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A Closer Look at Our Neighbors to the South: Air Quality Trends, Standards, and Monitoring Programs of Latin American Countries

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ABSTRACT

Air monitoring data from over 50 countries throughout the world are collected and analyzed as part of the Global Environment Monitoring System for Air (GEMS/Air). The GEMS/Air program is sponsored by the United Nations Environment Program (UNEP) and the World Health Organization (WHO). Several countries in Latin America participate in the GEMS/Air program. As part of a technical systems agreement between the United States Environmental Protection Agency and the UNEP/WHO, collaborative reviews of eighteen Latin American cities were conducted over the past two years. The countries visited include Argentina, Brazil, Chile, Ecuador, and Venezuela. The findings of these reviews and the future direction of air pollution monitoring programs in these countries will be presented.

INTRODUCTION

Urban air pollution is a threat to human health and the environment. To develop control strategies and methods that will mitigate the damages associated with urban air pollution, it is necessary to determine the sources of pollutants, and their levels and distribution in an area. To meet these and other objectives, the World Health Organization (WHO) and the United Nations Environment Program (UNEP) developed, in 1975, the Global Environment Monitoring System for Air (GEMS/Air). Since its inception, the GEMS/Air program has achieved the following:[1]

1) establishment of a global network of over 270 monitoring sites in over 50 countries;
2) support of monitoring and assessment operations through training, expert advice, and logistic support;
3) support of quality assurance procedures through auditing of city monitoring networks;
4) development and publication of methodology handbooks;
5) publication of global assessments of monitoring data;
6) establishment of Regional Support Centers throughout the world; and
7) development and maintenance of a global data base housed at the United States Environmental Protection Agency (USEPA) Office of Air Quality Planning and Standards in Research Triangle Park, NC.

The USEPA is closely aligned with the GEMS/Air program and provides technical support in a number of areas. In 1993, the USEPA entered into an interagency agreement with the WHO and UNEP to continue this support. Under this agreement, the USEPA's National Exposure Research Laboratory (NERL) agreed to do the following:

1) assess the current status of the air monitoring stations in Latin America that are part of the GEMS/Air program;
2) identify the existing and anticipated needs (equipment, facilities, training, etc.) of the organizations operating these stations; and
3) establish a long-term technical cooperative effort with these organizations to address the needs identified.

EXPERIMENTAL METHOD

The USEPA/NERL effort in Latin America involved a two-member scientific team with technical expertise, as well as language and cultural knowledge. This team visited selected organizations in various countries operating GEMS/Air stations. During these visits the USEPA team determined the availability of equipment, facilities, and trained staff to operate the GEMS/Air stations; any short- and long-term needs of the organization; the extent of their quality assurance programs; and the future direction of their air monitoring programs. Upon completing the review, the USEPA team submitted findings and recommendations to the WHO.

To better accomplish the goals of the project, the USEPA team used a different approach than was used by other GEMS/Air audit teams in other parts of the world. First, the USEPA team adopted the phrase "collaborative reviews" -- instead ~~of using the word~~ "audit" -- to denote a cooperative, rather than a policing, effort. This approach promoted a free exchange of information and a high degree of cooperation. Secondly, the USEPA team used the data collection requirements followed by the ~~US~~ State and Local Monitoring Stations (SLAMS) only as guidance, not as strict assessment criteria. The emphasis was on blending sound science and quality assurance with the economic, political, and social conditions of the area, not to enforce USEPA methods, *per se*. Thirdly, the USEPA team considered the broad situation of the region: geographical location; possible language and cultural barriers; available resources, infrastructure, and technical staff; access to spare parts and repair facilities; access to associations with other countries, universities, scientists, and donor funds; political support for environmental programs; and current and potential sources of pollutants. And lastly, the USEPA team continued their involvement with each participating agency once the reviews were completed. The USEPA team assisted each country in implementing the agreed-upon strategies for improving their air monitoring networks.

As shown in Table 1, the USEPA team first visited Latin America in 1994 and then again in 1996.[2,3] The collaborative reviews conducted during this two-year period were arranged through the Pan American Health Organization (PAHO) -- the Latin American branch of the WHO. The PAHO Country Engineers served as the official hosts for the USEPA team.

RESULTS and DISCUSSION

Primary Sources of Pollution

Without exception, each of the cities visited attribute their air pollution problems to two primary sources: mobile and industrial. Major cities such as São Paulo, Rio de Janeiro, Buenos Aires, Santiago, Caracas, and Quito have high levels of vehicular traffic. For instance, Avenida Brasil in Rio de Janeiro is travelled by more than 206,000 vehicles per day. In areas where leaded gasoline is still used, vehicular traffic contributes to blood-lead levels. In Quito, a 1991 study reported levels of 28.8 μg/dl and 28.2 μg/dl, for school-age children and road-side vendors, respectively.[4] These values are almost three times above the acceptable limit.[4] Other cities, such as Cubatão (located 28 miles from São Paulo), San Lorenzo, Rio Tercero, Mendoza, Maracaibo, and Puerto Ordaz, have large industrial areas. Some of the industries located in these cities are: petrochemical plants; coal refineries; steel manufacturers; toxic-waste incinerators; and cement, glass, wood, and fertilizer companies. Both vehicular and industrial sources contribute to the levels of particulate matter, volatile organics, and gaseous pollutants. Coupled with these pollutant sources, many of the areas have topographical features and climatic conditions that prevent adequate pollutant dispersion. For example, São Paulo, Santiago, Quito, and Mendoza are affected by mountainous terrain and stable inversion layers. In addition to these factors, some areas do not have adequate zoning laws that separate industrial areas from residential areas. Rio Tercero and Maracaibo are prime examples of this situation.

Environmental Programs

The primary organizations that coordinate, manage, and operate air monitoring programs in Latin American countries are under the federal, state, or local government, or are closely affiliated with them. The federal agencies often have satellite offices or state and local agencies that assist them with the air monitoring in a specific location. Table 2 shows the primary organizations which participated in the collaborative reviews and their designations. Some of the issues facing these organizations are limited technical staff, training, and resources. Within these organizations it was common to find a small group of scientists that were responsible for a wide variety of activities, such as overall coordination of the program; maintenance and calibration of equipment; air sampling, collection, and analysis; data collection and management; and report dissemination.

Air Quality Standards

Each of the countries visited have federal legislation that establishes national air quality standards to protect human health. In most cases, the individual states and municipalities follow the federal standards and guidelines, as well as their own environmental regulations. Table 3 shows the primary air quality standards for each country as established by federal law. It may be worth noting that while Argentina has a federal law for air quality (Ley N° 20.284, 4/16/73), it has not yet been sanctioned. For Venezuela, the table gives a range of values corresponding to an upper and lower limit. In this system a percentage is assigned to each limit. For example, in the case of total suspended particles (TSP), only 50% of the samples collected can exceed 75 $\mu g/m^3$, only 5% can exceed 150 $\mu g/m^3$, only 2% can exceed 200 $\mu g/m^3$, and only 0.5% can exceed 260 $\mu g/m^3$. Their complete set of standards is given in Reference 12. The air quality standards of the USEPA and the air quality guidelines of the WHO are also given for comparison purposes.[5-12] In some cases, where a country does not have a standard for a particular pollutant, a city may adopt a value as a "working standard." For example, Santiago, Chile uses the USEPA standard for inhalable particles (PM-10), while Quito, Ecuador uses a local standard of 58.8 $\mu g/m^3$ for smoke.

Air Monitoring Networks

All of the countries visited are currently operating manual air monitoring networks. These networks may include High-Volume Samplers, sulfur dioxide and/or nitrogen dioxide impingers, smoke shade filter samplers, and sedimented dust pails. São Paulo, Rio de Janeiro, and Santiago also have automated monitoring networks, which include continuous monitors for gaseous pollutants and meteorological parameters.[2,3,6,13] Table 4 shows the number of stations managed by each agency for the primary pollutants measured. Where this information is known, a superscript is placed next to each number to denote the sampling method(s) used. The stations included in this table are those that routinely operate and report data. Those stations not yet included in the GEMS/Air program are in the process of being added to the global data base.

Quality Assurance Programs

The quality assurance programs followed by the air monitoring organizations include routine calibration checks; maintenance and repair of equipment; and verification and validation of their data. They also have standard operating procedures for routine activities. A recurring deficiency in all of the countries was insufficient transfer standards for use in calibrating or auditing their equipment and laboratory instruments. Most of the countries do not have a reference lab from which they can obtain transfer standards that are traceable to a primary standard. Some of the countries do not have certified gas suppliers or a way to check the accuracy of what is provided.

Air Quality Data/Trends

Figures 1, 3, 5, 7, and 8 show actual air monitoring data for TSP, PM-10, smoke, sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). For each data set, the city is listed first with the name of the station below it. Also noted in these figures are the Air Quality Standards (AQS) as given in

Table 3. The stations were chosen based on the highest concentration levels in that city. For example, of all the stations in Rio de Janeiro, the station Bonsucesso, reported in Figure 1, consistently showed the highest values of TSP over the 11-year period. If the figure does not report data for a particular year, it is because the data were unavailable or because the station was inactive during that year. For example, Guayaquil did not measure TSP until 1994. Therefore, only two values are given in Figure 1.

Figures 2, 4, and 6 show the percent of stations in a given city that exceeded the AQS in a given year. For example, in 1985, nearly 70% of the air monitoring stations in Rio de Janeiro exceeded the AQS of 80 $\mu g/m^3$. The number of stations reporting data for a given year in a given city varied. For TSP (Figure 2), Rio de Janeiro had 3-16 stations reporting data during the given time period; Cubatão had 2 stations; São Paulo had 8-9 stations; Santiago had 6-9 stations; and Guayaquil had 1 station. For PM-10 (Figure 4), Cubatão had 2-3 stations; São Paulo had 14-21 stations; and Santiago had 4-5 stations. For smoke (Figure 6), Mendoza had 2-5 stations; São Paulo had 7 stations; Santiago had 1-2 stations; and Quito had 2-3 stations.

Each station that reported levels of particulate matter (Figures 1, 3, and 5) exceeded the designated AQS for every year except for 1988, when station Cerqueira César was below the AQS for PM-10. Some stations showed a declining trend, but still exceeded the AQS. In other parts of the same city, levels were also consistently high for TSP, PM-10, and smoke, except for some years when less than 50% of the stations in Rio de Janeiro, Cubatão, and São Paulo were above the AQS.

On the other hand, the stations reporting SO_2 and NO_2 (Figures 7 and 8) are consistently below the AQS. The two exceptions occur in 1990 for SO_2 and in 1986 for NO_2, when stations Tatuapé and #6 exceeded the AQS, respectively. The other stations reporting SO_2 and NO_2 throughout the same cities during these same years had equal or lower values than the ones shown.

CONCLUSIONS

Mitigating the environmental and health hazards of air-born pollutants is important to the WHO. Therefore, the WHO, with the support of the UNEP, established the GEMS/Air program. Through this program and its Regional Support Centers, like the USEPA, the over 50 participating countries have received technical support and access to the GEMS/Air global data base. Various Latin American countries have also participated in collaborative reviews. These collaborative reviews, conducted by a scientific team from USEPA/NERL, were designed to assess the current air monitoring programs in each country and to recommend and implement improvements.

Based on the collaborative reviews conducted in 1994 and 1996, the USEPA/NERL team recommended that the WHO: provide technical assistance in specific areas; simplify the data reporting system of GEMS/Air; and continue regular contact with each participating city. The USEPA/NERL team has since provided technical assistance to all of the cities in the following areas: siting criteria; dispersion modeling; air pollution data bases, monitoring systems, and measurement methods; passive sampling; quality assurance/quality control programs; and audit devices.

Since the collaborative reviews, many of the cities have reported continued growth and improvements in their air monitoring programs. São Paulo (CETESB) recently remodeled their automated network through funding by the World Bank. Rio de Janeiro (FEEMA) is improving their data management and computer systems and will perhaps join with the city government to increase their monitoring efforts. Buenos Aires (MSyAS) was planning an air quality assessment campaign through the local university and private companies. Venezuela (MARNR) was being evaluated by a private company to assess the potential for expanding their network. The City of Quito was planning another eight stations based on funding from the Inter-American Development Bank.

Air monitoring and control strategies continue to improve in Latin America. The GEMS/Air program has assisted in this growth. The WHO hopes to continue this program and to focus on the other countries throughout Central and South America that are now in the beginning stages of air pollution monitoring and control.

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Table 1. Itinerary of the Collaborative Reviews.

Date	Country	Cities
Feb. 1-4, 1994	BRAZIL	São Paulo
Feb. 5-8, 1994	CHILE	Santiago
Feb. 9-12, 1994	ECUADOR	Quito
April 8-12, 1996	BRAZIL	São Paulo, Rio de Janeiro
April 13-20, 1996	ARGENTINA	Buenos Aires, Santa Fé, Rosario, San Lorenzo, Córdoba, Rio Tercero, Mendoza
June 3-9, 1996	VENEZUELA	Caracas, Maracaibo, Valencia, Puerto Ordaz
June 10-15, 1996	ECUADOR	Quito, Cuenca, Guayaquil, Ambato

Table 2. Primary Organizations that Participated in the Collaborative Reviews.

Agency/Organization	Location of Main Office	Designation
Ministerio de Salud y Acción Social (MSyAS)	Buenos Aires, ARGENTINA	Federal
Municipalidad de Córdoba, Subsecretaría del Ambiente	Córdoba, ARGENTINA	Local
Companhia de Tecnologia de Saneamento Ambiental (CETESB)	São Paulo, BRAZIL	State
Fundação Estadual de Engenharia do Meio Ambiente (FEEMA)	Rio de Janeiro, BRAZIL	Technical Advisors to State government
Servicio de Salud del Ambiente de la Región Metropolitana (SESMA)	Santiago, CHILE	Federal
Ministerio de Desarrollo Urbano y Vivienda (MIDUVI)	Quito, ECUADOR	Federal
Distrito Metropolitano de Quito, Dirección de Medio Ambiente	Quito, ECUADOR	Local
Ministerio del Ambiente y los Recursos Naturales Renovables (MARNR)	Caracas, VENEZUELA	Federal
Instituto Para el Control y la Conservacion de la Cuenca del Lago de Maracaibo (ICLAM)	Maracaibo, VENEZUELA	State (once affiliated with MARNR)

Table 3. National Air Quality Standards for Argentina, Brazil, Chile, Ecuador, and Venezuela.

Pollutant	Sampling Period	Primary Standard $\mu g/m^3$ (ppm)							Measurement Methods
		USEPA	WHO	AR	BR	CH	EC	VE	
TSP	24-hour average*	260	150-230	----------	240	260	250	75-260	High-Volume Sampler/ Gravimetric
	30-day average	----------	----------	150	----------	----------	----------	----------	
	AGM**	75	60-90***	----------	80	75	80	----------	
PM-10	24-hour average	150	----------	----------	150	----------	----------	----------	Weight Separation/ Filtration
	AAM***	50	----------	----------	50	----------	----------	----------	
Smoke	24-hour average	----------	100-150	----------	150	----------	----------	----------	Reflectance
	AAM	----------	40-60	----------	60	----------	----------	----------	
SP	30-day sample	----------	----------	1 mg/cm^2	----------	----------	1 mg/cm^2	----------	Gravimetric
SO_2	10-min average	----------	500 (0.19)	*	----------	----------	----------	----------	Pararosaniline Fluorescence
	3-hour average	----------	----------		----------	----------	1500 (0.57)	----------	
	24-hour average	365 (0.14)	125 (0.047)		365 (0.14)	365 (0.14)	400 (0.15)	80-365	
	AAM	80 (0.031)	50 (0.019)		80 (0.031)	80 (0.031)	80 (0.031)	----------	
CO	1-hour average	40,000 (35)	30,000 (26)	*	40,000 (35)	40,000 (35)	40,000 (35)	----------	Nondispersive infrared
	8-hour average	10,000 (9)	10,000 (9)		10,000 (9)	10,000 (9)	10,000 (9)	10,000-40,000	
O_3	1-hour average	235 (0.12)	----------	*	160 (0.082)	160 (0.082)	200 (0.10)	240 (0.12)	Chemiluminescence
	8-hour average	----------	120 (0.061)		----------	----------	----------	----------	
NO_2	1-hour average	----------	200 (0.11)	*	320 (0.17)	----------	----------	----------	Sodium Arsenite Chemiluminescence
	AAM	100 (0.053)	40 (0.021)		100 (0.053)	100 (0.053)	100 (0.053)	100-300 (0.16)	
Pb	24-hour average	----------	----------	----------	----------	----------	----------	1.5-2.0	Atomic Absorption
	3-month average	1.5	----------	----------	----------	----------	1.5	----------	
	AAM	----------	0.5	----------	----------	----------	----------	----------	

* Short-term standards (24 hours and less) are not to be exceeded more than once per year. Long-term standards are maximum permissable concentrations that are never to be exceeded.

** Annual Geometric Mean

*** Annual Arithmetric Mean

TSP=Total Suspended Particles; PM-10=Inhalable Particles; SP=Sedimented Particles; SO_2=Sulfur Dioxide; CO=Carbon Monoxide; O_3=Ozone; NO_2=Nitrogen Dioxide; Pb=Lead

Table 4. Monitoring Stations in Argentina, Brazil, Chile, Ecuador, and Venezuela.

Agency/Cities	# of Stations Measuring each Parameter and Methods Used								
	TSP	PM_{10}	Sm	SP	SO_2	CO	O_3	NO_2	Met
MSyAS:									
Buenos Aires	-	-	-	-	-	-	-	-	-
Mendoza	-	-	13^{R}	-	13^{P}	-	-	9^{Gs}	1
Rosario	-	-	-	4^{G}	4^{P}	4^{E}	-	4^{S}	-
Santa Fé	-	-	2^{R}	-	-	-	-	-	-
San Lorenzo	-	-	-	-	4^{P}	-	-	-	-
Municipalidad de Córdoba:*									
Córdoba	2^{H}	2^{H}	-	-	2^{F}	2^{N}	2^{Ch}	2^{Ch}	2
Rio Tercero	-	-	-	-	-	-	-	-	-
CETESB:									
São Paulo	9^{H}	23^{B}	7^{R}	-	$7^{A}/24^{CF}$	7^{N}	6^{Ch}	6^{Ch}	15
Cubatão	2^{H}	3^{B}	-	-	3^{CF}	-	2^{Ch}	-	1
Other Cities	-	-	18^{R}	-	18^{A}	-	-	-	-
FEEMA:**									
Rio de Janeiro	16^{H}	-	-	-	$1^{A}/2^{F}$	2	2	$1^{S}/2$	2
Other Cities	5^{H}	-	-	-	1^{A}	-	-	1^{S}	-
SESMA:									
Santiago	7^{H}	5^{BDT}	1^{R}	5^{G}	$6^{P}/5^{F}$	5^{N}	5^{ChU}	$6^{S}/5^{Ch}$	6
MIDUVI:									
Ambato	-	-	1^{R}	1^{G}	1^{A}	-	-	-	-
Cuenca	-	-	1^{R}	1^{G}	1^{A}	-	-	-	-
Guayaquil	1^{H}	-	-	1^{G}	-	-	-	-	-
Quito	2^{H}	1^{H}	2^{R}	3^{G}	2^{A}	-	-	-	-
MARNR:									
Caracas	4^{H}	-	-	-	4^{I}	-	-	4^{S}	-
Puerto Ordaz	1^{H}	-	-	-	-	-	-	-	-
Valencia	2^{H}	-	-	-	-	-	-	-	-
Other Cities	5^{H}	-	-	-	-	-	-	-	-
ICLAM:									
Maracaibo	6^{H}	-	-	-	6^{H}	-	-	6^{H}	-

* The two stations owned and operated by Córdoba are state-of-the-art mobile stations.
** The manual stations for SO_2 and NO_2 reported data only for a special study in 1994.

Parameters:
TSP=Total Suspended Particles; PM_{10}=Inhalable Particles; Sm=Smoke; SP=Sedimented Particles; SO_2=Sulfur Dioxide; CO=Carbon Monoxide; O_3=Ozone; NO_2=Nitrogen Dioxide; Met=Meteorological Parameters

Methods:
A=Acidimetric Method; B=Beta gauge; C=Coulometric; Ch=Chemiluminescence; D=Dichotomous Sampler; E=Electrochemical cell; F=Fluorescence; G=Gravimetric; Gs=Griess-Saltzman Method; H=High-Volume Sampler; I=Ion chromatography; N=Nondispersive infrared; P=Pararosaniline Method; R=Reflectance; S=Sodium Arsenite; T=TEOM; U=Ultraviolet

FIGURE 1

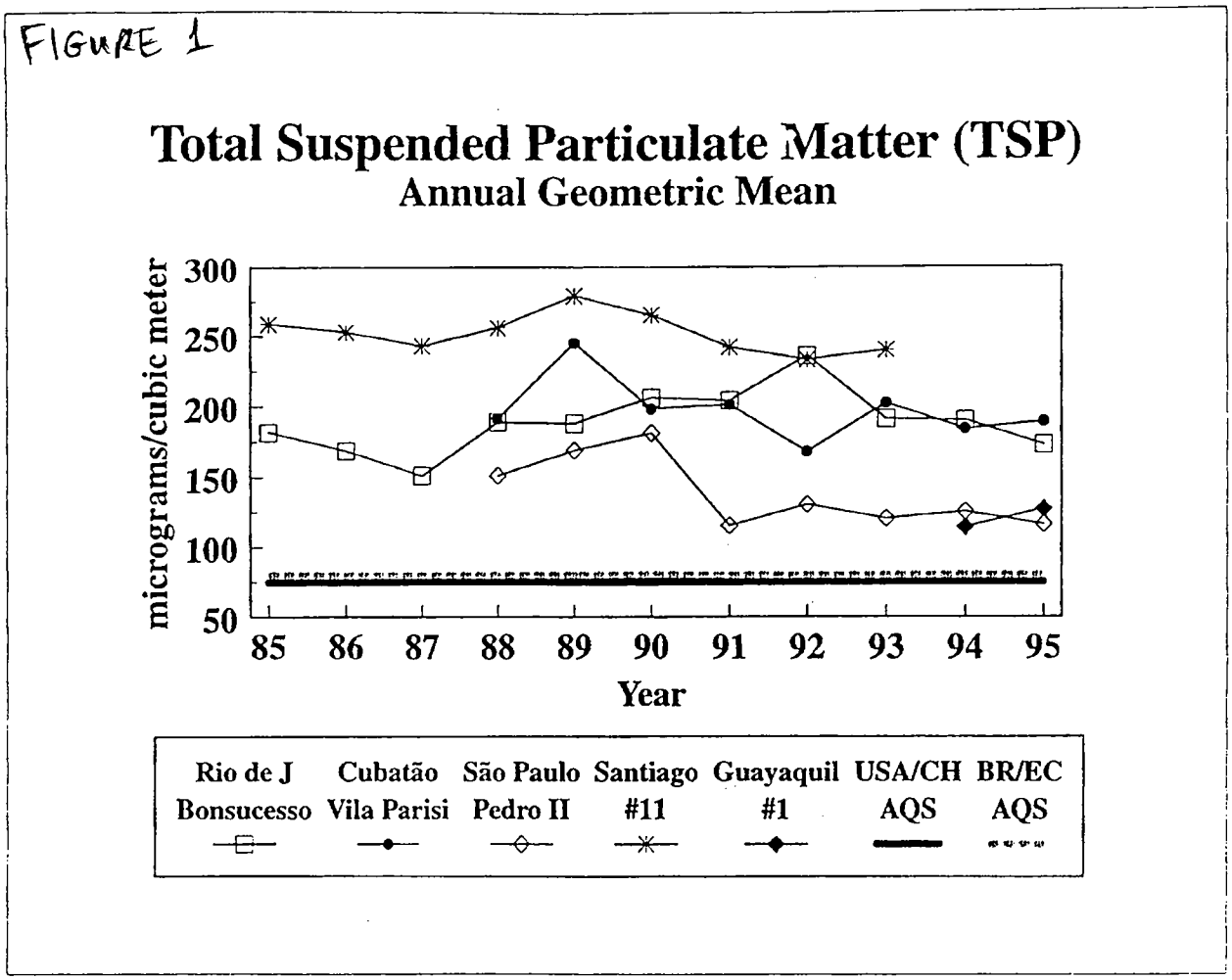


FIGURE 2

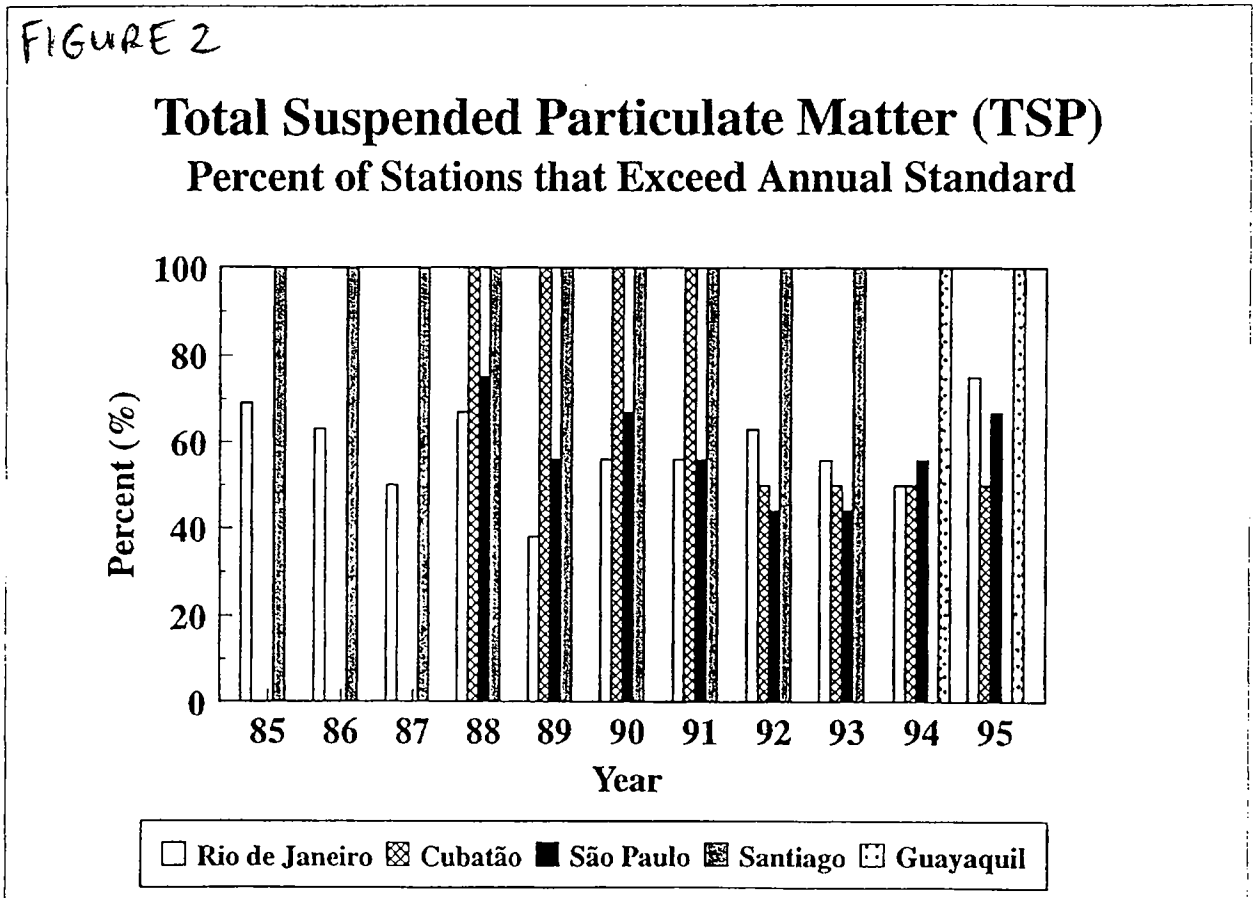


FIGURE 3

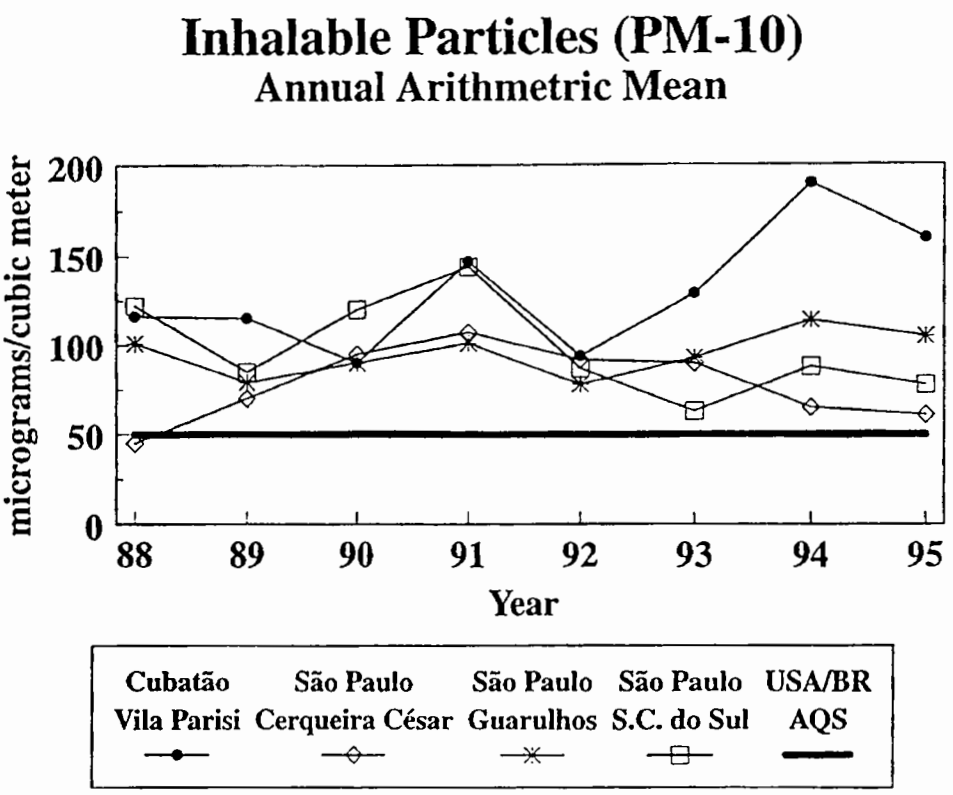
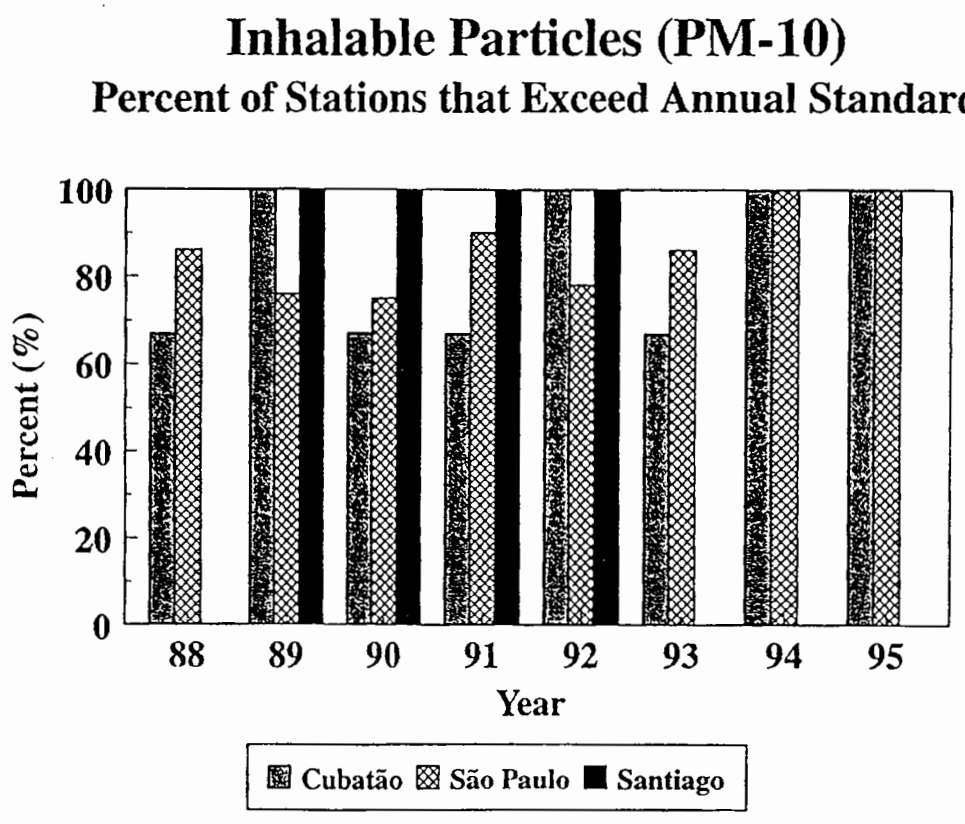


FIGURE 4



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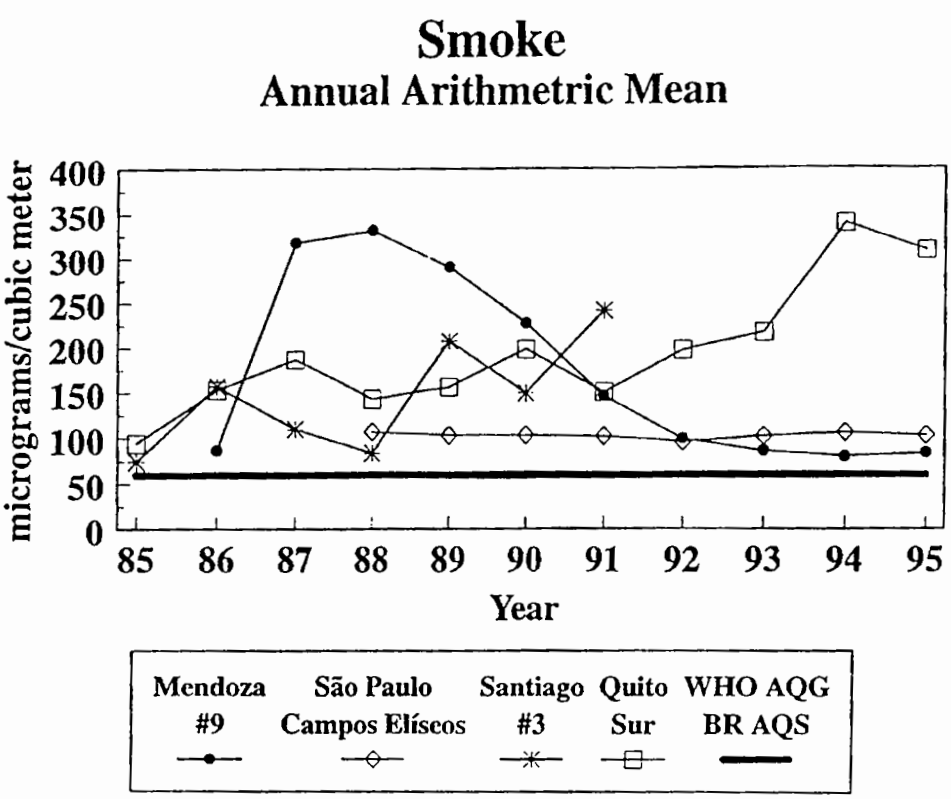

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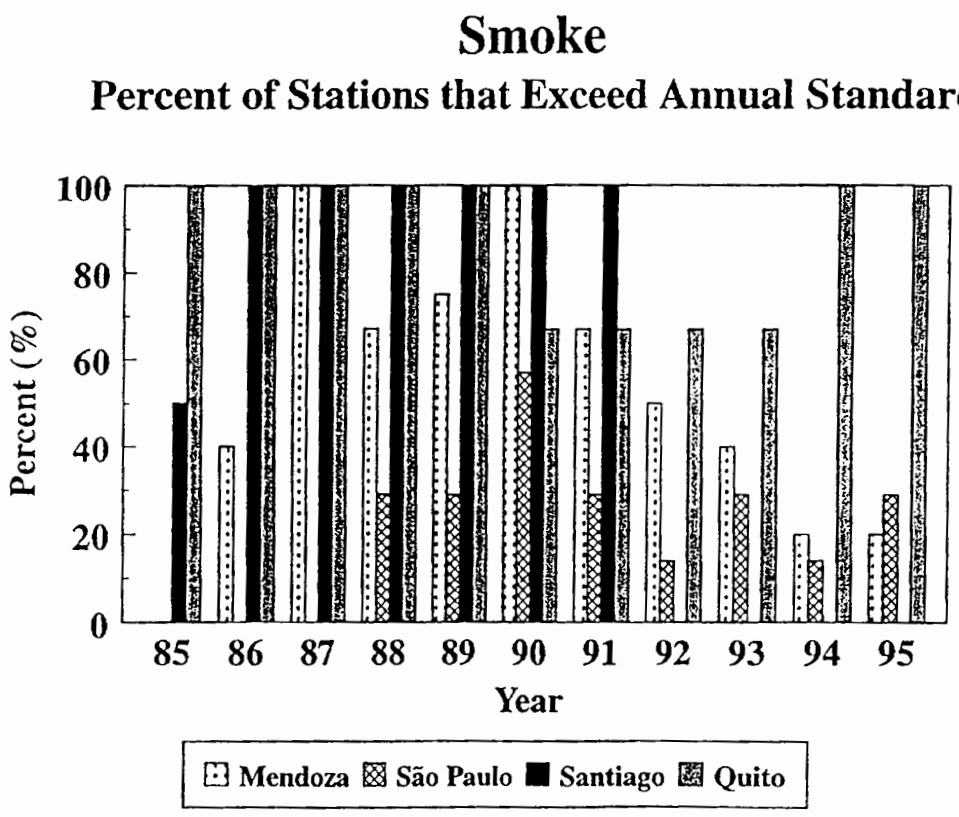
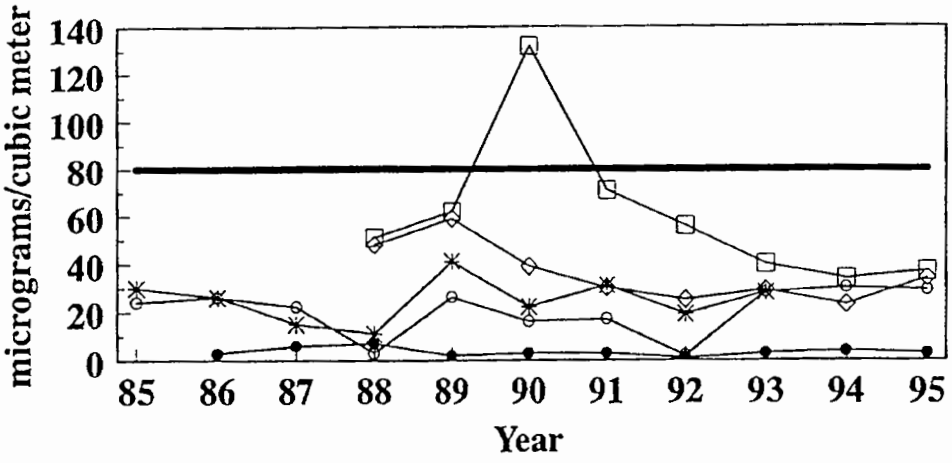


FIGURE 7

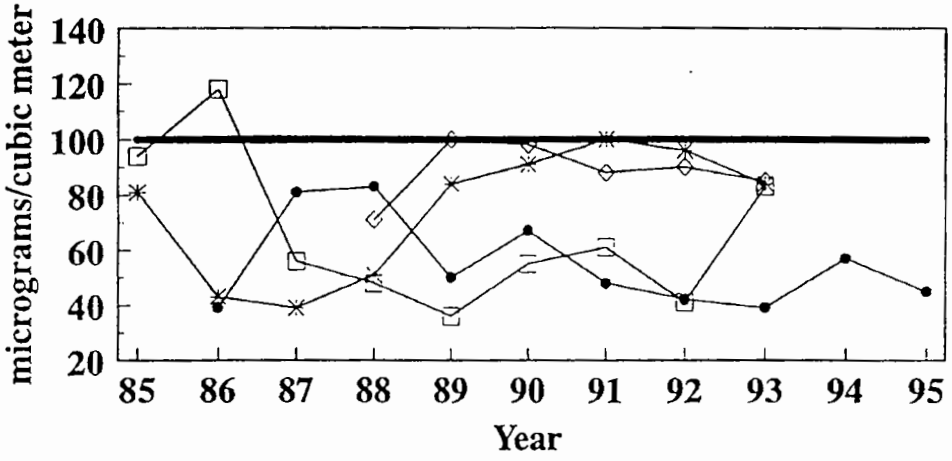
Sulfur Dioxide (SO_2)
Annual Arithmetic Mean



*Automated station

FIGURE 8

Nitrogen Dioxide (NO_2)
Annual Arithmetic Mean



* Automated station - the '92 and '93 data were reported as non-representative.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

The Global Environment Monitoring System (GEMS/Air) is a program in which air monitoring data from over 50 countries throughout the world are collected and analyzed. The GEMS/Air program is sponsored by the United Nations Environment Program (UNEP) and the World Health Organization (WHO). Several countries in Latin America participate in the GEMS/Air program. As part of a technical systems agreement between the United States Environmental Protection Agency and the UNEP/WHO, collaborative reviews of eighteen Latin American cities were conducted over the past two years. The countries visited include Argentina, Brazil, Chile, Ecuador, and Venezuela. The findings of these reviews and the future direction of air pollution monitoring programs in these countries will be presented.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/ OPEN ENDED TERMS	c. COSATI
Quality Assurance, Latin America, World Health Organization, Global Environment Monitoring System, GEMS/Air, Air Pollution Monitoring Programs		

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