Area of the Valley of Mexico (ZMVM)	Y	46	Automatic: O_3, NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$ Manual: TSP, PM_{10} and $PM_{2.5}$	32 Automatic and 14 manual	The ZMVM also includes the cities of Netzahuacóyotl, Ecatepec, Tlalnepantla, and Naucalpan, which for the purpose of this study were selected as separate urban centers. The automatic stations form the RAMA monitoring network and the manual stations form the REDMA monitoring network .
	Monterrey (ZMM)	Y	5	O_3, NO_2, NO, NO_x, SO_2, CO, PM_{10}, $PM_{2.5}$	Automatic	The ZMM also includes the city of Guadalupe, which for the purpose of this study was selected as a separate urban center. Two additional mobile units are used in case of environmental necessity or if one of the automatic stations breaks down.
	Naucalpan (ZMVM)*	N	1	O_3, SO_2, NO_2, PM_{10}	Automatic	This station is part of the larger automatic monitoring network of the ZMVM (RAMA).
	Nezahualcóyotl (ZMVM)*	N				It had one automatic station that measured PM_{10} operating until 2002. This station was part of the larger automatic monitoring network of the ZMVM and is no longer functioning.

Country	City	Operating Monitoring Network (Yes/No) [2]	Number of Stations[3]	Pollutants monitored	Monitoring Methods[3] (Automatic/ Manual)	Observations[1]
	Puebla (ZMP)	Y	4	O_3, PM_{10}, NO_x, SO_2, PM_{10}	Automatic	The monitoring network has been in place since 2000.
	Querétaro	Y	7	TSP, SO_2	Manual	An additional mobile unit monitors O_3, SO_2, NO_2, PM_{10}, and CO.
	Saltillo	N				
	San Luis Potosí	N				The Government of San Luis Potosí acquired 2 fixed stations and 1 mobile one, all with the capacity to monitor CO, SO_2, NO_x, O_3, and TSP. They were expected to start operating in October 2005 if funds were approved. No further information is available.
	Tampico	N	1	PM_{10}	Manual	This station is part of the larger Network for Air Quality Monitoring of the State of Tamaulipas (REMA).
	Tlalnepantla (ZMVM)*	Y	3	O_3, SO_2, NO_2 and PM_{10} Manual: $PM_{2.5}$	2 Automatic and 1 manual	The automatic stations are part of the larger automatic monitoring network of the ZMVM (RAMA), while the manual station is part of the larger manual monitoring network of the ZMVM (REDMA).
	Toluca (ZMVT)	Y	9	O_3, NO_2, SO_2, CO, TSP, PM_{10}	7 Automatic stations and 2 active samplers for TSP	
	Veracruz	N				
	Villahermosa	Y	3	O_3, SO_2, NO_2, PM_{10}, CO	1 automatic station and 2 manual station	The 2 manual stations are located in the municipalities of Cárdenas and Comalcalco, both located in the greater Villahermosa area.
	Tijuana–Rosarito	Y	6	Automatic: O_3, NO_2, SO_2, CO and PM_{10} Manual: PM_{10}	4 automatic stations and 2 manual ones	
	Torreón	Y	6	PM_{10}, TSP, O_3, NO_2, No, NO_x, CO	5 manual and 1 automatic station	.
	Zapopan (ZMG)*	Y	2	CO, SO_2, O_3, NO, NO_x, PM_{10}	Automatic	These stations are part of the larger network of the Metropolitan Area of Guadalajara mentioned above.
Nicaragua	Managua	N				There has been no formal monitoring station since 2002 due to lack of funds. Previously, under the "Aire Puro" Project there were 6 manual stations monitoring TSP, PM_{10}, O_3, NO_2, and CO
Panama	Panama City	Y	4	Manual: NO_2, O_3, PM_{10} and $PM_{2.5}$ Automatic: CO	Manual/Automatic	All stations are equipped with manual analyzers for SO_2, NO_2, O_3, and PM_{10}; one is also equipped with an automatic analyzer for CO.
Paraguay	Asunción	N/A				
Peru	Arequipa	N	1	CO, SO_2, PM_{10}, TSP	Manual	An additional mobile automatic station of DIGESA has monitored CO and SO_2 for some temporal studies and one fixed station that monitors gases, PM_{10} and TSP.
	Lima–Callao	Y	5	TSP, NO_2, SO_2, $PM_{2.5}$	Automatic	Of all 5 stations, 3 are mobile but have stayed in the same location for over a year. They are all managed by DIGESA.

Country	City	Operating Monitoring Network (Yes/No) [2]	Number of Stations[3]	Pollutants monitored	Monitoring Methods[3] (Automatic/ Manual)	Observations[1]
	Trujillo	N				A temporal study is available. For further details see next table.
Uruguay	Montevideo	Y	7	Àutomatic: NO_2, SO_2, CO Manual: PM_{10}, TSP, and SO_2	3 automatic and 4 manual station	An additional PM_{10} station would start operating in January 2006.
	Barcelona	N	1	TSP	Manual	This station forms part of the National Air Quality Monitoring Network, which also has stations in Caracas, Valencia, San Cristóba.l and Puerto La Cruz. The latter is also located in the same state as Barcelona, i.e., the State of Anzoatgui
Venezuela	Barquisimeto	N				
	Caracas	Y	7	PM_{10}, TSP, CO, SO_2, NO_2, O_3, VOC	3 automatic, 1 Automatic/Manual station and 3 Manual ones (active with high volume samplers)	The three automatic stations belong to PDVSA and are operated by INTEVEP. In addition, PDVSA finance the operation of the other 4 stations under the responsibility of MARN, which form part of the National Air Quality Monitoring Network. The national network also has stations in Valencia, San Cristóbal, Puerto La Cruz, and Barcelona. The two groups of stations do not operate as a network.
	Ciudad Guyana	N				
	Maracaibo	Y	6	N/A	N/A	Six stations are distributed between Maracaibo and San Francisco, but there is no certainty about the numbers of stations within the city limits of Maracaibo. PDVSA has one station that is operated by INTEVEP, but there is no certainty about whether this station would be in addition to the 6 included in this table.
	Maracay	N				
	Valencia	Y	2	TSP	Manual	These stations form part of the National Air Quality Monitoring Network, which also has stations in Caracas, San Cristóbal, Puerto La Cruz, and Barcelona

Notes:

*: The table also provides information for several urban centers located within the territory of the metropolitan regions of São Paulo, Rio de Janeiro, ZMVM, Monterrey, and Guadalajara.

1. Many cities that lack a monitoring network have undertaken temporal studies. If so, this is indicated under the observations column.
2. For the purpose of this study, a monitoring network is defined as at least two stations that provide ambient concentration information on a regular basis.
3. More details about monitoring stations and monitoring methods are provided in separate document, can be requested from the authors.
4. Smoke is defined as a solid or liquid material in suspension (other than gas) which affects the degree of visibility (darkness) of the instrument used to measure opacity.

Regional Table 7: Countries with Air Quality Studies

Country	City	Number of stations	Pollutants measured	Type of station	Characteristics of study
Argentina	Rosario	4	SO_2, NO, NO_2, CO	Manual	A study took place in 1995 with 4 manual stations: 2 located in the city and 2 in the northern and southern suburbs.
		19 sampling points	NO_2	Manual (passive tubes)	Another study took place between Aug. 98 and Oct. 99 with 19 sampling points distributed across the city that only monitored NO_2.
Costa Rica	San José	4	PM_{10}, SO_2, NO_2	Manual	Temporary monitoring of NO_x, Monitoring if SO_2 and PM_{10} took place through a pilot plan with 4 stations implemented in 2004. Another study also monitored PM_{10} and NO_2 between 1993 and 2003.
Dominican Republic	Santo Domingo	8	O_3, CO, SO_2, NO_2, $PM_{2.5}$	Manual	Study carried out in 2002 with 8 stations measuring 4 pollutants (O_3, SO_2, NO_2, CO, $PM_{2.5}$).
Ecuador	Guayaquil	1 mobile	PM_{10}, O_3, CO, SO_2, NO_2	Automatic	"Estudio de la Calidad del Aire en la Ciudad de Guayaquil: Diagnóstico e Investigación Referencial" undertaken in 2004. Pollutants were monitored in two phases. The first selected 51 locations, where pollutants were monitored three times for a period of 15 minutes each. In the second phase, pollutants were monitored three times for a period of 20 minutes in those locations that registered the highest concentrations during the first phase.
Guatemala	Guatemala City	6	TSP, PM_{10}, NO_2	Manual	There is no formal monitoring network, only manual measuring of 3 pollutants since 1995 at 6 stations (4 monitor TSP and PM_{10} and 6 monitor NO_2).
Honduras	San Pedro Sula	3	TSP, PM_{10}, O_3, NO_2		There is no formal monitoring, only occasional air quality monitoring in 3 locations (105 Brigada, Municipalidad SPS, and Salida la Toyota).
Peru	Trujillo	4	TSP, $PM_{2.5}$, SO_2, NO_2, CO, PM_{10}	1 Automatic and 3 manual stations	A study was carried out for the period May 16–23, 2002 and included the districts of Trujillo and Victor Larco

Only includes those studies for urban centers where no monitoring data were available.
Sources:

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- San José: "Calidad del Aire en la Capital entre 1993 y 2003," S. Rodríguez, J. Herrera, Revista semestral de la Escuela de Ciencias Ambientales, Universidad Nacional, Costa Rica, June 2004
- Santo Domingo: "Diagnóstico Ambiental y Análisis Económico/Fiscal, Cap. 6: Calidad del Aire. Abt. Associates, December 2002
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- Guatemala City: "Monitoreo del Aire en la Ciudad de Guatemala, Informe Anual 2004:, Pablo Ernesto Oliva Soto, Universidad de San Carlos de Guatemala, Facultad de Ciencias Químicas y Farmacia, Guatemala, March 2005
- San Pedro Sula: www.ccad.ws
- San Luis Potosí: information obtained from Mr. Francisco Enrique Hernández of SEGAM (Secretariat of Ecology and Environmental Management)

Trujillo: "Evaluación de la Calidad del Aire de la Ciudad de Trujillo," Dirección Ejecutiva de Ecología y Medio Ambiente (DIGESA)

Regional Table 8: List of Suspect Critical Pollutants[1]

City	PM_{10}	$PM_{2.5}$	TSP	O_3	CO	NO_2	SO_2	Category[2]	Emission inventory[3]
ARGENTINA									
Bahía Blanca								7	•
Buenos Aires								11	
Córdoba								7	
La Plata								11	
Mar de Plata								11	
Mendoza								11	
Posadas								12	
Rosario								11	
Tucumán								11	
BOLIVIA									
Cochabamba								4	•
La Paz								7	
El Alto								7	
Santa Cruz								7	
BRAZIL									
São Paulo Metropolitan Region								1	•
Rio de Janeiro Metropolitan Region (AMRJ)[4]								3	•
City of Rio de Janeiro[5, 6]								4	•
Belo Horizonte								10	•
Porto Alegre Metropolitan Region								7	
Recife Metropolitan Region								7	•
Salvador								12	
Fortaleza								11	
Curitiba Metropolitan Region								3	
Brasilia								11	
Belém								12	
Goiânia								11	
Santos								11	
Manaus								12	
Grande Vitória								4	
Campinas								10	•
São Luís								12	
Natal								12	
Guarulhos[6]								7	•
Maceió								12	
Nova Iguaçú[6]								7	•
Teresina								12	
João Pessoa								12	
São Gonçalo[6]								7	•
Duque de Caxias[6]								7	•
São José dos Campos								8	•
Ribeirão Preto								8	
Aracajú								12	
Cuiabá								12	
São Bernardo do Campo[6]								10	•
Florianópolis								12	
Campo Grande								12	
Osasco[6]								7	•

City	PM_{10}	$PM_{2.5}$	TSP	O_3	CO	NO_2	SO_2	Category[2]	Emission inventory[3]
Santo André[6]								4	•
Londrina								12	
Sorocaba								8	•
Jaboatão[6]								11	•
CHILE									
Santiago Metropolitan Region								1	•
Greater Valparaíso								4	•
Greater Concepción								2	•
COLOMBIA									
Barranquilla								7	
Bogotá								4	•
Bucaramanga								3	
Cali								7	
Cartagena								12	
Cúcuta								11	
Medellín								3	•
Pereira								11	
COSTA RICA									
San José								7	
DOMINICAN REPUBLIC									
Santo Domingo								7	•
ECUADOR									
Guayaquil								7	•
Quito								1	•
EL SALVADOR									
San Salvador								7	
GUATEMALA									
Guatemala								7	
HONDURAS									
San Pedro Sula								11	
Tegucigalpa								7	
JAMAICA									
Kingston								7	
MEXICO									
Acapulco								12	•
Aguascalientes								4	•
Chihuahua								12	•
Ciudad Juárez								3	•
Coatzalcoalcos								12	•
Cuernavaca								11	•
Culiacán								12	•
Ecatepec (ZMVM)[6]								1	•
ZMG								3	•
Guadalupe (ZMM)[6]								7	•
Hermosillo								12	•
León								7	•
Matamoros								4	•
Mérida								12	•
Mexicali								11	•
ZMVM								1	•
ZMM								3	•
Naucalpan (ZMVM)[6]								7	•

City	PM_{10}	$PM_{2.5}$	TSP	O_3	CO	NO_2	SO_2	Category[2]	Emission inventory[3]
Nezahualcóyotl (ZMVM)[6]	Red	Yellow		Yellow	Green	Yellow	Green	7	•
ZMP	Red	Yellow		Red	Green	Green	Green	3	•
Querétaro	Red	Yellow		Pink	Green	Green	Green	7	•
Saltillo	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	12	•
San Luis Potosí	Yellow	Yellow	Pink	Pink	Pink	Pink	Pink	12	•
Tampico	Green	Yellow		Yellow	Yellow	Yellow	Yellow	10	•
Tlalnepantla (ZMVM)[6]	Green	Red		Red	Green	Red	Green	7	•
ZMVT	Red	Yellow		Red	Green	Red	Green	3	•
Veracruz	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	12	•
Villahermosa	Green	Yellow		Green	Pink	Green	Green	10	•
Tijuana–Rosarito	Pink	Yellow		Pink	Pink	Pink	Pink	11	•
Torreón	Pink	Yellow	Red	Pink	Pink	Pink	Yellow	7	•
Zapopan (ZMG)[6]	Green	Yellow		Red	Green	Red	Green	4	•
NICARAGUA									
Managua	Red	Yellow		Pink	Green	Green	Yellow	7	
PANAMA									
Panama City	Red	Pink		Pink	Yellow	Green	Yellow	4	
PARAGUAY									
Asunción	Pink	Pink	Pink	Pink	Pink	Pink	Pink	11	
PERU									
Arequipa	Red	Yellow		Yellow	Red	Yellow	Red	7	
Lima–Callao	Yellow	Red		Pink	Yellow	Green	Green	4	•
Trujillo	Yellow	Red		Yellow	Yellow	Green	Green	7	
URUGUAY									
Montevideo	Green	Yellow		Green	Pink	Green	Green	10	
VENEZUELA									
Barcelona	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Yellow	7	
Barquisimeto	Pink	Pink	Pink	Pink	Pink	Pink	Pink	11	
Caracas	Pink	Yellow	Green	Pink	Pink	Green	Pink	11	
Ciudad Guyana	Pink	Pink	Pink	Pink	Pink	Pink	Pink	11	
Maracaibo	Pink	Pink	Pink	Pink	Pink	Pink	Pink	11	
Maracay	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	12	
Valencia	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	11	

Green: highest concentration did not exceed the value of the relevant standards
Red: highest concentrations exceeded the value of the relevant standards
Yellow: no monitoring
Pink: no or insufficient information
White: TSP data are considered when there are no data for particulate matter (PM_{10} o $PM_{2.5}$).
Notes:

1. For the purpose of this study, suspected critical pollutants are defined as those whose worst-case scenario concentrations, that is, the highest among the latest available concentrations of each pollutant (maximum hourly, 8 hours, 24 hours, or annual averages depending on the pollutant and the averaging times), have exceeded the value of either the short-exposure (e.g., 24 hours for PM_{10}, $PM_{2.5}$, NO_2 and SO_2, and 1 hour for O_3 and CO) or long-exposure (e.g., 1 year for PM_{10}, 8 hours for O_3 and CO) applicable standards.
2. Extracted from Table Classification of Urban Centers.
3. Indicates whether there is a study that provides at least some insight about sources of emissions. Based on the information provided in Regional Table 4.
4. Considers the stations under the responsibility of FEEMA only.
5. Considers the stations under the responsibility of the Municipality of Rio de Janeiro only.
6. The table also provides information for several urban centers located within the territory of the Metropolitan Regions of São Paulo, Rio de Janeiro, ZMVM, Monterrey, and Guadalajara.

Regional Table 9: Classification of Urban Centers

Urban Center	Classification	Observations
ARGENTINA		
Bahía Blanca	7	• Data were available for the years 2003 and 2004 • Concentrations of PM_{10} (24 hours and annual), O_3 (1 hour), and NO_2 (1 hour) exceeded the value of the standards • No concentrations above the value of the norm of CO (1 hour) and SO_2 (1 hour) were registered • $PM_{2.5}$ was not monitored
Buenos Aires	11	• Despite the existence of two stations, one started operating only in the second half of 2005 and therefore was classified in category 11 • Concentrations of NO_2 (1 hour WHO) exceeded the value of the standard • No concentrations above the value of the norm of SO_2 (20 minutes) and CO (1 hour and 8 hours) were registered • No information was available for PM_{10}, $PM_{2.5}$, and O_3
Córdoba	7	• Data were obtained from a study carried out in the year 2000 • Concentrations of PM_{10} (24 hours and annual) exceeded the value of the standards • No concentrations above the value of the norm of SO_2 (annual), O_3 and NO_2 (annual) were registered • No information on CO was available
La Plata	11	• No information available
Mar de Plata	11	• No information available
Mendoza	11	• Monitoring network exists but no information was available
Posadas	12	• No monitoring capability
Rosario	11	• The city had some spot studies in the past that only analyzed NO_2, SO_2,and CO but no data were found
BOLIVIA		
Cochabamba	4	• Concentrations of PM_{10} (24 hours), NO_2 (WHO's annual and WHO's 1 hour) and CO (8 hours) exceeded the value of the standards • Only data on PM_{10} and NO_2 from the manual network were available for more than one year (from 2002 to 2005). For all other pollutants, information was only available for a few months of 2002, 2003, and 2004; in total this accounted for at least one year's worth of information. • No concentrations exceeding the value of the norm for O_3 (automatic network) and SO_2 were registered • It was not possible to obtain annual mean concentrations of PM_{10} because monitoring takes place only on Wednesdays, when concentrations of this pollutant are thought to be higher due to the market fair that takes place that day. As a result, the mean value of these concentrations may not be representative because it would overestimate the real annual mean concentration. • Annual mean concentrations of NO_2 exceeded the WHO annual reference value but not that of the US EPA. In this case, concentrations were compared with the value of the WHO annual reference value because this was the comparison standard used in the document from which data were obtained: "Resultados del Monitoreo de la Calidad del Aire en la Ciudad de Cochabamba" by the Universidad Católica Bolivariana
La Paz	7	• Information was only available for the year 2005 • Concentrations of PM_{10} (annual) exceeded the value of the standard • No concentrations exceeding the value of the standard of NO_2 (annual US EPA) were registered

Urban Center	Classification	Observations
		• $PM_{2.5}$, SO_2, and CO were not monitored
El Alto	7	• Data for gases were available for the period 2003–2004, while data for PM_{10} were partially available for the 2003–2005 period • Concentrations of PM_{10} (annual) exceeded the value of the standard • No concentrations exceeding the value of the norm of NO_2 (annual EPA) were registered • $PM_{2.5}$, SO_2, and CO were not monitored
Santa Cruz	7	• Data were only available for the periods from August to December of 2004 and 2005 • Concentrations of PM_{10} (annual) exceeded the value of the standard • No concentrations exceeding the value of the norm of NO_2 (annual EPA) were registered • $PM_{2.5}$, SO_2, and CO were not monitored
BRAZIL		
São Paulo Metropolitan Region	1	• Validated data from 2000 until 2004 were available for all pollutants analyzed. Validated data for PM_{10} and O_3 were also available for 2005 • Concentrations of PM_{10} (24 hours and annual), $PM_{2.5}$ (US EPA annual), ozone (1 hour), NO_2 (WHO 1 hour), and CO (8 hours) exceeded the value of the standards. PM_{10}, $PM_{2.5}$, O_3, and CO have all been recognized as critical pollutants at least since 2000 • Although $PM_{2.5}$ data from 2004 indicate that the value of the daily standard was not exceeded, the daily maximums of the previous years did exceed it • No concentrations exceeding the value of the norm of SO_2 were registered
Rio de Janeiro Metropolitan Region (AMRJ)	3	• Data were available for 2002, 2003, and 2004 from FEEMA's automatic and manual networks, but the classification considered the PM_{10} data registered in the manual station only • Concentrations of PM_{10} (24 hours and annual, manual network), ozone (1 hour), CO (8 hours), and NO_2 (WHO and local 1-hour norm) exceeded the value of the standards • No concentrations above the value of the standard of SO_2 was registered • $PM_{2.5}$ was not monitored • PM_{10} concentrations registered in the manual network are different from those registered in the automatic network. Although the automatic equipment is located in the same place as the manual one, the former did not register any concentrations exceeding the value of the standard, while the latter did.
City of Rio de Janeiro[1]	4	• Data available for 2000–2005 • Among all pollutants monitored, concentrations of O_3 were the only ones that exceeded the value of the standards • It only considered data registered in the stations under the responsibility of the Municipality of the City of Rio de Janeiro • Concentrations of PM_{10} (24 hours), NO_2 (1 hour WHO), CO, and SO_2 exceeded the value of the standards • Although annual concentration data for PM_{10} were available, they were not taken into consideration because they represented averages of all four stations • Regarding NO_2, no annual concentration could be estimated because only data for the second part of 2004 were available

Urban Center	Classification	Observations
		• $PM_{2.5}$ was not monitored
Belo Horizonte	10	• The most recent monthly data are available on FEAM's Web site, but additional information was obtained from Belo Horizonte's Grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project" of December 2005. This document indicated that the local standards were never exceeded during 2005. The available data from FEAM's Web page also indicated that the WHO's 1-hour reference value for NO_2 was never exceeded • $PM_{2.5}$ was not monitored
Porto Alegre Metropolitan Region	7	• Data were available for the year 2002 only • Concentrations of PM_{10} (24 hours), NO_2 (annual WHO) and O_3 (1 hour) exceeded the value of the standards • No concentrations above the value of the norm of PM_{10} (annual) and SO_2 were registered • $PM_{2.5}$ and CO were not monitored
Recife Metropolitan Region	7	• TSP, NO_2,and SO_2 are the only pollutants monitored • TSP data were available for 2002–2003. The only data available for gases were the monthly mean for January 2003 for NO_2 and SO_2; therefore, it could not be compared to any of the relevant standards • TSP concentrations exceeded the value of the US EPA standards, but not those of the Brazilian norm
Salvador	12	• No monitoring capability
Fortaleza	11	• According to Fortaleza's Grant proposal for "World Bank's LAC Regional GEF Sustainable Transportation Project" of December 2005, among all selected pollutants TSP and SO_2 were the only ones monitored • Concentrations of both pollutants registered during 2004 were classified as regular, which is equivalent to being below the value of the local standards • Although data for TSP and SO_2 were available, the city was classified as category 11 because TSP concentrations did not exceed the standards and only one gas was monitored
Curitiba Metropolitan Region	3	• Data were available for both Curitiba and Araucária for 2002 and 2003 • Concentrations of PM_{10} (24 hours in Araucária), O_3 (1 hour in Araucária), NO_2 (1 hour WHO in Curitiba), and CO (8 hours in Curitiba) exceeded the value of the standards • With the exception of an isolated case in Araucária, no concentrations above the value of the norm of SO_2 were registered • Despite the availability of annual mean concentrations of PM_{10}, the values are not representative and therefore it cannot be inferred if the real mean concentrations have exceeded the value of the standard • $PM_{2.5}$ was not monitored
Brasília	11	• Of all selected pollutants, only PM_{10}, TSP and SO_2 were monitored • Data for PM_{10} was available for only part of March and April 2004 (during this period no daily concentrations above the value of the standard were registered) • Regarding SO_2, the only value available was the mean for half of the year 2000 • Because the available TSP data were from two different groups of stations and from different periods that provided different results, Brasília was classified in category 11. Data from the stations belonging to the government were available for only part of 2000 and the mean concentration of these values was much higher than the value of the annual and daily standards. On the other hand, the data registered at the stations belonging

Urban Center	Classification	Observations
		to the University in 2004 showed daily and annual values that did not exceed the value of the standard
Belém	12	• No monitoring capability
Goiânia	11	• TSP was the only pollutant monitored • Data available only included mean concentrations for the months of May, June, July of an unspecified year obtained from the Web page of the Environmental Agency of the State of Goiás. None of the monthly means exceeded the value of the annual standard
Santos	11	• SO_2 was the only pollutant monitored; its concentrations registered during the 2000–2005 period did not exceed the value of the annual standard • Because no other pollutant was monitored, Santos was classified in category 11
Manaus	12	• No monitoring capability
Grande Vitória	4	• Data were available for 2001, 2003, and 2004 • PM_{10} was the only pollutant that registered daily mean concentrations above the value of the standard. This only happened in 2004. • No concentrations above the value of the norm of PM_{10} (annual), O_3 (1 hour), NO_2, CO and SO_2 were registered • $PM_{2.5}$ was not monitored
Campinas	10	• Validated data were available for 2000–2005 from one station only • No concentrations above the value of the standards of any monitored pollutants were registered: PM_{10}, NO_2, CO (1 and 8 hours), and SO_2 (annual) • $PM_{2.5}$ and O_3 were not monitored
São Luís	12	• No monitoring capability
Natal	12	• No monitoring capability
Guarulhos[1]	7	• Validated data were available for 2000 until 2005 from the sole monitoring station located in Guarulhos that only monitors PM_{10} • Concentrations of PM_{10} exceeded the annual standard
Maceió	12	• No monitoring capability
Nova Iguaçú[1]	7	• Data were available for 2002, 2003, and 2004 from FEEMA's automatic and manual networks, but the classification considered the PM_{10} data registered in the manual station only • Concentrations of PM_{10} (24 hours and annual from the manual network), O_3 (1 hour), and NO_2 (WHO of 1 hour) exceeded the value of the standards • No concentrations above the value of the standards of CO and SO_2 were registered • $PM_{2.5}$ was not monitored • It is important to point out the differences between the PM_{10} concentrations registered in the manual network from those registered in the automatic network. Although the automatic equipment is located in the same place as the manual one, the former did not register any concentrations exceeding the value of the standard, while the latter did.
Teresina	12	• No monitoring capability
João Pessoa	12	• No monitoring capability
São Gonçalo[1]	7	• Data were available for 2002, 2003, and 2004 from the automatic and manual networks of FEEMA, but the

Urban Center	Classification	Observations
		classification considered the PM_{10} data registered in the manual station only • Concentrations of PM_{10} (24 hours and annual from the manual network) and NO_2 (WHO and local 1 hour norm) exceeded the value of the standards • No concentrations above the value of the norm of O_3 (1 hour), CO, and SO_2 were registered • $PM_{2.5}$ was not monitored • PM_{10} concentrations registered in the manual network were different from those registered in the automatic network. Although the automatic equipment is located in the same place as the manual one, the former did not register any concentrations exceeding the value of the standard, while the latter did
Duque de Caxias[1]	7	• Data available for 2002, 2003, and 2004 from the sole station located in Duque de Caxias, which only monitors PM_{10} • Concentrations of PM_{10} (24 hours and annual) exceeded the value of the standards
São José dos Campos	8	• Validated data were available for 2000–2005. For the classification, the data obtained from the automatic as well as the manual stations (which only measures SO_2) were considered • Ozone concentrations (1 hour) exceeded the value of the standard • No concentrations above the value of the norm of PM_{10} and SO_2 were registered • $PM_{2.5}$, NO_2, and CO were not monitored
Ribeirão Preto	8	• Validated data were available for the 2000–2005 period. For the classification, the data obtained from the automatic as well as from the manual stations (which only measures PM_{10} and SO_2) were considered • O_3 concentrations (1 hour) exceeded the value of the standard in the only station that monitors this pollutant • No concentrations above the value of the norm of PM_{10}, NO_2, and CO (1 and 8 hours) were registered • PM_2 was not monitored
Aracajú	12	• No monitoring capability
Cuiabá	12	• No monitoring capability
São Bernardo do Campo[1]	10	• Validated data were available for 2000–2005 • The single automatic station located in São Bernardo do Campo which measures only PM_{10} never registered concentrations above the value of the standard
Florianópolis	12	• No monitoring capability
Campo Grande	12	• No monitoring capability
Osasco [1]	7	• Validated data were available for 2000–2005. For the classification, only the data obtained from the automatic station were considered. • Concentrations of PM_{10}, O_3 (1 hour), and NO_2 (1 hour WHO) exceeded the standards • Monitoring of O_3 stopped in November 2003; therefore, data from 2002 were considered for the classification • No concentrations above the value of the norm of CO (1 and 8 hours) and SO_2 were registered • $PM_{2.5}$ was not monitored
Santo André[1]	4	• Validated data were available for 2000–2005. For the classification, only the data obtained from the automatic station were considered. • Concentrations of O_3 (1 hour) and CO (8 hours) exceeded the standards

Urban Center	Classification	Observations
		• No concentrations above the value of the standards of PM_{10} and CO (1 hour) were registered • $PM_{2.5}$, NO_2 and SO_2 were not monitored • Only one isolated episode of an 8-hour average concentration of CO above the value of the standard was registered
Londrina	12	• No monitoring capability
Sorocaba	8	• Validated data were available for 2000–2005. Data from the only automatic station where PM_{10} and O_3 are monitored as well as data obtained from the 2 manual stations (which only measure SO_2) were taken into consideration for the classification • Concentrations of O_3 (1 hour) exceeded the standard • No concentrations above the value of the norm of PM_{10}, NO_2, SO_2 were registered • $PM_{2.5}$ and CO were not monitored
Jaboatão[1]	11	• TSP, NO_2,and SO_2 are the only pollutants monitored • TSP data were available for 2002–2003. The only data available for gases was the monthly mean for January 2003 for NO_2 and SO_2; therefore, it could not be compared to any of the relevant standards • Annual TSP concentrations of TSP did not exceed the value of either local or US EPAs standards, but not those of the Brazilian norm • No daily concentration data for TSP, NO_2, and SO_2 are available • Although data for TSP were available, the city was classified in category 11 because TSP concentrations did not exceed the standards and only a few other gases were monitored
CHILE		
Santiago	1	• Data were available for 2000–2004 for all pollutants and for 2005 for some pollutants • Concentrations of PM_{10} (24 hours and annual), $PM_{2.5}$ (24 hours and annual), O_3 (1 hour), and CO (8 hours) exceeded the value of the standards. PM_{10}, $PM_{2.5}$, O_3, and CO have all been recognized as critical pollutants at least since 1997. • No concentrations above the value of the norm of SO_2 and NO_2 were registered
Greater Valparaíso	4	• Data were available for 2000–2004 • Concentrations of PM_{10} (24 hours) exceeded the value of the standard • No concentrations above the value of the norm of O_3 (1 hour), CO, and SO_2 were registered • Although $PM_{2.5}$ and NO_2 were monitored, no data were available • Even if SO_2daily concentrations never exceeded the value of the local standard, they exceeded that of the US EPA in various years. The exception was 2004 when neither of the standards was exceeded
Greater Concepción	2	• Data were available for 2000–2004 • Concentrations of PM_{10} (24 hours and annual) and $PM_{2.5}$ (24 hours and annual) exceeded the standards • No concentrations above the value of the norm were registered for SO_2 • Although O_3, NO_2 and CO were monitored, no data were available
COLOMBIA		
Barranquilla	7	• Data were available for the first half of 2005 • Concentrations of PM_{10} (24 hours) exceeded the standard

Urban Center	Classification	Observations
		• No concentrations above the value of the norm of CO, NO_2, and SO_2 were registered • $PM_{2.5}$ was not monitored • Despite the O_3 data for all six months, nothing could be reported because it was not clear whether the values reported were maximums, mean, 1- or 8-hour concentrations
Bogotá	4	• Data were available for 2000–2004 • Concentrations of PM_{10} (24 hours and annual) and CO exceeded the standards • No concentrations above the value of the norm of O_3, NO_2,and SO_2 were registered • $PM_{2.5}$ was not monitored
Bucaramanga	3	• Data were available for the period 2001–2005 • Concentrations of O_3 (1 hour), PM_{10} (24 hours), and NO_2 (1 hour WHO) exceeded the value of the standards • No concentrations above the value of the standards of CO (1 hour) and SO_2 (24 hours) were registered • $PM_{2.5}$ was not monitored
Cali	7	• Data were available for the 2003–August 2004 period • Concentrations of O_3 (1 hour), PM_{10} (24 hours and annual), and CO (8 hours) exceeded the value of the standards • No concentrations above the value of the norm of SO_2 (annual and 24 hours) were registered • $PM_{2.5}$ was not monitored • No data were available for NO_2
Cartagena	12	• Cartagena had 4 stations that stopped operating in October 2000. The equipment is currently dismantled. • In addition, CARDIQUE has equipment to monitor PM_{10} (hi volume) and analyzers for CO and O_3. No data on these pollutants were available
Cúcuta	11	• Cúcuta has 5 stations that are currently not operating (they operated from 1998 until 2003), but no data were available • $PM_{2.5}$ and O_3 were not monitored
Medellín	3	• Data were available for 2002–2005 • Concentrations of PM_{10} (24 hours and annual), O_3 (1 hour), and CO (8 hours) exceeded the value of the standard • No concentrations above the value of the norm of NO_2 (24 hours and annual) and SO_2 (24 hours and annual) were registered • $PM_{2.5}$ was not monitored
Pereira	11	• A network monitors PM_{10}, O_3, NO_2, CO, and SO_2, but no data were available • $PM_{2.5}$ is not monitored.
COSTA RICA		
San José	7	• Information was obtained from a study carried out during 1996–2003 • PM_{10} concentrations (annual) exceeded the value of the standard • NO_2 data did not register annual concentrations above the standards • Although SO_2 was monitored, no data were available • $PM_{2.5}$, O_3 and CO were not monitored

Urban Center	Classification	Observations
ECUADOR		
Guayaquil	7	• The Municipality of Guayaquil indicated that all available data comes from studies that lack historical continuity • The longest study, entitled "Estudios de la Calidad del Aire en la Ciudad de Guayaquil: Diagnóstico e Investigación Referencial," monitored PM_{10}, O_3, No_2, CO, and SO_2 for very short periods which do not allow hourly, daily or annual means to be estimated • Other monitoring campaigns during 2004 and 2005 indicate that the value of the 24 hour standard of PM_{10} was exceeded • Regarding the results of O_3 in the aforementioned study, all samples (15–20 minutes) registered concentrations below the value of the hourly norm • Regarding the results of CO in the same study, in certain locations and depending on the hour of the day, when traffic congestion was increasing, maximum mean concentrations (15–20 minutes) above the hourly norm were registered
Quito	1	• The monitoring network has been operating since June 2003 • Concentrations of PM_{10} (24 hours and annual), $PM_{2.5}$ (annual), 0_3 (1 and 8 hours) and NO_2 (1 hour) exceeded the value of the standards • No concentrations exceeding the value of the standards of CO and SO_2 were registered
DOMINICAN REPUBLIC		
Santo Domingo	7	• Information was obtained from a study carried out in 2002 (INTEC study) • Concentrations of $PM_{2.5}$ (24 hours) exceeded the value of the standard • No concentrations above the value of the norm of CO, NO_2, and SO_2 were registered • PM_{10} was not monitored
EL SALVADOR		
San Salvador	7	• Only partial information was available for 2004–2005, for PM_{10} and NO_2 • Concentrations of PM_{10} (annual) and NO_2 (annual WHO) exceeded the value of the standards • No O_3 concentration exceeding the value of the hourly norm was registered but this pollutant was monitored once every 7 days • CO, SO_2, and $PM_{2.5}$ were not monitored
GUATEMALA		
Guatemala	7	• Information was obtained from a 2004 study • Concentrations of PM_{10} (US EPA annual) and NO_2 (WHO annual) exceeded the value of the standards • Annual mean concentrations of NO_2 exceeded the value of the WHO annual reference value, but not that of the US EPA. In this case, the WHO reference value was used for the classification because this was the one used for comparison in the study • O_3, CO, SO_2, and $PM_{2.5}$ were not monitored
HONDURAS		
San Pedro Sula	11	• Only sporadic information for 2001 and 2004 was available • NO_2 concentrations (annual WHO) did not exceed the value of the standard • Only annual ozone data were available but did not allow comparison to the standards

Urban Center	Classification	Observations
		• There was insufficient information about PM_{10} concentrations • CO, SO_2, and $PM_{2.5}$ were not monitored
Tegucigalpa	7	• Data were available for 2003 • PM_{10} concentrations (annual) exceeded the value of the standard • No concentrations above the value of the norm of NO_2 (annual WHO) were registered • Only annual ozone data were available but did not allow comparison to the standards
JAMAICA		
Kingston	7	• The classification was based on TSP data because PM_{10} data were available for only 4 months. However, daily values during theses 4 months never exceeded the daily standard
MEXICO		
Acapulco	12	• No monitoring capability
Aguascalientes	4	• Information was available for 2000–2003 for O_3, and for 2000–2005 for PM_{10} • PM_{10} concentrations (annual) exceeded the value of the standard • No concentrations above the value of the norm of PM_{10} (24 hours) and O_3 (8 and 1 hour) were registered • No information was available for NO_2, CO, and SO_2 • $PM_{2.5}$ was not monitored
Chihuahua	12	• The monitoring network stopped operating in 1993. Monitoring of PM_{10}, O_3, CO, NO_2, and SO_2 with mobile units took place until 2004, but no data were available
Ciudad Juárez	3	• Data were available for 2000–2004 • Concentrations of O_3 (1 hour US EPA) and PM_{10} (24 hours and annual) exceeded the value of the standard • No concentration above the value of the norm of CO (8 hours) was registered • $PM_{2.5}$, NO_2, and SO_2 were not monitored
Coatzacoalcos	12	• No monitoring capability
Cuernavaca	11	• No data were available for the single automatic station that monitors O_3, CO, NO_2, and SO_2
Culiacán	12	• No monitoring capability
Ecatepec (ZMVM)[1]	1	• Data were available for 2000–2005 for the 2 existing monitoring stations • Concentrations of O_3 (1 and 8 hours), $PM_{2.5}$ (24 hours and annual), and PM_{10} (24 hours) exceeded the value of the standards • No concentrations above the value of the standards of NO_2 (1 hour), CO (1 and 8 hours), and SO_2 (24 hours and annual) were registered
Zona Metropolitana de Guadalajara (ZMG)	3	• Concentrations of O_3 (1 hour), PM_{10} (24 hours and annual), NO_2 (1 hour and annual EPA), and CO (1 hour and 8 hours) exceeded the value of the standards • SO_2 concentrations did not exceed the value of the annual and daily standards in 2004 and 2003, but daily concentrations exceeded the value of the standard in previous years • $PM_{2.5}$ was not monitored
Guadalupe (ZMM)[1]	7	• Data were available for 2000–2004 • The only existing station presented concentrations exceeding the value of the standard of O_3 (1 hour) and PM_{10}

Urban Center	Classification	Observations
		(24 hours and annual) • No concentrations above the value of the norm of NO_2, CO and SO_2 were registered • $PM_{2.5}$ was monitored but no data were available
Hermosillo	12	• There is no monitoring capability at present. One network composed of four stations that existed in the past monitored PM_{10}, TSP, NO_2, and SO_2., but no data were available
León	7	• Information was available only for April 2004–September 2005 for NO_2, CO, and SO_2, and for 2004–2005 for PM_{10} and O_3 • PM_{10} concentrations (24 hours and annual) exceeded the value of the standards • No concentrations above the value of the standard of O_3 (1 and 8-hour) NO_2 (1 hour), CO (8 hours), O_3 (1 and 8 hours), and SO_2 (24 hours) were registered • $PM_{2.5}$ was not monitored
Matamoros	4	• Data were available for 2003–2004 • PM_{10} concentrations (24 hours and annual) exceeded the value of the standards • O_3, $PM_{2.5}$, NO_2, CO, and SO_2 were not monitored
Mérida	12	• No monitoring capability
Mexicali	11	• Mexicali was classified in category "11" because, although O_3, PM_{10}, NO_2, CO, and SO_2. were monitored, no online data were yet available and data could not be obtained from any other source • The only available O_3 data are for 1997–1999; this indicates that the hourly norm was exceeded 47 times. Because this information is prior to the year 2000, it was not considered for the purpose of the classification • $PM_{2.5}$ was not monitored
Zona Metropolitana del Valle de México (ZMVM)	1	• Information was available for 2000–2005 • Concentrations of O_3 (1 and 8 hours), PM_{10} (annual and 24 hours), $PM_{2.5}$ (annual and 24 hours), and NO_2 (1 hour and annual EPA) exceeded the value of the standards. PM_{10}, $PM_{2.5}$, O_3, and NO_2 have all been recognized as critical pollutants at least since 2000. • PM_{10} and $PM_{2.5}$ data came from the automatic as well as the manual networks • No concentrations above the value of the norm of CO and SO_2 were registered • No SO_2concentrations exceeding the value of the norm were registered in the last few years (2002–2004), but concentrations exceeding the 24 hour norm were registered in the previous years (2000 and 2001)
Monterrey (ZMM)	3	• Data were available for 2000–2004 • Concentrations of O_3 (1 hour) and PM_{10} (24 hours and annual) exceeded the value of the standards • $PM_{2.5}$ was monitored but no data were available • No CO concentrations exceeding the value of the 8 hour norm were registered in the last few years (2003 and 2004) but concentrations above this norm were registered in 2002 • NO_2 and SO_2 did not present concentrations exceeding the value of the standard
Naucalpan (ZMVM)[1]	7	• Information was available for 2000–2004 from the only existing station • Concentrations of O_3 (1 and 8 hours) and PM_{10} (24 hours) exceeded the value of the standards • No concentrations exceeding the value of the standard of NO_2 (1 hour and US EPA annual), SO_2 (annual and 24 hours) and CO (8 hours and US EPA 1 hour) were registered

Urban Center	Classification	Observations
		• $PM_{2.5}$ was not monitored
Nezahualcóyotl (ZMVM) [1]	7	• Data were available for 2000–2004 • Concentrations of PM_{10} (annual) exceeded the value of the standard • No concentrations exceeding the value of the standard of CO (8 hours and US EPA 1 hour) and SO_2 (annual and 24 hours) were registered • The only available data for PM_{10} data was for 2000 because the automatic station stopped working that year • $PM_{2.5}$, O_3, and NO_2 were not monitored
Puebla Metropolitan Region (ZMP)	3	• Data were available for 2000–2005 • Concentrations of O_3 (1 and 8 hours) and PM_{10} (24 hours) exceeded the value of the standards • NO_2, CO, and SO_2 did not present concentrations exceeding the value of the standards • $PM_{2.5}$ was not monitored
Querétaro	7	• Data were only available for 2002–2004 • Concentrations of PM_{10} (24 hours) exceeded the value of the standard • No concentrations exceeding the value of the standard of NO_2 (1 hour and US EOA annual), CO (8 hours), and SO_2 (24 hours and annual) were registered • No data were available for O_3 • $PM_{2.5}$ was not monitored
Saltillo	12	• No monitoring capability
San Luís Potosí	12	• A monitoring network was expected to be implemented in October 2005, but there is no information confirming any monitoring so far
Tampico	10	• PM_{10} was the only pollutant monitored at the single existing station • No concentrations exceeding the value of the annual standard for 2002–2004 were registered but no daily concentration data were available
Tlalnepantla (ZMVM)[1]	7	• Data were available for 2000–2005 • Concentrations of O_3 (1 and 8 hours), $PM_{2.5}$ (annual), and NO_2 (annual) exceeded the value of the standards; O_3 and $PM_{2.5}$ were only measured at 1 station • No concentration above the value of the standard of PM_{10} (annual and 24 hours), SO_2 (annual and 24 hours), and CO (1 and 8 hours) were registered; PM_{10} was only measured at 1 station • No SO_2concentrations exceeding the value of the norm were registered in the last year for which there was information available but values above the norm were registered in the previous year
Metropolitan Zone of the Valley of Toluca (ZMVT)	3	• Data were available for 2000–2004 • Concentrations of O_3 (1 and 8 hours), PM_{10} (24 hours and annual), and NO_2 (annual US EPA and 1 hour) exceeded the value of the standards • No concentrations exceeding the value of the standard of CO (1 hour US EPA, 8 hours) and SO_2 (24 hours and annual) were registered • $PM_{2.5}$ was not monitored
Veracruz	12	• No monitoring capability

Urban Center	Classification	Observations
Villahermosa	10	• Only partial data for 2001 (gases, PM_{10}) and 2002 (PM_{10}) were available • PM_{10} (24 hours), NO_2 (1 hour), SO_2 (annual), and O_3 (1 hour) did not register concentrations exceeding the value of the standards • No data were available for CO • $PM_{2.5}$ was not monitored • Although no O_3 data are available for 8-hour concentrations, most 1-hour maximum concentrations (maximum value within a month) are below the 8-hour standard; thus, it may be assumed that the chances of exceeding the 8-hour standards are minimal
Tijuana–Rosarito	11	• Tijuana–Rosarito has an automatic network that monitors for PM_{10}, NO_2, CO, and SO_2 but no data were available • O_3 data were only available for 1997–1999. These data indicates that the 1-hour standard was not exceeded • $PM_{2.5}$ was not monitored
Torreón	7	• Data were only available for 2004 • TSP concentrations (annual) exceeded the value of the standard • No information was available for NO_2, O_3, PM_{10}, and CO • $PM_{2.5}$ and SO_2 were not monitored
Zapopan (ZMG)[1]	4	• Information was available for 2000–2004 • Concentrations of O_3 (1 hour) and NO_2 (1 hour and US EPA annual) exceeded the value of the standards • No concentrations exceeding the value of the standard of PM_{10} (annual and 24 hours), CO (1 and 8 hours), and SO_2 (annual and 24 hours) were registered • $PM_{2.5}$ was not monitored
NICARAGUA		
Managua	7	• Only incomplete information for 2000–2001 was available because the network has not functioned since 2002 • PM_{10} concentrations (annual EPA) exceeded the value of the standard • No concentrations above the value of the standard of CO (8 hours WHO) and NO_2 (annual WHO) were registered • Only annual ozone data were available and did not allow comparison to the standards • $PM_{2.5}$ and SO_2 were not monitored
PANAMA		
Panama City	4	• Information was available for 2000–2005 • PM_{10} concentrations (24 hours and annual US EPA) exceeded the value of the standards • No concentration above the value of the standard of NO_2 (annual US EPA) was registered • No information was available for $PM_{2.5}$ • Only annual ozone data were availableand did not allow comparison to the standards • SO_2 and CO were not monitored
PARAGUAY		
Asunción	11	• No information available

Urban Center	Classification	Observations
PERU		
Arequipa	7	• Only information for 2005 was available • Concentrations of PM_{10} (annual), CO (8 hours), and SO_2 (24 hours) exceeded the value of the standards • $PM_{2.5}$, O_3, and NO_2 were not monitored
Lima–Callao	4	• $PM_{2.5}$ concentrations (annual) exceeded the value of the standard • No NO_2concentrations exceeding the value for the annual norm were registered during 2001–2005, but in 2000 the annual norm was exceeded at 2 stations, with one of the stations presenting an excess of more than 100% of the norm (254.94 µg/m³). Information for concentrations of 1-hour was not available. • No concentrations exceeding the value of the SO_2 norm (annual) was registered • No data were available for O_3 • CO and PM_{10} were not monitored
Trujillo	7	• Data were obtained from a study that monitored air quality during 2003 in 5 stations • Concentrations of $PM_{2.5}$ (24 hours) exceeded the value of the standard • No concentrations exceeding the value of the standard of SO_2 (24 hours) and NO_2 (24 hours WHO) were registered • PM_{10}, O_3, and CO were not monitored
URUGUAY		
Montevideo	10	• Data were available for 2004 and 2005, but 2005 data were incomplete due to operational problems • Montevideo did not present concentrations exceeding the value of the norm of SO_2 (24 hours and annual), O_3 (1 hour), PM_{10} (annual and 24 hours), and NO_2 (24 hours and annual) • No data were available for CO due to various operational problems at the automatic stations
VENEZUELA		
Barcelona	7	• Information was only available for TSP for 2004 • TSP concentrations (24 hours and annual) exceeded the value of the standards • NO_2, PM_{10}, $PM_{2.5}$, CO, O_3, and SO_2 were not monitored
Barquisimeto	11	• No information available
Caracas	11	• Information was only available for 2004 • Caracas did not register any concentrations exceeding the value of the norm of TSP and NO_2 • Available information for PM_{10} was the annual average for all stations during 2005, but no details on the highest registered concentration in any one station were obtained • No information was available for CO, SO_2, and O_3 • $PM_{2.5}$ was not monitored
Ciudad Guyana	11	• No information available
Maracaibo	11	• ICLAN has a network of 6 stations but no further information was available
Maracay	12	• No monitoring capability
Valencia	11	• Valencia did not register concentrations exceeding the value of the TSP standards • PM_{10}, $PM_{2.5}$, O_3, CO, SO_2, and NO_2 were not monitored

Notes:
The classification was based on the methodology described in Table 3.
1. The table also provides information for several urban centers located within the territory of the metropolitan regions of São Paulo, Rio de Janeiro, ZMVM, Monterrey, and Guadalajara.

ANNEX 1: Description, origin and health effects of most common air pollutants

An air pollutant may be considered a substance in the air that, in sufficiently high concentrations, produces a detrimental effect on the environment, health, or well-being. A pollutant can affect the health of humans, plants, and animals. It can also have an effect on nonliving materials such as paints, metals, and fabrics.

There are hundreds of pollutants in the air. The two basic forms of air pollutants are particulate matter and gases. Particulate matter includes small solid and liquid particles such as dust, smoke, sand, pollen, and mist. Gases include substances such as carbon monoxide, sulfur dioxide, nitrogen oxides, and volatile organic compounds.

Currently more than 90% of air pollution is caused by a small number of pollutants that are mainly generated by the use of fossil fuels. These pollutants are classified by the US EPA as criteria pollutants and are used as indicators of air quality throughout the United States. They include carbon monoxide (CO), sulfur oxides (SO_x), nitrogen oxides (NO_x), ozone (O_3), particulate matter (PM), and lead (Pb).

Origin of most common air pollutants

A distinction between primary and secondary pollutants is made based on their origin. Primary pollutants refer to those that are directly emitted by a source, while secondary pollutants refer those that are produced by chemical reactions of precursor pollutants in the atmosphere. Particulate matter is both a primary and secondary pollutant, where SO_2 and NO_x are the main contributors to the formation of secondary particles, while ozone is a secondary pollutant, where NO_x and volatile organic compounds (VOCs) are the main precursors. In this sense, precursor pollutants, besides having direct detrimental effects on health and welfare, also have indirect repercussions as precursors of secondary pollutants.

- *Carbon Monoxide (CO)* is a colorless, odorless gas formed when carbon in fuel is not burned completely. It is considered a primary pollutant (emitted directly by its sources) and is quite stable in the atmosphere, not reacting with any other compounds. The main source of this pollutant is motor vehicle exhaust, followed by nonroad engines such as construction equipment and boats, as well as industrial processes, residential wood burning, and natural sources such as wood fires. Higher levels of CO, generally found in areas with high traffic congestion, typically occur during the cold months of the year when nighttime inversion conditions are more frequent.

- *Sulfur Oxides (SO_x)* are colorless gases formed when fuels containing sulfur, such as coal and oil, are burned, when gasoline is extracted from oil, or when metals are extracted from ores. The criteria pollutant indicator of pollution with SO_x in the air is sulfur dioxide (SO_2). Most of the SO_2 quantities released in the air come from electric utilities, especially from those burning coal. Other sources of SO_2 are industrial facilities such as petroleum refineries, cement manufacturing, and metal processing facilities. SO_2 also contributes to the formation of secondary particulate matter.

- *Nitrogen Oxides (NO_x):* This term is used to describe the sum of NO, NO_2, and other oxides of nitrogen. NO_x are part of a group of highly reactive gases that play a major role in the formation of ground-level ozone and secondary particulate matter, especially $PM_{2.5}$. Nitrogen oxides are colorless and odorless. However, nitrogen dioxide along with particles appears as a reddish-brownish layer over main urban areas. NO_x are formed as a result of incomplete combustion and their main sources are motor vehicles, electric utilities, and other sources that burn fuel (diesel or gasoline).

- *Ozone (O_3):* Ozone is a colorless gas that has an electrical-discharge-type odor. Ozone is a secondary pollutant because it is not directly emitted into the air but rather is the result of a photochemical reaction of various chemicals, of which NO_x and VOCs are the main constituents. The concentration of this pollutant in any given place can vary depending on the concentration of its precursors, the intensity of sunlight, and local weather conditions.

- *Particulate matter (PM):* This is a term used for a mixture of solid particles and liquid droplets found in the atmosphere. They include smoke, dust, dirt, soot, and liquid droplets. They can have various dimensions, from microscopic to visible by the human eye, and can be primary or secondary pollutants. Primary particles are emitted directly into the air; their main sources are automotive vehicles, construction sites, unpaved roads, wood burning, and natural sources. Secondary particles are formed when gases from burning fuels react with sunlight and water vapors. These can result from combustion processes at power plants or from other industrial processes. Particulate matter includes all three total suspended particles (TSP), "coarse" particles with an aerodynamic diameter less than or equal to 10 micrometers (PM_{10}), and "fine" particles with an aerodynamic diameter less than or equal to 2.5 micrometers ($PM_{2.5}$). Secondary particulate matter, most of which is $PM_{2.5}$, is formed by chemical reactions of primary pollutants such as NO_x, SO_2, ammonia (NH_3), and VOCs.

Health effects of most common pollutants in the air

Exposure to levels of pollutants above the maximum allowed limits[89] is associated with various negative effects on human health such as pulmonary, cardiac, vascular, and neurological diseases. The effects vary greatly from group to group and are more pronounced among pregnant women, children, and the elderly. Acute effects are usually immediate and are reversible once exposure to pollutants stops. Chronic effects are not immediate and not reversible once exposure to the pollutant ends. Chronic health effects include lung cancer which results from long-term exposure to high levels of pollutants.

The following is a brief description of some of the main adverse effects of the criteria pollutants on human health:

- *Carbon monoxide* impairs the normal transportation of oxygen in the blood. Depending on the quantity present in the air and the exposure time, it can cause loss of visual precision, headaches, drowsiness, reduced mental alertness, and, in extreme cases, worsening of cardiovascular diseases, heart attacks, and even death.
- *Sulfur oxides* generally cause problems of the upper respiratory system, such as chest tightness, eye and throat irritation, shortness of breath, and lung damage. The damage is greater when, together with humidity and particulate matter existing in the air, they form sulfuric acid haze (also called acid rain). They also have indirect effects as precursors of particulate matter.
- *Nitrogen oxides* cause susceptibility to respiratory infections in sensitive persons such as asthma patients and small children. These infections may include cough, chest pain, and difficult breathing. They also have indirect effects as precursors of particulate matter and ground-level ozone.
- *Ozone* causes eye and throat irritation, coughing, and respiratory tract problems. It can also have negative effects on asthma patients and can even lead to lung cancer.
- *Particulate matter* is consistently linked with serious health effects, where effects on mortality are arguably the most important.[90] It causes respiratory tract damage such as asthma, bronchitis, lung

[89] See above section on ambient air quality standards.

[90] Ostro Bart. 2004. Outdoor Air Pollution: Assessing the Environmental Burden of Disease at National and Local Levels. Environmental Disease Series, N 5. WHO, Geneva 2004.

damage, and cancer. It can even cause heavy metal poisoning and cardiovascular effects. In addition, it intensifies the negative effects of other gaseous pollutants. Fine particles are more dangerous than coarse particles because their size and specific physical, chemical, and biological characteristics, including the presence of metals, PAHs (polycyclic aromatic hydrocarbons), other organic components, or certain toxins can have harmful health effects.

Cohen, A.J, Anderson, H.R., Ostro, B., Pandey, K.D., Krzyzanowski, M., Kuenzli, N., Gutschmidt, K., Pope, C.A., Romieu, I., Samet, J.M., and Smith, K.R. 2004. Mortality Impacts of Urban Air Pollution. In Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors. Eds. M. Ezzati, A.D. López, A. Rodgers, and C.U.J.L. Murray, vol. 2. Geneva: World Health Organization.

ANNEX 2: Description of ambient air quality standards for gaseous pollutants among selected countries

Carbon Monoxide

Because carbon monoxide is a very reactive gas and therefore disappears in the air very rapidly, ambient concentrations of this gas are monitored for short periods only, 1 and 8 hours. Of the 19 countries considered, Figure 4 shows that 14 countries legislate standards for this gas, either a 1- or 8-hour averaging time, In this case specifically, most countries set standards for both averaging times; 13 and 14 set standards for periods of 1 and 8 hours, respectively.

Figure 5 indicates that in 13 of the 14 cases where an 8-hour standard exists, it is equal in value to the 8-hour standard of the US EPA (10 mg/m³), except for Mexico which has a less stringent standard (13 mg/m³).

Figure 4 indicates that 13 countries have set a 1-hour standard. Figure 5 shows that three[91] of these countries (Bolivia, Peru, and Uruguay [Montevideo]), equivalent to 23%, follow stricter values than those of the US EPA (40 mg/m³) which are followed by most other countries (69%). The exception is the National Law of Argentina (50 mg/m³). In addition, the current legislation of the City of Buenos Aires (Ordinance 39.025) provides a 20-minute standard of 15 mg/m³ that will be replaced by the 1-hour standard of 40 mg/m³ (equal to US EPA) of Law 1356 of 2004, once the law is regulated. The three countries setting stricter standards follow the WHO reference value (30 mg/m³).

Sulfur Dioxide

Most countries, similar to the US NAAQS and guidelines of the WHO, set SO_2 standards for 1 year and 24 hours only. Figure 4 indicates that 13 countries have a 1-year standard, while 14 have a daily standard. Several countries go beyond the international benchmarks by also providing standards for 3-hour (Colombia, Costa Rica, Province and City of Buenos Aires) or 1-hour (Chile, the Dominican Republic, Jamaica) periods. Interestingly, the 1-hour SO_2 standards in the region are more stringent than those specified by the EU, the only international benchmark value available for 1-hour SO_2 levels.[92]

Before comparing the regional standards with those of the international benchmarks, it is worth noting that the US NAAQS and WHO guideline reference values are quite different from each other. At 50 μg/m³ for 1 year and 125 μg/m³ for 24 hours, the WHO guidelines' reference standards are 1.6 and 2.7 times more stringent than those of the US NAAQS, respectively.

As shown in Figure 5, the 1-year standard for 10 countries is very similar to the US NAAQS value of 79 μg/m³.[93] In contrast, the 24-hour standard is equal to that of the US NAAQS in only one country in the region (Mexico). In general, these standards tend to be less strict than the US benchmark (which itself is less strict than values recommended by the WHO), although in four countries the standard is stricter.[94] In addition, proposed legislation in Chile would tighten the current 24-hour standard from 365 μg/m³ to 250 μg/m³.

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[91] In addition, the new revised values of Chile's legislation reduce the 1-hour standard from 40 to 30 μg/m³. In order to verify compliance with the 1-hour standard, the norm states that the value used for comparison should be the average of three yearly 99 percentile values of the maximum 1-hour concentrations registered each day, meaning that although the revised standard became effective in January 2006, it will not be applicable for three more years.

[92] The EU 1-hour standard for SO_2 is 350 μg/m^3.

[93] The exceptions are Montevideo with a stricter standard of 60 μg/m³, and the Dominican Republic with a less strict standard of 100 μg/m³.

[94] Argentina's National Law [70 μg/m³], Colombia [250 μg/m³], the Dominican Republic [150 μg/m³], and Montevideo [125 μg/m³].

Nitrogen Dioxide

As Figure 4 shows, all 14 countries whose legislation establishes ambient air quality standards include this gas in those standards, but measurement periods differ substantially among countries. Eleven of them set annual standards, while only 7 and 8 set daily and 1-hour standards, respectively. Even among international benchmarks, there is a fair amount of variation. None includes daily-averaging values, and the WHO guideline value for one-year average (40 μg/m³) is over twice as stringent as the equivalent value in the NAAQS (100 μg/m³). The US does not set a standard for a 1-hour averaging period, although both the WHO guidelines and EU standard values are set at 200 μg/m³.

Colombia's and Peru's 1-hour standards for NO_2 are the same as the EU/WHO guideline value, but all others are less stringent than the international benchmarks. One-year standards across selected countries, with the exception of Uruguay/Montevideo (40 μg/m³), are the same as those of the US NAAQS (100 μg/m³). This information is summarized in Figure 5.

Ozone

All countries whose legislation establishes ambient air quality standards include ozone in those standards (14 as shown in Figure 4), but measurement periods vary substantially among countries. One-hour standards are more widely available than 8-hour standards (in 13 and in 7 countries, respectively), even though both international benchmarks use an 8-hour rather than 1-hour standard. EPA replaced its 1-hour standard in 1997, although it still provides the 1-hour value as a reference.[95] One country, El Salvador, maintains an annual averaging standard for ozone, although the public health purpose of such a standard is unclear, since documented health effects are associated with short-term exposure.[96]

Figure 5 indicates that five of the seven countries with an 8-hour standard follow the more stringent reference value of the WHO guidelines (Colombia, Ecuador, El Salvador, Peru, and Uruguay [Montevideo]) than the US NAAQS value. Mexico and the Dominican Republic have set it at a level equal or very similar to that of the US NAAQS.[97] Proposed legislation in Chile would replace the current 1-hour standard with the WHO's 8-hour standard.

Five of 13 countries that set 1-hour standard do so at the same or at a slightly less strict standard of the US EPA's 1-hour reference value of 235 μg/m³[98] (Bolivia, the Dominican Republic, El Salvador, Jamaica, and Venezuela).[99] The rest (8 countries) have a stricter standard that is not comparable to any international benchmark.

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[95] The 8-hour standard is more directly associated with the health effects of most concern cited in several 6- to 8-hour exposure studies, conducted at more typical exercise levels and at lower exposure levels than the 1-hour studies. For more information, see http://www.epa.gov/ttn/oarpg/naaqsfin/o3fact.html.

[96] For further information refer to WHO Europe Air Quality Guidelines, second edition. WHO Regional Publications, European Series, Number 91.

[97] The City of Buenos Aires' new Law 1356, once regulated, will replace current Ordinance 30.025. The new law contemplates an 8-hour standard equal to that of the US EPA.

[98] Converted to 235 μg/m³ from 0.12 ppm using the following conversion formula: ppm*M/0.02447=μg/m³, where M is the molecular weight of ozone equal to 48.

[99] The Province and City of Buenos Aires also have a 1-hour standard equal to that of the US EPA (235 μg/m³).

ANNEX 3: Description of a monitoring network and methods for sampling air quality concentrations

What is an air quality monitoring network?

A monitoring network is a collection of fixed or mobile monitoring stations with the necessary automatic, semiautomatic, and/or manual equipment to measure the ambient concentration of pollutants and meteorological variables in a particular geographical area, with respect to the design objectives of the respective network.

There are no set rules for the establishment of monitoring networks because it depends greatly on the final goals that need to be achieved by the entity implementing the network. Nevertheless, the US EPA, WHO, and WMO have defined guidelines for the design of monitoring networks.[100]

In practice, the number of stations to be established depends on the area to be covered and the spatial distribution of the pollutants measured, the location of exposed populations, and the final use of the data collected. In general, the following factors are used for the selection of stations depending on the final goals: population affected, environment affected, geographic scale of the issue studied, geographical conditions, sources and emissions of the delimited area, weather pattern and topography of the selected area.

Regardless of how monitoring networks are designed, stations must be selected in a way that assures that the data collected are representative.

Methods and instruments used for air quality monitoring[101]

Various technical air monitoring methods are used to determine air pollutants in the atmosphere, each with its own advantages and disadvantages depending on the costs of equipment installation and maintenance, number of personnel needed, and training capacity needed, among others.

The air monitoring systems currently in use are: passive samplers, active samplers, automatic analyzers, remote sensors, and bioindicators.[102] Passive and active samplers are usually referred to as *manual* methods.

- *Passive samplers* or passive monitoring systems are based on the absorption of a pollutant onto a specific surface that retains the substance to be analyzed. After exposure of the sample for a certain period, varying from a few hours to a month, the sample is taken to the laboratory where it is analyzed. The main advantage of these monitoring systems is their very low initial cost and their simplicity. They are appropriate for certain baseline studies. Among the disadvantages is the

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[100] The US EPA's guidance documents for monitoring programs can be found at http://www.epa.gov/ttn/amtic/. IDEAM published a document that summarizes design guidelines for these three organizations' air quality monitoring networks: *Anexo 1 del Documento de Soporte del Proyecto de Norma de Calidad del Aire: Revisión de las condiciones actuales de las redes de monitoreo de calidad del aire en el país.* Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), Colombia. Available at http://www.ideam.gov.co/biblio/paginaabierta/Anexo%201.pdf.

[101] For further information about methods and equipment see "*Introducción al Monitoreo Atmosférico*," available online at http://www.cepis.org.pe/bvsci/e/fulltext/intromon/intromon.html.

[102] Bioindicators consist of the use of plants to determine certain pollutants in the air, such as the use of parsley for lead or tobacco for ozone. They are very cheap, useful methods to determine the existence of pollutants, but they pose a problem in terms of standardizing their methodology and some require laboratory analyses. They are mainly used for scientific research rather than for permanent monitoring and are also used for cross-checking and analyzing the consistency of monitoring data obtained with other types of analyzers. Porto Alegre uses bioindicators in addition to its automatic network.

fact that they cannot be used for certain pollutants; in general they only offer weekly and monthly values and require the existence of a laboratory for analyses.

- *Active samplers (semiautomatic)* or active monitoring systems are based on the passage of air with the help of a suction pump using a specific chemical substance or a physical collecting method. These systems allow hourly and daily values of pollutants to be obtained. They are more expensive than passive samplers but still are relatively low-cost, easy to operate, and reliable. One of the disadvantages is that they require intensive work and laboratory analysis.
- *Automatic analyzers* utilize a certain physical or chemical characteristic of the pollutant which can be continuously detected and quantified, generally by optical-electronic methods. Despite their precision and the frequency of data availability (hourly or even fractions of hourly periods), they are very complex and expensive and require trained personnel to operate them. They also have high periodic operation costs.
- *Remote sensors* can provide integrated monitoring of various components in a specified area (normally larger than 100 mt) compared to automatic analyzers which only provide data for a certain pollutant in a specific point. They are generally used for vertical measurement of gas pollutants, such as the distribution of ozone in the troposphere. The disadvantages are that these systems are very costly and complex, they are difficult to operate and calibrate, and the data are not always comparable to those generated by conventional analyzers.

Automatic analyzers are not necessarily superior to active and passive samplers, so it is common to use them in parallel; it is a good way to obtain complementary information in order to reduce errors. Automatic analyzers could generate erroneous data if used in places that do not comply with US EPA recommendations. Sources of interference could be the presence of electrical or fuel generators, parking places, or fuel and chemical deposits. Furthermore, technical failure may occur for various reasons. In this case, they require a great deal of costly maintenance and the know-how of trained personnel.

The most common analytical methods used for gaseous pollutants include spectrophotometry,[103] chemiluminescence,[104] and gas chromatography,[105] and for particulate matter, gravimetry.[106] The US EPA designates a list of federal reference methods (FRM) and federal equivalent methods (FEM) to sample and analyze air pollutants in the air that are updated as needed. Both methods can be manual or automatic. Manual methods are techniques that must be used when sampling and analyzing pollutants. Automatic techniques are instruments approved by the US EPA that must meet certain technical requirements for accurate data collection.[107] [108]

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[103] Spectrophotometry is used to determine the amount of sulfur dioxide and ozone by measuring the amount of light absorbed by a given sample. This indicates the amount of pollutant present in the sample.

[104] Chemiluminescence is used for measuring nitrogen dioxide and ozone. It is based upon the generation of electromagnetic radiation as light by the release of energy from a chemical reaction.

[105] Gas chromatography is used for volatile organic compounds.

[106] The measurement of particulate matter (TSP, PM_{10}, and $PM_{2.5}$) is usually carried out with manual measurement methods using gravimetric principles whereby particles are trapped or collected on filters which are then weighed to determine the volume of the pollutant.

[107] According to the US EPA, the methods specify precise procedures that must be followed for any monitoring activity related to the compliance provisions of the Clean Air Act. These procedures regulate sampling, analysis, calibration of instruments, and calculation of emissions. The specific method chosen for an analysis depends on a number of factors, the most important being the chemical characteristics and status of the pollutant. All the reference methods are designed to determine the actual concentration of a pollutant in a sample. The concentration is expressed in terms of mass per unit of volume, usually micrograms per cubic meter ($\mu g/m^3$). For a list of designated reference and equivalent methods as well as the conditions under which these methods can be used, see “List of Designated and Equivalent Methods, October 2004,” available online at http://www.epa.gov/ttn/amtic/criteria.html.

[108] Accepted methods for monitoring ambient concentration of pollutants are usually defined by law in the corresponding air quality management legislation. Most countries use the methods adopted by the US EPA.

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LATIN AMERICA AND THE CARIBBEAN
AIR QUALITY MAP

AIR QUALITY CLASSIFICATION

Existence of Air Quality Monitoring Capability		Availability of Data	Which Pollutants Exceeded The Value of The Applicable Standards[2,3]	Category
Existence of a network (of at least two stations) that provided data on a regular basis	AND	Data for at least two years	At least PM_{10}[1] and O_3 and $PM_{2.5}$	1
			At least $PM_{2.5}$ AND [PM_{10}[1] or O_3]	2
			At least PM_{10}[1] and O_3	3
			At least $PM_{2.5}$ or PM_{10}[1] or O_3	4
			NO_2 and/or CO and/or SO_2	5
			None	6
Existence of only one station, or Existence of a network not providing data on a regular basis (due to technical and/or financial difficulties), or Only temporal studies	OR	Data for less than two years	At least $PM_{2.5}$ and/or PM_{10}[1]	7
			At least O_3	8
			NO_2 and/or CO and/or SO_2	9
			None	10
No information or insufficient information				11
No monitoring[4]				12

1. TSP was considered only when (a) there were no data for PM_{10} or $PM_{2.5}$, either due to lack of monitoring or unavailability of data, and (b) the maximum registered concentrations exceeded the value of the relevant TSP standard (see note 2).
2. Applicable standards refer to those used for comparing ambient air quality data. Where local or national standards are available, and are at least as strict as international benchmarks, the local standard has been used. Otherwise, the international benchmarks (US NAAQS or WHO guidelines, in that order) have been used.
3. For each pollutant, the maximum registered value in any given station is compared with the value of the applicable standard and not the standard itself, because the standard usually specifies not just the value but all other conditions under which it is considered a violation (e.g., when the 98th percentile exceeds the standard, when the average of the three last years exceeds the standard, etc.).
4. Refers to absence of permanent or temporal monitoring, and where no data could be obtained from previous monitoring, if it ever existed.

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