ELSEVIER

The Science of the Total Environment 307 (2003) 141–165

the Science of the Total Environment
An International Journal for Scientific Research into the Environment and its Relationship with Man

www.elsevier.com/locate/scitotenv

Air quality data from large cities

J.M. Baldasano*, E. Valera, P. Jiménez

Laboratory of Environmental Modelling, Technical University of Catalonia (UPC), Diagonal 647 10.23, 08028 Barcelona, Spain

Received 11 July 2002; received in revised form 22 October 2002; accepted 24 October 2002

Abstract

This paper presents an assessment of the air quality for the principal cities in developed and developing countries. Part of the vast and widely dispersed information on air quality that is available at this time on the Internet was compiled, thus making possible a comprehensive evaluation of the tendencies that emerged at the end of the 20th century. Likewise, these values are compared to the air quality thresholds recommended by two international organizations: guideline levels of the World Health Organization (WHO) and limit values of the European Union (EU), in order to determine air quality concentration levels in large cities around the world. The current situation of air quality worldwide indicates that SO_2 maintains a downward tendency throughout the world, with the exception of some Central American and Asian cities. NO_2 maintains levels very close to the WHO guideline value around the world. For particulate matter, it is a major problem in almost all of Asia, exceeding 300 $\mu g/m^3$ in many cities. Ozone shows average values that exceed the selected guideline values in all of the analyses demonstrating that it is a global problem. In general, the worldwide trend is to a reduction in the concentrations of pollutants because of the increasingly strong restrictions which local governments and international organizations impose. However, in poor countries and those with low average incomes, concentrations of air pollutants remain high and the trend will be the elevation of their ground levels as they develop, making the problem even worse.

Keywords: Urban air quality data; Nitrogen dioxide; Sulfur dioxide; Particulate matter; Ground level ozone

1. Introduction

In the last 50 years, most of mankind has been transformed into city dwellers. However, this rush towards urbanization has brought a multitude of problems, including air pollution, whose consequences are just beginning to be recognized. More than 75% of all people in developed nations now live in cities. The developing world is being urbanized even faster, with twice as many people now living in urban areas as 50 years ago, although developing nations are still more rural, with just 35% of citizens living in cities. Studying the human health effects of air pollution has often been challenging, because it is difficult to isolate from other factors that also influence health, such as smoking, diet, and exposure to poor indoor air quality.

Therefore, developed countries have made great efforts to improve air quality through the adoption of clean air plans which have included measures

*Corresponding author. Tel.: +34-93-401-1746; fax: +34-93-334-0255.
E-mail address: jose.baldasano@upc.es (J.M. Baldasano).

0048-9697/03/$ - see front matter © 2002 Elsevier Science B.V. All rights reserved.
PII: S0048-9697(02)00537-5

such as: demanding emission and air quality regulations, continuous air quality monitoring in urban and industrial centers, and use of cleaner fuels such as natural gas. At the same time, in developing countries, there is a clear phenomenon of migration from the countryside to the city, which has brought as a consequence greater emissions into the atmosphere, mainly produced by the increase of traffic (Scholorling, 2000), with the additional difficulty that in these countries the tendency is to have a stock of old, badly maintained vehicles. On the other hand, the number of vehicles in circulation has likewise increased. These factors have produced far-reaching changes in air quality in urban contexts, especially in the 1990s, when the majority of clean air plans were tightened up.

In addition, an enormous amount of air quality information is currently available on the Internet. In this study, we present a compilation of air quality information in a form that makes possible an overall evaluation of the trends that emerged in

Table 1
Compilation of international air quality regulations (data in μg/m³)

Area	Pollutant zone	SO_2			NO_2			PM_{10}			Ozone		
		1 year	24 h	1 h	1 year	24 h	1 h	1 year	24 h	1 h	24 h	8 h	1 h
World	WHO	50	125	500 (10 m)	40		200					120	
Europe	EU	20[a]	125	350	30[a]		200	40[b]	50			120	180[c]
North America	Canada												
	Desirable	30	160	500	60								100
	Acceptable				100	200	400						165
	Tolerable		875			300	1000						300
	Mexico	79	341				395	50	150				216
	USA	80	365	1300 (3 h)	100			50	150			157	235
Latin America	Argentina	70 (1 month)		2620		282	846						195
	Bolivia	80	365			150	400	50	150				236
	Brazil	80	365		100		320	50	150				160
	Chile	80	365		100				150				160
	Colombia	100	400	1500 (3 h)		100							170
	Costa Rica	80	365	1500 (3 h)	100		400	50	150				160
	Cuba		50	500 (20 m)		40	85				30		160 (20 m)
	Ecuador	80	400	1500 (3 h)	100								200
	Venezuela		80 365			100 300							240
Asia	Brunei	50	125	350		100	300	60	100			60	120
	China												
	Sensitive areas	20	50	150	40	80	120	40	50				120
	Urban and rural areas	60	150	500	40	80	120	100	150				160
	Industrial areas	100	250	700	80	120	240	150	250				200
	India												
	Sensitive areas	15	30		15	30		50	75				
	Residential, rural and other areas	60	80		60	80		60	100				
	Industrial Areas	80	120		80	120		120	150				
	Japan		110	260		80 110			100	200			120
	Thailand	100	300	780			320	50	120				200
Oceania	Australia	57		715			301						244
	New Zealand	50	125	350		100	300	40	120			100	150

[a] For protection of ecosystem.
[b] To be meet by 2005.
[c] Threshold included in new EU directive.

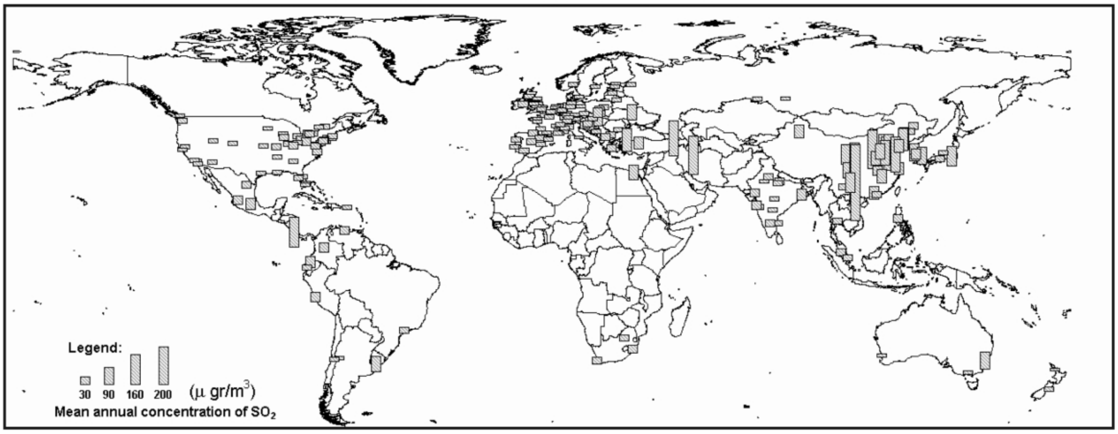

Fig. 1. Average annual values for SO_2 concentrations.

the 1990s in air quality in both developed and developing countries. In the same way, the values found will be compared with the guideline levels of atmospheric pollutants recommended by the WHO and limits values of the EU in order to give an overview of the state of air quality in the megacities of the world.

The current study is an analysis of the data collected up to the present date, because new information on air quality is continuously being published. The compilation includes the concentrations measured in the main cities of each country for the following pollutants: nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter (such as TSP, PM_{10} or black smoke), and ground level ozone (O_3). The most important city was selected for each country, in addition to any others with large populations (especially those of over 1 million inhabitants). Furthermore, in developed countries and various developing countries, the use of fossil fuels with a high sulfur content has been restricted, leading to a reduction of SO_2 emission, and therefore giving way to lower concentrations. Thus, in many cities, the presence of SO_2 is no longer a problem, and it is therefore no longer measured.

Processing these data was difficult, since in developed countries there is a great deal of information from various sources, with different processing criteria and often-contradictory results. In contrast, information is scant and difficult to find in developing countries. Furthermore, it is becoming a regular practice to present air quality information through a country- or city-specific air quality index, which makes comparison of values difficult and of limited usefulness.

In this study, information was treated in order to be presented in a way that is easy to interpret and process. The data for each pollutant are indicated in concentration units ($\mu g/m^3$) and based on common time periods. This was quite difficult, especially for ozone, since in some countries the regulations refer to average annual values and time-based maximums, while in others they refer to time-based maximums and 8-h averages. In data presented herein, reference will be made to the measurement period to which the values correspond.

2. Main information sources

Nowadays, a large number of countries have automated and manual air quality measurement networks. In more developed countries, automated networks have been operative since the end of the 1970s, with information available on the Internet. In this section, we summarize the main information sources gathered in this paper. An important reference on this topic is the work published by the United Nations Environment Programme and

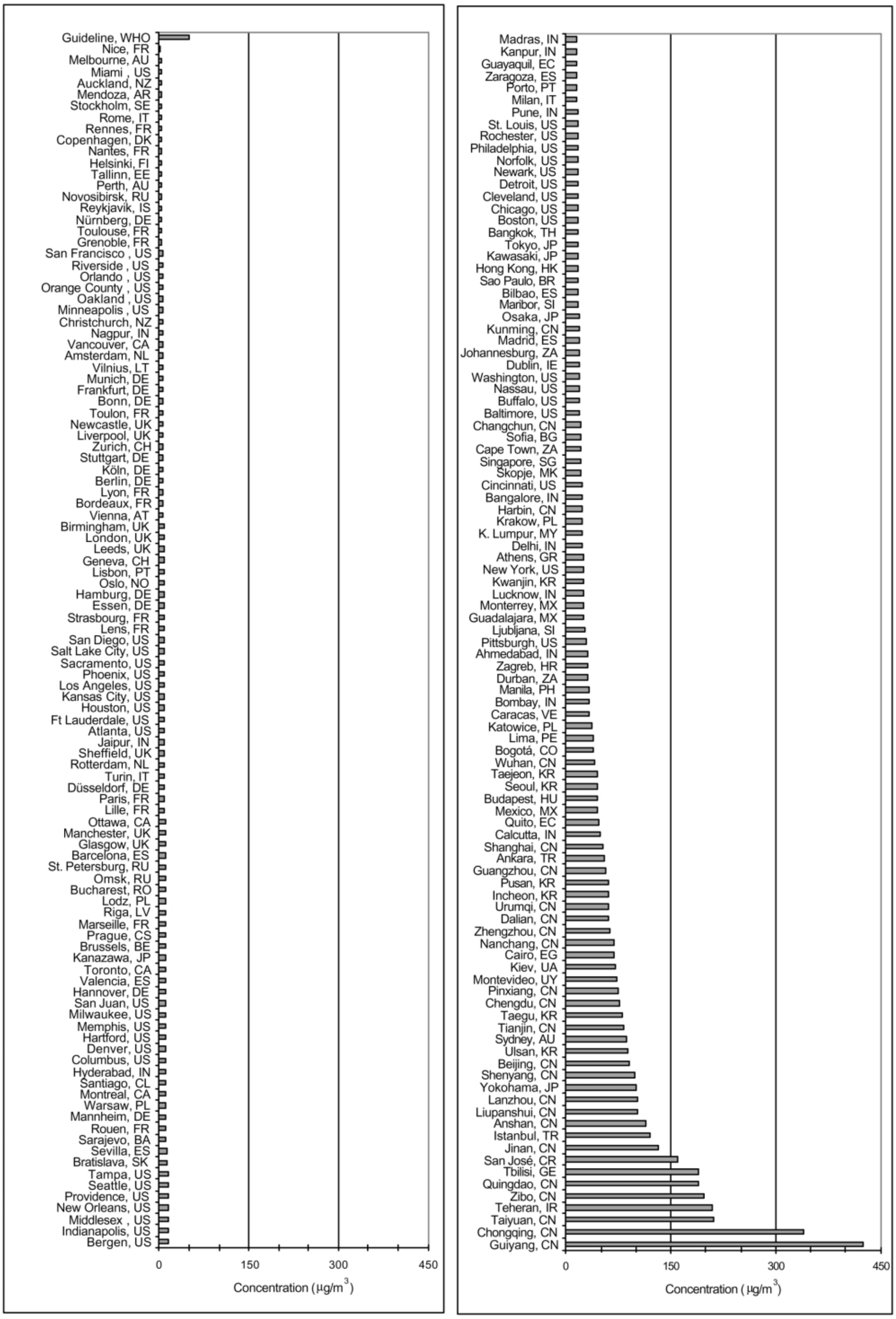

Fig. 2. Mean annual concentration of SO_2.

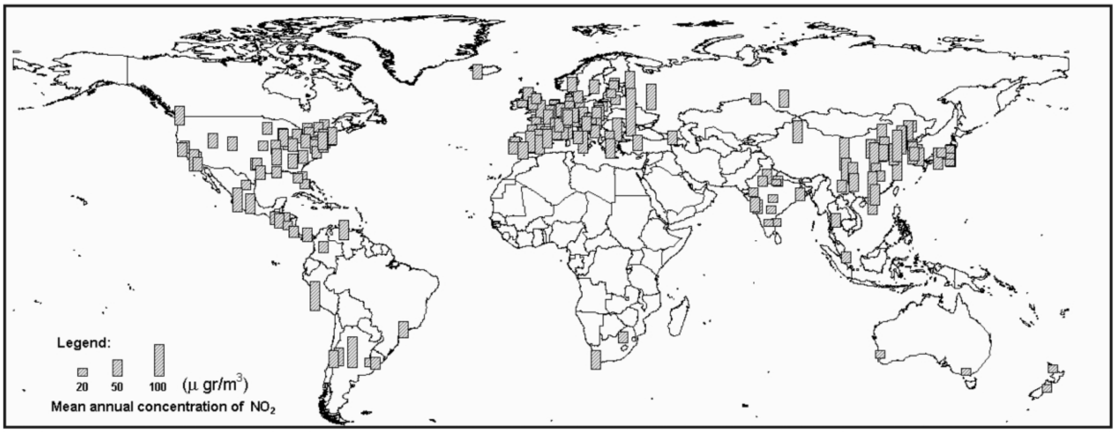

Fig. 3. Average annual values for NO_2 concentrations.

World Health Organization (1992); Kukkonen et al. (1999) and Ministère de l'Aménagement du Territoire et de l'Environnement du France (2001).

The EU presents the concentration values of the main atmospheric pollutants from over 1450 measuring stations through the European Topic Centre on Air Quality (ETCAQ), covering 350 cities all over Europe. Furthermore, in most large European cities the local governments have on-line information on pollutant concentrations and data processed from prior years (European Environment Agency, 1995).

In the USA, measurements of over 1000 cities throughout the country are available through the US Environmental Protection Agency database (USEPA, 2001).

Latin America has manual and automated measurement networks, and values can be obtained from the Pan-American Health Engineering Centre (CEPIS) database, or from the web pages of specialized organizations. There is also an Initiative for Clean Air in Latin American Cities that exists under the aegis of the World Bank and the Clean Air in Central America Program, financed by the Swiss Agency for Development and Cooperation (COSUDE) and carried out by the Swiss Cooperation Foundation for Technical Development (Swisscontact).

In Africa, data are very limited, and databases are available in only a few countries, such as South Africa, Ghana, Kenya and Egypt.

Measurements from Asia were obtained searching in databases of China, Japan, Korea, India (Central Pollution Control Board, 1994), Indonesia, Malaysia, Philippines, Thailand (National Environmental Board (1995); Wangwongwatana (1999)) and Turkey, in addition to smaller countries like Brunei, Georgia, Hong Kong (Pang et al., 1999), Kuwait, Singapore and Taiwan.

In addition, international organizations (such as the World Bank or the World Resource Institute) provide air quality databases where worldwide data is compiled. The WHO also keeps an air quality database on over 100 cities around the world through the AMIS Program, which has been in force since the 1990s.

3. Air quality regulations

Several guidelines and regulations have been adopted to define air quality levels. The WHO considers the Guideline Values (GD); the EU labels the Limits Values for Air Quality (LVAQ), while the US Environmental Protection Agency defines the National Ambient Air Quality Standards (NAAQS). These criteria, in addition to some other from certain countries, were compiled in order to have an overall idea of the air quality regulation status around the world (see Table 1).

The worldwide reference continues to be the air quality guideline of the WHO (1987), and therefore it will be the reference for air quality analysis

Fig. 4. Mean annual concentration of NO_2.

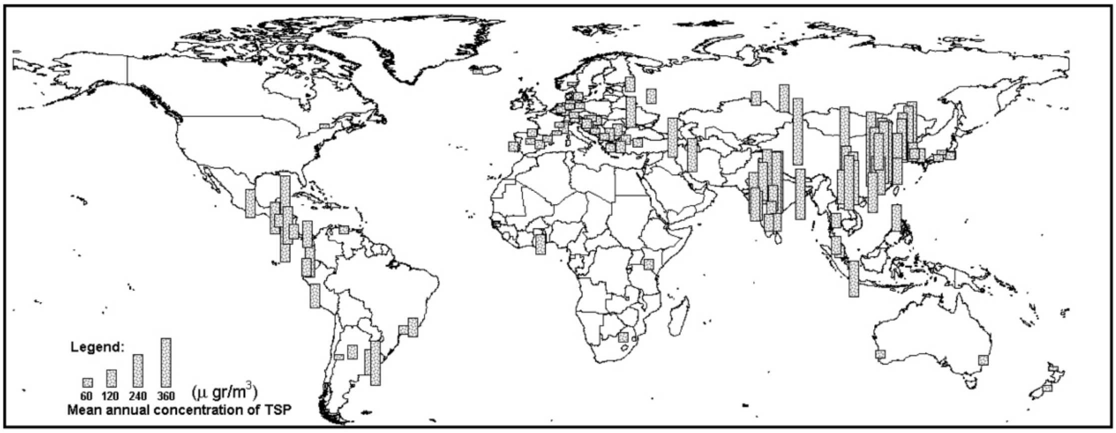

Fig. 5. Average annual values for total suspended particle (TSP) concentrations.

made below. For the pollutants considered in this paper, the guidelines values are: 50 μg/m³ for SO_2; 40 μg/m³ for NO_2 (1-year average in both cases) (WHO, 1999); and 60–90 μg/m³ range for Total Suspended Particles (TSP) (WHO, 1979). For particulate matter, there is a tendency to monitoring PM_{10} and $PM_{2.5}$, although the WHO does not provide a guideline value for these pollutants since according to its criteria, there is not sufficient evidence to establish a threshold value for which adverse effects on human health are found (WHO, 1999). For ground level-ozone, the WHO guideline sets up a value of 120 μg/m³ for 8-h averages.

Table 1 offers a compilation of air quality regulations worldwide. For SO_2, the strictest values for annual means are 15 μg/m³ for sensitive areas in India and 20 μg/m³ for sensitive areas in China and for vegetation protection in the EU. The latest regulations values are found for a 1-h average in Argentina (2620 μg/m³) and [for 3-h averages (1500 μg/m³)] in Colombia, Ecuador and Costa Rica.

In the case of NO_2, the strictest values are 15 μg/m³ for sensitive areas in India and 30 μg/m³ for vegetation protection (in the EU), up to 1000 μg/m³ (and 846 μg/m³) as the maximum tolerable level in Canada and Argentina, respectively.

Regarding the PM_{10}, the strictest values range from 40 μg/m³ stipulated for the EU (20 μg/m³ will be the limit value in 2010, which is a provisional level that is to be reconsidered during 2003), China and New Zealand, 50 μg/m³ for the USA, up to 250 μg/m³ stipulated as the 1-h average in industrial areas of China.

European policy for ground-level ozone (or tropospheric ozone) requires a special mention. In February 2002, the EU (2002) established long-term objectives, target values, an alert threshold and an information threshold for concentrations of ozone in ambient air in the Community. The target values for 2010 with respect to ozone concentrations in ambient air are: 120 μg/m³ as the maximum daily 8-h mean not to be exceeded on more than 25 days per calendar year averaged over 3 years. This value is also a long-term objective for the protection of human health. This directive also includes: 180 μg/m³ for 1-h average as an information threshold and 240 μg/m³ for 1-h average as alert threshold. The EU, in this directive, also presents a reference level related to damage to materials; 40 μg/m³ as the annual mean. Comparing the values of this directive with other countries, it can be seen that the most demanding values are set in Cuba (30 μg/m³ as an average 24-h value) and Canada, with 100 μg/m³ as a maximum desirable concentration for 1-h average. In the USA, the established value for an 8-h average is 157 μg/m³.

Despite the works of the WHO, difficulties in unifying threshold values at a worldwide level are obvious, as there exist a wide diversity of limit and guideline values according to the different countries and their diverse characteristics (Korc et al., 2000).

4. Air quality in large cities

In Figs. 1, 3, 5, 7, 9 and 11, world maps are depicted to show air quality status in the largest cities of the world. On these maps, bars are used to illustrate the most recent average annual concentrations by city and pollutant, in an effort to show the locations where the problem is important and the differences between different world regions. Fig. 11 shows the maximum annual hourly concentrations for ozone, and this parameter is considered because it is often used as a reference to compare the different guidelines for O_3. More detailed data can be found on the bar graphs of Figs. 2, 4, 6, 8, 10 and 12.

For SO_2, Fig. 1 illustrates the most recent mean annual concentrations for the cities included in the present study, (reference level = 50 $\mu g/m^3$; WHO, 1999). The greatest problems related to sulfur dioxide occur in Asia (mainly, in Chinese cities

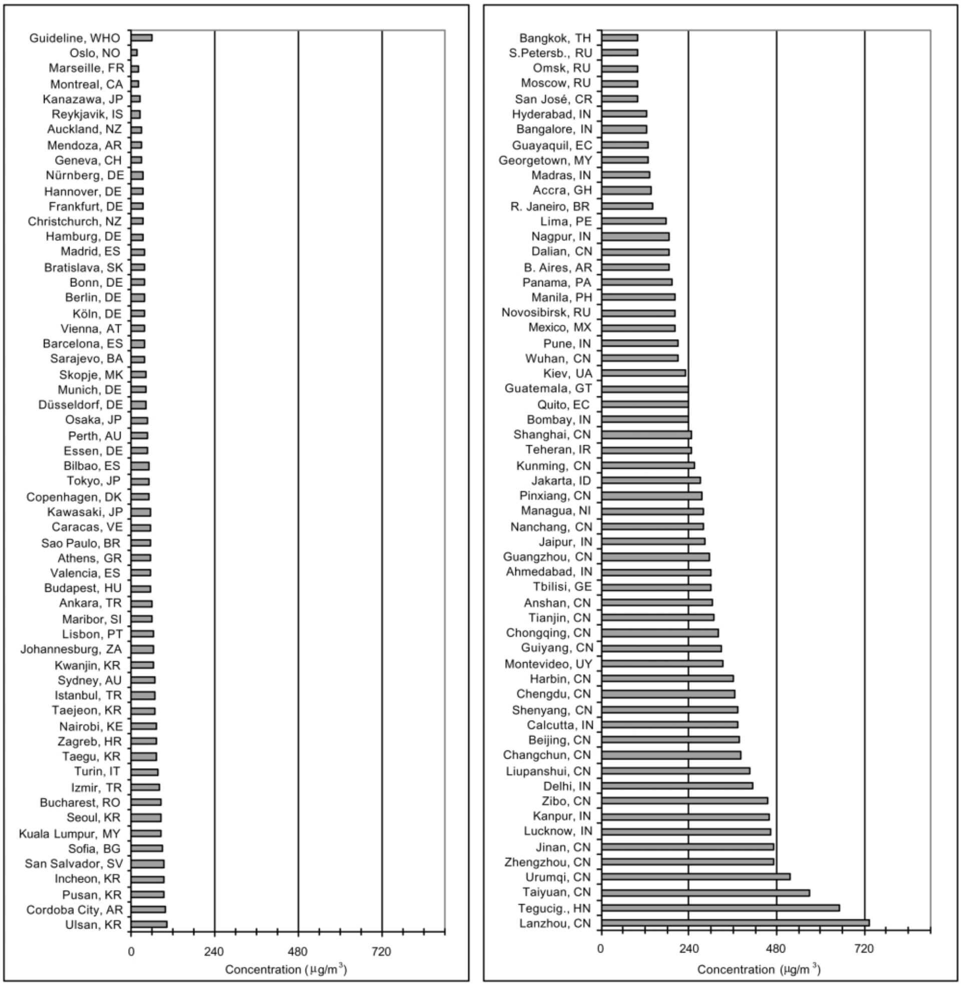

Fig. 6. Mean annual concentration of TSP.

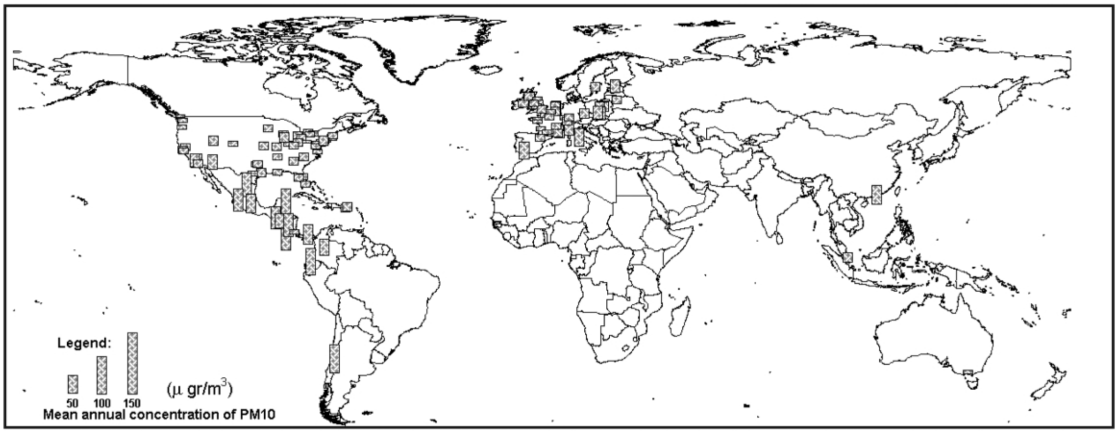

Fig. 7. Average annual values for PM_{10}.

and some Middle-East cities such as Teheran, Tbilisi and Istanbul), in contrast with the low levels measured in Europe and North America. In developing countries, industry is the leading cause of SO_2 pollution due to the burning of coal, which is the main source of energy, thus causing SO_2 emissions. It must be borne in mind that over 75% of the energy produced comes from coal, much of which has a high sulfur content, and that the measures for monitoring sulfur emissions are inadequate. In Fig. 2, there are surprising cases such as Guiyang (424 $\mu g/m^3$ in 1995) with average annual values of more than 6 times the WHO guideline value. Most of the evaluated cities (165 of 222) have figures under the WHO guideline value.

In the case of NO_2 concentrations (reference level=40 $\mu g/m^3$; WHO, 1999), highest values are found for a combination of cities in both developed and developing countries (Fig. 3), where the common denominator is the high number of vehicles, which are clearly the main source of NO_2 emissions in cities worldwide. Hence, highest ground values of NO_2 are from the principal cities of America, Europe and Asia. Fig. 4 shows that maximum NO_2 concentrations compiled in this work are found in Kiev (155 $\mu g/m^3$ for year 1998; CEROI, 2001), and several Chinese cities with figures over 100 $\mu g/m^3$. Also, Fig. 4 presents the low values for cities such as Porto (7 $\mu g/m^3$ in 1999; Airbase 2001).

Total suspended particles concentrations are featured in Fig. 5. Reference air quality criteria used are: TSP 60–90 $\mu g/m^3$ (WHO, 1979). As particles are usually related to sulfur dioxide, a clear correlation can be established between SO_2-polluted cities in Asia and Latin America and those places with high TSP levels. Values obtained for TSP in the world's major cities are depicted in Fig. 6. Especially noteworthy is the observation that most of the cities are Chinese, such as Lanzhou (732 $\mu g/m^3$ in 1995). The city of Tegucigalpa is also listed therein, with an extremely high value (652 $\mu g/m^3$ in 2000). The lowest figures for TSP are from cities in developed countries like Oslo (15 $\mu g/m^3$ in 1995) and Marseille (18 $\mu g/m^3$ in 2000).

With respect to PM_{10}, the reference levels used are 40 $\mu g/m^3$ (to be met in 2005; EU, 1999). Fig. 7 shows that this parameter is measured mainly in Europe, USA and some cities in Central America, where PM_{10} attains the top values. Fig. 8 shows the most recent PM_{10} concentrations obtained in the compilation carried out. Cities of Latin American countries, such as Tegucigalpa (157 $\mu g/m^3$ in 2000) and Santiago de Chile (77 $\mu g/m^3$ in 2000), have the worst air quality with respect to PM_{10}. Tegucigalpa not only presents high values

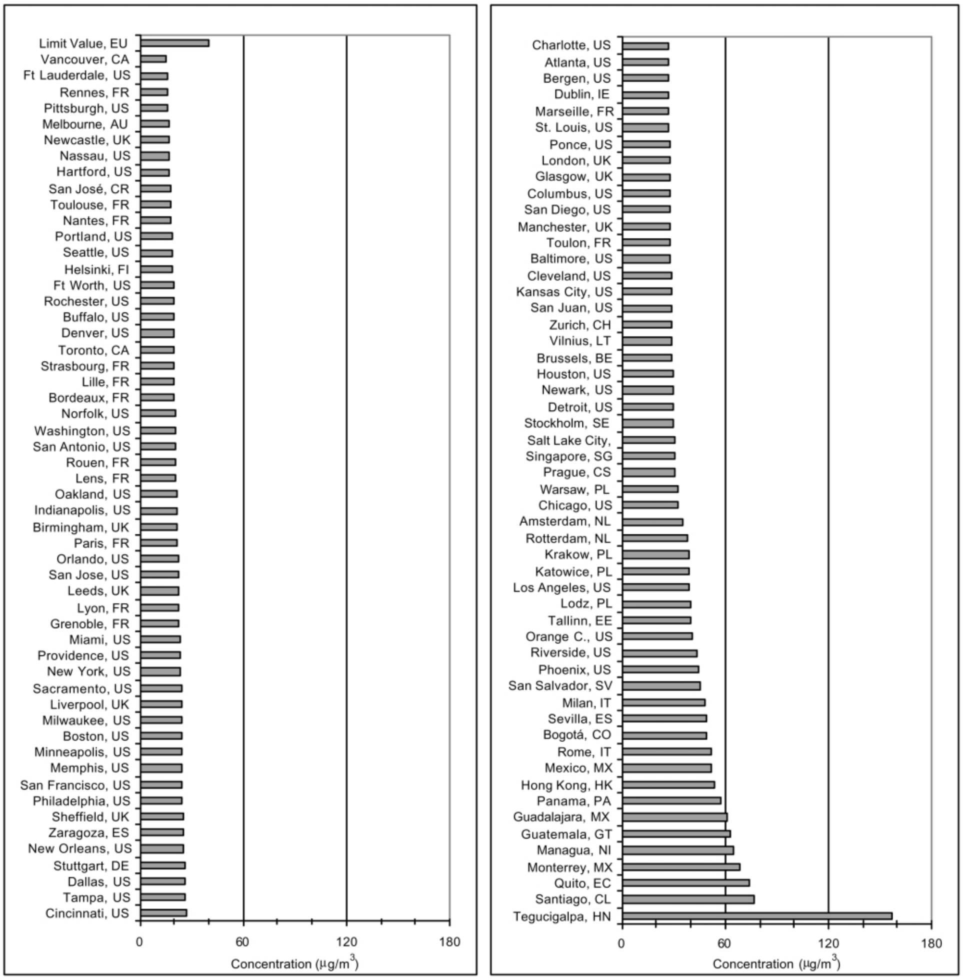

Fig. 8. Mean annual concentration of PM_{10}.

related to TSP, but also attains important values of PM_{10} (nearly four times over the EU PM_{10} reference value). A mixture of industrial and traffic sources is responsible for particle emissions, especially in those cities where vehicles tend to be older and use diesel fuel. Other cities from developed countries present high values, like Phoenix and Riverside (both with 44 $\mu g/m^3$ in 1999; USEPA, 2001). In addition to the aforementioned sources, high concentrations may be due to the presence of mineral dust with a desert origin. This is also the case with the Spanish city of Seville (49 $\mu g/m^3$ in 1999), where elevated background PM_{10} levels can be explained due to Saharan dust intrusions. The city with the best air quality evaluated from the mean annual concentration of PM_{10} is Vancouver, Canada (15 $\mu g/m^3$ in 1999). Values obtained for PM_{10} reported from San José de Costa Rica (18 $\mu g/m^3$ in 2000) by CEPIS (2001) must be carefully considered, because this city presents serious troubles with ground values from other pollutants like TSP (114 $\mu g/m^3$ in 1999 and 101 $\mu g/m^3$ in 2000) and SO_2 (80 $\mu g/m^3$ in 1999 and 160 $\mu g/m^3$ in 2000).

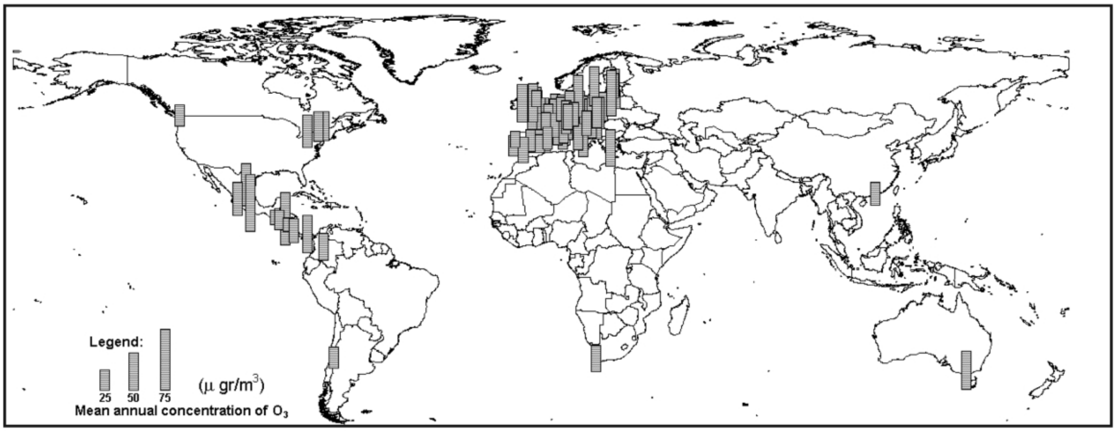

Fig. 9. Average annual values of ground-level ozone concentrations.

Ground-level ozone is another of the monitored pollutants in the world's largest cities, especially in developed countries. This pollutant is formed photochemically from nitrogen oxides and volatile organic compounds, and so is considered as a secondary organic pollutant. Fig. 9 shows the annual mean ground-level ozone concentration compiled values in Europe and some cities from Canada, Central America and Asia. Fig. 10 shows the figures for the average annual ozone concentration values. It is stated that Mexico City (77 $\mu g/m^3$ in 1999) has the highest value for mean annual ozone concentration, similar to other Central American locations: Tegucigalpa (67 $\mu g/m^3$ in 2000) and Monterrey (55 $\mu g/m^3$ in 1999). European cities like Riga (60 $\mu g/m^3$ in 1999) and Copenhagen (53 $\mu g/m^3$ in 1999) also show important O_3 values. Managua, Guatemala City and Zaragoza (under 25 $\mu g/m^3$ in 1999 and 2000) present the lowest annual mean concentration of ground-level ozone.

No guideline value is presented in this analysis to judge the air quality for selected cities in relation to the average annual value of ozone, because this threshold is not included in the guideline values recommended for the two international organizations used in this paper, WHO and EU.

World distribution of the maximum highest hourly concentration in the selected cities is depicted in Fig. 11. Most of the figures are from USA and Europe. It is important to emphasize the lack of data in a number of cities. Fig. 12 shows the extreme ozone concentrations compiled as maximum daily hourly values. As shown, Mexico City (491 $\mu g/m^3$ in 1999) is clearly the city with the greatest photochemical 'smog' problem, followed by other Latin-American cities like Sao Paulo (403 $\mu g/m^3$ in 2000) and Santiago (351 $\mu g/m^3$ in 2000). The cities with the lowest maximum hourly concentration of ozone are the European cities of Tallinn (91 $\mu g/m^3$ in 1999) and Helsinki (108 $\mu g/m^3$ in 1999).

5. Comparative analysis of annual averages for data available on selected cities

Table 2 shows the annual averages of air pollutant concentrations considered for sets of countries grouped according to their Gross National Income (GNI). This grouping is carried out in accordance with the division made by the World Bank (2002). Economies are divided according to 2000 GNI per capita, calculated using the World Bank Atlas method. The groups are: low income, \$755 or less; lower middle income, \$756–\$2995; upper middle income, \$2996–\$9265; and high income, \$9266 or more. This information is summarized in Table 3.

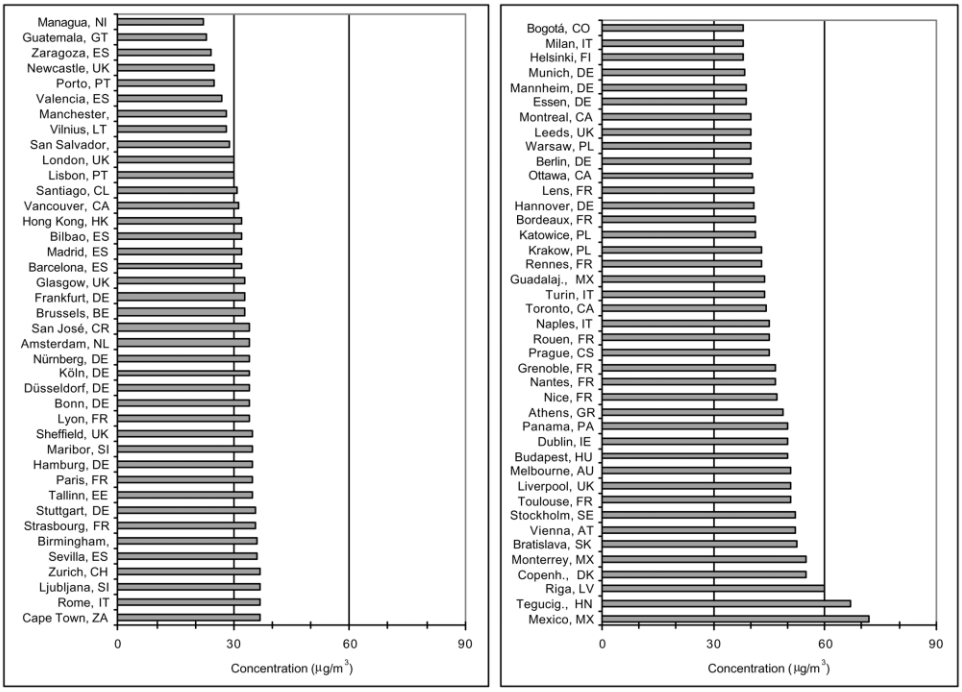

Fig. 10. Mean annual values of ground-level O_3 concentrations in the world.

High-income countries do not have problems related to SO_2 or, generally speaking, with particulate matter. Nitrogen oxides are between WHO guideline and EU limits and ozone reaches average levels above the selected guideline values, due to intensive automobile usage in cities. Cities belonging to countries with upper-middle income present SO_2 averages between WHO guideline and EU limits, while nitrogen dioxide, ozone and particles have values that exceed both the WHO guideline

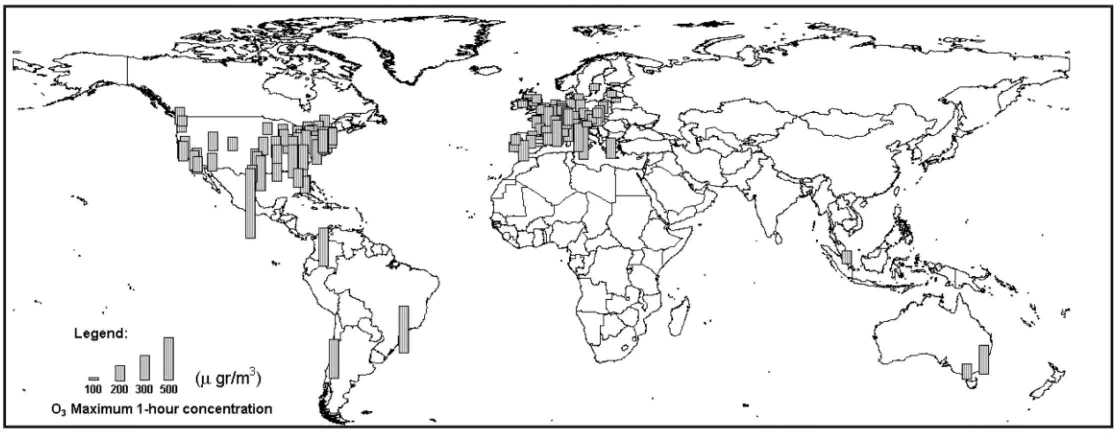

Fig. 11. Maximum-1 h concentration of ground-level ozone.

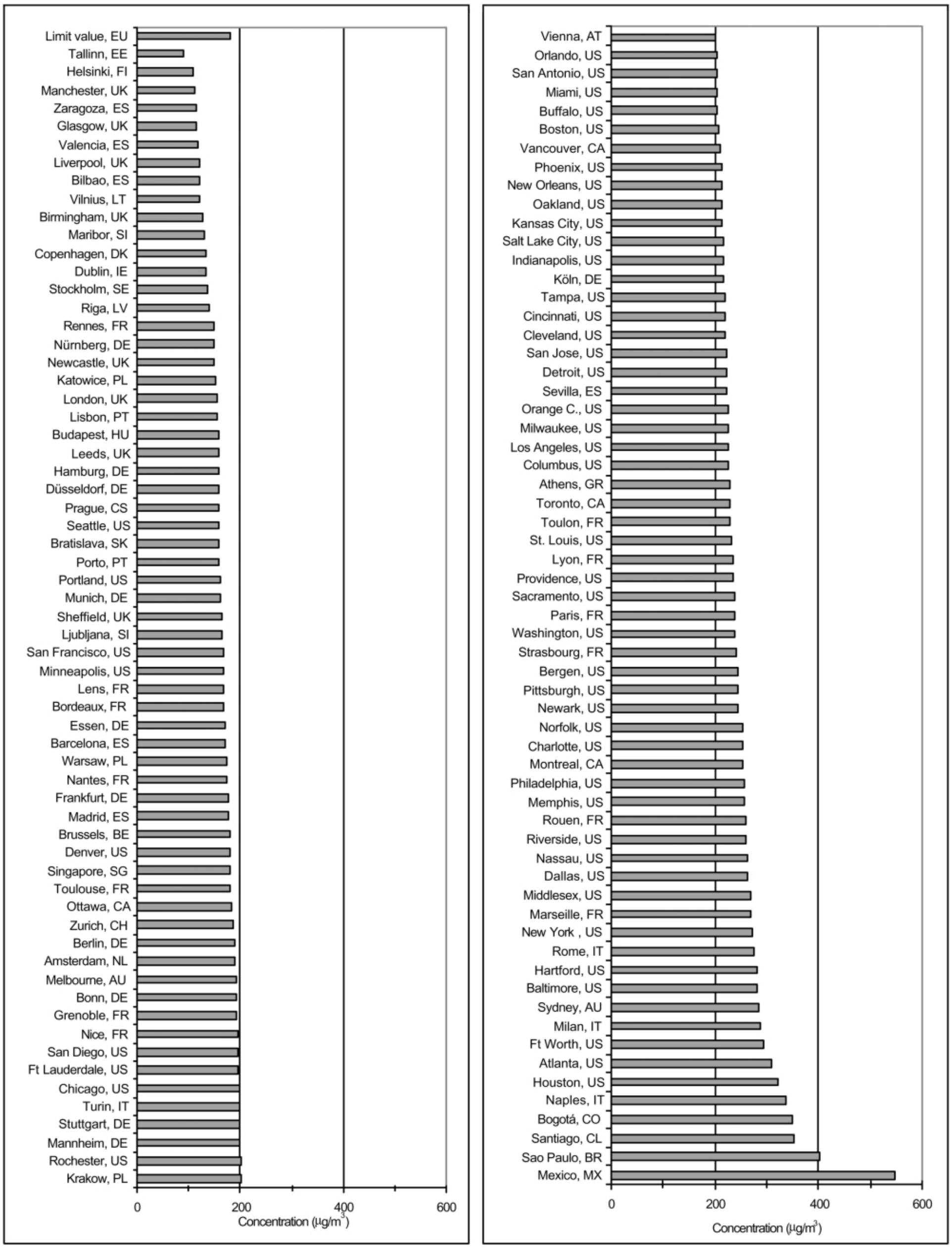

Fig. 12. Maximum 1-h concentration of ground-level ozone by cities.

and EU limits values. For cities of lower-middle income countries, pollutants exceed the WHO guideline and EU limits values. Cities in countries with low income have averages for suspended particles below the WHO guideline and EU limits values and SO_2 and NO_2 have figures between these references. In these countries, there are no references for ground-level ozone.

Table 2
Air quality mean levels for selected cities related to different indicators

Indicator	SO_2 (μg/m³)	NO_2 (μg/m³)	Particulate matter		Ozone	
			TSP (μg/m³)	PM_{10} (μg/m³)	Annual (μg/m³)	Max 1 h (μg/m³)
GNI						
1.->$9266	12	39	40	26	38	205
2.-$2996–9265	32	45	94	49	46	239
3.-$756–$2995	82	58	265	62	40	204
4.-<$755	36	35	246	65	22	
Region						
Africa	35	44	89		37[b]	
Europe	12	42	58	28	39	176
North America	13	39	21	25	39	229
Latin America	41	46	187	66	42	412
Asia	74	51	251	43	32	181
Oceania	4	18	43	17	51[b]	237
Mill. of inhabitants						
>8	28	54	186	33	46	306
3–8	57	51	198	34	41	252
1–3	32	43	199	29	39	212
<1	12	36	82	35	39	169
Reference						
WHO guideline	50	40	60[a]			
EU limit	20	30		40		180/240

[a] WHO guideline of 1979.
[b] Average calculated with few values.

If the analysis is made for each individual pollutant, Table 2 indicates that, in the case of SO_2, only the average values calculated for Asia exceed the WHO guideline value. Latin America and Africa have mean values between the WHO guideline and EU limits values. Averages calculated for NO_2 exceed the WHO guideline value in almost all of the zones except Oceania and North America, which have an average not too distant from this value. EU limits are exceeded in all areas, except Oceania. Considering the mean concentrations calculated for particulate matter, in the case of TSP only North America and Oceania have low values. For PM_{10}, the EU limit is exceeded in Asia and Latin America. Ozone shows average values that exceed the EU limit in all of the regions except Europe, which is close to the limit. This demonstrates that ground-level ozone is a global problem.

Furthermore, this analysis can be made in the context of the number of inhabitants of the cities (UN, 1995). When considering this parameter, (see Table 2), it is observed that in mega-cites (> 8 million inhabitants) almost all of the EU thresholds and WHO guideline values are exceeded except those for SO_2 and PM_{10}. The average for SO_2 is a value between both references. Large cities (3–8 million inhabitants) also show average values that exceed the references values, with the exception of those for PM_{10}, which is a parameter mainly measured in developed countries. Mid-sized cities (1–3 million inhabitants) do not show severe problems either with SO_2, for which the value is between both references, or PM_{10}, although they generally present important troubles related to NO_2, ozone and TSP. Small cities (less than 1 million inhabitants) exhibit inconveniences related to particles.

Table 3
Compilation of air quality data of selected cities of the world[a]

City name	City Popul. ($\times 10^3$)	O_3 MAC[b] ($\mu g/m^3$)	Max 1 h[c] ($\mu g/m^3$)	TSP MAC ($\mu g/m^3$)	PM_{10} MAC ($\mu g/m^3$)	SO_2 MAC ($\mu g/m^3$)	NO_2 MAC ($\mu g/m^3$)	WB/ CE[d]	Years of data	Sources
Africa										
Cairo, EG	6800					69		3	1993	WRI-WB
Accra, GH	1673			137				4	1990	WRI-WB
Nairobi, KE	1162			69				4	1995	WRI-WB
Cape Town, ZA	2671	37				21	57	2	1994–1997	CEROI
Durban, ZA	1149					32		2	1998	Durban Metro
Johannesburg, ZA	1849			61		19	31	2	1995	WRI-WB
Europe										
Vienna, AT	1539	52	201	36		7	30	1	1999	Airbase
Brussels, BE	960	33	181		29	10	39	1	1999	Airbase
Sarajevo, BA	529			38		12	36	3	1995	GRID
Sofia, BG	1189			89		21	20	3	1995–1999	WRI/Airbase
Zagreb, HR	868			71		31		2	1995	WRI
Prague, CS	1217	45	158		31	10	33	2	1999	Airbase
Copenhagen, DK	1353	55	133	49		3	32	1	1999–2000	NERI/ Airbase
Tallinn, EE	448	35	91		40	4	30	2	1998–1999	Airbase
Helsinki, FI	1016	38	108		19	4	31	1	1999	Airbase
Bordeaux, FR	925	41	169		20	7	22	1	2000	MATE/AIRAQ
Grenoble, FR	515	47	194		23	5	34	1	2000	MATE/ASCOPARG
Lens, FR	553	41	169		21	8	33	1	2000–2001	MATE
Lille, FR	1143				20	9	34	1	2000	MATE
Lyon, FR	1648	34	234		23	7	43	1	2000–2001	MATE/COPARLY
Marseille, FR	1516		270	18	27	10	37	1	2000	MATE/airmaraix
Nantes, FR	711	47	174		18	4	24	1	2000	MATE/AIRPL
Nice, FR	933	47	195			2	33	1	2000	MATE/QUALITAIR
Paris, FR	11 175	35	238		22	9	43	1	2000	Air Parif
Rennes, FR	521	43	148		16	3	22	1	2000	MATE/AIR BREIZH
Rouen, FR	518	45	259		21	12	36	1	1999–2001	MATE/AIRNORMAND
Strasbourg, FR	612	36	242		20	8	37	1	2000	MATE/ASPA
Toulon, FR	565		230		28	6	35	1	2000	MATE/airmaraix
Toulouse, FR	965	51	181		18	5	31	1	2000	MATE/ORAMIP
Berlin, DE	3472	40	188	35		7	37	1	1999	Airbase
Bonn, DE	293	34	191	35		6	35	1	1999	Airbase
Dusseldorf, DE	573	34	158	42		9	34	1	1999	Airbase
Essen, DE	618	39	170	45		8	38	1	1999	Airbase
Frankfurt, DE	652	33	176	33		6	49	1	1999	Airbase
Hamburg, DE	1706	35	158	34		8	35	1	1999	Airbase
Hannover, DE	526	41		33		11	27	1	1995–1999	Airbase/ETCAQ
Köln, DE	964	34	218	36		7	33	1	1999	Airbase
Mannheim, DE	316	39	200			12	39	1	1999	Airbase/ETCAQ

Table 3 *(Continued)*

City name	City Popul. ($\times 10^3$)	O_3 MAC[b] ($\mu g/m^3$)	Max 1 h[c] ($\mu g/m^3$)	TSP MAC ($\mu g/m^3$)	PM_{10} MAC ($\mu g/m^3$)	SO_2 MAC ($\mu g/m^3$)	NO_2 MAC ($\mu g/m^3$)	WB/CE[d]	Years of data	Sources
Munich, DE	1245	38	162	42		6	47	1	1999	Airbase
Nurnberg, DE	496	34	149	33		5	44	1	1999	Airbase
Stuttgart, DE	588	36	0		26	7	45	1	1995–1999	Airbase
Athens, GR	3073	49	228	55		25	58	1	1997–1999	Airbase
Budapest, HU	1963	50	157	56		45	48	2	1997	Airbase
Reykjavik, IS	153			24		5	42	1	1995	WRI
Dublin, IE	916	50	134		27	20	17	1	1993–2000	WRI/Airbase
Milan, IT	1371	38	287		48	16	74	1	1999	Airbase
Rome, IT	2693	37	276		52	3	37	1	1999	Airbase
Turin, IT	962	44	0	74		9	71	1	1998–1999	Airbase
Naples, IT	1055	45	336				80	1	1998–1999	Airbase
Riga, LV	848	60	141			10	22	3	1999	Airbase
Vilnius, LT	582	28	122		29	6	22	3	1999	Airbase
Skopje, MK	448			40		22		3	1999	Airbase
Amsterdam, NL	1101	34	189		35	6	41	1	1999	Airbase
Rotterdam, NL	1076				38	9	44	1	1999	Airbase
Oslo, NO	759			15		8	43	1	1993–1995	WRI
Katowice, PL	360	42	152		39	38	30	2	1999	Airbase
Krakow, PL	744	43	201		39	23	44	2	1999	Airbase
Lodz, PL	836				40	10	27	2	1999	Airbase
Warsaw, PL	1643	40	174		32	12	24	2	1999	Airbase
Lisbon, PT	2561	30	155	61		8	43	1	1995–1999	WRI -AirBase
Porto, PT	1174	25	159			15	7	1	1999	AirBase
Bucharest, RO	2061			82		10	71	3	1995	WRI
Moscow, RU	8663			100			80	3	1992	OECD
Omsk, RU	1186			100		10	30	3	1993	OECD
St Petersburg, RU	4828			100		10	80	3	1993	OECD
Novosibirsk, RU	1401			0		5	50	3	1993	OECD
Bratislava, SK	451	53	159	35		14	31	2	1999	Airbase
Ljubljana, SI	280	37	166			27		1	1998–1999	Airbase
Maribor, SI	130	35	131	58		18	39	1	1997–1999	Airbase
Barcelona, ES	2626	32	172	37		10	55	1	1999–2000	Ajunt. Bcn/GenCat
Madrid, ES	2976	32	177	35		19	63	1	2001	Ayto. Madrid
Bilbao, ES	551	32	122	48		18	50	1	1999	Airbase-Gen. Val.
Sevilla, ES	679	36	224		49	13	52	1	1999	Airbase
Valencia, ES	749	27	117	56		11	57	1	1999–2000	Airbase
Zaragoza, ES	598	24	115		25	15	50	1	1999	Airbase
Stockholm, SE	880	52	137		30	3	39	1	1999	Airbase
Zurich, CH	921	37	185		29	7	38	1	1999	Airbase
Geneva, CH	439			29		8	38	1	1995–1998	Wri-Ceroi
Kiev, UA	2646			229		71	155	4	1998	CEROI
Birmingham, UK	1008	36	126		22	8	30	1	2000	NETCEN

Table 3 *(Continued)*

City name	City Popul. ($\times 10^3$)	O_3 MAC[b] ($\mu g/m^3$)	Max 1 h[c] ($\mu g/m^3$)	TSP MAC ($\mu g/m^3$)	PM_{10} MAC ($\mu g/m^3$)	SO_2 MAC ($\mu g/m^3$)	NO_2 MAC ($\mu g/m^3$)	WB/ CE[d]	Years of data	Sources
Glasgow, UK	680	33	116		28	10	53	1	2000	NETCEN
Leeds, UK	724	40	158		23	8	37	1	2000	NETCEN
Liverpool, UK	1409	51	120		24	7	35	1	2000	NETCEN
London, UK	10 570	30	154		28	8	51	1	2000	NETCEN
Manchester, UK	2320	28	110		28	10	33	1	2000	NETCEN
Newcastle, UK	284	25	150		17	7	29	1	2000	NETCEN
Sheffield, UK	786	35	166		25	9	40	1	2000	NETCEN
America										
Montreal, CA	3320	40	254	21		12	35	1	1999–2000	NAPS/C.U.M.
Ottawa, CA	1057	41	183			10	23	1	1999	NAPS/GVRD
Toronto, CA	4319	44	229		20	11	52	1	1999	NAPS/Min.Env
Vancouver, CA	1823	31	209		15	6	56	1	1999	NAPS/Min.Env
Atlanta, US	2960		309		27	9	41	1	1999	EPA
Baltimore, US	2382		280		28	20	45	1	1999	EPA
Bergen, US	1278		244		27	14	53	1	1999	EPA
Boston, US	3228		207		24	17	49	1	1999	EPA
Buffalo, US	1189		205		20	20	36	1	1999	EPA
Charlotte, US	1162		254		27		34	1	1999	EPA
Chicago, US	7411		9		32	17	51	1	1999	EPA
Cincinnati, US	1526		219		27	23	36	1	1999	EPA
Cleveland, US	2202		221		29	17		1	1999	EPA
Columbus, US	1345		225		28	11		1	1999	EPA
Dallas, US	2676		264		26		30	1	1999	EPA
Denver, US	1623		181		20	11	38	1	1999	EPA
Detroit, US	4267		223		30	17	39	1	1999	EPA
Ft. Lauderdale, US	1255		197		16	9	21	1	1999	EPA
Ft. Worth, US	1361		294		20		32	1	1999	EPA
Hartford, US	1158		280		17	11	34	1	1999	EPA
Houston, US	3322		323		29	9	38	1	1999	EPA
Indianapolis, US	1380		217		22	14	34	1	1999	EPA
Kansas City, US	1583		215		29	9	23	1	1999	EPA
Los Angeles, US	8863		225		39	9	66	1	1999	EPA
Memphis, US	1007		258		24	11	47	1	1999	EPA
Miami, US	1937		205		23	3	23	1	1999	EPA
Middlesex, US	1020		270			14		1	1999	EPA
Milwaukee, US	1432		225		24	11	30	1	1999	EPA
Minneapolis, US	2539		168		24	6	30	1	1999	EPA
Nassau, US	2609		264		17	20	45	1	1999	EPA
New Orleans, US	1285		213		25	14	32	1	1999	EPA
New York, US	8547		272		24	26	70	1	1999	EPA
Newark, US	1916		246		30	17	55	1	1999	EPA
Norfolk, US	1443		254		20	17	32	1	1999	EPA

Table 3 *(Continued)*

City name	City Popul. ($\times 10^3$)	O_3 MAC[b] ($\mu g/m^3$)	Max 1 h[c] ($\mu g/m^3$)	TSP MAC ($\mu g/m^3$)	PM_{10} MAC ($\mu g/m^3$)	SO_2 MAC ($\mu g/m^3$)	NO_2 MAC ($\mu g/m^3$)	WB/CE[d]	Years of data	Sources
Oakland, US	2083		215		21	6	36	1	1999	EPA
Orange C., US	2411		225		41	6	55	1	1999	EPA
Orlando, US	1225		203		22	6	23	1	1999	EPA
Philadelphia, US	4922		258		25	17	43	1	1999	EPA
Phoenix, US	2238		213		44	9		1	1999	EPA
Pittsburgh, US	2385		246		16	29	39	1	1999	EPA
Ponce, US	3443				28			1	1999	EPA
Portland, US	1515		160		19			1	1999	EPA
Providence, US	1134		235		24	14	45	1	1999	EPA
Riverside, US	2589		260		43	6	47	1	1999	EPA
Rochester, US	1062		201		20	17		1	1999	EPA
Sacramento, US	1340		238		24	9	32	1	1999	EPA
Salt Lake City, US	1072		217		30	9	43	1	1999	EPA
San Antonio, US	1325		205		21			1	1999	EPA
San Diego, US	2498		197		28	9	39	1	1999	EPA
San Francisco, US	1604		166		25	6	39	1	1999	EPA
San Jose, US	1498		223		23			1	1999	EPA
San Juan, US	1836				29	11		1	1999	EPA
Seattle, US	2033		158		19	14		1	1999	EPA
St. Louis, US	1836		233		27	17	38	1	1999	EPA
Tampa, US	2068		219		26	14	24	1	1999	EPA
Washington, US	4223		240		21	20	39	1	1999	EPA
Mexico City, MX	15 048	72	546	201	52	46	55	2	2000	Cepis
Guadalajara, MX	2870	44			61	26	71	2	1999	Cepis
Monterrey, MX	2563	55			68	26	25	2	1999	Cepis
San José, CR	1186	34		101	18	160	31	3	2000	Cepis
San Salvador, SV	415	29		92	45		40	3	2000	Cepis
Guatemala, GT	1676	23		237	63		37	3	2000	Cepis
Tegucigalpa, HN	598	67		652	157		36	3	2000	Cepis
Managua, NI	608	22		279	65		22	4	2000	Cepis
Panama, PA	452	50		196	57		37	2	2000	Cepis
Cordoba, AR	1198			97			97	2	1991–1992	Cepis
Mendoza, AR	774			28		3	54	2	1998	WRI
Buenos Aires, AR	10 686			185			20	2	1998	Cepis
Rio de Janeiro, BR	10 181			139				2	1995	Cepis
Sao Paulo, BR	16 533		403	53		18	47	2	2000	Cepis-WRI
Santiago, CL	4230	31	351		77	12	51	2	1999–2000	Cepis- CONAMA
Bogotá, CO	6079	38	348		49	40	31	3	2000	DAMA
Guayaquil, EC	1508			127		15		3	1990–1995	WRI
Quito, EC	1298			238	74	47		3	1998	Cepis
Lima, PE	6415			176		39	92	3	2000	DIGESA
Montevideo, UY	1360			335		73	32	3	1999	Cepis

Table 3 *(Continued)*

City name	City Popul. ($\times 10^3$)	O_3 MAC[b] ($\mu g/m^3$)	Max 1 h[c] ($\mu g/m^3$)	TSP MAC ($\mu g/m^3$)	PM_{10} MAC ($\mu g/m^3$)	SO_2 MAC ($\mu g/m^3$)	NO_2 MAC ($\mu g/m^3$)	WB/CE[d]	Years of data	Sources
Caracas, VE	2784			53		33	57	2	1994–1995	WRI
Asia										
Beijing, CN	7362			377		90	122	3	1995	WRI
Chengdu, CN	3484			366		77	74	3	1995	WRI
Chongqing, CN	3123			320		340	70	3	1995	WRI
Guangzhou, CN	3918			295		57	136	3	1995	WRI
Harbin, CN	3597			359		23	30	3	1995	WRI
Liupanshui, CN	1844			408		102		3	1995	WRI
Quingdao, CN	5125					190	64	3	1995	WRI
Shanghai, CN	8206			246		53	73	3	1995	WRI
Shenyang, CN	4655			374		99	73	3	1995	WRI
Tianjin, CN	5804			306		82	50	3	1995	WRI
Wuhan, CN	3833			211		40	43	3	1995	WRI
Zibo, CN	2484			453		198	43	3	1995	WRI
Dalian, CN	3132			185		61	100	3	1995	WRI
Jinan, CN	3019			472		132	45	3	1995	WRI
Changchun, CN	2523			381		21	64	3	1995	WRI
Taiyuan, CN	2502			568		211	55	3	1995	WRI
Pinxiang, CN	2040			276		75		3	1995	WRI
Zhengzhou, CN	1999			474		63	95	3	1995	WRI
Kunming, CN	1942			253		19	33	3	1995	WRI
Guiyang, CN	1792			330		424	53	3	1995	WRI
Lanzhou, CN	1747			732		102	104	3	1995	WRI
Anshan, CN	1648			305		115	88	3	1995	WRI
Nanchang, CN	1646			279		69	29	3	1995	WRI
Urumqi, CN	1643			515		60	70	3	1995	WRI
Tbilisi, GE	1268			300		190	40	4	1998	CEROI
Hong Kong, HK	6190	32			54	18	61	1	2000	EPD
Ahmedabad, IN	3711			299		30	21	4	1994	WRI
Bangalore, IN	4799			123		23	13	4	1991	WRI
Bombay, IN	15 138			240		33	39	4	1994	WRI
Calcutta, IN	11 923			375		49	34	4	1994	WRI
Delhi, IN	9948			415		24	41	4	1994	WRI
Hyderabad, IN	5477			123		12	17	4	1994	WRI
Jaipur, IN	1483			283		9	28	4	1994	WRI
Kanpur, IN	2227			459		15	14	4	1994	WRI
Lucknow, IN	2078			463		26	25	4	1994	WRI
Madras, IN	6002			131		15	17	4	1994	WRI
Nagpur, IN	1851			185		6	13	4	1994	WRI
Pune, IN	2955			208		17	40	4	1991	WRI
Jakarta, ID	8621			271				4	1990	WRI
Teheran, IR	6830			248		209		3	1993	WRI

Table 3 *(Continued)*

City name	City Popul. ($\times 10^3$)	O_3 MAC[b] ($\mu g/m^3$)	Max 1 h[c] ($\mu g/m^3$)	TSP MAC ($\mu g/m^3$)	PM_{10} MAC ($\mu g/m^3$)	SO_2 MAC ($\mu g/m^3$)	NO_2 MAC ($\mu g/m^3$)	WB/CE[d]	Years of data	Sources
Kanazawa, JP	448			23		11	25	1	1994	WRI
Kawasaki, JP	1202			52		18	62	1	1994	WRI
Osaka, JP	10 609			43		19	63	1	1993–1994	WRI
Tokyo, JP	26 959			49		18	68	1	1993–1995	WRI
Yokohama, JP	3301					100	13	1	1995	WRI
Incheon, KR	2340			93		60	45	2	1995	WRI
Kwanjin, KR	1424			64		26	38	2	1995	WRI
Pusan, KR	4082			94		60	51	2	1994–1995	WRI
Seoul, KR	11 609			84		44	60	2	1995	WRI
Taegu, KR	2432			72		81	62	2	1995	WRI
Taejeon, KR	1285			68		44	39	2	1995	WRI
Ulsan, KR	758			99		89		2	1994	WRI
Georgetown, MY	220			130				2	1993	WRI
Kuala Lumpur, MY	1145			85		24		4	1990–1993	WRI
Manila, PH	8594			0		33		3	1993–1995	WRI
Singapore, SG	2987		181		31	22	30	1	2000	M. of Env–Sing.
Bangkok, TH	5876			100		18	39	3	1998	MSTE
Ankara, TR	3103			57		55	46	3	1995	WRI
Istanbul, TR	7784			66		120		3	1995	WRI
Izmir, TR	2018			81				3	1995	WRI
Oceania										
Melbourne, AU	3189	51	191		17	3	15	1	1999	NSW-EPA
Perth, AU	1220			45		5	19	1	1995	EPA-Victoria
Sydney, AU	3539		284	65				1	1998	NSW-EPA
Auckland, NZ	910			26		3	20	1	1995	WRI
Christchurch, NZ	313			34		6	17	1	1995	WRI

[a] Conversion factor: 1 ppm = 2710, 1950 and 2030 $\mu g/m^3$ SO_2, NO_2, and O_3, respectively, at 1 atm and 15 °C.

[b] MAC = mean annual concentration.

[c] Max 1 h = maximum annual 1-h concentration.

[d] WB/CE refers to World Bank Classification of Economies by Gross National Income. The groups are: high income, $9266 or more; upper middle income, $2996–$9265; lower middle income, $756–$2995; and low income, $755 or less.

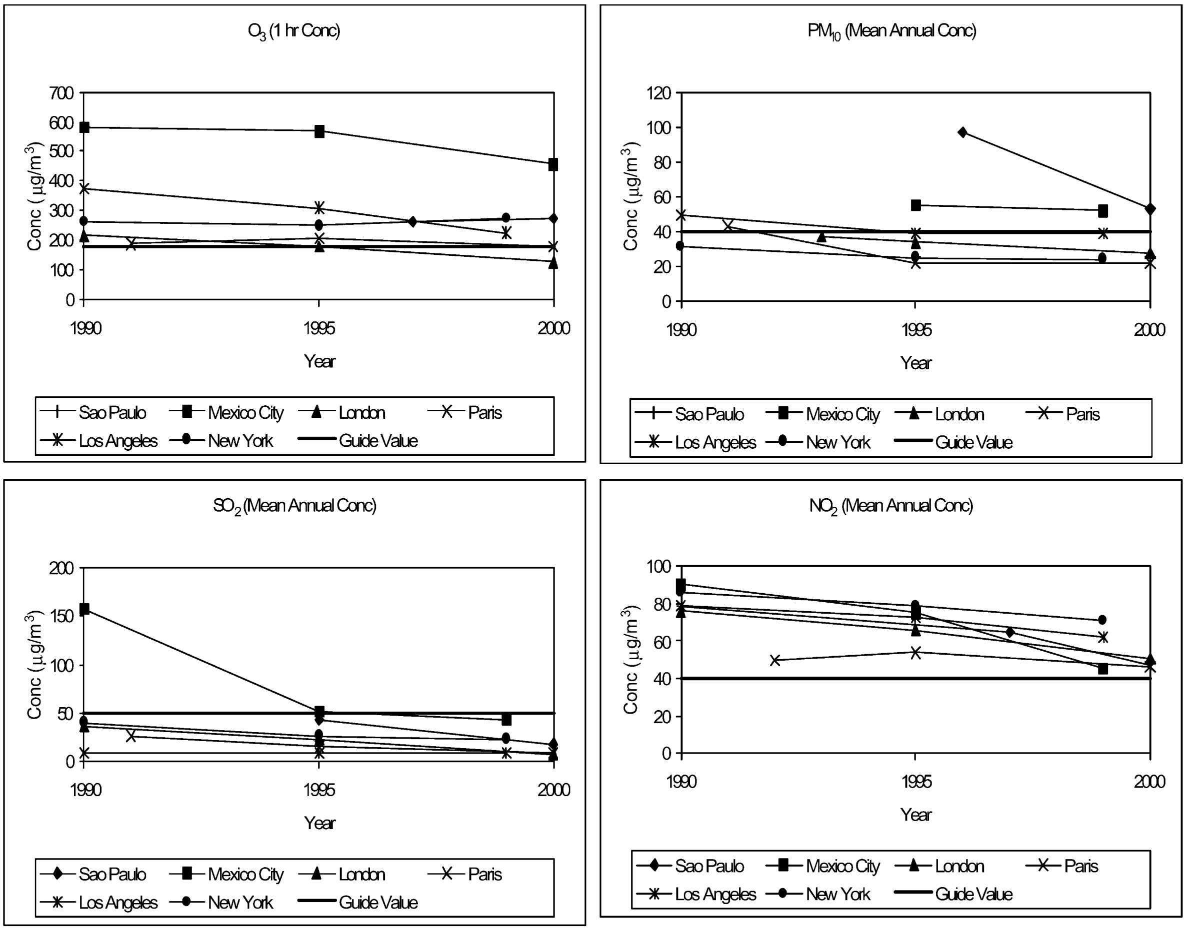

Fig. 13. Air quality tendencies in megacities.

6. Concentration trends in large cities

Fig. 13 shows the annual variation in pollutant concentrations in the selected large cities of the USA, EU and Latin America.

For ozone, it is clear that all of the mega-cities evaluated have figures that exceed the guideline value, except London in the year 2000. Mexico City levels are clearly the highest, maintaining a mark approximately 2.5 times the guideline value, albeit with a downward trend, like other cities such as London, Paris and Los Angeles. This is not the case with Sao Paulo or New York, which exhibit upward trends.

In the case of PM_{10}, it can be observed that the average annual values of Los Angeles, New York, London and Paris show a clear decline, staying below the guideline value in recent years. Mexico City and Sao Paulo also exhibit downward concentration trends, though they exceed the EU limit value of 40 $\mu g/m^3$.

Fig. 13 also shows annual variations in SO_2 concentration for the selected large cities of the US, Latin America and the EU. In all of these areas, it is clear that the average annual values for the cities selected are declining, falling or remaining below the WHO guideline value (50 $\mu g/m^3$).

The annual trends for the NO_2 concentration in the selected cities, are downwards although they remain higher than the WHO guideline value (40 $\mu g/m^3$).

7. Conclusions

In this paper, part of the vast and widely dispersed information on air quality that is available at this time on the Internet was compiled. An important aspect to bear in mind when managing information is careful examination of measurements, the discarding of corrupt or bad quality data and the corresponding homogenization of records before the comparison of the results, as well as necessary harmonization of methods and periods of measurements.

The current state of air quality worldwide indicates that SO_2 maintains a downward tendency throughout the world, with the exception of some Central American and Asian cities.

NO_2 maintains levels very close to the WHO guideline value throughout the world. However, in certain cities such as Kiev, Beijing and Guangzhou the figures are approximately three times higher than the WHO guideline value.

Particulate matter is a major problem in almost all of Asia, exceeding 300 $\mu g/m^3$ in many cities, like two Latin-American cities, Tegucigalpa and Montevideo. In the Asian databases consulted, only Japan showed really low figures.

Ground-level ozone presents average values that exceed the selected guideline values in all of the analysis by regions, income level and number of inhabitants, demonstrating that this is a global problem with consequences for rich and poor countries, large and medium cities and all the regions.

In general, the worldwide tendency is to reduce the concentrations of pollutants owing to the increasingly strong restrictions which local governments and international organizations impose. However, in poor countries and those with low average incomes, concentrations of air pollutants remain high and the tendency will be to increase their emission levels as they develop, making the problem worse.

Acknowledgments

This paper was made possible thanks to the EUROTRAC-2 SATURN and GENEMIS subprojects, IMMPACTE project from the Generalitat de Catalunya, REN2000-1020-C02-02/CLI from Spanish Government and Mutis Scholarship Program of Agencia Española de Cooperación Internacional (AECI). Special thanks to Pedro Jiménez for the review of the English manuscript.

Appendix A: Databases:

Airbase (2002). European Topic Centre of Air Quality (ETCAQ). http://www.etcaq.rivm.nl/databases/airview.html. Data downloaded in September 2001.

AIRAQ (2002). Association pour la Surveillance de la Qualité de l'Air en Aquitaine, France. www.airaq.asso.fr. Data Downloaded in February 2002.

AIRBREIZH (2002). Association Régionale de Surveillance de la Qualité de l'Air en Bretagne. Website: http://www.airbreizh.asso.fr. Data downloaded in February 2002.

AIRMARAIX (2001). L'association Airmaraix, Marseille, France. Website: http://www.airmaraix.com/. Data downloaded in July 2001.

AIRNORMAND (2002). Association pour la Mise en Oeuvre du Réseau d'Etude, de Mesure et d'Alarme pour la Prévention de la Pollution Atmosphérique de la Basse-Seine. Website: http://www.airnormand.asso.fr. Data downloaded in February 2002.

AIRPARIF (2002). Surveillance de la qualité de l'air en Ile-de-France. Website: http://www.airparif.asso.fr/english/polluants/default.htm. Data downloaded in October 2001.

Ajunt. Bcn (2001). L'Ajuntament de Barcelona, Anuari Estadístic de la Ciutat de Barcelona. 2001. Website: http://www.bcn.es/estadistica/catala/dades/anuari/cap01/index.htm. Data downloaded in July 2001.

ASCOPARG (2002). Association pour le Contrôle et la Préservation de l'Air dans la Région

Grenobloise. Website: http://www.atmo-rhonealpes.org. Data downloaded in February 2002.

AIRPL. AIR PAYS DE LA LOIRE (2002). Réseau de Surveillance de la Qualité de l'Air des Pays de la Loire. Website: http://www.airpl.org. Data downloaded in February 2002.

ASPA (2002). Association pour la Surveillance et l'Etude de la Pollution Atmosphérique en Alsace. Website: http://www.atmo-alsace.net. Data downloaded in February 2002.

Ayto. Madrid (2001). Ayuntamiento de Madrid. Sistema de Información Medioambiental. Website: http://195.76.84.11/historicos/Ficheros/index.cfm. Data downloaded in July 2001.

CUM (2001) Communauté Urbaine de Montréal. Rapport annuel de la qualité de l'air 2000. Website: http://www.rsqa.cum.qc.ca/framrsqf.htm. Data downloaded in September 2001.

CEPIS (2001) Centro Panamericano de Ingeniería Sanitaria. Website: http://www.cepis.ops-oms.org/. Data downloaded in July 2001.

CEROI (2001) Cities Environment Reports On the Internet. Website: http://www.ceroi.net/. Data downloaded in July 2001.

CMC (2001) Cape Metropolitan Council. Website: http://www.capetown.gov.za/soe. Data downloaded in June 2001.

CONAMA (2001) Comisión Nacional del Medio Ambiente Región Metropolitana, Santiago, Chile. Website: http://www.conama.cl/rm/. Data downloaded in July 2001.

COPARLY (2001) Comité pour le contrôle de la Pollution Atmosphérique dans le Rhône et la région Lyonnaise, Lyon, France. Website: http://www.atmo-rhonealpes.org/coparly/. Data downloaded in July 2001.

DIGESA (2001) Dirección General de Salud Ambiental. Lima, Perú. Website: http://www.digesa.sld.pe/aire/index.html. Data downloaded in July 2001.

EEA (2001) European Environment Agency. The Air Quality Monitoring Situation in Europe. State and Trends. Website: http://reports.eea.eu.int/92-9167-058-8/en. Data downloaded in July 2001.

Env.Can (2001) Minister of the Environment. Website: http://www.ec.gc.ca/air_e.html. Data downloaded in July 2001.

EPA (2001) Environmental Protection Agency. Website: http://www.epa.gov/airtrends/. Data downloaded in October 2001.

EPA-Victoria (2001) Environment Protection Authority Victoria. Melbourne, Australia. Website: http://www.epa.nsw.gov.au/. Data downloaded in July 2001.

EPD (2001). Environmental Protection Department, Hong Kong. Website: http://www.info.gov.hk/epd/. Data downloaded in July 2001.

ETCAQ (2001) Air-Europe's Environment: The Dobris Assessment (Chapter 04) Air quality in large European cities. EEA. Website: http://reports.eea.eu.int/C4I92-826-5409-5/en. Data downloaded in July 2001.

GenVal (2001) Generalitat Valenciana. Valencia, España. Website: http://gva.es/coma/Educacion_Calidad_Ambiental/. Data downloaded in July 2001.

GenCat (2001) Generalitat de Catalunya. La calidad del aire en Cataluña. Evolución de los niveles de la calidad del aire. Website: http://www.gencat.es/mediamb/aire/pdf/caire99-4.pdf. Data downloaded in July 2001.

GRID (2001) Global Resource Information Database of United Nations Environment Programme (UNEP). Website: http://www.grida.no/index.htm. Data downloaded in July 2001.

GVRD (2001) Greater Vancouver Regional District. Website: http://gvrd.bc.ca/services/air. Data downloaded in July 2001.

M. of Env-Sing. (2001) Ministry of the Environment, Singapore. Website: http://www.env.gov.sg/cop/pad/AR2000/overview.htm. Data downloaded in July 2001.

MATE (2001). Ministère de l'Aménagement du Territoire et de l'Environnement du France. Website: http://www.environnement.gouv.fr/dossiers/air/bilans. Data downloaded in October 2001.

Ministry of Environment Canada (2001). Website: http://www.msc.ec.gc.ca/aq_smog/index_e.cfm. Data downloaded in July 2001.

Ministry of Environment Ontario (2001), Canada. Website: http://www.airqualityontario.com/. Data downloaded in July 2001.

MSTE (2001). Ministry of Science, Technology and Environment, Pollution Control Department, Thailand. Website: http://www.pcd.go.th/. Data downloaded in July 2001.

NAPS (2002). National Air Pollution Surveillance Network. Environment Canada. Website: http://www.etcentre.org/main/e/pubs/NAPS/naps_lib_99.html. Data downloaded in February 2002.

NERI (2001). National Environmental Research Institute, Denmark. Website: http://www.umweltbundesamt.de/whocc/NL21/geerna1.htm. Data downloaded in July 2001.

NETCEN (2001) UK National Environmental Technology Centre, National Air Quality Information Archive Website: http://www.aeat.co.uk/netcen/airqual/welcome.html. Data downloaded in September 2001.

NSW-EPA (2001). Environment Protection Authority New South Wales, Sidney, Australia. Website: http://www.epa.nsw.gov.au/soe/. Data downloaded in July 2001.

OECD (2001). Organisation for Economic Cooperation and Development. Environmental information system in the Russian Federation: an OECD assessment. Website: http://www.md.mos.ru/eng/index.htm. Data downloaded in July 2001.

OECD (2001). Organization for Economic Cooperation and Development Website: http://www.oecd.org/dac/indicators/. Data downloaded in July 2001.

ORAMIP (2002). Observatoire Régional de l'Air en Midi-Pyrénées. Website: http://www.oramip.org. Data downloaded in February 2002.

QUALITAIR (2002). Association agréée pour la Surveillance de la Qualité de l'Air des Alpes-Maritines, des Alpes de Haute-Provence et des Hautes-Alpes. Website: http://www.atmo-qualitair.net. Data downloaded in February 2002.

WB (2002). World Bank. Classification of economies. Website: http://www.worldbank.org/data/-databytopic/class.htm#Classification. Data downloaded in February 2002.

WB (2001). World Bank. Air Pollution, Table 3.13. Website: http://www.worldbank.org/data/wdi2001/pdfs/tab3_13.pdf. Data downloaded in September 2001.

WRI (2001). World Resource Institute. City Air Pollution 1990–95, Table 8.5. Website: http://www.wri.org/wri/facts/data-tables-population.html. Data downloaded in July 2001.

References

Central Pollution Control Board. National ambient air quality standards. Delhi, India. 1994. Website: http://envfor.nic.in/cpcb/cpcb.html. Data downloaded in February 2002.

European Environment Agency. Air Europe's environment. In: Stanners D, Bourdeau P, editors. The Dobris assessment, chapter 4 1995. Downloaded in February 2002, website: http://reports.eea.eu.int/92-826-5409-5/.

EU (1999). Council Directive 1999/30/EC relating to limit values for sulfur dioxide, nitrogen dioxide and lead in ambient air. Off J Eur Communities (OJ L 163 29.6.1999), pp. 14-30, 1999.

EU (2002). Council Directive 2002/3/EC relating to ozone in ambient air. Off J Eur Communities (OJ L 67, 9.3.2002), pp. 14-30, 2002.

Korc M, Farías F, Cerda R. El Proceso de fijación y revisión de normas de calidad del aire. OPS/CEPIS/PUB/00.50. Lima: CEPIS, 2000. Downloaded in February 2002, website: http://www.cepis.ops-oms.org/bvsci/E/fulltext/normas/normas.html.

Kukkonen J, Salmi T, Saari H, Konttinen M, Kartastenpää R. Review of urban air quality in Finland. Finnish Meteorological Institute. Boreal Environ Res 1999;4:55–65.

Ministère de l'Aménagement du Territoire et de l'Environnement du France. Bilan de la qualité de l'air dans les grandes agglomérations 1991–2000 les chiffres. 2001. Downloaded in January 2002, website: http://www.environnement.gouv.fr/dossiers/air/bilans/010116-bilan-air-91-2000.htm.

National Environmental Board. Ambient air standards of Thailand. Notification of National Environmental Board no. 10 (1992) under the Enhancement and Conservation of National Environmental Quality Act B.E.2535 (1992). Royal Government Gazette 1995;112(52):. B.E.2538.

Pang S, Ha K, She W, Luie P. Air pollution of Hong Kong. 92nd Annual Meeting and Exhibition International, Urban Environmental Infrastructure Forum. June 20–24. St. Luis, Missouri, USA: Air and Waste Management Association, 1999. (8 p).

Scholorling M. Urban transport and its compliance with future air quality standards. Sixth International Conference on-

Urban Transport and the Environment for the 21st Century. July 26–28, Cambridge, UK. 2000. (9 p).

USEPA. Latest findings on national air quality: 2000 status and trends. EPA report no. 454/K-01-002. Research Triangle Park, NC. 2001. Downloaded in February 2002, website: http://www.epa.gov/oar/aqtrnd00/.

Wangwongwatana S. Air pollution control strategies in Thailand. 92nd Annual Meeting and Exhibition, International Urban Environmental Infrastructure Forum. June 20–24. St. Luis, Missouri, USA: Air and Waste Management Association, 1999. (22 p).

WHO. Sulfur oxides and suspended particulate matter, Environ Health Criteria, 8, Geneva, 1979.

WHO. Air quality guidelines for Europe. WHO regional publications, European series no. 23. Copenhagen: Regional Office for Europe, World Health Organization, 1987.

WHO. Air quality guidelines. Geneva: World Health Organization, 1999. Downloaded in February 2002, website: http://www.who.int/peh/air/Airqualitygd.htm.

United Nations Environment Programme and World Health Organization. Urban air pollution in megacities of the world. Oxford, UK: Blackwell Publishers, 1992.

UN. Demographic yearbook 1995. United Nations publication. 1995. Sales no. E/F.97.XIII.1, table 8. Downloaded in February 2002, website: http://www.un.org/Depts/unsd/demog/index.html.