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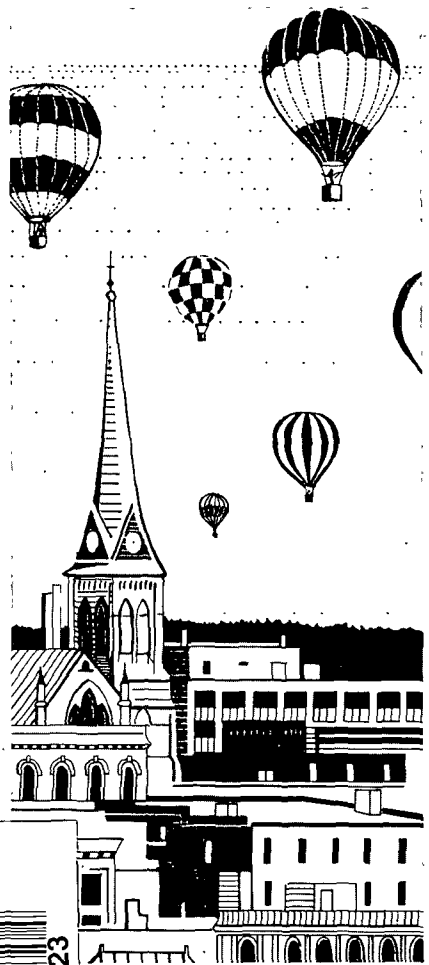

National Urban Air Quality Trends 1981-1990

Report EPS 7/UP/4
October 1994

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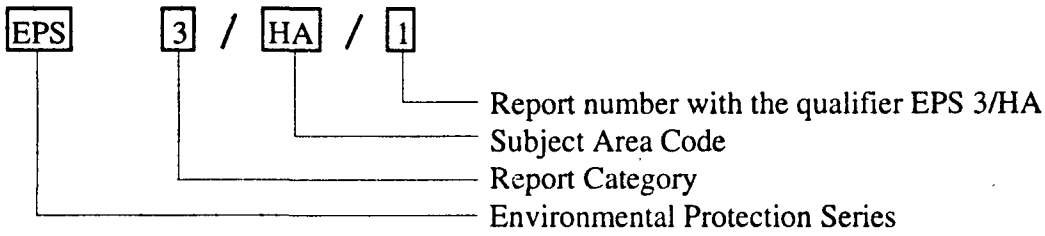

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National Urban Air Quality Trends 1981-1990

by

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This report has also been edited by the staff of the EPS Publication Unit, Technology Outreach Section.

Abstract

The air quality data analyzed in this report came from the National Air Pollution Surveillance (NAPS) monitoring network, which consists of air monitoring stations in most Canadian cities with populations of over 100 000. The periods for which these data are available and the contaminants to be considered are:

- *sulphur dioxide, 1974 to present*
- *nitrogen dioxide, 1977 to present*
- *carbon monoxide, 1974 to present*
- *ozone, 1979 to present*
- *suspended particulate, 1974 to present*
- *lead, 1974 to present*
- *soiling index, 1974 to present*

In this report, monitoring data have been analyzed to determine national trends in average and peak concentrations of these contaminants annually from 1981 to 1990. Data have also been compared with the National Ambient Air Quality Objectives, which define three levels of contaminant concentration: Maximum Desirable, Maximum Acceptable, and Maximum Tolerable.

The NAPS data represent pollution levels at individual sampling sites and may not necessarily represent community-wide air quality. Community-wide comparisons can only be made by using data from all available sampling stations within a city, and interpreting these data on the basis of specific sampling and site characteristics.

The annual mean concentrations have been derived as arithmetic means for all contaminants except suspended particulate matter and particulate lead, where geometric means have been used.

Résumé

Les données sur la qualité de l'air analysées dans le présent rapport proviennent du Réseau national de surveillance de la pollution atmosphérique (RNSPA), qui exploite des stations de surveillance dans la plupart des villes canadiennes de plus de 100 000 habitants. Voici les polluants visés ainsi que les dates à partir desquelles on dispose de données les concernant :

- *anhydride sulfureux, 1974;*
- *dioxyde d'azote, 1977;*
- *monoxyde de carbone, 1974;*
- *ozone, 1979;*
- *particules en suspension, 1974;*
- *plomb, 1974;*
- *indice d'opacité, 1974.*

Dans le présent rapport, on a analysé les données de surveillance pour déterminer l'évolution des concentrations moyennes et maximales de ces polluants à l'échelle nationale, sur une base annuelle, de 1981 à 1990. On a aussi comparé ces données aux objectifs nationaux de qualité de l'air ambiant, qui définissent trois niveaux de concentration : le maximum souhaitable, le maximum acceptable et le maximum admissible.

Les données fournies par le RNSPA correspondent aux niveaux de pollution mesurés sur les lieux d'échantillonnage et peuvent ne pas refléter nécessairement la qualité de l'air dans l'ensemble d'une agglomération. Les comparaisons à l'échelle des agglomérations ne sont possibles que si l'on utilise les données de toutes les stations d'échantillonnage de chaque ville et qu'on interprète ces données en tenant compte des caractéristiques particulières d'échantillonnage et d'emplacement qui s'y rapportent.

Les concentrations moyennes annuelles sont exprimées sous forme de moyennes arithmétiques, sauf pour les particules en suspension et le plomb, pour lesquels on a utilisé les moyennes géométriques.

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Summary

The National Air Pollution Surveillance (NAPS) network, which is responsible for monitoring the quality of air, has undergone many refinements since its inception in 1970. Since the mid-1970s, the NAPS network has attained the size needed to show geographic and periodic variations in national urban air quality. The quality of the air is defined according to three levels of National Ambient Air Quality Objectives: desirable, acceptable, and tolerable. The "acceptable" level is that required for the protection of human health as well as the general environment, which includes vegetation, animals, soil, water and air quality.

Routine monitoring results from the NAPS (urban) network for the 1974-1990 period show considerable improvements in ambient air quality, as can be seen in the following tables.

Table S.1 Summary of Seven Pollutants Measured by NAPS Network

Pollutant	1990 Annual Mean Concentration		Percent Decline 1981 to 1990	Percent Decline 1974 to 1990
Sulphur Dioxide	6	ppb	21	53
Nitrogen Dioxide	21	ppb	8	26
Carbon Monoxide	0.8	ppm	45	67
Total Suspended Particulate	38	$\mu g/m^3$	34	51
Particulate Lead	0.02	$\mu g/m^3$	93	96
Coefficient of Haze	0.29	COH	no change	24
Ozone	18	ppb	+20	NA

NA - not available for 1979 (NO_2 measurements started in 1977)

Table S.2 Percent of NAPS Stations Attaining the Acceptable (NAAQO) Level in 1974 and 1990

Pollutant	Annual Objective 1974 to 1990		1-hour Objective 1974 to 1990		8-hour Objective 1974 to 1990		24-hour Objective 1974 to 1990	
Sulphur Dioxide	82	99	87	88	-	-	85	88
Nitrogen Dioxide*	96	100	86	100	-	-	84	100
Carbon Monoxide	-	-	97	100	71	98	-	-
Ozone*			18	39	-	-	-	-
Total Suspended Particulate	51	100	-	-	-	-	N/A	N/A

- No objective
* For NO_2 and O_3 the attainment rate is compared to 1977 and 1979 respectively.

It should be noted that the ozone levels recorded in this report are based on measurements taken at ground level. This ground-level ozone has been used to assess adverse effects on human health and vegetation. However, the ozone in the stratosphere miles above the earth, which screens out harmful ultraviolet rays from the sun, is not discussed in this report.

This report also features data analysis techniques that assess the significance of long-term and year-to-year changes in both average and peak maximum-level pollutant concentrations. For example, for the 1981-1990 analysis period, the average concentrations of the following pollutants have shown significant improvement (at 99% confidence): carbon monoxide, lead, and total suspended particulate. Coefficient of haze, sulphur dioxide, and nitrogen dioxide have shown no change in the past decade, while the ozone annual mean has shown a significant increase (at 99% confidence) for the first time.

The national trends in this report are augmented with graphs showing emissions of five common pollutants and particulate lead as well as average pollutant levels in selected cities across Canada.

Section 1

Introduction

1.1 Purpose and Scope

This is the eighth in a series of reports issued by Environment Canada on ambient air quality trends. Its purpose is to report trends in the ambient air quality data collected through the National Air Pollution Surveillance (NAPS) Network and to identify significant changes by statistical and other forms of analysis. The report covers the monitoring results for the period from 1981 to 1990.

The NAPS program was initiated in January 1970 to provide a nationwide database for determining air quality in the major urban centres of Canada. The trends reports document the effects on the urban environment of changing industrial activity, fuel use patterns, population density, more extensive use of pollution control equipment and other factors. Air monitoring stations are maintained in most Canadian cities having populations greater than 100 000. Monitoring instruments are usually located at sites where air pollution could present a problem and where a large number of people could be affected. These sites are referred to as "monitoring stations" and are classified according to the primary land use in their location:

1. C = commercial,
2. R = residential, or
3. I = Industrial.

Guidelines have been established categorizing NAPS stations as Class I and Class II. The "Class I" network is the permanent national network of comprehensive monitoring stations that are operated over the long term. These sites were selected to represent areas of highest population exposed to the prevailing air quality. The "Class II" stations may be operated on a shorter term when and where there is a demonstrated need for monitoring. They are pollutant-oriented, but not necessarily source-oriented. Any comparison of data between stations must take these designations into account.

The contaminants monitored are: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), suspended particulate (SP), and lead (Pb). In addition, the soiling or darkening potential of particulate in the atmosphere is measured as the soiling index or coefficient of haze (COH). Measurements of dustfall and sulphation rates are also recorded by the network, but are not analyzed in this report.

Since 1974, the NAPS annual summaries have reported only the annual mean of a contaminant for a station that met a set of completeness criteria. For SO_2, NO_2, O_3, CO and COH, monthly or annual means are not calculated unless at least 50% of the hourly observations are available for the period concerned. Furthermore, the annual mean is not reported unless monthly means can be calculated for at least two months in each quarter. For suspended particulate and lead, a monthly mean is not reported in the NAPS annual summaries unless a minimum of three samples is available for that month. The conditions for reporting the annual geometric mean are a minimum of

40 samples in the year with at least eight valid samples for each quarter.

Beginning in 1985, the NAPS annual summary data for SO_2 and NO_2 were reported to an additional decimal place as recommended by the United States Environmental Protection Agency's "Quality Assurance Handbook for Air Pollution Measurement Systems, Vol. 1" (U.S. EPA, 1984). According to the U.S. EPA, calculated values can be reported to one decimal place more than the observed value.

1.2 Air Monitoring Program

When established in January 1970, the NAPS network had 40 monitoring instruments in 14 cities, measuring SO_2, SP, Pb, and COH. In December 1990, the number of instruments had stabilized at about 400 in 59 cities across Canada, and the list of contaminants monitored had expanded to include CO, NO_2 and O_3.* The growth of the network is illustrated in Figure 1, while Figure 2 shows the cities where monitoring instruments are located. To emphasize the relationship between the allocation of monitoring stations and population, Figure 2 includes a population density map. The Class I Stations, their addresses and current status are listed in Table 1.

A completed set of Class I stations will monitor all air quality objective parameters including fine particulate (such as coefficient of haze). Most of these stations are located in downtown or major residential areas with a potential for poor air quality, as specified in the site selection criteria.

1.3 National Ambient Air Quality Objectives

National Ambient air quality objectives (NAAQOs) have been established as guides in developing programs to reduce the damaging effects of air pollution (Federal-Provincial Committee on Air Pollution, 1976). These programs are designed to meet the following objectives:

1) assist in establishing priorities for reducing contaminant levels and determining the extent of pollution control needed;

2) provide a uniform measure for assessing air quality in all parts of Canada; and

3) indicate the need for and extent of monitoring programs.

The **maximum acceptable level** is intended to provide adequate protection against adverse effects of pollutants on humans, animals, vegetation, soil, water, materials, and visibility. The **maximum desirable level** defines the long-term goal for air quality and provides a basis for an anti-degradation policy in unpolluted areas of the country. The **maximum tolerable level** is determined by time-based concentrations of air contaminants. When air pollutants reach this level of concentration, appropriate action is required without delay to protect the health of the general population. Desirable, acceptable, and tolerable levels of the contaminants for the different averaging times in the present analysis are presented in Table 2. Examples of the effects of pollutants in the air quality objective ranges are presented in Table 3.

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* Another 52 instruments were used to measure dustfall and sulphation rate, but these particular indicators of air pollution are not dealt with in this report.

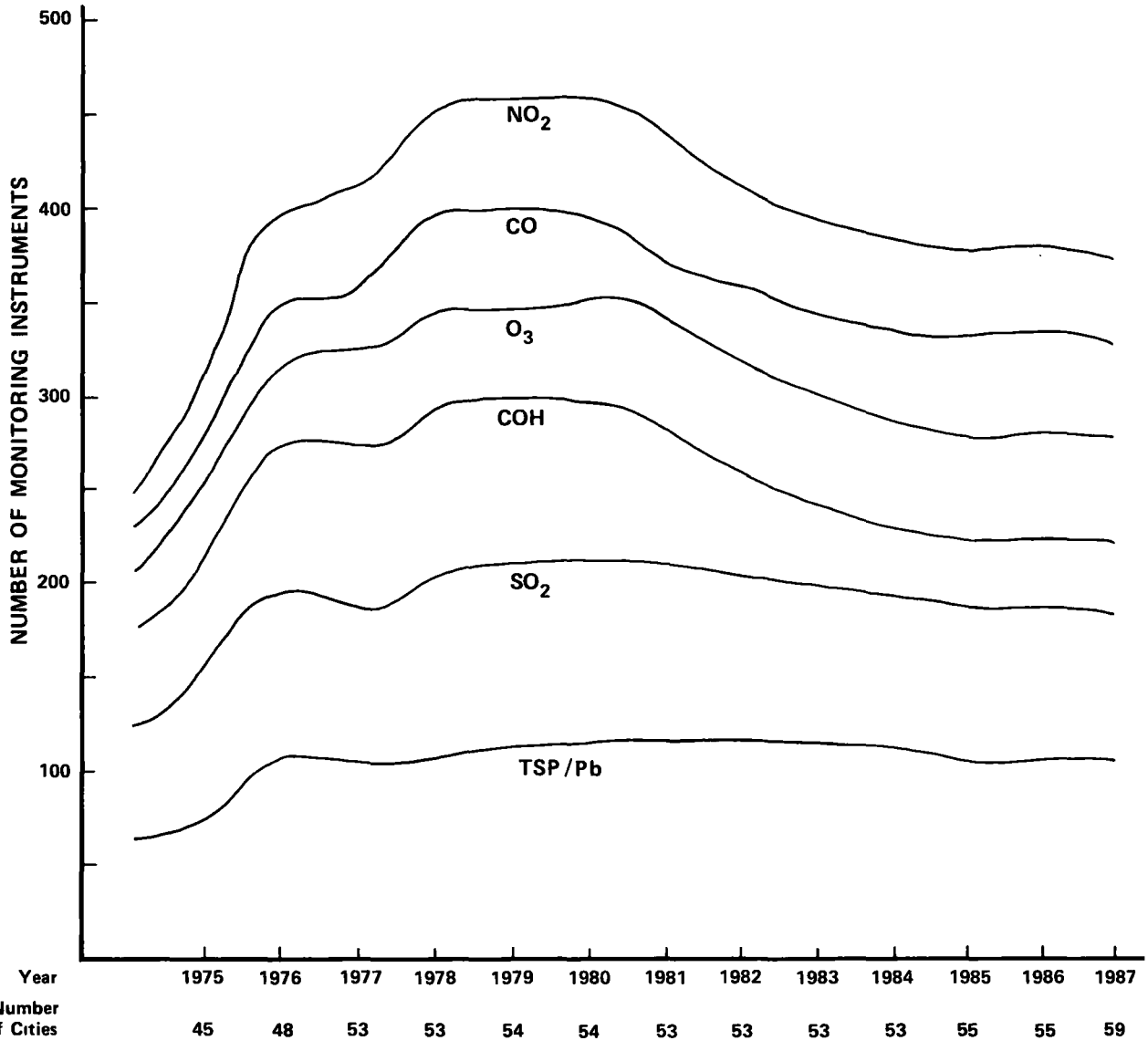


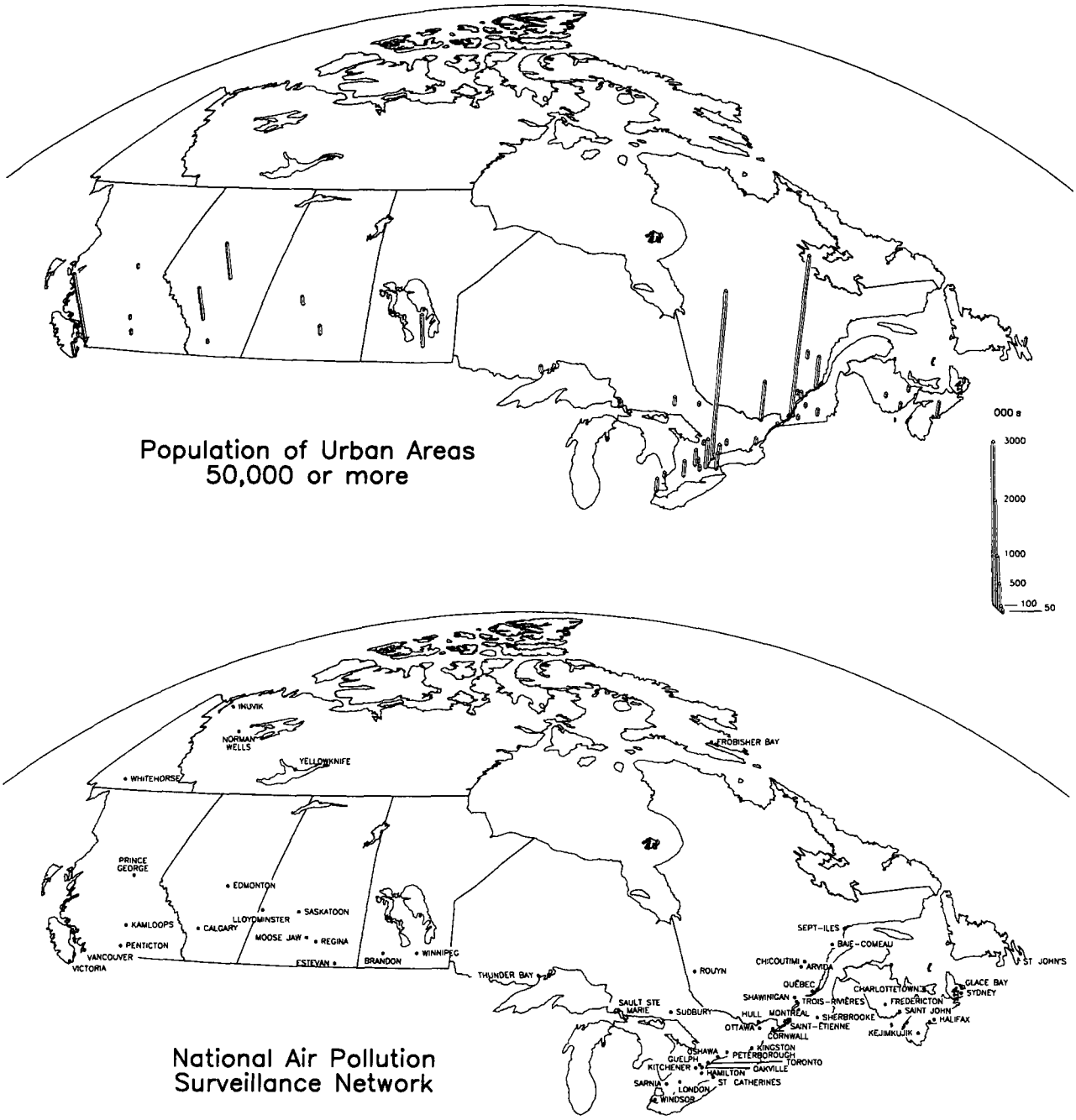
Figure 1 Profile of NAPS Network Instrumentation (1974 to 1987)

1.4 Analytical Methods

1.4.1 Typical Pollutant Levels in Selected Cities

Cities with Class I stations were selected for this analysis because these stations are designed to monitor air pollution over the long term and therefore offer a measure of consistency in the number of pollutants measured, the location of the site, and the size of population, which is usually greater than 250 000.

In this analysis, all available stations in the city were used to determine the city annual mean values for the period from 1986 to 1990. The range then is the highest and lowest annual mean value, while the average city level represents the composite average of the five-year means. Where data are not sufficient to determine the five-year average, an annual mean value or a peak level was



Source 1981 Census of Canada
Maps produced by the Geocartographics Subdivision and the Environmental Statistics Unit Statistics Canada 1987

Figure 2 National Air Pollution Surveillance Network (March, 1987)

Table 1 National Air Pollution Surveillance Class I Stations (status as of December 31, 1987)

City	Station	Location	Comments
Newfoundland			
St John's	10101C	Duckworth and Ordinance	no O_3 or NO_2 monitors
Nova Scotia			
Halifax	30116C	Barrington and Duke	high-volume sampler located at site 30101C
New Brunswick			
Saint John	40202C	Post Office	high-volume sampler located at site 40201C
Quebec			
Montreal	S011SC	Metcalfe and Maisonneuve	
	50116R	3161 Joseph, Verdun	
	50102R	Jardin Botanique	no soiling index monitor
	50109C	Duncan and Decarie	
	50112C	Boul Laurentides	no soiling index monitor
	50110C	Parc Pilon, Montreal-Nord	
	50119R	1700 Bourassa, Longueuil	no soiling index monitor
Hull	50203R	Gamelin and Joffre	no O_3 monitor
Quebec City	50307C	Parc Cartier-Brébeuf	no soiling index monitor
Ontario			
Ottawa	60101C	88 Slater St	
	60104R	Rideau and Wurtemburg	
Windsor	60204C	471 University Ave.	
Toronto	60417C	26 Breadalbane St	
	60403I	Evans and Arnold	
	60410R	Lawrence and Kennedy	
	60415R	Queensway W and Hurontario	no soiling index monitor
	60402R	Don Mills, Science Centre	no soiling index monitor
	60413R	Elmcrest Road	
Hamilton	60501C	Barton and Sanford	
London	60901C	King and Rectory	
St Catharines	61301C	North and Geneva	
Kitchener	61501C	Edna and Frederick	no soiling index monitor
Manitoba			
Winnipeg	70119C	65 Ellen St	
	70118R	Jefferson and Scotia	
Saskatchewan			
Regina	80109C	1620 Albert St	no soiling index monitor
Alberta	90130C	10255-104th St.	no SO_2 analyzer
Edmonton	90122R	127 Street and 29th Avenue, N.W	no SO_2 analyzer
Calgary	90227C	1611 4th Street S W	high-volume sampler located at site 90204C
	90222R	39 Street and 29th Avenue N.W	no SO_2 analyzer
British Columbia	00112C	Robson and Hornby	high-volume sampler located at site 00109C
Vancouver	00106R	2294 West 10th Ave	no SO_2 analyzer
	00108I	250 West 70th Ave	
	00110R	E. Hastings and Kensington	
	00111I	Rocky Pt Park	
	00303C	125 Quadra St	
Victoria			

Note As of December 1987, there were no COH monitors in the Atlantic Region

Table 2 National Ambient Air Quality Objectives

Pollutant	Averaging Time	Maximum Desirable Concentration	Maximum Acceptable Concentration	Maximum Tolerable Concentration
Sulphur Dioxide	annual	11 ppb	23 ppb	-
	24-hour	57 ppb	115 ppb	306 ppb
	1-hour	172 ppb	344 ppb	-
Suspended Particulate	annual	60 $\mu g/m^3$	70 $\mu g/m^3$	-
	24-hour	-	120 $\mu g/m^3$	400 $\mu g/m^3$
Ozone	annual	-	15 ppb	-
	1-hour	50 ppb	82 ppb	153 ppb
Carbon Monoxide	8-hour	5 ppm	13 ppm	17 ppm
	1-hour	13 ppm	31 ppm	-
Nitrogen Dioxide	annual	32 ppb	53 ppb	-
	24-hour	-	106 ppb	160 ppb
	1-hour	-	213 ppb	532 ppb

* Conditions of 25°C and 101 32 kPa are used as the basis for conversion from $\mu g/m^3$ to ppm or ppb.

chosen (without a range) to approximate an average pollutant level for the community.

Annual average levels are presented for TSP, Pb, NO_2, SO_2, COH, and CO, while averages of peak concentrations are used for ozone. The method used to represent the average value and the range of values for a specific sample is illustrated in Figure 3.

In this example, City 2 and City 3 have the same five-year average level for NO_2, although City 3 has a much wider range of annual mean concentrations. The highest city five-year average level of NO_2 in this example has been measured in City 4. For City 1, however, there was not enough data available to determine the five-year average or an accurate range. A blank in the graph indicates that the pollutant was not monitored in that particular city. This method of illustrating typical city pollutant levels and ranges will be used for each pollutant.

1.4.2 Tukey's Multiple Comparison Test

This type of analysis is simply a trend line composed of composite averages with their associated 95% confidence intervals. These intervals allow comparisons to be made between any two years in the analysis period. A significant change between years is indicated where the confidence intervals do not overlap. With Tukey's Test, the confidence intervals are wide enough to compare the largest and smallest (yearly) averages in the analysis period with only a

Table 3 Examples of Types of Effects Used as Break Points [a,b]

National Ambient Air Quality Objectives Averaging Times	Carbon Monoxide[c] CO (1-hour, 8-hour)	Nitrogen Dioxide NO_2 (1-hour)	Ozone O_3 (1-hour)	Sulphur Dioxide SO_2 (1-hour, 24-hour)	Total Suspended Particulate[d] (24-hour)
Beyond Tolerable (Very Poor Range)	Physiological stress on individuals with cardiovascular and respiratory disease, possibly increased mortality	Increasing sensitivity in patients with asthma and bronchitis	Impairment of respiratory function, increased respiratory symptoms	Hypersensitive individuals may experience breathing difficulties, increased morbidity	Increasing sensitivity in patients with asthma and bronchitis
Maximum Tolerable (Poor Range)	Increasing cardiovascular symptoms in nonsmokers with heart disease Some visual impairment	Increased rate of respiratory illness from long-term exposure Odour and atmospheric discoloration	Decreasing performance by some athletes exercising heavily	Increasing sensitivity in patients with asthma and brochitis Odorous Increasing vegetation damage and sensitivity	Visibility decreased Soiling evident Increased frequency and severety of lower respiratory disease in children
Maximum Acceptable (Fair Range)	Increasing cardiovascular symptoms in smokers with heart disease Blood chemistry changing	No known human health effects	Increasing injury to some species of vegetation	Increasing (foliar) injury to some species of vegetation	Decreased visibility
Maximum Desirable (Good Range)	No effects	No objective	Materials are affected by ambiant air levels of oxidants	No effects	No objective

[a] Examples extracted from the National Ambient Air Quality Objectives published from 1974 to 1978

[b] Health Canada and Environment Canada advise that the matrix is provided as an example only and does not represent the full nature or extent of the health and environmental effects

[c] In order to protect all sensitive groups of the population, ambient concentrations of CO should be such that COHb levels do not exceed 5% saturation in nonsmokers

[d] The levels do not apply to chemically active particles

5% chance of falsely indicating a significant change.

The confidence intervals are calculated from an analysis of variance (ANOVA) of the concentration (means or peak concentrations) of interest for each pollutant at each site for the 10-year period. In this analysis, the set of stations must be the same for all years. This condition was met by using only stations that had valid data for at least seven of the 10 years. Any missing values were filled in by substituting estimated values. This treatment of the data should explain any differences in annual mean levels that occur between Tukey's Test results and the box plot analysis that is based on all network stations. For the box plots the data set is not modified (with no stations removed and no missing values filled in) because data completeness over 10 years is not required. An example of the plotting convention is shown in Figure 4. A more complete explanation of the method can be

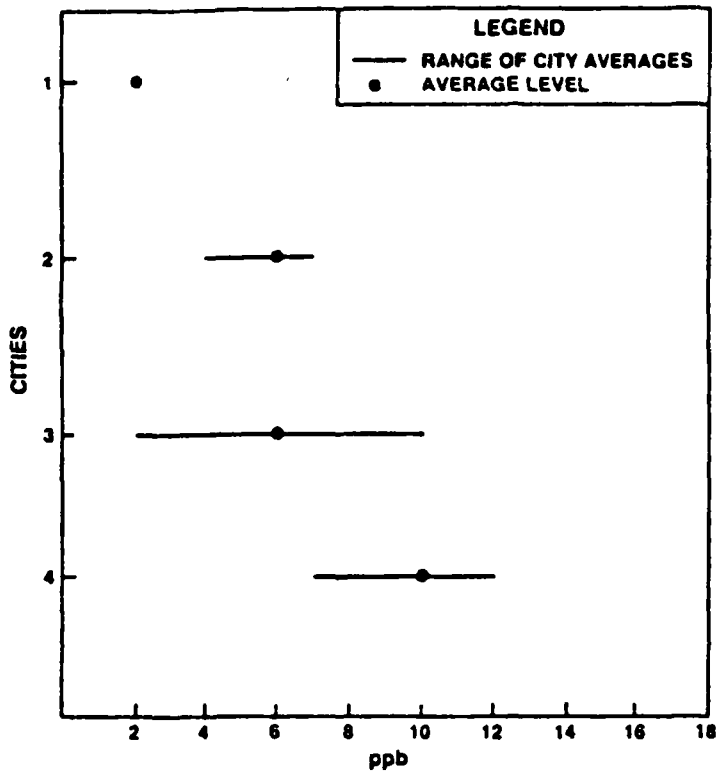


Figure 3 Sample of Plotting Method: Pollutant Concentration

found in a previous report (Environment Canada, 1986).

1.4.3 Long-term Trend Analysis (Linear Regression)

Tukey's Test is intended to be used for comparing the mean of one year to the mean of another. To test the significance of the long-term or 10-year trend, a linear regression analysis was performed on the mean data (on the same data set used for Tukey's Test) to determine whether the slope of the line was significantly greater or less than zero. The results of the linear regression analysis are presented in Table 4.

The 98th percentile of the hourly, eight-hour, or 24-hour running average concentration corresponds to the 175th out of 8760 readings taken by a continuous monitor in a year. This is the level that is exceeded by less than seven days per year. It is used to indicate year-to-year changes in high pollutant emission levels near a monitoring station while filtering out such variable factors as weather or measurement problems.

The 99.9th-percentile concentration corresponds to the 9th highest reading in the yearly data record. In this report, it is used to indicate the severity of ozone episodes. Ozone is not emitted directly but is formed in the atmosphere, and the high levels experienced during pollution episodes occur under optimal weather conditions. Unlike the 98th percentile, ozone levels are more sensitive to yearly changes in hot summer weather.

1.4.4 Box Plot Analysis

The box plot is a graphic technique used in exploratory data analysis to show the distribution of the annual means for "All Stations" calculated for the various

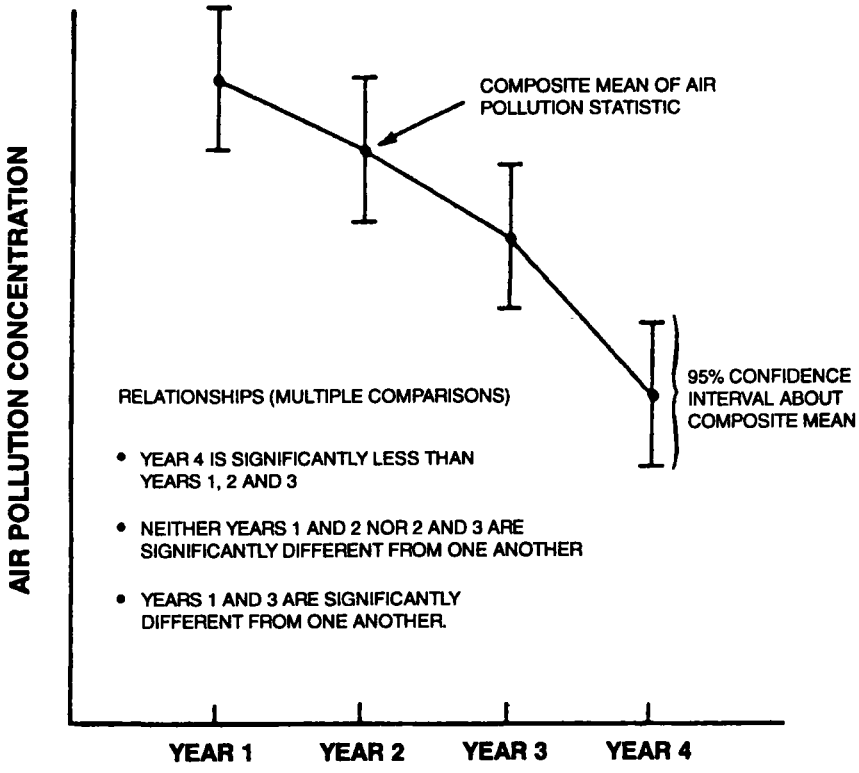


Figure 4 **Plotting Convention for Tukey's Multiple Comparison Test (Pollack, date unknown)**

Table 4 **Linear Regresssion Analysis for Long-term Trends (1981 to 1990)**

Pollutant	Indicator	10-year Average	Average Yearly Change
SO_2	Annual Mean	-	- 0.2
Total Suspended Particulate	Annual Mean	-	- 1.5*
NO_2	Annual Mean	6.5 ppb	- 0.2
Haze	Annual Mean	46.6 $\mu g/m^3$	- 0.003
Lead	Annual Mean	0.16 $\mu g/m^3$	- 0.03*
Ozone	Annual Mean	16.8 ppb	0.04*
Ozone	Peak Hourly	79.7 ppb	- 0.05
CO	Annual Mean	0.98 ppm	- 0.06*
CO	Peak Hourly	4.0 ppm	- 0.24*

* significant change at 99% confidence

contaminants. The plotting convention for the box plot is shown in Figure 5.

For a given contaminant, the annual averages (or geometric means in the case of suspended particulate and lead) for all stations are grouped and ranked.* The percentiles indicate the percentage of stations with annual averages less than the specific levels identified. In addition to the percentiles (10, 25, 50, 75, and 90), the annual average of "All Stations" for the pollutant in a given year is also displayed. The annual trends at the favorable (10- to 25-percentile), average (mean, median or 50-percentile), and unfavorable (75- and 90-percentile) stations, therefore, can be analyzed separately (see Appendix, Table J).

1.4.5 Analysis with Respect to National Ambient Air Quality Objectives

A third type of analysis used is based on the percentages of station data meeting or exceeding the NAAQOs in each year of the analysis period. This type of analysis is crude because it is insensitive to movement within the particular air quality ranges. For example, all stations recording an annual mean for a particular contaminant may experience a change in the mean concentration from one year to the next. If none of the annual means drops below a particular objective, this type of analysis would indicate no change.

This analysis is also insensitive to the number of times that an objective level is exceeded, particularly with regard to the short-term air quality objectives (one-hour, eight-hour, 24-hour). A single occurrence will register a station as exceeding a particular level, be it desirable, acceptable, or tolerable, even though this may be one in several thousand readings taken at that station. In Table 5, the one-hour desirable level for carbon monoxide (13 ppm) has been exceeded at five Toronto stations; the acceptable level (31 ppm) has been exceeded at one of these stations. If a comparison is made between station 60416C and 60401C, approximately 4.0% of the readings at station 60416C exceed the desirable level, whereas 0.4% of the readings at the other station exceed this same level. This type of analysis tends to identify potential air quality problems at specific sites. Consequently, NAAQO analysis is used more in a supportive role to substantiate the preceding types of analysis. For the same reason as in the box plot analysis, all stations have been used in calculating the percentage of stations with readings meeting or exceeding NAAQOs (Table 5).

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* All available stations were used in each year, and so the set of stations changes somewhat from year to year. This could possibly bias the annual average or percentiles calculated, distorting actual trends. To account for this, averages and percentiles were calculated for data from All Stations and Class I Stations. Values and corresponding trends for both were found to be similar. Consequently, because the total NAPS network provides a more representative national sample, data from all stations have continued to be used in the analysis.

Table 5 Comparison of Station Readings for Carbon Monoxide

Station	Location	One-hour Average CO, 1981		
		>Desirable	>Acceptable	Total Readings
60401C	67 College St.	14	0	3476
60402R	Don Mills, Science Centre	0	0	8105
60403I	Evans and Arnold	0	0	8387
60410R	Lawrence and Kennedy	1	0	8450
60412R	Bathurst and Wilson	1	0	8516
60413R	Elmcrest Road	0	0	7149
60414I	Sherbourne and Wilton	0	0	8299
60415R	Queensway W. and Hurontario	8	0	8607
60416C	381 Yonge St.	293	17	8481
60417C	26 Breadalbane	0	0	4297

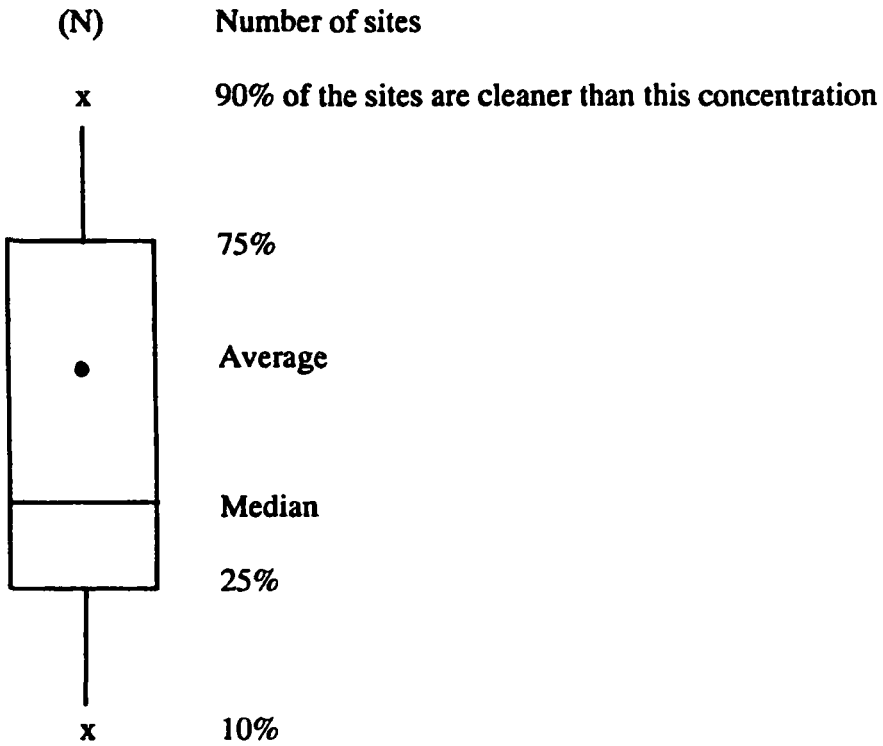


Figure 5 Concentration Box Plotting Levels

Section 2

Sulphur Dioxide

Sulphur dioxide (SO_2) is a colourless gas and normally is not present in urban air at concentrations high enough for its heavy, pungent odour to be detected. It is emitted into the atmosphere from industrial processes such as the smelting of non-ferrous metals, and from the combustion of fuels such as coal or heavy oil, which may have a high sulphur content. Sulphur dioxide is a major pollutant that adversely affects health, vegetation, and materials (see Tables 2 and 3).

From Figure 6, it is apparent that in many provinces industrial processes account for most of the SO_2 emissions. Fuel combustion is the second largest source of SO_2 emissions, with thermal power being the most prominent source in that category. On a national basis, two thirds of the SO_2 emissions are derived from industrial processes while the remaining third is derived from fuel combustion. The major industrial sources tend to be located in remote areas, whereas fuel combustion emissions are concentrated in more heavily populated areas (Environment Canada, 1989).

Figure 7 presents the SO_2 levels in 16 selected urban centres across Canada. In many cases, the current levels are at the low end of the ranges shown in Figure 7. All of the means and their associated ranges are well within the acceptable range of the annual air quality objectives.

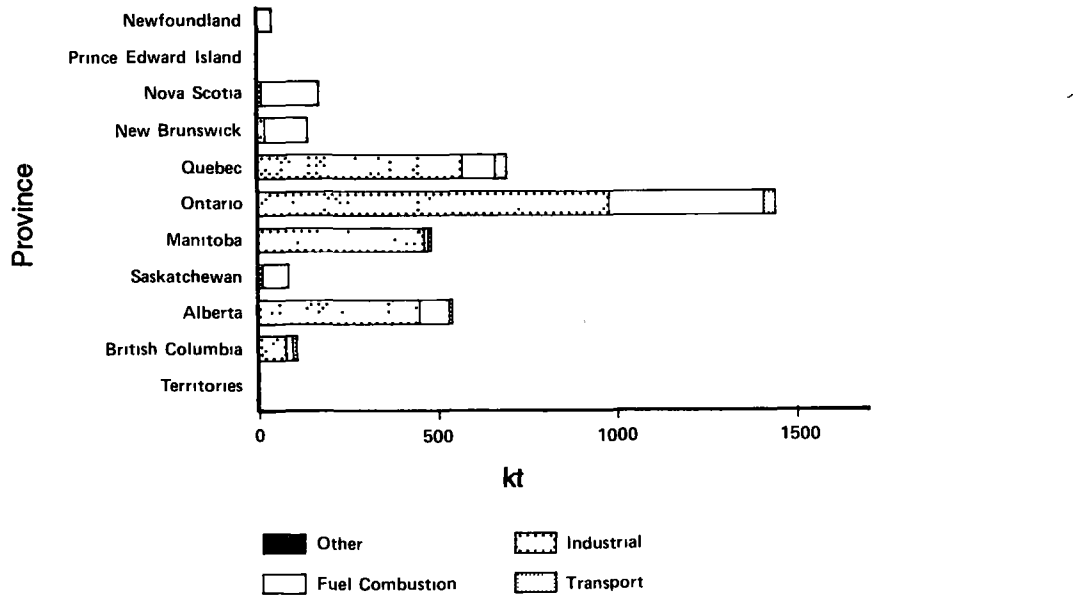


Figure 6 **Sulphur Dioxide Emissions ($\times 10^3$ tonnes) by Source Category and by Province (1985)**

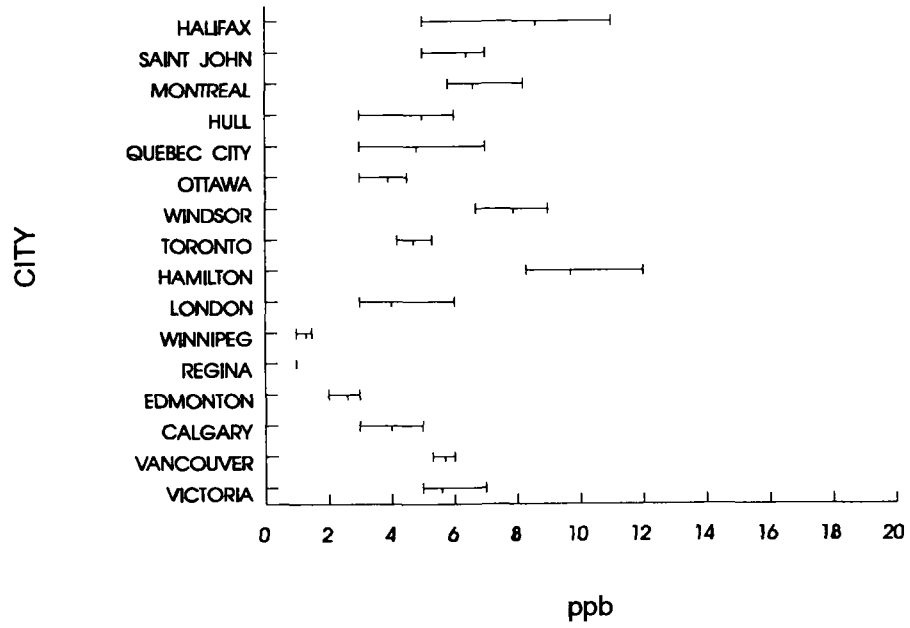


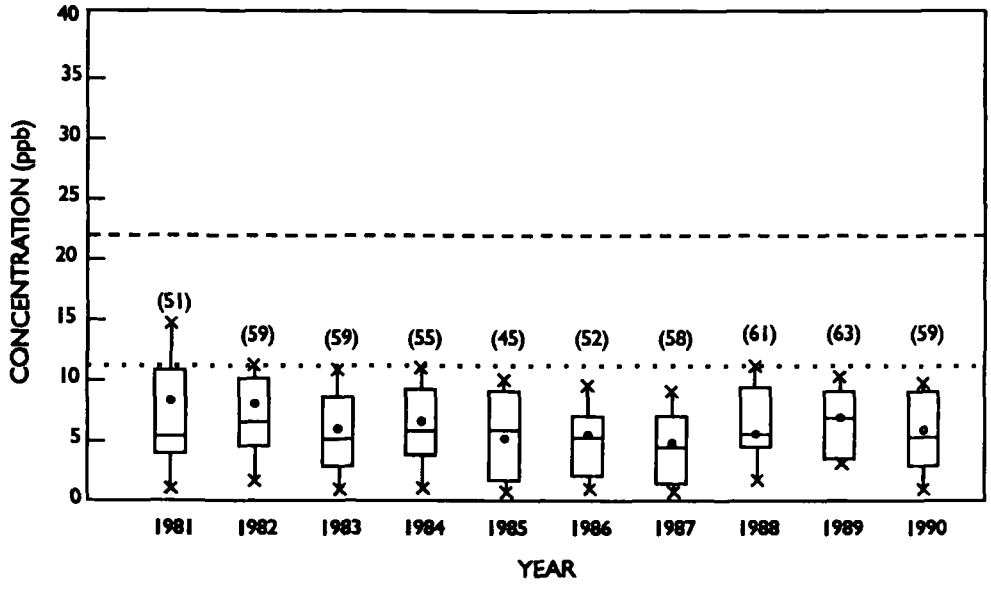
Figure 7 **Annual Average Levels of Sulphur Dioxide in Selected Cities (parts per billion) (1986 to 1990)**

2.1 Annual Means

The composite average of sulphur dioxide annual means recorded by the National Air Pollution Surveillance (NAPS) network decreased from 8 ppb in 1981 to 6 ppb in 1990 (see Figure 8). Sulphur dioxide levels are showing signs of stabilizing; little change has taken place in the network annual mean at the 90th-percentile concentration. In fact, the 90th-percentile concentration has been within the desirable range since 1982. The number of stations for which mean values are available for pairs of consecutive years is found in the Appendix (Table A). In the last 10 years, more than half of these stations have shown no change in annual mean concentrations.

Figure 9 shows trends in composite annual mean values for All Stations and for Class I Stations with 95% confidence limits (derived using Tukey's Test). By inspection it is evident that the data for Class I Stations and All Stations convey the same general trend. In the All Stations plot, there are no significant differences (where confidence intervals do not overlap) between years. It should be kept in mind that the number of stations in the analysis can affect the magnitude of the confidence limits, and also that Class I Stations generally monitor commercial and residential centres. The All Stations plot displays higher concentrations in this case because it contains data from smaller urban centres with an industrial SO_2 source, where higher SO_2 concentrations are expected.

In the past 10 years, more than 98% of the monitoring stations have reported annual mean values within the maximum acceptable objective level. Throughout the period from 1981 to 1990, there was a stabilization in the



--- maximum acceptable
. maximum desirable
(N) number of stations

Figure 8 **Sulphur Dioxide - Distribution of Station Annual Mean Data (1981 to 1990)**

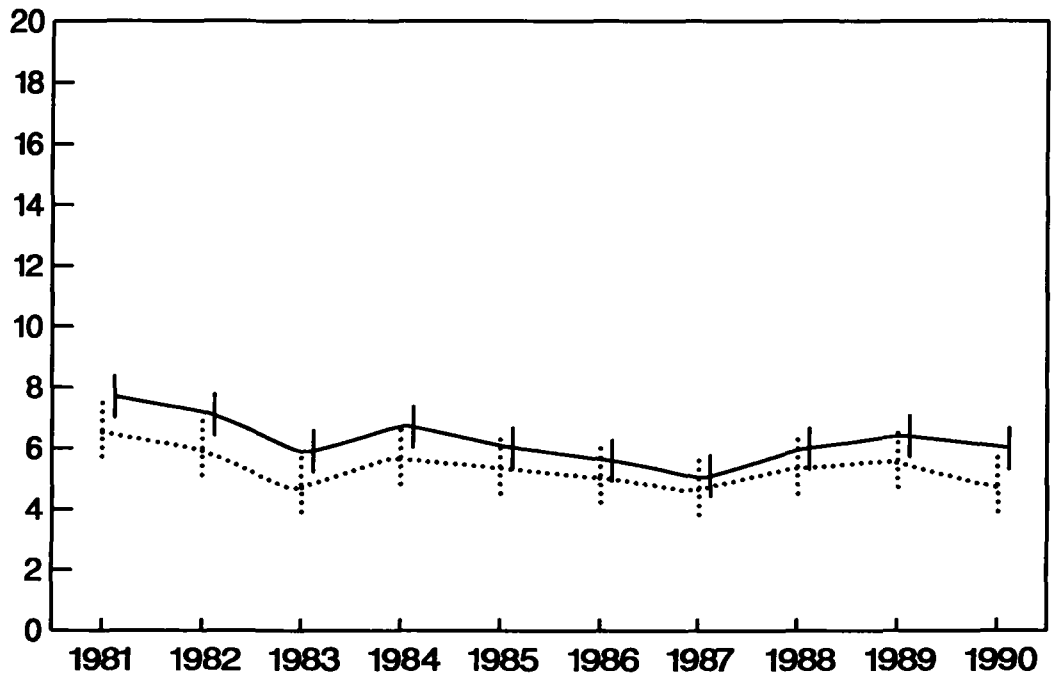


Figure 9 **Trends in Sulphur Dioxide Annual Mean Values (parts per billion*) for All Stations (—) and Class I Stations (...) with 95% Confidence Limits (1981 to 1990)**

* 1 billion = 1×10^9

number of sites that met the maximum desirable objective. Table 6 gives the percentage of stations with readings in various ranges with respect to the annual NAAQOs from 1981 to 1990. In the last three years there was an increase in the number of stations in the acceptable range, rising from 2% in 1987 to 12% in 1990; this follows a decrease in the percentage of stations in the desirable range from 98% in 1987 to 87% (1990).

Overall, the annual mean values across the NAPS network meet our most stringent objectives, although some stations historically have not done so. The stations with highest mean levels over the past 14 years are listed in in the Appendix (Table H). This table shows that the improvement at the worst sites to have been quite dramatic, particularly in Sudbury station 60606C and Montreal station 50115C. The annual mean levels at these stations exceeded the acceptable level objective but have since come down into the desirable range.

2.2 *Short-term Concentrations*

2.2.1 Twenty-four-hour Maximum Levels

During the period from 1981 to 1990, the percentage of stations meeting the maximum desirable level of the National Ambient Air Quality Objectives increased from 49% to 78%.

The maximum acceptable level was exceeded at 3% of the stations during the period from 1986 to 1987 and has rebounded to the 10% level in the past three years.

The maximum tolerable level was exceeded in the analysis period by less than 2% of the network stations, except in 1983 when three sites (4%) exceeded that level: the Quebec City station 50303I, the Baie Comeau station 51301R, and the Rouyn- Noranda station 50610C. These three stations are located near industrial as well as residential, commercial, and institutional heating sources. It is important to note that a single-day exceedance can be influenced by meteorological factors such as temperature inversion, wind speed and wind direction. Most stations register concentrations within the 24-hour acceptable range (i.e., 86% of the sites in 1983, 97% in 1987, and 88% in 1990).

During the period from 1981 to 1990, most stations met the maximum tolerable objective. The tolerable level was exceeded at sites in Quebec City, Trois-Rivières, Baie Comeau, and Rouyn.

The plots representing the composite average of the 98th-percentile concentrations show that there was a marked (95% confidence) improvement between 1990 and the years 1981, 1982, and 1984 in the All Stations plot. The Class I station plot shows a significant improvement only between 1990 and the years 1981 and 1982.

2.2.2 One-hour Maximum Levels

When the one-hour levels were analyzed with respect to the NAAQOs, a gradual change was apparent from 1981 to 1987; there was an increase in the percentage of stations meeting the maximum desirable level (Table 6) from the 55% range in 1981 to the 77% range in 1987. The last three years show a return to the situation of the early 1980s when 70% of stations met the desirable level. In 1981, a total of 85% of the NAPS stations met the maximum acceptable level of 344 ppb, compared with 93% in 1987 and 82% in 1990. Communities that experienced one-hour concentrations greater than the one-hour maximum acceptable level in 1990 were: Saint John, Quebec, Rouyn,

Table 6 **Sulphur Dioxide - Percentage of Stations with Readings in Various Ranges with Respect to the National Ambient Air Quality Objectives (1981 to 1990)**

Range (ppb)	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
A) Annual Means										
0 to 11*	75	84	89	91	96	94	98	89	90	87
12 to 23**	23	14	9	9	4	4	2	11	10	12
>23	2	2	2	-	-	2	-	-	-	1
No of stations	51	59	60	55	56	53	57	61	62	60
B) 24-hour Maximum										
0 to 57*	49	59	65	63	62	78	80	73	70	78
58 to 115**	38	35	21	29	33	18	17	19	21	10
116 to 306***	12	4	10	8	5	3	3	7	9	10
>306	1	2	4	-	-	1	-	1	-	2
No of stations	82	81	78	75	73	71	72	73	71	76
C) 1-hour Maximum										
0 to 172*	55	64	73	67	73	77	77	70	69	71
173 to 344**	30	27	17	24	19	13	16	18	18	17
>344	15	9	10	9	8	10	7	12	13	12
No of stations	82	81	78	75	73	71	74	73	71	76

* desirable level
** acceptable level
*** tolerable level

Shawinigan, Trois-Rivières, Baie Comeau, and Sudbury.

Quebec (1410 ppb), Sudbury (940 ppb), and Baie Comeau (950 ppb) recorded the highest one-hour concentrations of SO_2 in 1990. Industrial point sources contribute significantly to ambient sulphur dioxide levels at these sites.

In the past 10 years, there has been a significant improvement in the peak SO_2 concentrations that are within the maximum desirable level. The plots of the 98^{th}-percentile concentration composite averages show many significant decreases (see Figure 10). In the All Stations plot, a significant change (95% confidence) is indicated between 1981 and 1990.

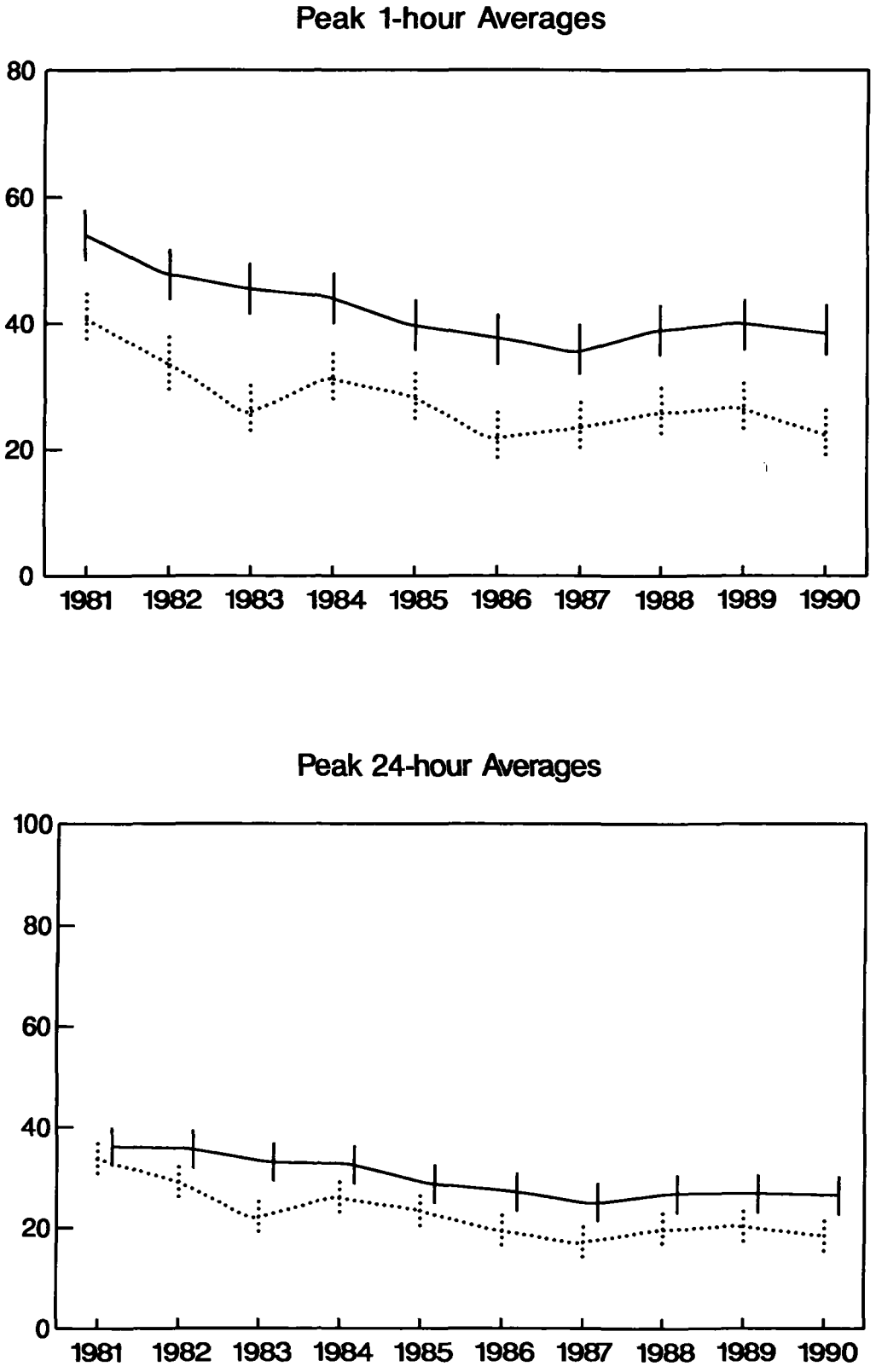


Figure 10 **Sulphur Dioxide: Composite Averages of the 98th-percentile Concentration (ppb) with 95% Confidence Limited for Class I (...) and All Stations (—) (1981 to 1990)**

Section 3

Nitrogen Dioxide

Nitrogen dioxide (NO_2) is a reddish-brown gas produced by the oxidation of nitric oxide (NO) in the atmosphere. The formation of NO_2 is the first step in the production of photochemical smog. Nitric oxide is primarily a product of combustion, which occurs when air is heated to high temperatures in engines and furnaces.

Figure 11 shows the emissions of nitrogen oxides (NO_x) by province and for four source categories. In most provinces the major contributor is the transportation category, which consists largely of cars and trucks. The next most important source category is fuel combustion. This category contains such stationary sources as thermal power plants as well as residential, commercial and industrial fuel combustion. Figure 11 does not show the natural sources of NO_x emissions such as electrical discharges during storms, forest fires, and bacterial action in soils.

In Figure 12, the range and five-year composite average levels of NO_2 are shown for selected cities across Canada. All city average levels are well within the maximum desirable range of the annual National Ambient Air Quality Objectives (NAAQOs).

3.1 Annual Means

From 1981 to 1990, the composite average of the network nitrogen dioxide annual means decreased somewhat from 23 to 21 ppb (Figure 13). However, there is no trend apparent as the composite annual mean value fluctuated between 21 ppb and 24 ppb throughout the decade. The number of stations indicating changes in annual means is listed in the Appendix (Table B). This analysis has been performed for stations that have valid annual mean data for pairs of consecutive years, and it is inconclusive. In the past 10 years, about half of the stations have shown no change. Figure 14 presents the composite averages of station annual mean values with their associated 95% confidence limits (derived from Tukey's Test) for All Stations and for Class I Stations in the period from 1981 to 1990. Both sets of stations show similar trends. However, measured concentrations at Class I Stations tend to be higher because the stations are located in urban cores, where population density is higher and where vehicle and fuel combustion sources are more concentrated.

In both Class I and All Stations, there is no significant change indicated for the 1981 to 1990 period.

The composite averages of station annual means for nitrogen dioxide remained within the desirable level throughout the 1981 to 1990 period. Over the past 10 years, the annual mean levels have remained in the 21- to 24-ppb range (see Appendix, Table J). As indicated in Table 7, the number of stations meeting the maximum desirable level rose from 1981 to 1983, reaching 97%, but has stabilized at the 90% level in the last two years. No individual station has registered readings in excess of the maximum acceptable level since 1977. The highest annual mean concentration (34 ppb) for nitrogen dioxide in 1990 occurred at commercial (city centre) sites in Calgary, Quebec City, and Montreal.

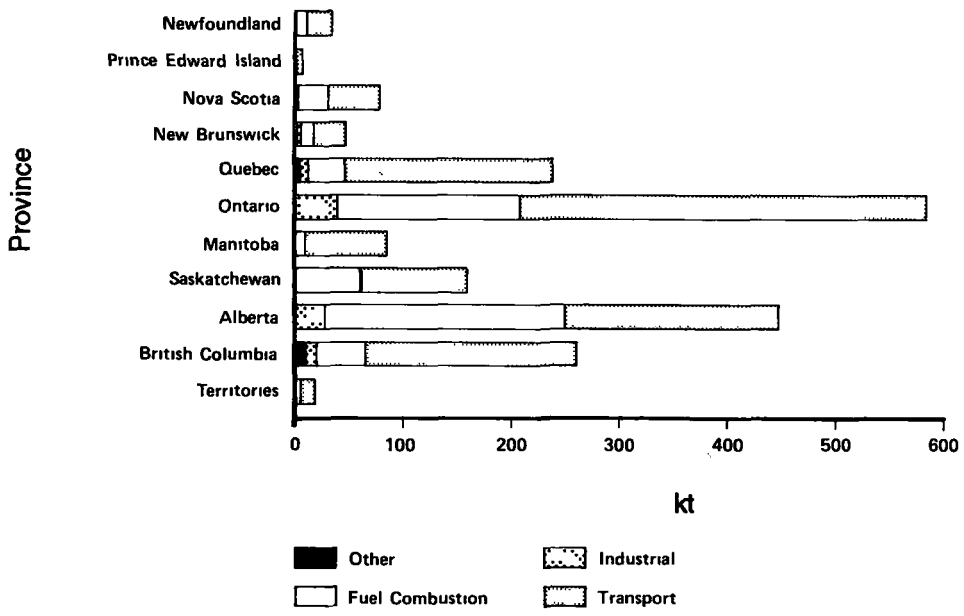


Figure 11 **1985 Emissions of Nitrogen Oxides by Source Category and by Province ($\times 10^3$ tonnes)**

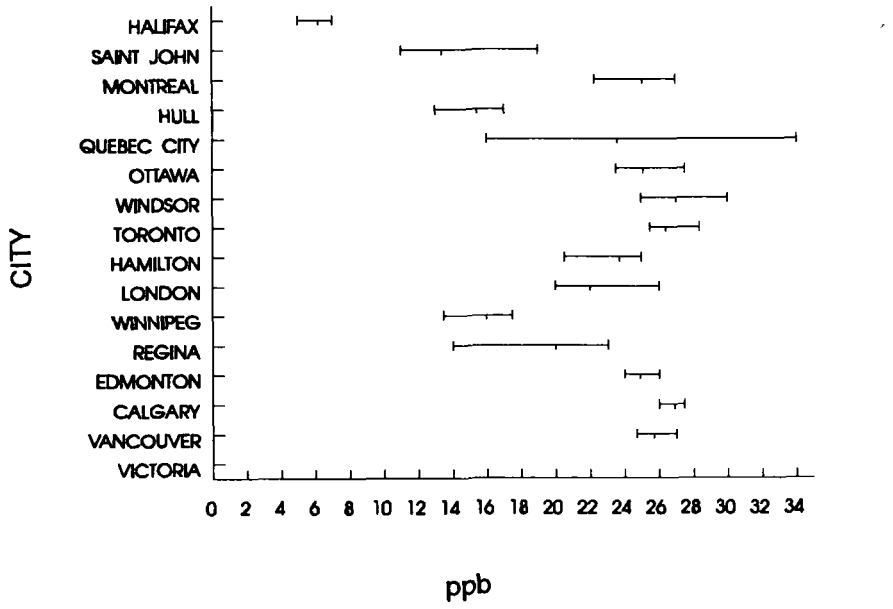
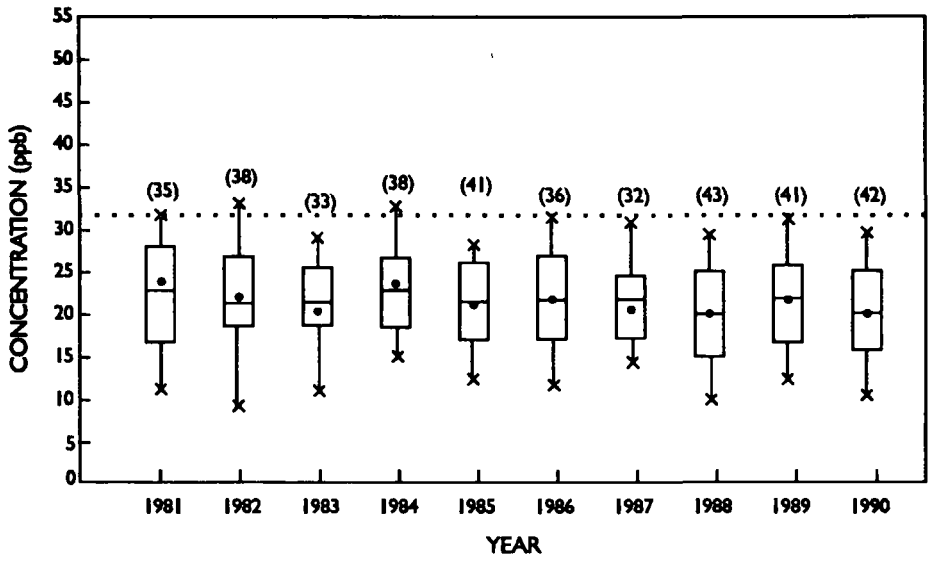


Figure 12 **Nitrogen Dioxide: Annual Average Levels (ppb) in Selected Cities (1986 to 1990)**



	maximum desirable
(N)	number of stations

Figure 13 **Nitrogen Dioxide - Distribution of Station Annual Mean Data (1981 to 1990)**

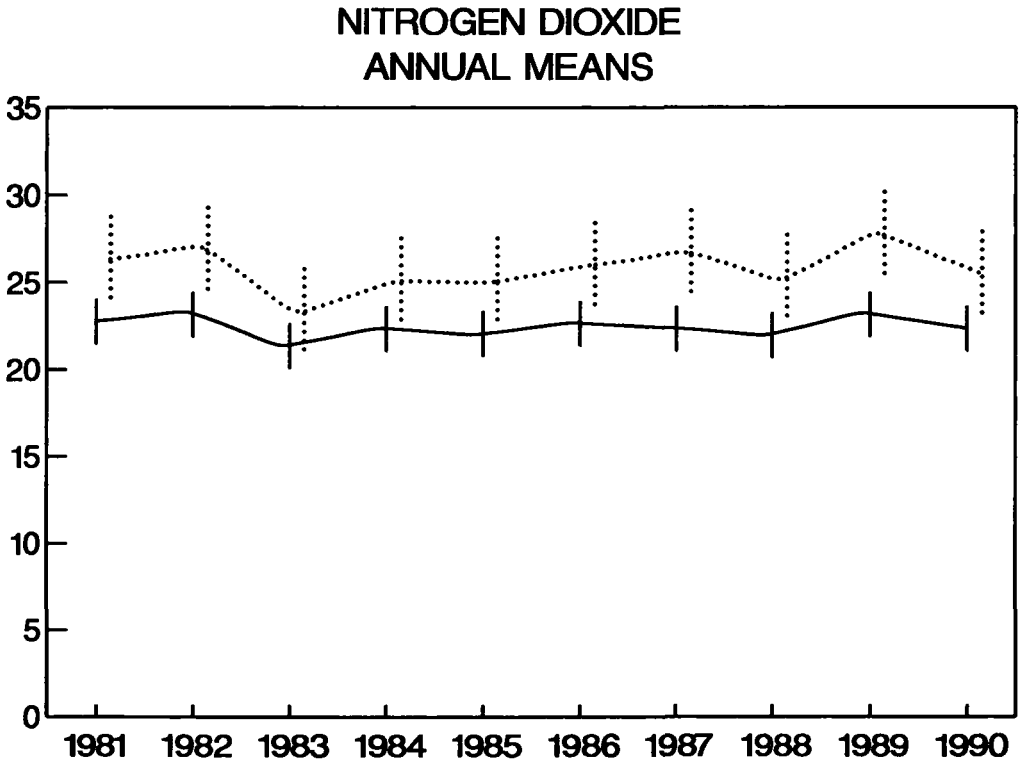


Figure 14 **Trends in Nitrogen Dioxide Annual Mean Values (parts per billion) for All Stations (—) and Class I (...) Stations with 95% Confidence Limits (1981 to 1990)**

Table 7 **Nitrogen Dioxide - Percentage of Stations with Readings in Various Ranges with Respect to the National Ambient Air Quality Objectives (1981 to 1990)**

Range (ppb)	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
A) Annual Means										
0 to 32*	86	86	97	87	90	89	87	86	88	91
33 to 53**	14	14	3	13	10	11	13	14	12	9
>53	-	-	-	-	-	-	-	-	-	-
No of stations	36	38	33	39	41	36	32	44	42	34
B) 24-hour Maximum										
0 to 106**	90	92	92	96	96	100	100	100	88	100
107 to 160***	8	8	8	4	4	-	-	-	10	-
>160	2	-	-	-	-	-	-	-	2	-
No of stations	49	50	50	51	51	50	49	51	52	45
C) 1-hour Maximum										
0 to 213*	86	96	96	98	100	100	100	100	100	100
214 to 532**	14	4	4	2	-	-	-	-	-	-
>532	-	-	-	-	-	-	-	-	-	-
No of stations	49	50	50	51	51	50	49	51	52	45

* desirable level
** acceptable level
*** tolerable level

3.2 *Short-term Concentrations*

3.2.1 *Twenty-four-hour Maximum Levels*

Figure 15 shows the long-term trend in annual mean nitrogen dioxide levels; it indicates no significant changes since all the 95% confidence limits overlap. As in the previous section, the number of stations meeting the 24-hour maximum acceptable level of 106 ppb (Table 7, Part B) shows some improvement from 1981 to 1987 and then returns to the levels of the early 1980s. In 1981, only 90% of the stations met the maximum acceptable level of 110 ppb, compared with 100% in the period from 1986 to 1988. For the past nine years all stations have met the maximum tolerable 24-hour level of 160 ppb.

3.2.2 *One-hour Maximum Levels*

The percentage of stations meeting the maximum acceptable one-hour level of 213 ppb was higher during the period from 1985 to 1990 than in previous years; this objective level was met at virtually all of the sites (Table 7, Part C). No station has recorded readings in excess of the maximum tolerable one-hour level (532 ppb) since 1979, and none did so before 1979.

Figure 15 shows the trend indicated by the composite average of the hourly 98th-percentile concentrations. There are no significant (95% confidence) changes apparent between 1981 and 1990 in the All Stations plot. The Class I Stations plot does not show any significant differences either; however, it is important to demonstrate that the general trend is the same.

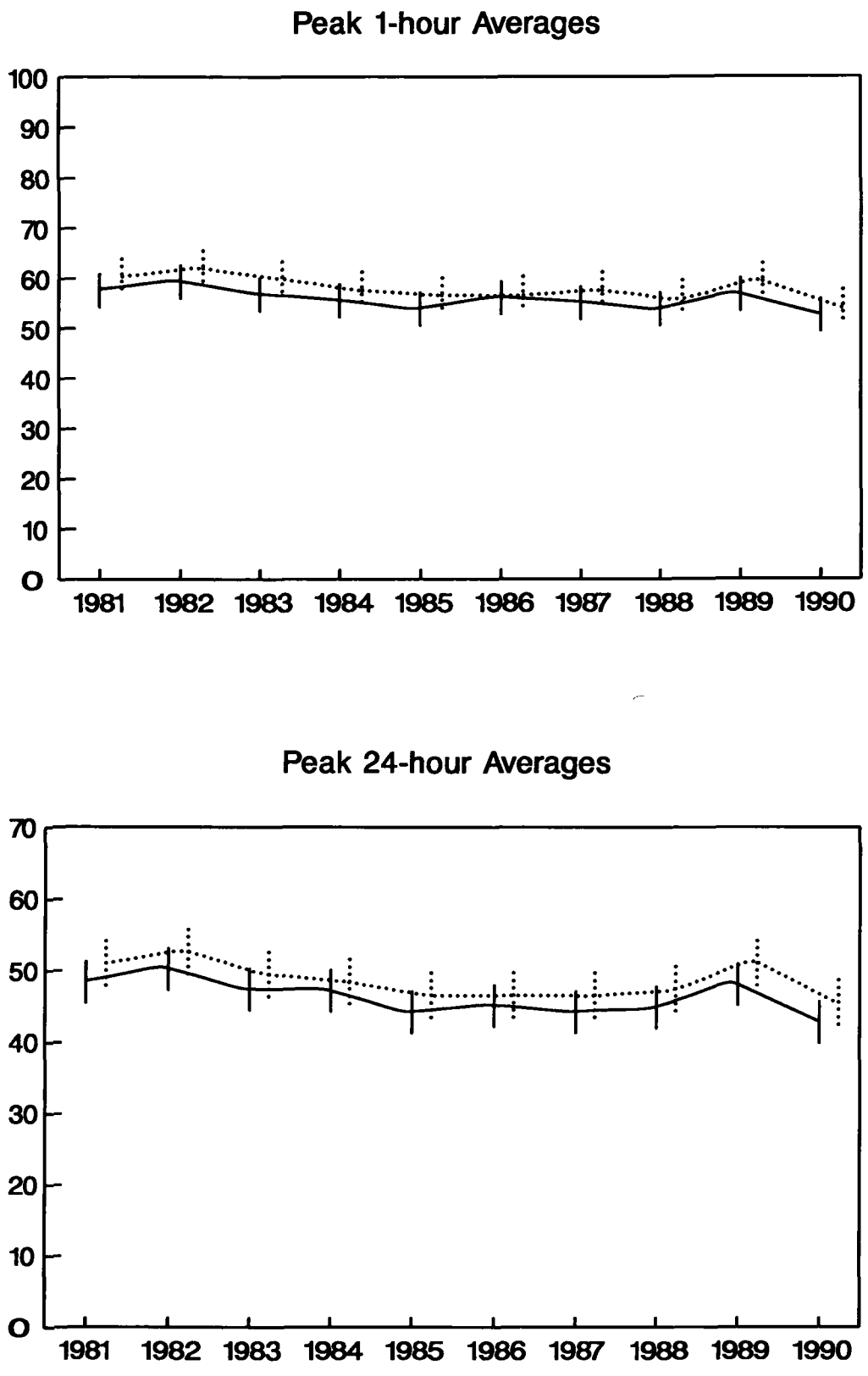


Figure 15 **Nitrogen Dioxide: Composite Averages of the 98th-percentile Concentration (parts per billion) with 95% Confidence Limits for Class I (...) and All Stations (—) (1981 to 1990)**

Section 4

Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless, highly toxic gas which is found in trace quantities in the natural atmosphere. It is produced by the incomplete combustion of fossil fuels. Carbon monoxide is a major air pollutant and can be harmful even in small amounts when inhaled over a certain period of time; the periods are defined in the National Ambient Air Quality Objectives (see Tables 2 and 3).

Figure 16 presents the four source categories for provincial CO emissions. In most provinces, the transportation category accounts for the greatest portion of CO emissions (approximately 75% nationally). Within this category, light-duty vehicles are the primary source of CO emissions. On a national basis, the industrial and fuel combustion categories contribute about five percent each. The impact of other CO sources will vary from one province to another. For example, in the province of British Columbia, the burning of wood waste by slash burning and wigwam burners is particularly prominent.

The levels of carbon monoxide in selected cities across Canada are shown in Figure 17. There is no annual air quality objective for CO but it is interesting that most of the composite five-year averages for cities are within one part per million (0.5 and 1.5 ppm).

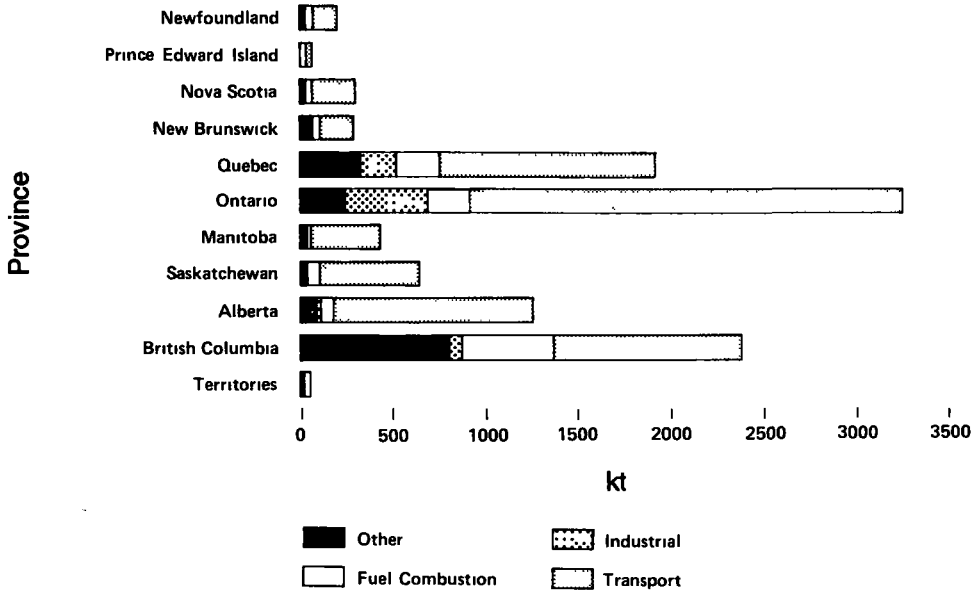


Figure 16 **1985 Emissions of Carbon Monoxide by Province and by Source Categories ($\times 10^3$ tonnes)**

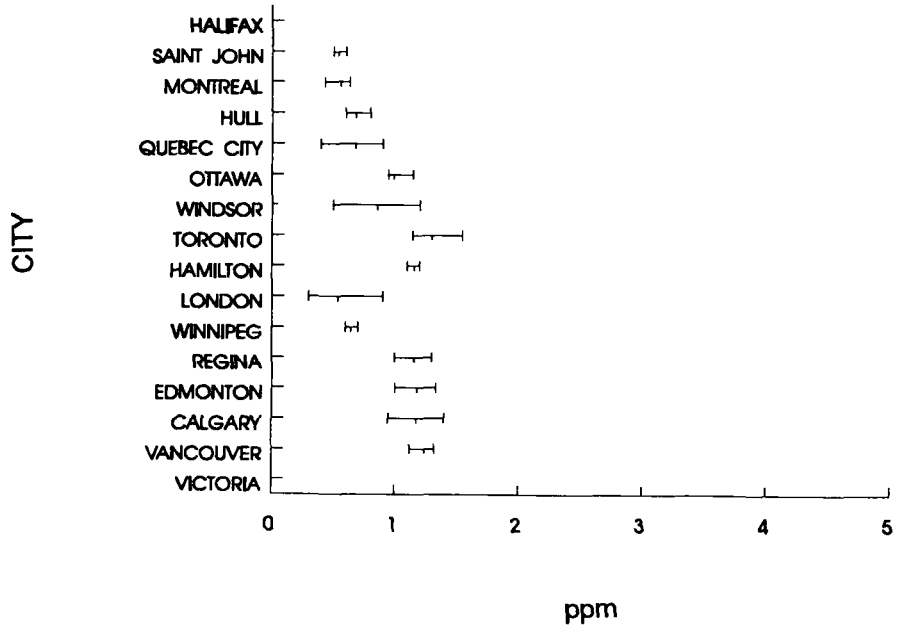


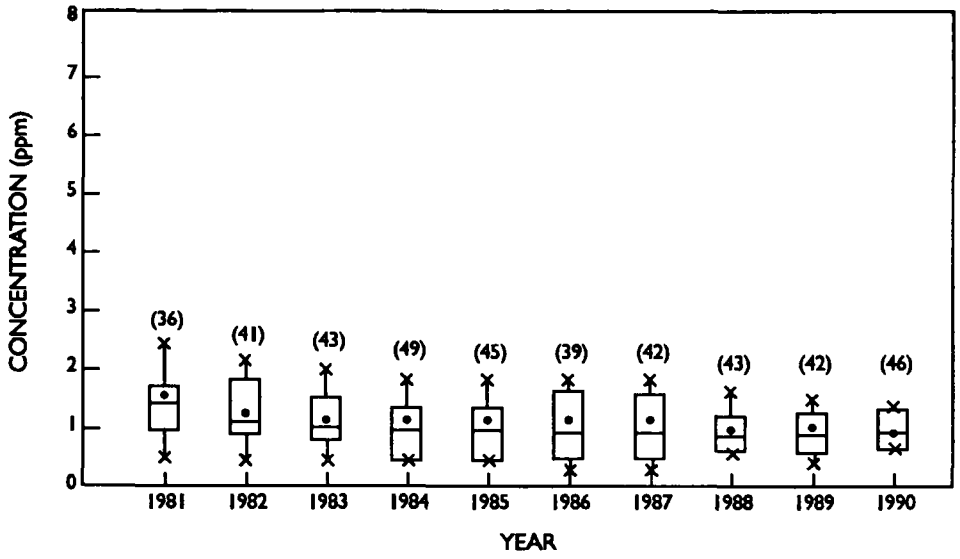
Figure 17 Carbon Monoxide Average Levels in Selected Cities (parts per million) (1986 to 1990)

4.1 Annual Means

The composite average of CO annual means for the NAPS network decreased from 1.5 ppm in 1981 to a level of 0.8 ppm (Figure 18) in 1990. The higher concentrations (90th percentile) were recorded at stations in more polluted areas, and they have decreased from a high of 2.3 ppm in 1981 to a level of 1.2 ppm in 1990.

The number of stations indicating changes in annual mean data for carbon monoxide is listed in the Appendix (Table C). These stations have valid annual mean data for pairs of consecutive years. In 1988, 1989, and 1990, over half of the paired stations showed no change, and most of the stations that have changed registered decreases in CO levels. In fact, the annual mean has dipped slightly below the 1.0 ppm level during this time.

Trends in the composite average of carbon monoxide annual means for All Stations and Class I Stations with 95% confidence limits are shown in Figure 19 (Tukey's Test). As with other pollutants, the trend (Class I and All Stations) is similar and it can be concluded that Class I Stations by themselves would provide a representative national sample of carbon monoxide levels. However, because of the greater number of stations involved in the analysis of variance (ANOVA), "All Stations" generally is a better indicator of year- to-year change. In this case, both Class I Stations and All Stations show the same long-term trend, with the average for All Stations being significantly lower in the 1986 to 1990 period than in 1983 (at 95% confidence) and previous years. These decreases have been brought about by improvements at sites that commonly registered the highest values.



(N) - number of stations

Figure 18 **Carbon Monoxide - Distribution of Station Annual Mean Data (1981 to 1990)**

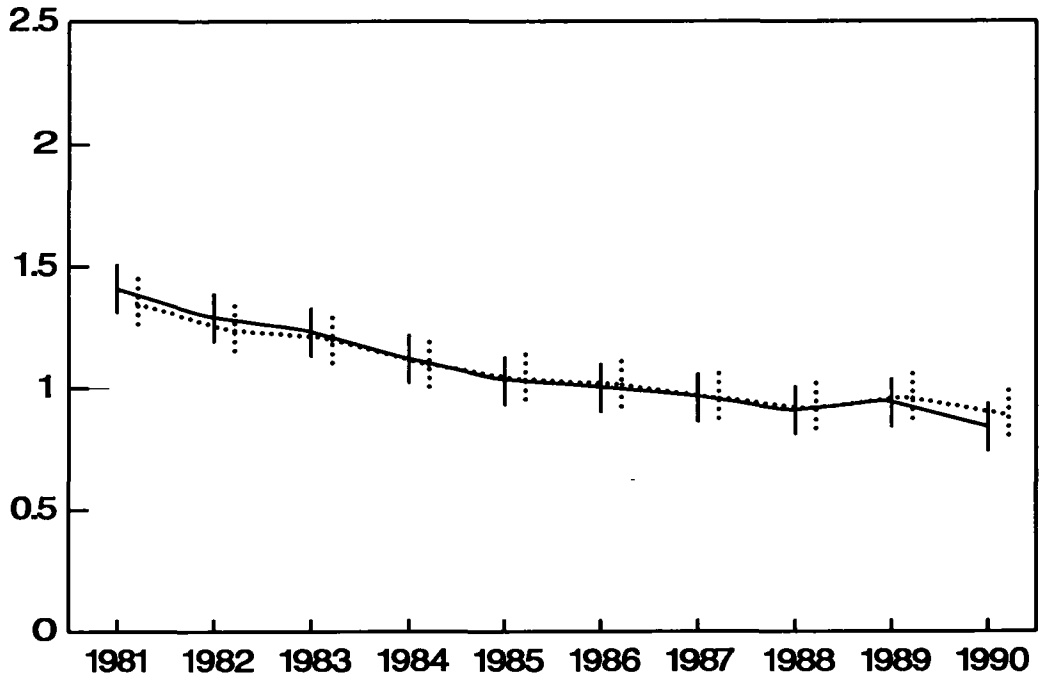


Figure 19 **Trends in Carbon Monoxide Annual Mean Values (ppm) for All Stations (—) and Class I Stations (...) with 95% Confidence Limits (1981 to 1990)**

The highest reported station annual means in 1990 — 1.9 ppm and 1.8 ppm — were recorded at commercial sites in Toronto and Vancouver. These levels as well as the number of stations that registered high CO readings have declined markedly in the 1980s. Since both stations are downtown sites located near major traffic arteries, the decrease probably reflects a general lowering of the individual car emission rate over the review period (Environment Canada, 1984). From a summary report, entitled "Canadian Energy Supply and Demand 1990 to 2010", there is evidence that in the 1980 to 1990 period the demand for heating fuel and gasoline declined slightly (National Energy Board, 1991). These factors also suggest a reduction in the ambient levels of carbon monoxide at sites that traditionally record the highest annual mean concentrations.

4.2 Short-term Concentrations

4.2.1 Eight-hour Maximum Levels

Table 8, Part A summarizes the distribution of stations reporting average eight-hour readings, in the various ranges described by the National Ambient Air Quality Objectives from 1981 to 1990. The percentage of stations meeting the eight-hour acceptable objective has remained in the 90% range. The percentage of stations meeting this objective ranged from 86% in 1981 to 98% in 1990. The number of stations meeting the maximum desirable level increased from 13% in 1981 to 60% in 1990, while the number of stations exceeding the tolerable level did not change much until 1989 to 1990, when no station exceeded the objective. The sites reporting the highest concentrations in 1990 were Toronto station 60416C at 10 ppm, Montreal station 50115C at 11ppm, Calgary station 90227C at 13 ppm, and Edmonton station 90122R at 12 ppm.

Table 8 Carbon Monoxide - Percentage of Stations with Readings in Various Ranges with Respect to National Ambient Air Quality Objectives (1981 to 1990)

Range (ppm)	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
A) 8-hour Maximum										
0 to 5.0*	13	15	27	24	36	43	49	50	46	60
5.1 to 13**	73	73	68	72	58	53	45	44	50	38
13.1 to 17***	12	6	-	2	4	2	2	4	4	2
>17	5	6	5	2	2	2	4	2	-	-
No. of stations	52	53	51	54	55	53	54	54	54	55
B) 1-hour Maximum										
0 to 13*	46	51	58	59	65	73	77	78	80	84
13 to 31**	46	42	39	39	33	27	21	20	20	16
>31	8	7	3	2	2	-	2	2	-	-
No. of stations	52	53	51	54	55	55	53	54	54	55

* desirable level
** acceptable level
*** tolerable level

Figure 20 shows the trend in the composite average of the 98th-percentile (8-hour) concentrations at Class I Stations and All Stations.

In this case, All Stations show more significant changes between years, with 1990 having a significantly lower composite average than 1986 and all previous years.

4.2.2 One-hour Maximum Levels

The number of stations reporting readings over the one-hour maximum desirable carbon monoxide level of 13 ppm has been decreasing steadily in the past 10 years from the 50% level to the 80% level (Table 8, Part B). The number of stations with readings exceeding the maximum acceptable level has stabilized at around 2% for the last eight years, down from a high of 7% in 1981.

Readings in excess of the maximum acceptable one-hour and eight-hour levels occurred at one Toronto site in 1985 (Station 60416C) and a Calgary site (90227C) in 1988.

Figure 20 shows the trend in the composite average of the one-hour 98th-percentile concentrations. Again the All Stations plot demonstrates more significant differences, with 1990 levels being significantly lower than 1987 levels and those from previous years.

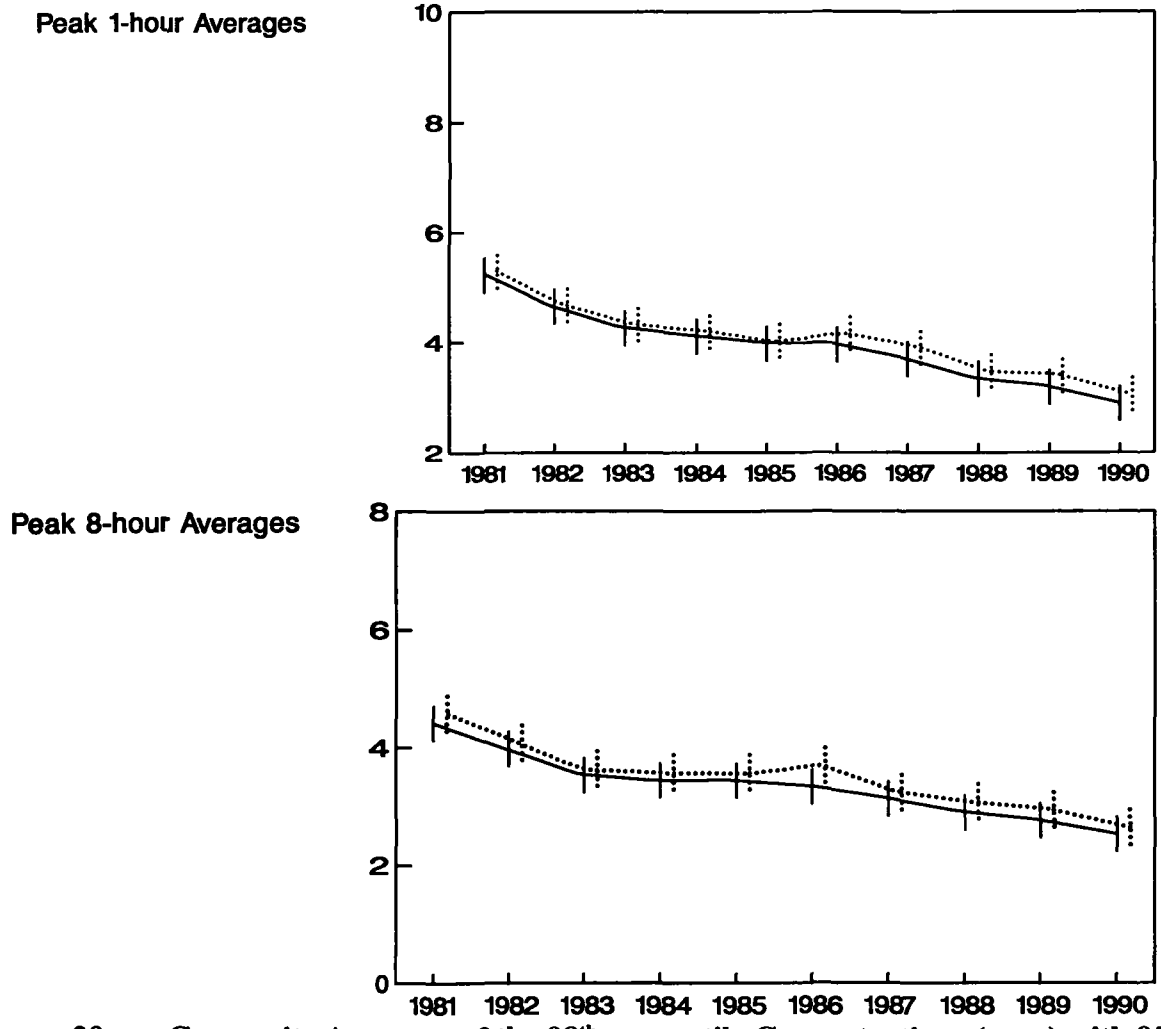


Figure 20 Composite Averages of the 98th-percentile Concentrations (ppm) with 95% Confidence Limits for Class I (...) and All Stations (—) 1981 to 1990

Section 5

Ozone

Ozone is the principal species of several oxidizing gases known collectively as total oxidants. Atmospheric or ground-level ozone is a secondary pollutant in that it is not emitted directly from a source. Instead ozone is formed as a result of a series of photochemical reactions in the air, these being energized by temperature and sunlight in a stagnant air mass. The conditions that produce ozone occur most frequently from late spring to early fall in most of the country.

Figure 21 displays the 1985 annual emission of volatile organic compounds (VOCs) by province and by source categories.

The transportation category is the most prominent source of VOCs, contributing about one half of national emissions (Figure 21). The principal sources of VOCs in the transportation category are cars, trucks and other gasoline-powered vehicles. In the "other" category, the most important sources are the gasoline distribution system, application of surface coatings (paints), general solvent use, and dry cleaning. Most of the industrial emissions come from petrochemical plants, plastics manufacturing, and refineries. For the fuel combustion category of emissions, the two most important sources are fuelwood and industrial fuel combustion.

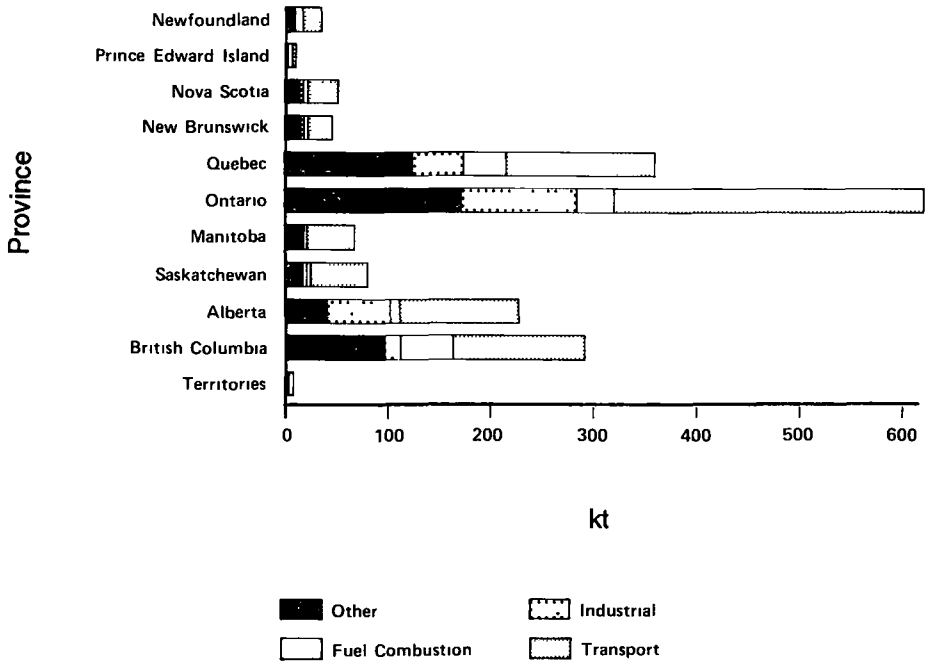


Figure 21 **1985 Emissions of Volatile Organic Compounds by Province and by Source Category ($\times 10^3$ tonnes) (Environment Canada, 1989)**

According to the "1985 Canadian Emissions Inventory of Common Air Contaminants" Summary Table (Environment Canada, 1989), fuel production, distribution, and combustion account for approximately half of the VOCs emitted annually in Canada and a quarter of nitrogen oxides. Ozone monitors were first installed in the NAPS network in 1973 (Figure 1). Data for the 1973 to 1974 period were presented in an earlier report (Nicholl and Choquette, 1977). Given the absence of a common calibration procedure for ozone monitors across the NAPS network, it was found that the data were unreliable. In order to avoid assessments based on unreliable data, it was decided to delay the interpretation of ozone data until all questions of methodology were resolved. The ozone measurements made throughout the network after 1978 are considered to be reliable and consistent.

Figure 22 shows averages of peak ozone levels for selected cities across Canada. The data sets for two of the 16 cities used for this analysis were incomplete, and therefore an average level was estimated with no range shown.

Cities in central Canada were found to exceed the NAAQO one-hour maximum acceptable level most often.

5.1 Annual Means

Annual ozone concentrations for the 1981 to 1990 period are presented in Figure 23. The composite average of ozone annual means for the NAPS network in 1990 was 18 ppb. The significant increase (20%, Table J) in the annual mean concentrations from 1981 to 1990 can be partially explained by the addition of rural sites to the NAPS database. Mean values for individual stations ranged from 6 ppb in Montreal (50115C) to 34 ppb in Fundy National Park, NB (40401R). Most station annual means in southern Ontario were in the 13-ppb to 24-ppb range. The number of stations indicating changes in annual mean ozone concentrations during

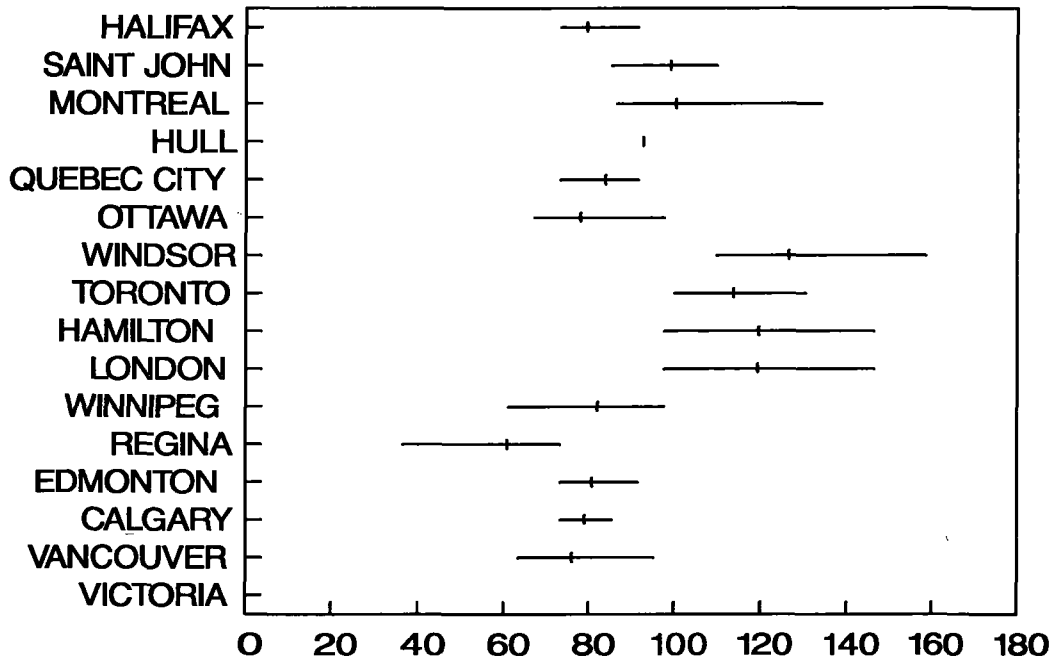
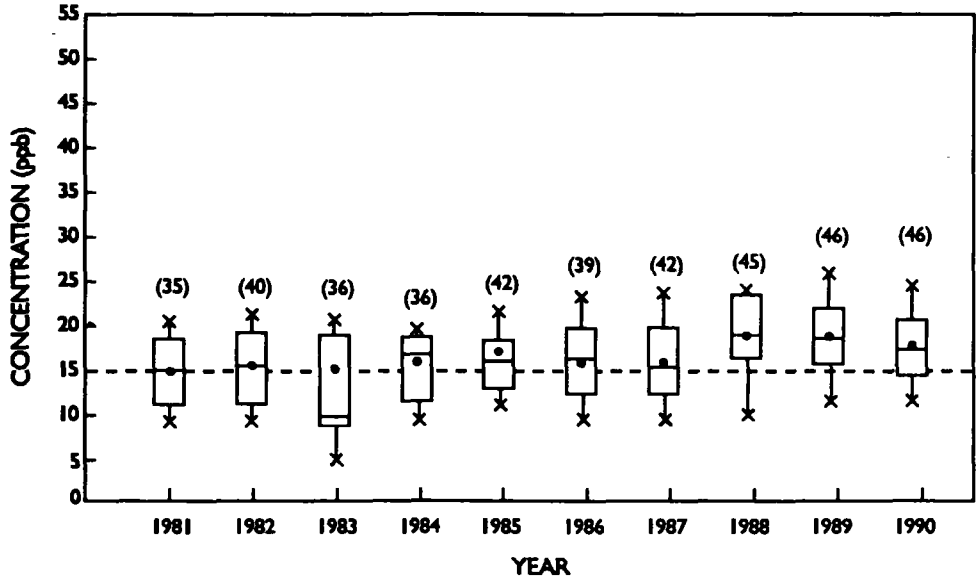


Figure 22 **Five-year Average of Peak Hourly Ozone Levels in Selected Cities (parts per billion) (1986 to 1990)**

the 1981 to 1990 period is listed in the Appendix (Table D). Stations with valid annual mean data for pairs of consecutive years were used in this analysis.

The analysis shows that, at about half of the sites, ozone increased in 1988. The following two years show a return to the more familiar pattern of more decreases than increases, with more than half of the stations in the "no change" column. In years when an increase in the number and severity of ozone episodes (days with ozone levels exceeding the acceptable objective) was observed, only a third of the network stations registered an increase in the annual mean of more than one part per billion. The years 1983 and 1987 are an example of this phenomenon, which is partially explained by meteorological conditions that favoured ozone formation in certain parts of the country. Figure 24 shows the average number of days across the country when the hourly acceptable objective was exceeded. In 1988, 1989, and 1990, the annual mean levels have been the highest on record and an examination of the box plot (Figure 23) shows that this can be attributed to an increase in the concentration levels at the "cleaner" sites as a result of higher values in the lower deciles and quartiles.

The maximum acceptable annual mean level (NAAQO) for ozone is 15 ppb. As shown in Table 9, Part A, about half of the monitoring sites met this objective in 1981, falling steadily to 28% in 1990. The sites exceeding this level were distributed across the network but were particularly dominant in southern Ontario. From 1982 to 1990,



--- maximum acceptable
(N) number of stations

Figure 23 Ozone - Distribution of Annual Mean Data (1981 to 1990)

Table 9 Ozone - Percentage of Stations with Readings in Various Ranges with Respect to National Ambient Air Quality Objectives (1981 to 1990)

Range (ppb)	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
A) Annual Mean										
0 to 15*	54	45	39	41	40	31	43	22	41	38
>53	46	55	61	59	60	69	57	78	59	62
No of stations	35	40	36	34	41	39	42	46	58	45
B) 1-hour Maximum										
0 to 50*	6	4	-	4	4	13	13	4	2	8
50 to 82**	26	25	34	40	45	39	32	27	26	31
83 to 153***	58	69	58	52	47	47	52	54	68	61
>153	10	2	8	4	4	1	3	9	4	-
No of stations	50	49	50	52	51	56	60	56	57	61

* desirable level
** acceptable level
*** tolerable level

the percentage of stations that have recorded readings in excess of the acceptable level increased beyond the 60% range to a high of 78% in 1988.

A report on global climate changes produced at the Goddard Institute for Space Studies, New York (1988) observed measurable warming in surface air temperatures for the first seven years of the 1980s. A graph showing Annual Mean Global Temperature Change indicates peaks for 1980, 1983, and 1987; these correspond to a higher frequency of ozone episodes. On the basis of this analysis, 1988 was the worst ozone year on record, setting highs in the number and severity of ozone episodes.

5.2 One-hour Maximum Levels

The composite average of the 99.9th percentile provides information about trends in extreme values (or ozone episodes) when the acceptable and tolerable air quality objectives are likely to be exceeded.

This average corresponds to the ninth highest concentration recorded at a station, as compared to the 175th highest value for the 98th percentile.

Table 9, Part B shows the percentage distribution of network stations that fall into the various objective ranges (NAAQO hourly desirable, acceptable, and tolerable). In the past four years, more than half of the stations exceeded the maximum acceptable (82 ppb) hourly objective level at least once, while the number of stations meeting the desirable level peaked at 13% for 1986, 1987 and has since declined to the 4% level.

The maximum tolerable objective was exceeded by a high of five sites in 1981 and 1988, and none in 1990. In the past 10 years the tolerable objective was exceeded at the following cities: Montreal (1981 to 1985, 1988); Toronto (1983); Oshawa (1983, 1988); Vancouver (1981, 1983); Saint John (1984); Quebec City (1981, 1985); Halifax (1986); Sarnia (1981, 1987, 1988); and Oakville (1987, 1988).

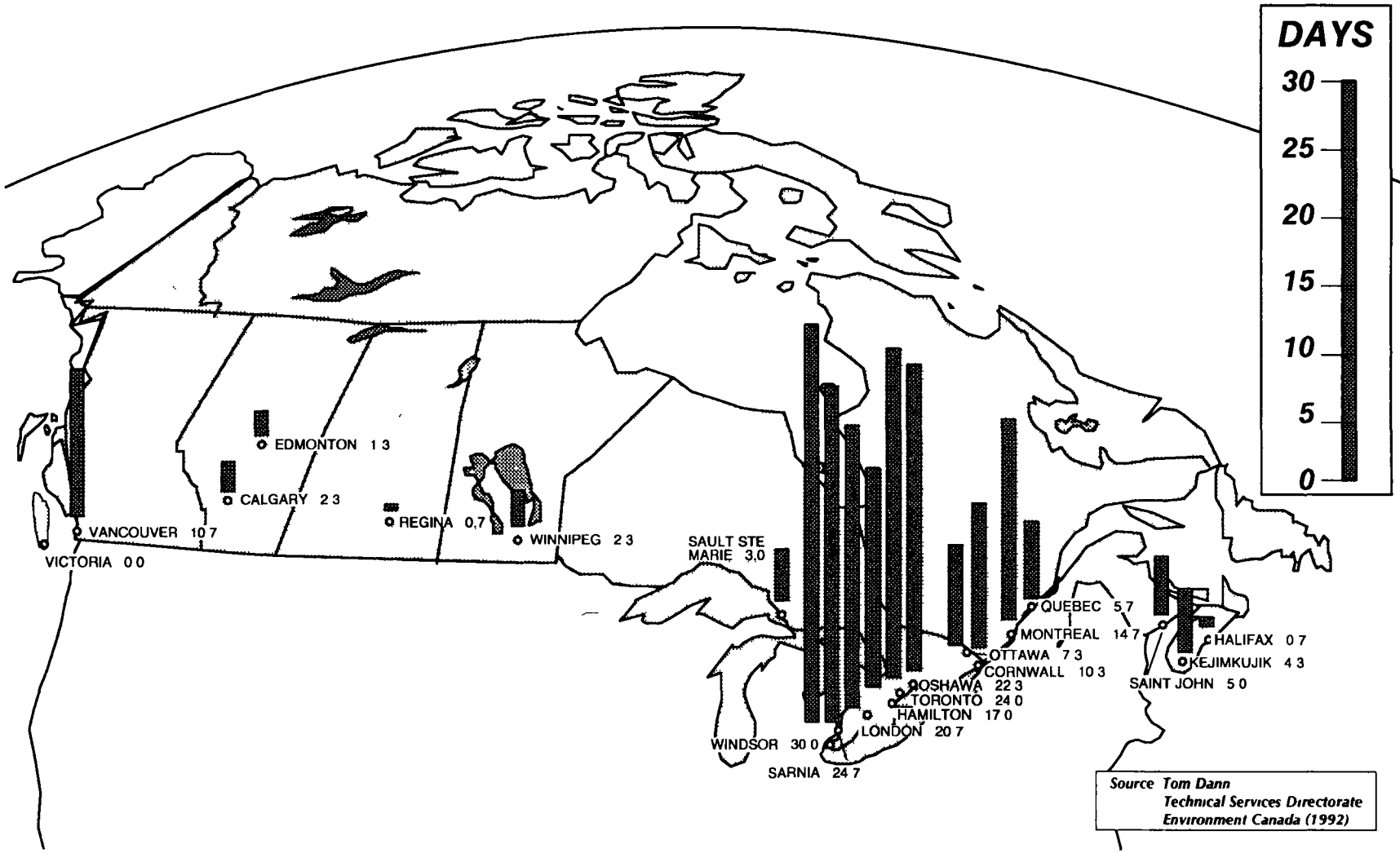


Figure 24 **Average Number of Days per Year Exceeding the Hourly Ozone Air QualityAcceptable Objective in Selected Cities (1983 to 1990)**

The trend in the peak hourly composite averages from 1981 to 1990 shows a 10% decline, and linear regression analysis (Table 4) does not indicate a significant change. This trend line is interrupted by higher values in 1981, 1983, and 1988. During these years, there were more ozone episode days, particularly in the Windsor-to-Quebec City corridor.

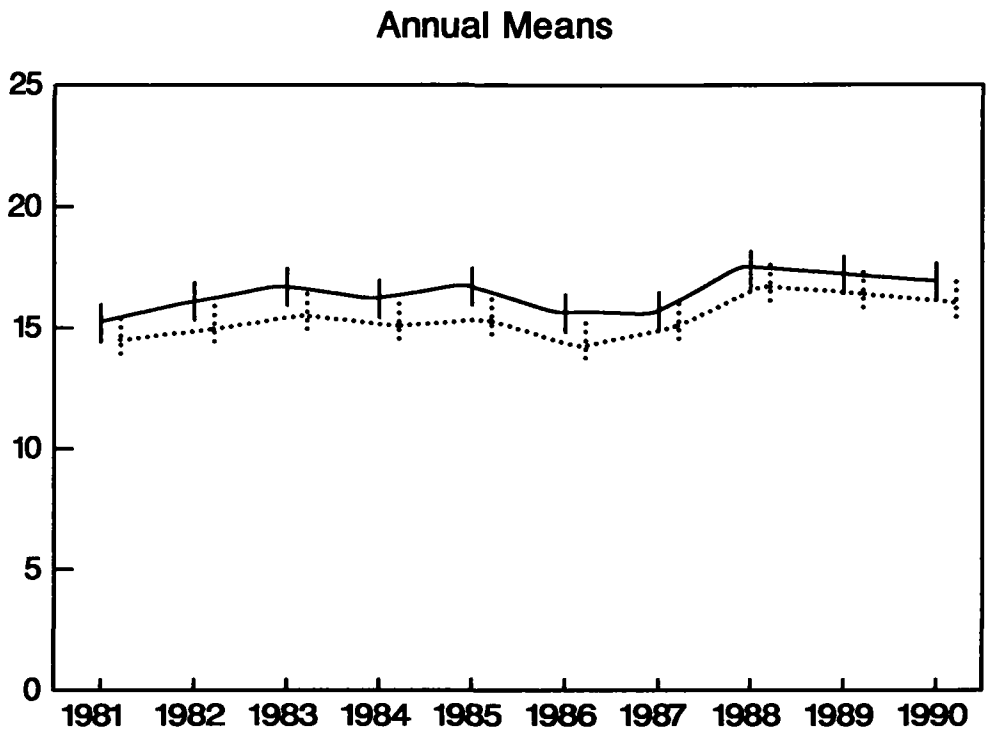
The comparison of year-to-year changes in peak ozone levels can be seen in Figure 25 (Tukey's Test). It is evident that 1986 had the lowest composite average value (from 1981 to 1990) and 1988 was the highest year on record. The 1988 mean concentration is significantly (95%) higher than all other years with the exception of 1981 and 1983. For most years, the Class I Station average levels are lower than those for All Stations. This is likely because of higher nitrogen oxide (and hence scavenging) levels at downtown monitoring sites where the majority of Class I Stations are located. It is interesting to note that the plot of peak hourly averages shows significant changes between years from 1981 to 1990 (Figure 25). In contrast, the plot showing annual averages does not indicate any significant changes. This analysis along with that of the box plot suggests that the higher ozone levels are being recorded generally, rather than that the bad sites are getting worse.

The number of days when the acceptable one-hour ozone objective level is exceeded for an hour or more has been recorded in NO_x / VOC reports. The stations with the highest average over the past eight years are:

62701	Long Point	(provincial park)	34 0 days
60419	Toronto	CN Tower	29 9 days
61005	Sarnia		21 4 days
62501	Tiverton		21 1 days
60204	Windsor		20 9 days
60413	Toronto	Elmcrest Rd	16.4 days
60515	Hamilton	Vickers Rd	13 1 days
60901	London		12 7 days

Other sites with more than 10 days when the acceptable one-hour ozone objective level is exceeded include Burlington, Simcoe, Guelph, Oshawa, Oakville, Kitchener, and St. Catharines. This information is important because most ozone damage occurs when the acceptable levels are repeatedly exceeded for an hour or more (Dann, 1992).

The air quality objectives (for ozone) are found in Table 2, while Table 3 lists some of the adverse effects on vegetation and human health that can be expected when the objectives are exceeded.



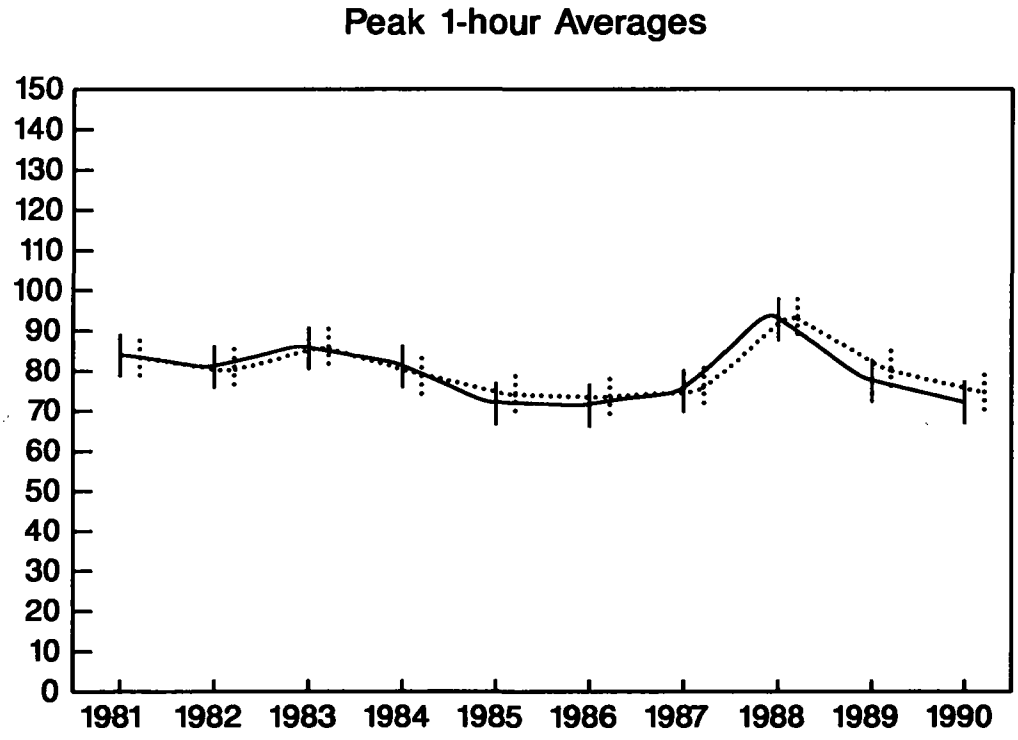


Figure 25 **Trends in Ozone Annual Mean and Peak 1-hour Concentrations (parts per billion) for All Stations (—) and Class I Stations (...) (1981 to 1990)**

Section 6

Suspended Particulate

Total suspended particulate (TSP) is a general term applied to a wide variety of solid or liquid particles that are of a size and configuration such that they remain suspended in the air. Particulate can be divided into two general sizes of fractions: coarse and fine. The coarse fraction is composed of crustal material while the fine fraction contains mostly (anthropogenic) soot and other combustion byproducts. These combustion byproducts can become involved in secondary (chemical) processes, which in turn can become involved in many air chemistry reactions, one example being acid formation.

Particulate matter is the most commonly perceived form of air pollution, causing reduced visibility, soiling of materials, and irritation of the respiratory tract. Particulate emissions from the most important human-made sources in Canada have been determined, and these are shown in Figure 26.

The anthropogenic or human-made sources of particulate matter fall into four main categories:

(1) Industrial emissions account for 50% of the national suspended

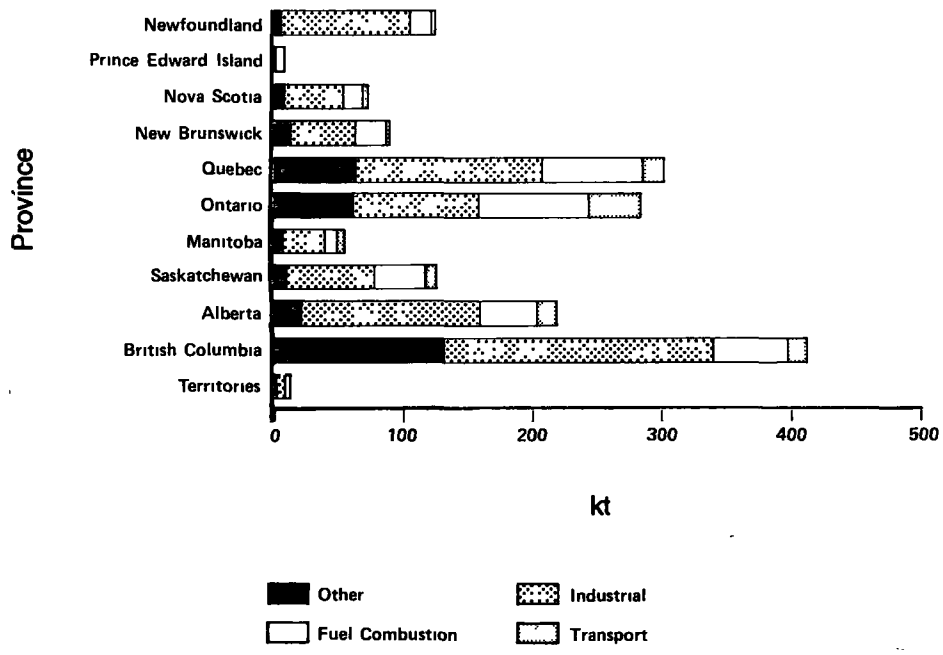


Figure 26 **1985 Emissions of Suspended Particulate Matter by Province and by Source Categories ($\times 10^3$ tonnes)**

particulate matter. These emissions have a variety of sources, including iron ore mining and beneficiation, mining and rock quarrying operations, and pulp and paper mills.

(2) Fuel combustion emissions come mainly from thermal power plants.

(3) Transportation emissions are produced chiefly by gasoline-powered motor vehicles.

(4) Other sources include incineration and slash burning.

There are also natural sources of particulate matter; these include dusting from storage piles and fields, pollens, sea spray, and forest fires. In addition, local weather conditions such as temperature, wind, precipitation, and ground cover affect particulate levels, especially in cities, where the re-entrainment of dust from road traffic is a major factor.

Figure 27 shows the five-year composite averages of particulate loadings in selected cities across Canada. Most of the city averages are within the desirable range of less than 60 $\mu g/m^3$. The only cities to exceed this level were Hamilton and Calgary.

National Ambient Air Quality Objectives and an "effects matrix" are contained in Tables 2 and 3 respectively for (suspended particulate) both the annual mean and the 24-hour average concentrations. However, given the NAPS schedule of sampling once every six days, only the annual mean was used for trend analysis (U.S. EPA, 1981).

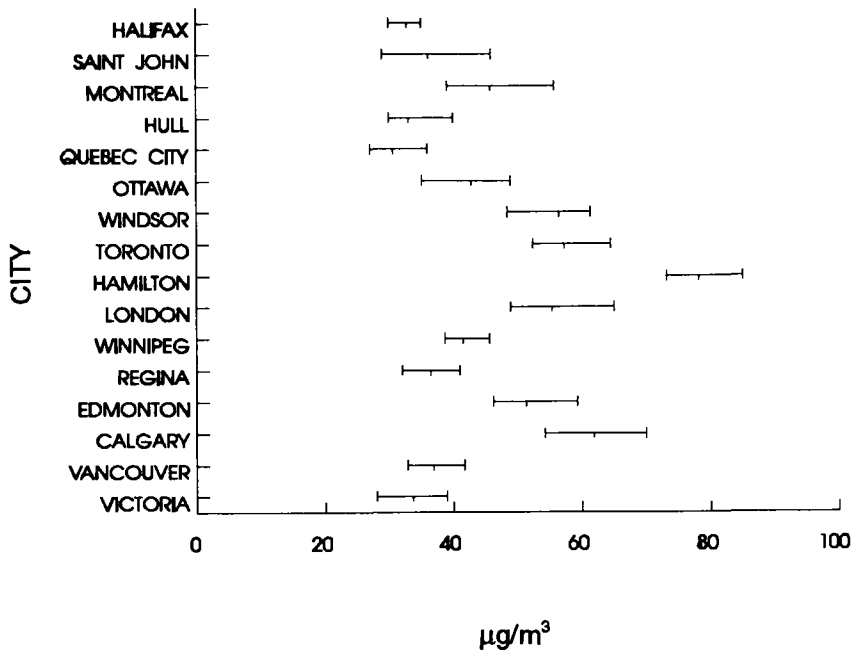


Figure 27 Total Suspended Particulate Average Levels in Selected Cities (micrograms per cubic metre) (1981 to 1990)

6.1 *Annual Geometric Means*

The composite averages of the station annual geometric means have decreased by 34% between 1981 and 1990, and the annual mean value for 1990 is the lowest on record at 38.5 $\mu g/m^3$ (Figure 28 and Appendix, Table J). The decrease in average levels can be attributed to improved conditions at the more polluted sites. It is also apparent that the 90th-percentile annual concentrations have declined in recent years to within the desirable range. The number of stations indicating changes in annual means greater than 4 $\mu g/m^3$ from 1981 to 1990 can be found in the Appendix (Table E). These stations have valid annual mean data for pairs of consecutive years. Table E shows that the lower annual mean in 1990 was the result of decreases at half of network sites; the other half showed no change.

The 10-year trend (Tukey's Test) in the composite annual mean values for All Stations and Class I Stations is shown in Figure 29. While the general trends indicated by the two sets of stations are similar, the absolute values shown by the Class I stations are higher. In recent years, the agreement is such that Class I Stations alone can provide a representative sample of TSP levels.

However, since a greater number of stations are used in the analysis (Tukey's Test), "All Stations" provide a better indicator of year-to-year change. By inspection we can see a significant (95% confidence) improvement in 1990 over all the preceding years with the exception of 1985 and 1989. From Figure 28, it is evident that the network annual means have been below the Annual Maximum Acceptable level (NAAQOs) since 1981.

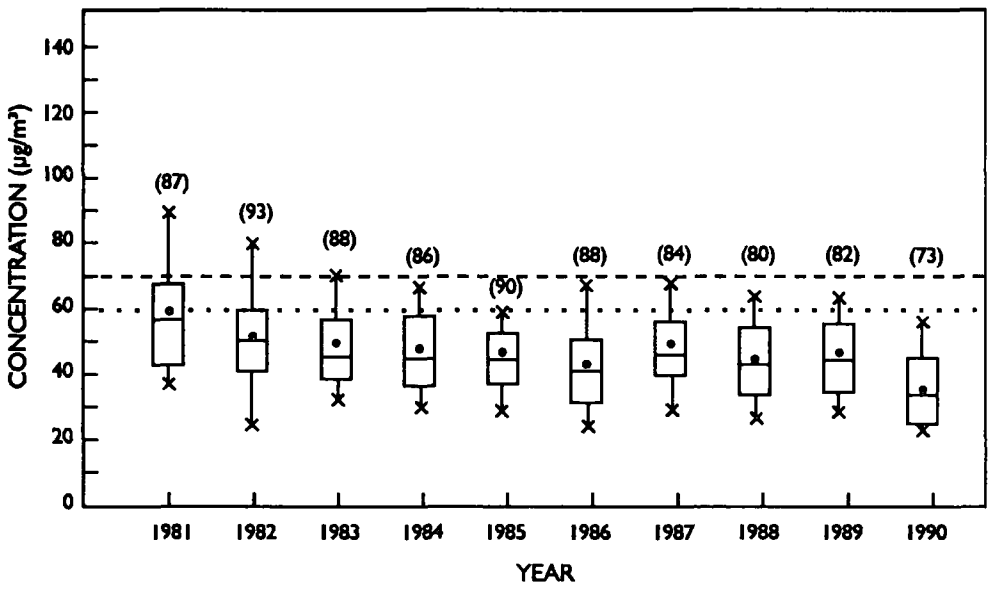


Figure 28 Suspended Particulate - Distribution of Station Annual Mean Data (1981 to 1990)

Across the country, there has been a general improvement in total suspended particulate levels. From 1986 to 1990, the 90th-percentile annual means, representing the more polluted sites, have been within the acceptable range (60 to 70 $\mu g/m^3$) of the NAAQOs, and in 1990 they were within the desirable range for the first time. The network annual mean levels have come down from 60 $\mu g/m^3$ to the 40 $\mu g/m^3$ range during the 1981 to 1990 period.

The higher annual mean levels during the previous few years of the analysis can be attributed to hot dry summers, conditions that are conducive to higher levels of wind-blown dust. A comparison of station annual mean concentrations with the annual objectives (NAAQOs) is shown in Table 10.

6.2 Desirable and Acceptable Levels

Another indicator of the improvement in particulate levels is the increasing percentage of stations that meet the desirable and acceptable levels. In 1985, only 2% of the stations exceeded the maximum acceptable TSP levels of 70 $\mu g/m^3$, and none did so in 1990. Similarly, the percentage of stations with annual means within the maximum desirable objective of 60 $\mu g/m^3$ increased from a low of 61% in 1981 to the 90% level in 1989 and 1990.

Stations reporting the highest annual means in the past few years were: Hamilton station 60503I, 77 $\mu g/m^3$; Montreal station 50109C, 106 $\mu g/m^3$; Calgary station 90204C, 85 $\mu g/m^3$. Other cities with stations reporting annual mean values in excess of the maximum desirable level of 60 $\mu g/m^3$ were Prince George, Vancouver, Edmonton, Kitchener, London, Toronto, and Windsor. Elevated total suspended particulate levels are usually associated with sites that are near a major traffic artery, heavy industry, or a construction site.

Table 10 Suspended Particulate - Percentage of Stations with Readings in Various Ranges with Respect to the National Ambient Air Quality Objectives (1981 to 1990)

Range ($\mu g/m^3$)	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Annual Geometric Means										
0 to 60*	61	80	81	79	92	88	83	88	89	95
60 to 70*	21	8	9	12	6	4	9	5	5	5
>71	18	12	10	9	2	8	8	7	6	-
No of stations	87	93	88	86	88	88	85	81	83	74

* desirable level
** acceptable level

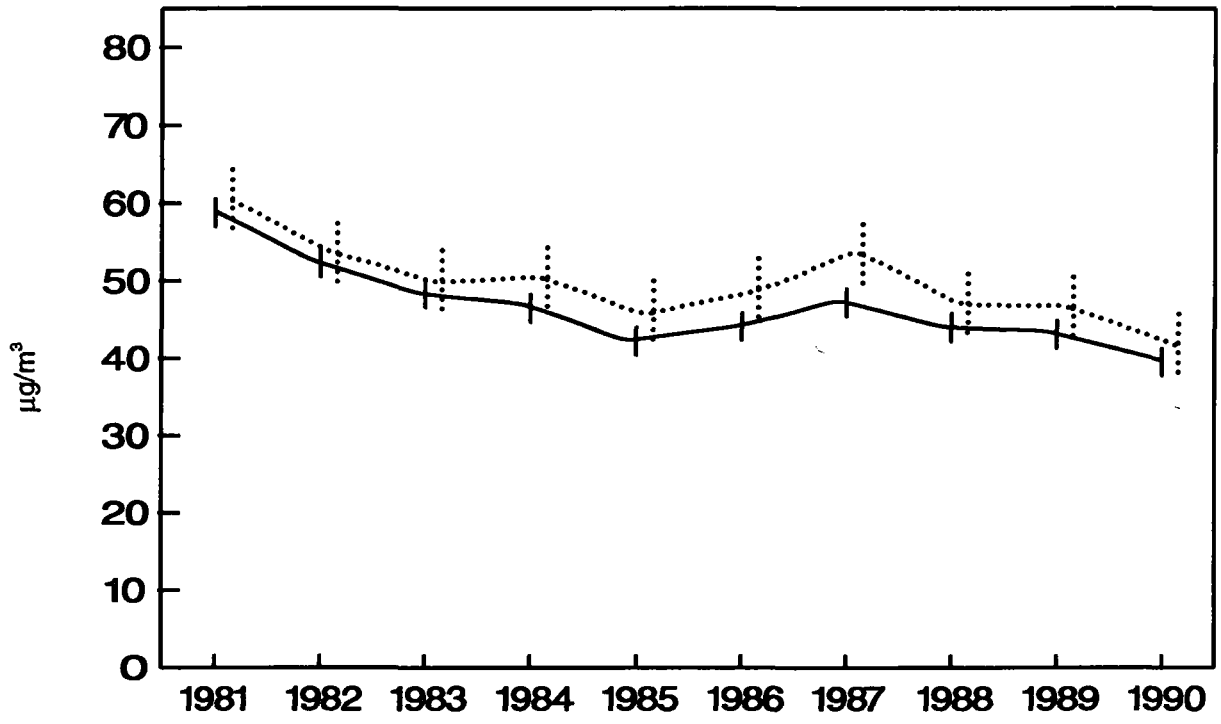


Figure 29 **Trends in Suspended Particulate Annual Mean Values (µg/m³) for All Stations (—) and Class I Stations (...) with 95% Confidence Limits (1981 to 1990)**

Section 7

Lead

Lead is a heavy metal that has long been recognized as potentially hazardous to humans if it is ingested or inhaled. It is particularly harmful to children under 10 years of age. Lead and lead compounds are present in the ambient air as components of total suspended particulate (TSP) matter. The concentration of lead is determined by the analysis of filters used for TSP sampling.

Figure 30 shows lead emissions from four source categories by province for 1987 (Jaques, 1989). Clearly the industrial category is the major contributor of lead emissions to the environment.

However, an Environment Canada report (1985) shows a strong positive correlation between the transportation category of lead emissions and measured ambient lead (particulate) levels. The sources of lead in Canada from various economic sectors such as mining, milling, and smelting are found in an Environment Canada report on the inventory of lead emissions (Jaques, 1989). As of 1987, vehicle emissions accounted for

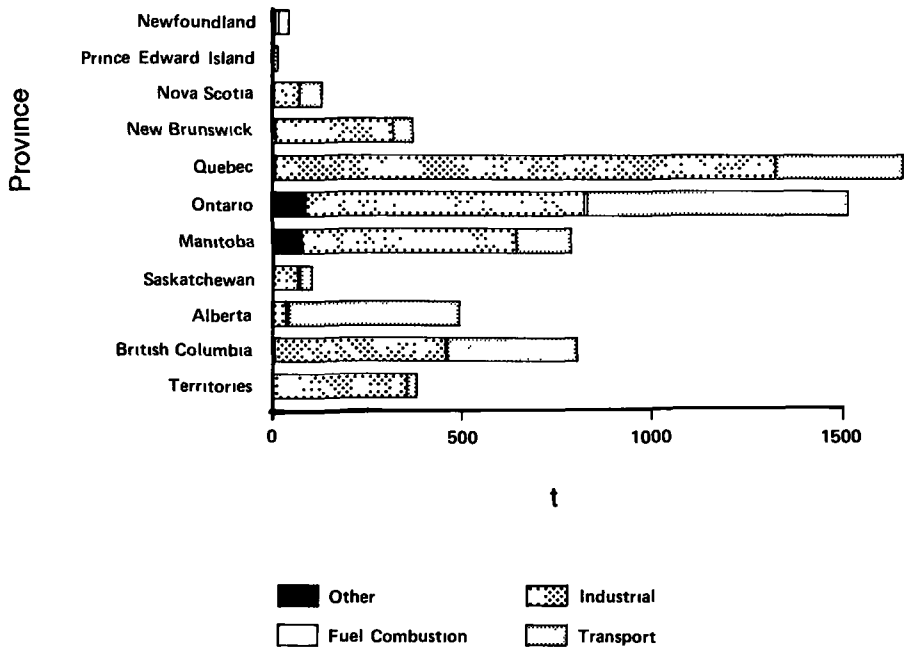


Figure 30 **1987 National Emissions of Lead by Province and by Source Category (tonnes) (Jaques, 1989)**

about a third of national lead emissions. This is a substantial reduction from the 63% share of national lead emissions contributed by this sector in 1982.

Figure 31 shows lead levels in selected cities for the past five years. In most cases, current levels are at the lower end of the ranges indicated for the five-year averages. In western Canada, the older* vehicle fleet would account for a greater use of leaded fuels. Table I (Appendix) shows dramatic improvements in lead levels at sites that recorded the highest levels in the past. Also noteworthy is the fact that the average and maximum levels in central and eastern Canada have declined more than those in western Canada.

The phaseout of lead in motor gasoline should result in similarly low levels in urban areas across the country.

The composite average of the network annual mean lead concentrations decreased by about 94% between 1981 and 1990 (see Appendix (Table J) and Figure 32). In fact, the annual average has delined by 80% since 1987. Stations in more polluted areas have shown consistent improvement as indicated by the decrease in the 90th-percentile concentration. The number of stations for which valid annual mean data are available for pairs of consecutive years is listed in the Appendix (Table F). Stations showing decreases of greater than 0.04 $\mu g/m^3$ are dwindling; stations showing increases are disappearing; and stations showing no

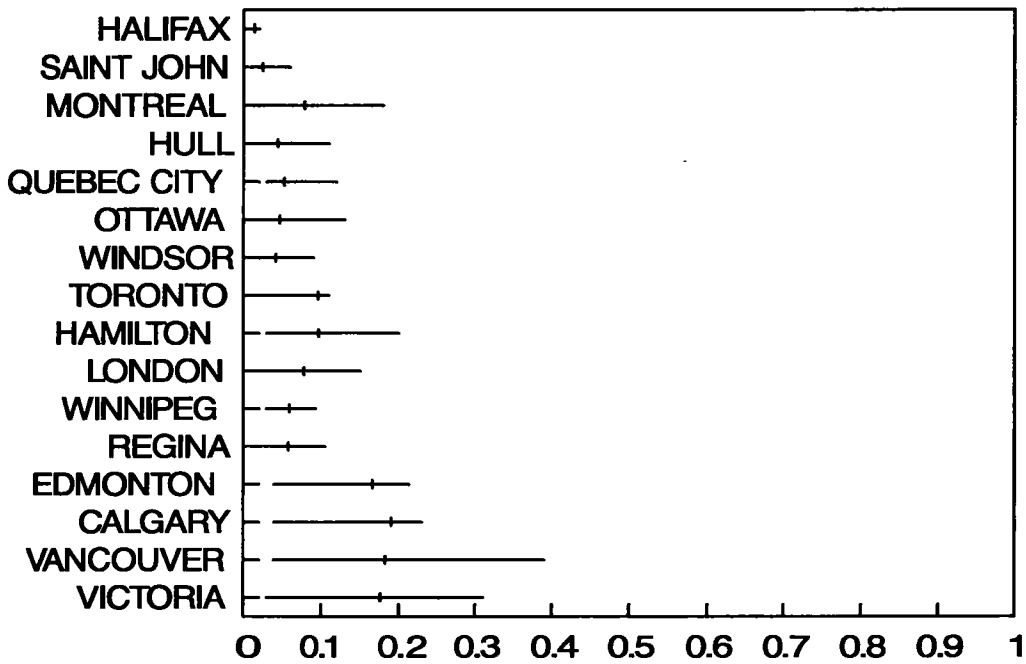


Figure 31 Particulate Lead: Five-year Annual Average Levels in Selected Cities ($\mu g/m^3$) (1986 to 1990)

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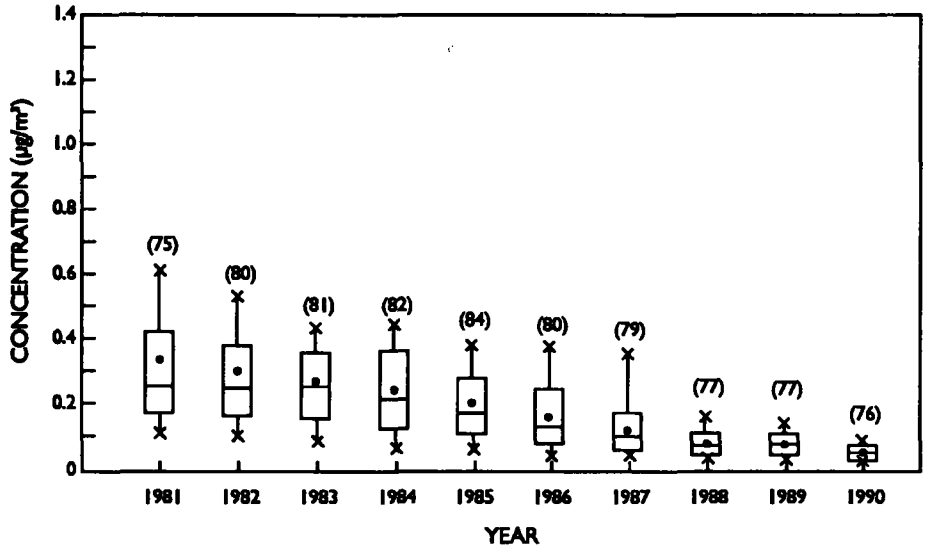
* The term "older" refers to the fact that cars tend to last longer in western Canada. It is estimated that 25% of the cars on the road in British Columbia are more than 10 years old. By contrast, only 7% of the cars in eastern Canada are more than 10 years old Older cars also have higher emission rates of NO_x, hydrocarbons, and CO.



(N) - number of stations

Figure 32 Lead - Distribution of Station Annual Mean Data (1981 to 1990)

change are dominant — as could be expected given the phaseout of lead in gasoline.

Composite average annual mean lead concentrations measured at selected stations (valid data for seven to 10 years) in the NAPS network are shown in Figure 33. Class I Stations show higher levels than do All Stations, a result that is consistent with the fact that Class I Stations tend to be located in downtown (central urban) areas where traffic density and lead levels are expected to be higher. The data indicate a convergence of the average levels measured by the two sets of stations, but the Class I average continued to be somewhat higher than the overall average from 1981 to 1990. In Figure 33 the long-term change using Tukey's Test is presented for All Stations (network), and there appears to have been a significant decrease every few years. The most recent trend results indicate that levels were significantly lower 1990 than in 1987 and all preceding years. As the use of lead additives in motor gasoline has effectively come to an end, the decrease should become stabilized and concentrations should approach background levels.

Historically the highest lead concentrations have occurred in cities. The Appendix (Table I) shows station parameters, concentration levels, and traffic density for the highest lead sites for 1983, and compares these to 1987 and 1990 levels. Some of these stations may be near an industrial source such as a smelter or a metal remelting operation, while other stations are far removed from industrial areas. However, one common feature is their proximity to high traffic density or, more specifically, to the major source of urban (suspended particulate) lead emissions — the gasoline-powered motor vehicle.

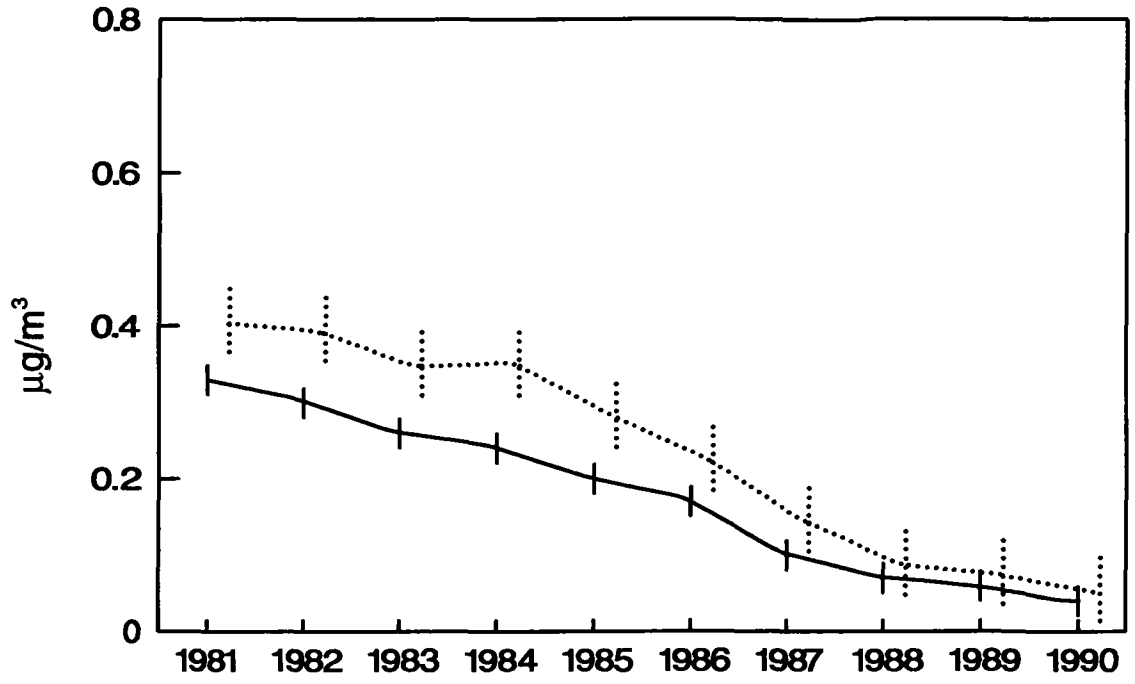


Figure 33 **Trends in Lead Annual Mean Values (µg/m³) for All Stations (—) and Class I Stations (...) with 95% Confidence Limits (1981 to 1990)**

Section 8

Soiling Index

The soiling index is a measurement of the soiling or darkening potential of fine particulate in the atmosphere, measured in coefficient of haze (COH) units. No National Ambient Air Quality Objectives (NAAQOs) have been set for this pollutant. Likely sources of fine particulate are fuel combustion, industrial processes, vehicle exhaust, agricultural burning, and slash burning.

As shown in Figure 34 and the Appendix (Table G), the composite average of the station annual means has changed little from 1981 to 1990. The soiling index peaked at 0.32 COH units during 1989 but has come down to 0.29 COH in 1990.

Coefficient of haze has remained in the 0.28-COH range with a margin of variance of 0.03 COH throughout the decade. Between 1989 and 1990, reduced levels at the more polluted sites accounted for most of the decrease in the average values. This is apparent from inspection of the 90th percentile from the box plot (Figure 34).

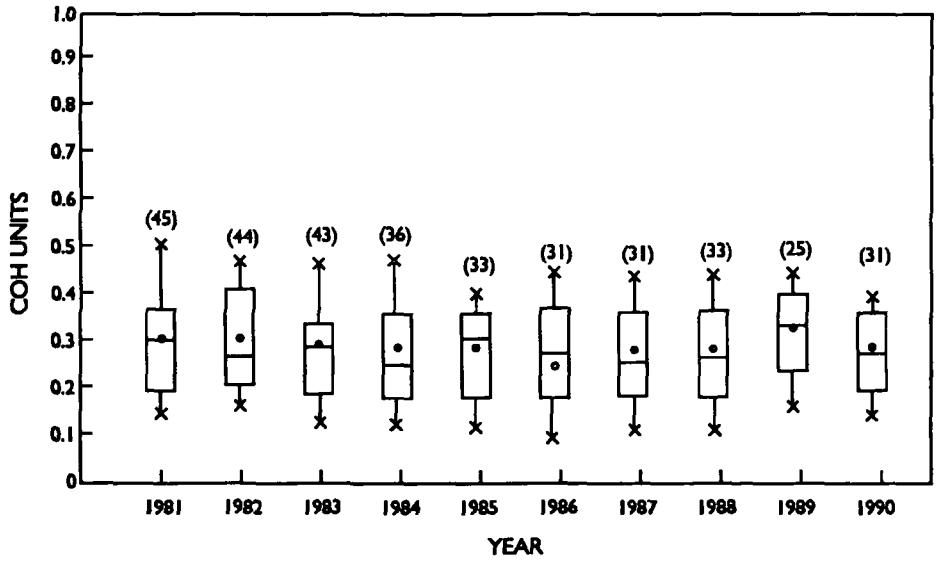
Despite the small improvement in average soiling index levels, statistical analysis (linear regression) of changes for the 10-year period from 1981 to 1990 indicates no significant change in COH levels at 95% confidence.

Average levels of COH for selected cities are shown in Figure 35. Apart from three cities in southern Ontario, all five-year averages fall within the 0.3-COH range. The Appendix (Table G) presents changes in stations for which annual mean data from COH monitoring sites are available for pairs of consecutive years. The number of stations measuring the soiling index has declined steadily from 53 sites in 1978 to 23 in 1987.

Figure 36 shows long-term changes using Tukey's Test in average annual mean soiling index values for Class I Stations and for all NAPS network stations. The trend lines for Class I Stations and All Stations almost coincide.

However, Class I Stations tend to have slightly higher index values than All Stations for the last few years; this is consistent with their central urban location. The results of Tukey's Test for All Stations do not indicate significant (95% confidence) changes in the levels of COH between 1978 and 1987, as all the confidence limits overlap.

The previously reported occurrence of higher soiling index values continues for stations in such cities as Montreal, Toronto, Hamilton, Windsor, and Vancouver continues (Souchen, 1979). The Barton and Sanford station 60501C in Hamilton reported the highest annual mean in 1987 (0.55 COH units).



(N) - number of stations

Figure 34 **Soiling Index - Distribution of Station Annual Mean Data (1981 to 1990)**

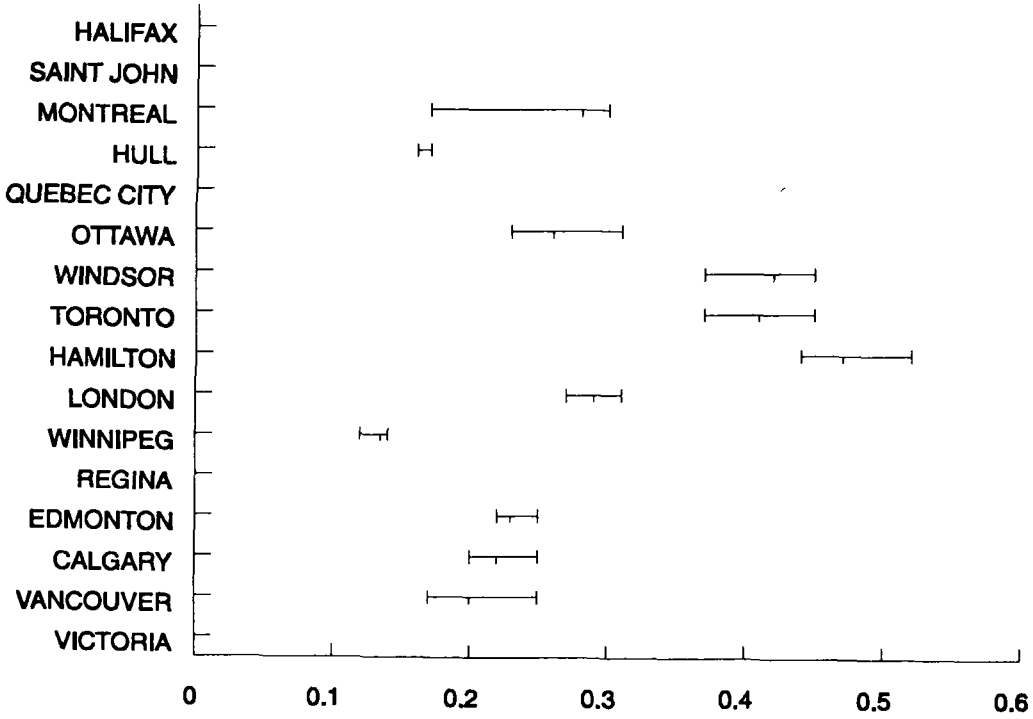


Figure 35 **Coefficient of Haze: Five-year Average Levels (COH units) in Selected Cities in Canada (1986 to 1990)**

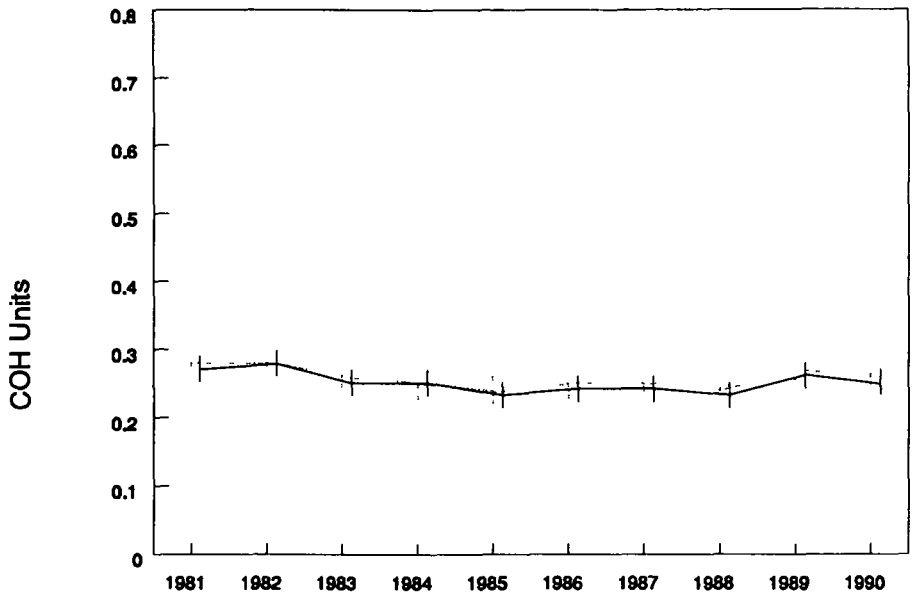


Figure 36 **Trends in Soiling Index Annual Mean Values (COH units) for All Stations (—) and Class I Stations (...) with 95% Confidence Limits (1981 to 1990)**

References

Byrkit, D.R., *Elements of Statistics* (2nd Edition), D. Van Nostrand Co., LC Cat. Card No. 74-25312, ISBN 0-442-21413-8 (1972).

Dann, T., personal communication, ozone exceedence days Pollution Division, Env. Canada (1992).

Dann, T., "Canadian Urban Monitoring Programs for Ozone, Nitrogen Oxides and Volatile Organic Compounds", Proceedings (final program) of Seminar on the Contemporary Oxidant Problem (February, 1989).

Environment Canada, "1985 Canadian Emissions Inventory of Common Air Contaminants", Environmental Protection Series Report, EPS 5/AP/3 (June, 1989).

Environment Canada, "National Urban Air Quality Trends 1974 to 1985", Environmental Protection Series Report, EPS 7/UP/2 (May, 1987).

Environment Canada, "National Urban Air Quality Trends 1974 to 1983", Environmental Protection Series Report, EPS 7/UP/1 (1986).

Environment Canada, "Emissions and Trends of Common Air Contaminants in Canada 1970-1980", Environmental Protection Series Report, EPS 7/AP/17 (September, 1986).

Environment Canada, "Ambient Air Particulate Lead Concentrations in Canada 1975-1983", Environmental Protection Series Report, EPS 7/AP/15 (September, 1985).

Environment Canada, "Status Report on Compliance with Secondary Lead Smelter Regulations, 1984", Environmental Protection Series Report, EPS 1/MM/1 (June, 1985).

Environment Canada, "Light Duty Vehicle Emissions and the Oxidants Issue in Canada", Environmental Protection Series Report, EPS 2/TS/3 (May, 1984).

Environment Canada, "Urban Air Quality Trends in Canada 1970-79", Environmental Protection Series Report, EPS 5-AP-81-14 (1981).

Environment Canada, National Air Pollution Surveillance, Annual Summaries, 1974 to 1990, Surveillance Reports, Air Pollution Control Directorate.

Federal-Provincial Committee on Air Pollution, "Criteria for National Air Quality Objectives", report by the Sub-Committee on Air Quality Objectives (November, 1976).

Furmanczyk, T., "National Urban Air Quality Trends (1974-1981)", Environmental Protection Series Report, EPS 7/AP/14, Environment Canada (1984).

"Global Climate Changes as Forecast by Goddard Institute for Space Studies, Three Dimensional Model", J. Geophys. Res., 93:8, pp. 9341-9364 (Aug. 20, 1988).

Hilborn, J.M. and M. Still, Draft Report on Air Pollution, State of Environment report series, Environment Canada (June, 1989).

Jaques, A.J., "National Inventory of Sources and Releases of Lead (1982)", Environment Canada, Environmental Protection Series Report, EPS 5/HA/3 (September, 1985).

Jaques, A.J., Update of "Sources and Releases of Lead 1987", unpublished data (1989).

National Energy Board, "Canadian Energy Supply and Demand 1990-2010", Summary Report (June, 1991).

Nicholl, C.S. and P.J. Choquette, "Ambient Air Quality 1970-74, A Statistical Analysis", Air Pollution Control Directorate, Environment Canada, Environmental Protection Series Report EPS 5-AP-76-14 (February, 1977).

Pollack, Allison K., "Analysis of Variance Applied to National Ozone Air Quality Trends", Systems Applications Inc., San Rafael, California (date unknown).

Souchen, P., "National Air Quality Trends 1970-77", Air Pollution Control Directorate, Environment Canada, Environmental Protection Series Report, EPS 5-AP-78-27 (April, 1979).

United Nations Environment Programme / World Health Organization, "Assessment of Urban Air Quality Worldwide", draft report (September, 1988).

U.S. EPA (United States Environmental Protection Agency), "National Air Quality and Emissions Trends Report", EPA-450/4-89-001 (1989).

U.S. EPA (United States Environmental Protection Agency), "Quality Assurance Handbook for Air Pollution Measurement Systems", EPA 600/9-76-005 (December, 1984).

U.S. EPA (United States Environmental Protection Agency), "Intra-Agency Task Force Report on Air Quality Indicators", EPA-450/4-81-015 (February, 1981).

Appendix

Summary Data - National Urban Air Quality Trends 1981 to 1990

Table A **Sulphur Dioxide - Number of Stations Indicating Changes in Annual Mean (1981 to 1990)**

Period	Number of Stations			
	Decrease	Increase	No Change*	Total
1981-82	15	9	19	43
1982-83	19	5	25	49
1983-84	13	5	25	43
1984-85	14	3	28	45
1985-86	9	6	24	39
1986-87	7	3	29	39
1987-88	5	17	26	48
1988-89	8	12	34	54
1989-90	12	5	36	53

* includes stations having differences greater than 1.0 ppb to ensure changes are not due to monitoring instrument inaccuracies or other errors

Table B **Nitrogen Dioxide - Number of Stations Indicating Changes in Annual Mean (1981 to 1990)**

Period	Number of Stations			
	Decrease	Increase	No Change*	Total
1981-82	9	9	13	31
1982-83	14	1	15	30
1983-84	3	12	13	28
1984-85	10	8	18	36
1985-86	5	10	17	32
1986-87	6	7	16	29
1987-88	7	8	14	29
1988-89	7	11	14	37
1989-90	21	4	11	36

* includes stations having differences greater than 1.0 ppb to ensure changes are not due to monitoring instrument inaccuracies or other errors

Table C Carbon Monoxide - Number of Stations Indicating Changes in Annual Mean (1981 to 1990)

Period	Number of Stations			
	Decrease	Increase	No Change*	Total
1981-82	13	1	18	32
1982-83	11	3	21	35
1983-84	15	2	22	39
1984-85	10	4	28	42
1985-86	6	3	28	37
1986-87	8	2	24	34
1987-88	12	7	18	37
1988-89	4	11	22	37
1989-90	15	2	22	39

* includes stations having differences of 1.0 ppb to ensure changes are not due to monitoring instrument inaccuracies or other errors

Table D Ozone - Number of Stations Indicating Changes in Annual Mean (1981 to 1990)

Period	Number of Stations			
	Decrease	Increase	No Change*	Total
1981-82	3	12	17	32
1982-83	5	10	16	31
1983-84	6	5	15	26
1984-85	4	9	18	31
1985-86	11	5	18	34
1986-87	2	10	20	32
1987-88	2	17	20	39
1988-89	10	7	23	40
1989-90	11	3	23	37

* includes stations having differences greater than 1.0 ppb to ensure changes are not due to monitoring instrument inaccuracies or other errors

Table E Suspended Particulate - Number of Stations Indicating Changes in Annual Mean (1981 to 1990)

Period	Number of Stations Decrease	Increase	No Change*	Total
1981-82	43	5	22	70
1982-83	39	10	29	78
1983-84	18	14	40	72
1984-85	33	9	33	75
1985-86	14	24	39	77
1986-87	7	33	38	78
1987-88	28	9	34	71
1988-89	22	10	41	73
1989-90	33	2	30	65

* includes stations with differences greater than 4 $\mu g/m^3$ to ensure changes are not due to monitoring instrument inaccuracies or other errors

Table F Lead - Number of Stations Indicating Changes in Annual Mean (1981 to 1990)

Period	Number of Stations Decrease	Increase	No Change*	Total
1981-82	32	2	31	65
1982-83	27	6	33	66
1983-84	17	7	42	66
1984-85	24	7	38	69
1985-86	20	2	46	68
1986-87	34	-	31	65
1987-88	19	-	45	64
1988-89	5	2	62	69
1989-90	10	-	52	62

* includes stations with differences greater than 0.04 $\mu g/m^3$ to ensure changes are not due to monitoring instrument inaccuracies or other errors

Table G Soiling Index - Number of Stations Indicating Changes in Annual Mean (1981-1990)

Period	Number of Stations			
	Decrease	Increase	No Change*	Total
1981-82	14	12	11	37
1982-83	15	6	7	28
1983-84	11	10	8	29
1984-85	12	5	7	24
1985-86	3	12	9	24
1986-87	8	8	7	23
1987-88	13	9	6	28
1988-89	4	11	10	25
1989-90	15	1	8	26

* includes stations with differences greather than 0.01 COH units to ensure changes are not due to monitoring instrument inaccuracies or other errors

Table H Sulphur Dioxide - A Sampling of the Highest Annual Means by City and Stations Over the Past 10 Years

City	Station	Annual means (ppb)									
		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Halifax	301116C	15	10	11	11	10	10	11	14	11	11
Quebec City	503031	--	--	34	21	12	24	ND	ND	ND	ND
Shawinigan	512011	17	12	--	12	10	23	17	16	21	21
Trois-Rivières	50801R	14	--	--	9	8	9	8	12	8	8
Arvida	50901R	20	15	16	17	9	9	8	15	12	13
Montreal	50104C	16	12	7				4	5	8	6
	50115C	--	--	8	9	9	11	7	8	9	5
	50103R	23	20	14	10	18	13	8	12	14	13
Ottawa	60101C	10	11	5	9	9	--	5	6	6	6
Sudbury	60606C	10	8	8	10	10	9	9	7	8	11
	60602R	10	10	9	10	10	8	9	7	9	13
Sarnia	61004R	14	12	10	9	11	8	7	9	8	12
Windsor	60204C	12	9	8	7	7	8	8	11	8	7
Cornwall	61204C	10	11	8	10	9	8	6	6	7	5
Hamilton	60501C	10	14	14	15	9	8	9	9	12	6

-- insufficient data for calculation of a valid mean

Table I Monitoring Sites* with Highest Measured Lead Concentrations in 1983, 1987, and 1990

Station No	City	Address	Annual Geometric Mean ($\mu g/m^3$) (1983)	Annual Geometric Mean ($\mu g/m^3$) (1987)	Annual Geometric Mean ($\mu g/m^3$) (1990)	Maximum 24-h Conc ($\mu g/m^3$) (1983)	Maximum 24-h Conc ($\mu g/m^3$) (1987)	Maximum 24-h Conc ($\mu g/m^3$) (1990)	Sampler Height (m)	Distance to Nearest Roadway (m)	Nearest Major Roadway Volume (vehicles/day)
50109	Montreal	Duncan/Decarie	0 72	0 21	0 02	1 8	0 8	0 1	4	20	100 000
50601	Rouyn	Hôtel de Ville	0 41	0 08	0 08	7 7	3 2	1 7	8	--	--
60403	Toronto	Evans/Arnold	0 46	0 18	0 02	1 7	0 6	0 1	2	120	150 000
60417	Toronto	Breadalbane	0 28	0 11	0.03	0 8	0 3	0.2	25	100	50 000
60501	Hamilton	Barton/Sanford	0 40	0 16	0 03	2 5	1 2	0 2	4	18	18 650
61501	Kitchener	Edna/Frederick	0 52	0 20	0 05	2 2	1 2	0 1	4 5	20	56 000
90204	Calgary	316-7th Ave	0 43	0 19	ND	2 2	0 7	ND	0 7	25	16 150
90218	Calgary	Bonny Brk/18th Street	0 39	0 22	0 23						
90122	Edmonton	127th Street/133 Avenue	0 32	0 14	0 18						
00104	Vancouver	27th/Ontario	0 50	0 33	0 04	1 8	1 1	0 2	18	200	10 800
00109	Vancouver	970 Burrard	0 56	0 24	0 04	1 9	1 1	0 2	4	20	21 200
00114	Richmond	Municipal Hall	0 46	0 17	0 03	2 1	0 8	0 5	15	100	29 000
00117	Vancouver	BCIT Burnaby	0 51	0 24	0 04	2 2	1 4	0 4	18	200	35 000
00303	Victoria	1250 Quadra	0 45	0 26	0 03	2 3	1 1	0 3	12	18	12 000

* Only NAPS stations with complete data record included

Table J Summary Data - Urban Air Quality in Canada, 1974 to 1990

Pollutant	Year	Number of Sites	Average of Annual Mean	Percentage of Sites with Annual Mean Lower than Given Values				
				90%	75%	50%	25%	10%
SO_2 (ppb)	1974	27	13	27	22	12	2	0
	1981	51	8	14	11	5	4	1
	1982	59	8	12	10	7	4	2
	1983	59	6	11	8	5	3	1
	1984	55	7	11	9	6	4	1
	1985	56	6	10	9	6	2	1
	1986	52	6	9	7	5	3	1
	1987	58	5	9	7	4	2	1
	1988	61	6	12	9	6	4	2
	1989	63	6	11	8	6	3	2
	1990	59	6	10	8	5	3	1
NO_2 (ppb)	1978	33	29	40	35	29	20	18
	1981	36	23	32	29	22	16	11
	1982	38	23	34	27	22	18	10
	1983	33	22	29	26	23	18	12
	1984	38	24	34	27	23	18	15
	1985	41	22	9	26	22	17	12
	1986	36	22	32	27	22	17	12
	1987	32	21	31	25	22	17	15
	1988	43	21	30	26	21	15	10
	1989	41	23	33	27	23	17	12
	1990	42	21	31	27	21	16	12
CO (ppm)	1974	18	2.4	5.0	3 0	2.2	1.2	0 7
	1981	36	1.5	2.3	1.6	1.4	0.9	0 5
	1982	41	1.3	2.2	1.9	1.2	0.9	0 5
	1983	43	1.2	2.1	1.4	1.0	0.7	0.5
	1984	49	1 1	1.8	1 3	0 9	0 5	0 5
	1985	45	1.0	1.8	1.3	0.9	0.5	0.5
	1986	39	1.0	1.7	1.3	0.8	0.5	0 3
	1987	42	1.0	1.6	1.2	0 8	0.5	0 3
	1988	43	0.9	1 3	1 1	0.8	0.6	0 4
	1989	42	1.0	1.4	1.2	0 9	0.6	0.5
	1990	46	0.8	1 2	1 1	0.8	0 5	0.4
Ozone (ppb)	1979	39	15	20	18	15	12	10
	1980	41	16	21	20	16	12	9
	1981	35	15	20	18	15	12	10
	1982	40	16	21	19	16	13	10
	1983	36	16	21	14	10	7	5
	1984	36	16	20	19	17	12	10

Pollutant	Year	Number of Sites	Average of Annual Mean	Percentage of Sites with Annual Mean Lower than Given Values				
				90%	75%	50%	25%	10%
Ozone (ppb)	1985	42	17	23	19	16	13	11
(continued)	1986	39	16	23	20	17	13	10
	1987	42	16	23	20	16	13	9
	1988	45	19	24	23	19	16	10
	1989	46	19	27	22	18	16	12
	1990	44	18	25	21	17	14	12
Suspended	1974	59	78.6	121.0	96.0	70 0	53.0	43.0
Particulate	1981	87	58.6	80.0	66.0	56.0	42.0	37.0
($\mu g/m^3$)	1982	93	51.8	77.0	58.0	49.0	39.0	33.0
	1983	88	47 6	68.0	53.0	43.0	36.0	30.0
	1984	86	46.5	66.0	56.0	42.0	33.0	28.0
	1985	90	42.9	59.0	50.0	42.0	35.0	27.0
	1986	88	43.0	67 0	50.0	40 0	32.0	26.0
	1987	84	48 0	68.0	55.0	43.0	37.0	32.0
	1988	80	44.3	62.0	53.0	42.0	34.0	28.0
	1989	82	44.4	61.0	55.0	41.0	32.0	29.0
	1990	73	38.5	55.0	43.0	37.0	29.0	27.0
Lead ($\mu g/m^3$)	1974	58	0.68	1.22	0.97	0.53	0.26	0.15
	1981	75	0.32	0.62	0.41	0.24	0 17	0.11
	1982	80	0.27	0.53	0.37	0.23	0.14	0.09
	1983	81	0.25	0.45	0.35	0.24	0.14	0.08
	1984	82	0.23	0.44	0.35	0 19	0.11	0.05
	1985	84	0.18	0.39	0.25	0.15	0.10	0 05
	1986	80	0.15	0.34	0 23	0 12	0 06	0.03
	1987	79	0.10	0.21	0 14	0.08	0.05	0.02
	1988	77	0.06	0.16	0.08	0.04	0.03	0.02
	1989	77	0 06	0.12	0.09	0.04	0.02	0.02
	1990	71	0.02	0.04	0.03	0.02	0.01	0.01
Soiling Index	1974	35	0.38	0.67	0.46	0.34	0.20	0.14
	1981	45	0.30	0.54	0.35	0.29	0.18	0.12
	1982	44	0 30	0.46	0.41	0.26	0.20	0.13
	1983	35	0 28	0.47	0.33	0.27	0.18	0.12
	1984	36	0.27	0.47	0.36	0.23	0.17	0.12
	1985	33	0.28	0.41	0.36	0.30	0.17	0.10
	1986	31	0.25	0.45	0.37	0.27	0.18	0.10
	1987	31	0 28	0.44	0.36	0.25	0.18	0.11
	1988	33	0.28	0.44	0.37	0.26	0.19	0.10
	1989	25	0.32	0.45	0.40	0.33	0.23	0.18
	1990	31	0.29	0.42	0 37	0.28	0.21	0.15