Air Pollution Problems in Latin America[1]

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Air pollution and associated health problems in Latin America are on the rise. This article provides an overview of conditions indicated by the admittedly limited data available, notes some of the present situation's health implications, and points out areas where air pollution data procurement and control measures could be improved.

Air quality in many cities, especially in the rapidly growing capitals of developing countries, has deteriorated to such an extent that it is having a significant respiratory impact upon susceptible individuals. The World Health Organization (WHO) estimates that over 600 million people are now being exposed to sulfur dioxide concentrations far in excess of what could be considered inoffensive, and that over a billion people are being exposed to suspended particle concentrations exceeding WHO-recommended limits.

In recent times we have become increasingly aware of hazards posed by indoor air pollution—such as the pollution caused by burning wood or coal to heat or cook in poorly ventilated spaces, a practice common to rural areas of many developing countries that regularly exposes women and children to high levels of air pollution. Beyond that, of course, we know that in the world's urban areas population growth combined with significant increases in industrialization, energy production, interior heating, and motor vehicle traffic have substantially boosted levels of air pollution. Furthermore, winds can carry pollution great distances, far from its points of origin, and phenomena such as acid rain show that air quality is frequently not what it used to be. Today, keeping the air healthy means facing the costs of implementing antipollution measures. Clean air, as it once was, is no longer free (*1*).

In Latin America, as elsewhere, urban population growth has made a major contribution to increases in the concentrations of urban atmospheric pollutants. As of 1950, some 15 million people lived in Latin American cities of over one million inhabitants. By 1980 this figure had risen to about 101 million, and by the year 2000 it is expected to reach 232 million. Of course, the amount of pollution released into the air depends not only on the number of people but also their degree of concentration, the concentration of industrial emitters of pollutants, energy consumption patterns, the number of motor vehicles in use, and the particular roles played by various specific sources of pollution. In this regard, going beyond simple population growth and urbanization, patterns of increased energy consumption and motor vehicle use tend to serve as good indicators of rising air pollution levels.

Two other pollution indicators, one partly and the other mainly related to

[1]Condensed version of an article by the same author published in Spanish in the *Boletín de la Oficina Sanitaria Panamericana*, Vol. 112, No. 2, pp. 97–109.

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motor vehicle use, are levels of carbon dioxide (CO_2) emission and levels of airborne lead particles produced by burning gasoline. According to information published by the World Resources Institute, in 1950 Latin America was responsible for an estimated 1% of the CO_2 emitted as a result of human activity; by 1965 this figure had reached 3%, and by 1985 it had risen to 6%. Regarding the hazard of airborne lead particles, it is worth noting that the gasolines used in Latin America and the Caribbean have been found to possess the highest lead content in the world, this content ranging from 0.64 to 0.84 g/l in 1984, for example, as compared to 0.15 to 0.40 g/l in Europe that same year (2).

Some Latin American cities, including Mexico City and Santiago, confront serious problems posed by the phenomenon of thermal inversion (an increase in temperature with altitude), which suppresses the vertical mixture of pollutants and results in stratification and reduced dispersion. Thermal inversions commonly occur in winter in affected cities and account for the relatively high concentrations of pollutants often found during that season in those cities. Of course, this is only one key way in which air quality is more generally influenced by climate, acting through a variety of specific meteorologic factors including temperature, humidity, wind, precipitation, atmospheric pressure, and solar radiation, all of which can significantly affect the chemistry or concentration of pollutants.

Overall, it appears that while pollution levels in some Latin American cities are still within the limits established by WHO, many of these same cities will experience air pollution problems within a few years' time if present trends continue.

Table 1 provides information about growing levels of energy consumption and motor vehicle numbers in seven of the larger Latin American countries as well as data on rates of increasing urbanization in selected metropolitan areas. The energy consumption data show varying but generally substantial national increases in energy consumption during the 1974–1986 period, while the motor vehicle data show that the numbers of vehicles in use rose even faster in each country over the shorter 1975–1984 period. The air pollution implications of these trends are compounded by urbanization

Table 1. Variations in certain factors influencing the emission and concentration of air pollutants in selected Latin American countries.

	Rates of growth (%) over indicated period in:		Average annual population increase in the indicated metropolitan areas, 1970–1980[c]	
Country	Energy consumption (1974–86)[a]	No. of vehicles (1975–84)[b]	Metropolitan area	% increase
Argentina	26	50	Buenos Aires	1.6
Brazil	50	85	São Paulo	4.4
Chile	16	107	Santiago	2.7
Colombia	47	132	Bogotá	3.0
Mexico	76	107	Mexico City	4.0
Peru	9	46	Lima	3.7
Venezuela	80	142	Caracas	1.9

[a]Calculated in carbon equivalent from all sources of commercial generation. Source: reference 3, pp. 566–97.
[b]Includes both passenger and commercial vehicles. Source: reference 3, pp. 714–16.
[c]Source: Reference 4.

trends such as those shown in the last column of the table, which indicate average annual population growth of 1.6% to 4.4% in the indicated metropolitan areas during the 1970–1980 period. Figures based on motor vehicle growth trends suggest that emissions could double in some cases by the end of this century, while urbanization data suggest that pollutant concentrations in certain cities could triple if observed growth trends persist and no corrective measures are taken to control pollution.

AIR QUALITY MONITORING

In recent decades Latin America has been increasing its participation in work on global air pollution problems, and there is now some information about air quality in several cities of the region.

One entity, the Pan American Air Pollution Sampling Network (REDPANAIRE), was established by the Pan American Center for Sanitary Engineering and Environmental Sciences (CEPIS) in 1967 and published its final report in 1982. This report (5), which provides a detailed review of REDPANAIRE's work, includes data from samples taken at over 100 stations set up throughout the Americas. These data indicate that during the network's operation some 70% of the dustfall particle samples, 20% of the suspended dust samples, and 28% of the sulfur dioxide (SO_2) samples exceeded reference levels, indicating excessive pollution.

Seven Latin American nations (among a total of 50 countries worldwide) have also participated in the Global Environmental Monitoring System (GEMS), established in 1975, by providing air quality data to that body (6). Published GEMS data show that as of 1980–1984 three cities (Rio de Janeiro, São Paulo, and Santiago) had annual average SO_2 levels above the maximum permissible concentration

Table 2. Air quality data (suspended particle levels) at specific sites in certain Latin American cities.

Country, city, and sampling site	Total suspended particles in $\mu g/m^3$: Annual average	24-hour maximum
[Maximum permissible concentration under WHO standards]	[60–90]	[100–150]
Brazil		
Cubatão (1988)		
Vila Nova	58	146
Vila Parisi	208	818
Rio de Janeiro (1984)		
São João de Meriti	123	488
Santa Teresa	45	106
Copacabana	66	108
Bonsucesso	151	268
São Paulo (1988)		
Cambuci	66	326
Santo André-Centro	186	536
Santo Amaro	140	1,068
S. Bernardo de Campo	158	1,160
Chile		
Santiago (1988)		
Ministry of Health	242	665
Providencia	195	1,142
Pudahuel	308	975
Colombia		
Bogotá (1986)		
Sena Artes	180	620
Andes	60	250
Costa Rica		
San José (1986)		
Metropolitan Police	91	333
Karen Olsen	49	127
Ministry of Health	80	191
Mexico		
Mexico City (1987)		
Xalostoc	490	1,209
Museum of Anthropology	250	1,494
Nezahualcoyotl	250	990
Federal Electric Company	150	355
Pedregal	143	550
Venezuela		
Caracas (1986)		
El Silencio	98	247
California	43	71
Maracaibo (1986)	100	244
Maracay (1986)	85	227
Valencia (1986)	80	168

Sources: References *7–14*.

established by WHO for this pollutant. Two cities (Rio de Janeiro and Caracas) had annual total suspended particle (TSP) averages above the WHO maximum, while another (Medellín) was at the WHO TSP maximum. One city (Santiago) had an annual average nitrogen dioxide (NO_2) level above the maximum established by WHO. And one city (São Paulo) had average eight-hour maximum carbon monoxide (CO) values above the WHO maximum.

Additional data on relevant air quality indicators in certain cities, provided through reports prepared by various state and national organizations (*7–14*), are shown in Tables 2 through 6. In some instances the comparability of the data from one city to the next is open to question, because the study methods used by the various entities involved were not necessarily the same. Obviously, in each case responsibility for the accuracy of the data lies with the organization supplying the information.

Although WHO and PAHO collect and publish this information (previously through REDPANAIRE and currently through GEMS), no international procedure exists to control the information's

Table 3. Air quality data (SO_2 levels) at specific sampling sites in certain Latin American cities.

Country, city, and sampling site	SO_2 in $\mu g/m^3$ Annual average	24-hour maximum
[Maximum permissible concentration under WHO standards]	[40–60]	[100–150]
Brazil		
Cubatão (1988)		
Vila Nova	11	79
Vila Parisi	14	90
Rio de Janeiro (1984)		
Bonsucesso	164	
Copacabana	91	
Maracana	105	
São Paulo (1988)		
Cambuci	47	204
Santo André-Centro	29	84
Santo Amaro	13	84
S. Bernardo de Campo	18	82
Chile		
Santiago (1988)		
Ministry of Health	38	143
Providencia	9	29
Pudahuel	16	68
Mexico		
Mexico City (1987)		
Xalostoc	129	369
Museum of Anthropology	77	225
Nezahualcoyotl	62	326
Federal Electric Company	69	122
Pedregal	126	252

Sources: References *7–9, 12*.

Table 4. Air quality data (NO_2 levels) at specific sampling sites in certain Latin American cities.

Country, city, and sampling site	NO_2 in $\mu g/m^3$ Annual average	24-hour maximum
[Maximum permissible concentration under WHO standards]	[100]	[150]
Brazil		
São Paulo (1988)		
Mooca	49	
Congonhas	105	
Cerqueira Cesar	62	
Chile		
Santiago (1988)		
Fire Department	88	284
La Granja	26	85
Mexico		
Mexico City (1987)		
Merced	226	620
Cerro Estrella	156	526
Pedregal	151	564
Venezuela		
Caracas (1985)		
El Silencio	56	125
Trinidad	22	100

Sources: References *7, 9, 12, 13*.

Table 5. Air quality data (O_3 levels) at specific sampling sites in certain Latin American cities.

Country, city, and sampling site	O_3 in ppm[a] (1 hr. max)
[Maximum permissible concentration under WHO standards]	[0.075–0.10]
Brazil	
Cubitão (1988)	
Vila Nova	0.17
Vila Parisi	0.14
São Paulo (1988)	
Mooca	0.16
Congonhas	0.10
Lapa	0.29
Mexico	
Mexico City (1987)	
Merced	0.36
Cerro Estrella	0.22
Pedregal	0.34
Xalostoc	0.14

Sources: References *7*, *12*.
[a]0.1 ppm O_3 = 200 μg/m³.

validity. Nevertheless, it is assumed that the responsible organizations take steps to ensure the quality of the data is as good as possible, since these data are used to provide a basis for control programs at the national level.

In each case, the data involved may be compared with the maximum permissible standards established by WHO, standards that are internationally accepted, as a means of determining the quality of air breathed by the inhabitants of these cities.

As indicated in Table 6, neither all the cities nor all the sampling stations involved measured all four pollutants being considered (TSP, SO_2, NO_2, and O_3), the most frequently measured being TSP and the least frequently measured being ozone (O_3). Even so, it is possible to make comparisons between the measurements reported and the WHO standards for each type of pollutant shown in Table 11. The results of this comparison, which can be seen in Table 6, indicate that the WHO standard for any one of the four pollutants was exceeded at a substantial share (between 40% and 89%) of the sampling stations.

Another way of looking at pollution levels is currently used in three Latin American cities (Mexico City, São Paulo, and Santiago) to provide the public with daily air quality information. This method

Table 6. Summary of air quality data from sampling sites in certain Latin American cities (see Tables 2–5).

Type of pollutant and measurement	No. of sampling stations	Stations recording levels above the maximum levels permissible under the WHO standards	
		No.	%
TSP			
Annual average	28	17	60
24-hour maximum	28	23	82
SO_2			
Annual average	17	8	47
24-hour maximum	14	5	36
NO_2			
Annual average	10	4	40
24-hour maximum	7	4	57
O_3			
1-hour maximum	9	8	89

uses an air quality index with values ranging from 0 to 500, where 100 indicates a normal (acceptable) pollution level. Pollution levels substantially above 100 may adversely affect health, providing grounds for announcing "alert," "warning," and "emergency" situations (at index values of 200, 300, and 400, respectively).

If one considers individual pollutants instead of overall pollution in this way and lists one-hour or 24-hour maximums instead of daily readings, presented according to a modified scheme proposed for the United States (*15*) and using recently published data, the results can be charted as shown in Table 7. This approach provides a way of rating the cities involved in terms of pollution levels during the most critical season for each of the pollutants shown in Tables 2 through 6.

AIR POLLUTION INVENTORY

To help orient air-quality control programs and assess the relative contributions of various sources of pollutants, it is appropriate to make an inventory of the pollution being emitted by emission source and type of pollutant. Such inventories, based mainly on the rapid assessment (emission source) technique (*17*), have been made in Latin America for many years. Studies of various major cities—Caracas, Mexico City, Panama City,

Table 7. The health effects of poor air quality and the air quality status indicated by the sampling stations with the highest values in 11 cities (see Tables 2–5).

Index value	Description of health threat	Air quality level	Level of pollutants ($\mu g/m^3$): TSP (24 hr)	SO_2 (24 hr)	O_3(1 hr)	NO_2 (24 hr)
	Very hazardous[a]		Mexico City São Paulo Santiago			
500		Significant harm	1,000	2,620	1,200	
	Hazardous					
400		Emergency	875	2,100	1,000	750
	Hazardous		Bogotá Cubataõ			Mexico City
300		Warning	625	1,600	800	565
	Very unhealthful		Rio de Janeiro		Mexico City São Paulo	Santiago
200		Alert	375	800	400[a]	282
	Unhealthful		San José	Mexico City Rio de Janeiro	Cubatõ	
100		Standard[b]	260	365	160	150[c]
	Moderate		Caracas Maracaibo Maracay Valencia	São Paulo Santiago Cubataõ		Caracas
50		50% of standard[b]	75[d]	80[d]	80	100[d]
	Good					
0			0	0	0	0

Source: Reference *15*.
[a]Health threat category and pollution level added by the author (HW).
[b]United States Environmental Protection Agency, National Ambient Air Quality Standards (NAAQS).
[c]EURO/WHO Value Guide.
[d]United States Environmental Protection Agency standard for annual average.

Rio de Janeiro, San José, Santiago, and São Paulo, among others—are now available in the form of presentations made to technical meetings or publications.

Most of these inventories group the emission sources into two basic categories—mobile sources and fixed sources. Mobile sources consist of motor vehicles. Most of the fixed sources are point sources, among them industrial sources grouped into categories of industries that are important polluters. There are very few instances in which a classification of "point sources" and "area sources" has been used.

The types of pollutants most commonly included in the inventories are CO, hydrocarbons (HC), nitrogen oxides (NO_x), SO_2, and TSP. In general, the main sources of each type are as follows:

Motor vehicles: CO, NO_x, and HC
Industrial sources: TSP and SO_2

Table 8 shows results of pollution emission inventories compiled in five major Latin American cities. Taking the total pollution emitted in metric tons, as listed in the table, and dividing by the estimated population of each city in the year in question, it is possible to estimate the pollution emitted per capita (in kg/capita/year) in each city. These results are as follows:

City	*kg/capita/year*
Mexico City	280
Caracas	180
São Paulo	130
Rio de Janeiro	120
Santiago	80

Although comparison of the above figures is interesting, no conclusions should be drawn from them without more detailed analysis. Neither should it be assumed that simply because CO is the largest single pollutant by weight it is necessarily the most important—since its relative effect on both health and the environment vis-à-vis other pollutants such as TSP and SO_2 must also be considered.

EFFECTS ON HEALTH

Studies carried out in other countries indicate that the most susceptible population groups are the elderly, children, and those suffering from chronic heart or

Table 8. Estimated totals of the indicated air pollutants emitted (metric tons per year) in five Latin American cities.

Type of pollutant[a]	São Paulo (1987)	Santiago (1988)	Mexico City (1987)	Rio de Janeiro (1983)	Caracas (1980)
TSP	91,500	46,830	420,241	121,426	30,123
SO_2	131,200	22,434	243,291	127,202	11,540
NO_x	226,300	12,822	179,324	52,000	29,461
HC	271,300	29,001	447,390	173,968	53,429
CO	1,391,000	227,242	3,626,427	638,350	542,115
Total	2,111,600	338,242	4,916,673	1,213,546	696,666

Sources: References *7*, *8*, *12*, and *15*.
[a]TSP = total suspended particles
SO_2 = sulfur dioxide
NO_x = nitrogen oxides
HC = hydrocarbons
CO = carbon monoxide

lung diseases. In general, pollution levels above the maximum permissible WHO standard cause irritation of the eyes, nose, and throat. When levels increase to between two and three times the maximum WHO standard, respiratory symptoms become more acute and tolerance of physical activity diminishes. At levels three to four times the maximum WHO standard, the beginnings of cardiorespiratory diseases may be observed.

Latin America currently lacks adequate information for any systematic and rigorous evaluation of health consequences suffered by populations exposed daily to air pollution. However, pollution levels prevailing in many of the region's cities make it reasonable to conclude that considerable numbers of people are experiencing pollution-related health problems, more are suffering some degree of irritation, and still more are experiencing discomfort in their daily lives.

While greater resources will be needed in order to collect relevant health data and better assess what is happening, it is possible to adopt certain working hypotheses and to extrapolate from studies performed in the United States and the United Kingdom on controlled population groups. Proceeding in this manner, we have estimated that some 75 million people in Latin America are exposed to TSP levels above the maximum WHO standard (*18*).

This figure, combined with data received from air quality monitoring stations in certain cities, suggests that some 2.8 million excess cases of chronic cough occur annually among Latin American children 0–14 years of age, that roughly 120,000 excess chronic bronchitis cases annually afflict people over 60 years of age within the region, and that excess respiratory ailments among adults between 15 and 59 years old cause the loss of something like 55 million days of productive activity per year (Table 9).

SURVEY OF AIR POLLUTION MONITORING AND CONTROL

Recently, the Pan American Center for Human Ecology and Health (ECO) conducted a survey to find what the governments in Latin America and the Caribbean were doing to measure and combat air pollution (*22*). Table 10 shows the 14 questions included in the questionnaire and the number of the 29 responding countries that provided affirmative answers to each question. As indicated in the table, 11 countries have enacted air pollution control legislation, six have established air quality standards, and four have carried out epidemiologic studies designed to assess the health impact of air pollution.

Table 11 shows the air quality standards adopted by three countries (Brazil, Chile, and Mexico) with respect to specific pollutants and compares them to the aforementioned air quality standards of WHO. Generally speaking, the standards established by the three countries are very similar to those of WHO—and also very similar to those established by the United States Environmental Protection Agency.

CONCLUSIONS AND RECOMMENDATIONS

Air pollution in Latin America is a mounting problem whose growth has not been matched by the growth of assessment and control efforts. Limited basic information is available that does permit crude evaluation of the current situation and trends in quantified terms for the entire Region. However, very few Latin American countries are participating in the GEMS global urban air quality monitoring program. Few countries have established air quality standards. Most air quality monitoring stations in the region record only TSP, and very few measure O_3 concentrations. Despite the impor-

Table 9. Estimated health effects of exposure to different total suspended particle (TSP) levels and size of exposed populations in Latin American cities.[a]

	Average annual TSP level (in $\mu g/m^3$)			
	250	150	100	Total
Exposed population (in millions):				
Children (0–14 years)	5.7	8.2	15.4	29.3
Adults (15–59 years)	8.1	11.8	22.1	42.0
Old people (≥60 years)	0.7	1.0	2.0	3.7
Rate in excess of:				
Chronic cough in children (% per year)[b]	24.5	10.6	4.1	
RRAD[c] in adults (days/person/year)[d]	4.0	1.5	0.2	
Chronic bronchitis in old people (%)[e]	6	4	2	
Quantity in excess of:				
Chronic cough cases in children (million per year)[b]	1.4	0.87	0.63	2.9
RRAD[c] in adults (million days per year)[d]	32.4	17.7	4.4	54.5
Chronic bronchitis cases in old people (million per year)[e]	0.04	0.04	0.04	0.12

[a]Source: Reference *5*.
[b]Based on application of a chart prepared by Ware et al. (*19*).
[c]RRAD = Respiratory-related restriction in activity days.
[d]Based on data in Ostro (*20*).
[e]Based on data in Lambert and Reid (*21*).

tance of recording emitters and types of air pollutants for the purpose of maintaining effective control programs, such inventories have been compiled in very few cities, and those compiled have been incomplete.

Furthermore, the information available on the relationship between air pollution and health in the region is very limited, perhaps because of the difficulties involved in carrying out epidemiologic studies and the limited resources allocated to this task.

By way of recommendations for action, it seems clear that the largest cities in the Americas—at least those 34 shown in Table 12 with over a million inhabitants—should measure their air quality. The air quality monitoring stations employed for this purpose should measure not only TSP and SO_2 (the most frequently analyzed pollutants) but should also measure NO_2 and, especially, O_3.

Beyond that, at least those 14 cities with over two million inhabitants (see Table 12) should compile complete and periodically updated inventories of air pollution emitters and significant types of pollutants emitted.

Finally, all the countries of the Americas should be preparing air quality standards that can serve as a technical and legal frame of reference, so that they will have the ability to take appropriate control measures if and when such measures are required.

Table 10. Results of a country air pollution survey in Latin America and the Caribbean (29 countries responded).

Question No.	Question	No. of affirmative responses
1	Have laws been enacted to control air pollution?	11
2	Have air quality standards been established?	6
3	Are air quality considerations taken into account in making decisions about economic development programs?	7
4	Are air quality impact evaluations being made with regard to development projects?	10
5	Is the magnitude of air pollution problems known and documented?	6
6	Do stations routinely measure air quality in some cities?	10
7	Have inventories been made of air pollution sources?	9
8	Is information available on the number of motor vehicles and kinds of fuels being used?	27
9	Is information available on the characteristics of the vehicle fuels being used? (For example, lead content in gasoline and sulfur in diesel oil.)	21
10	Is information available from censuses or other sources on the kinds of fuels used in dwellings for cooking and heating?	17
11	Do consultants or consulting firms exist with the equipment needed to analyze smokestack emissions and/or design equipment for the control of emissions?	10
12	Is quantified information available on actions for the control of air pollution? (For example, expenditures made, amount of emission reduced.)	4
13	Is the health sector (ministry of health or health services) involved in activities for evaluating and/or controlling air pollution?	17
14	Have any epidemiologic studies been made to evaluate the impact of air pollution on health?	4

Source: Reference *22*

Table 11. Air quality standards of Brazil, Chile, Mexico, United States, and WHO.

Pollutant	Measurement period	Brazil	Chile	Mexico	United States (EPA)	WHO
Total suspended particles ($\mu g/m^3$)	Annual	80	75	—	75	60–90
	24 hours	240	260	275	260	100–150
SO_2 ($\mu g/m^3$)	Annual	80	80	—	80	40–60
	24 hours	365	365	375	365	100–150
	1 hour	—	—	—	1,050	350
NO_2 ($\mu g/m^3$)	Annual	100	100	—	100	—
	24 hours	—	300	—	—	150
	1 hour	470	—	395	—	400
O_3 ($\mu g/m^3$)	8 hours	—	—	—	—	100–120
	1 hour	160	160	220	235	150–200
Hydrocarbons, except methane ($\mu g/m^3$)	3 hours	160	160	160	160	—
Carbon monoxide (mg/m^3)	8 hours	10	10	14	10	10
	1 hour	40	40	—	40	30

Table 12. Cities in Latin America with over one million inhabitants (the asterisks denote cities with over two million inhabitants).

Argentina	Cuba
*Buenos Aires	Havana
Rosario	Dominican Republic
Córdoba	Santo Domingo
Bolivia	Ecuador
La Paz	Quito
Brazil	Guayaquil
*São Paulo	Guatemala
*Rio de Janeiro	Guatemala City
*Belo Horizonte	Mexico
*Recife	*Mexico City
*Porto Alegre	*Guadalajara
*Salvador	*Monterrey
Brasília	Puebla
Curitiba	Toluca
Fortaleza	Peru
Belem	*Lima
Chile	Uruguay
*Santiago	Montevideo
Colombia	Venezuela
*Bogotá	*Caracas
Medellín	Maracaibo
Cali	Valencia
Barranquilla	

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