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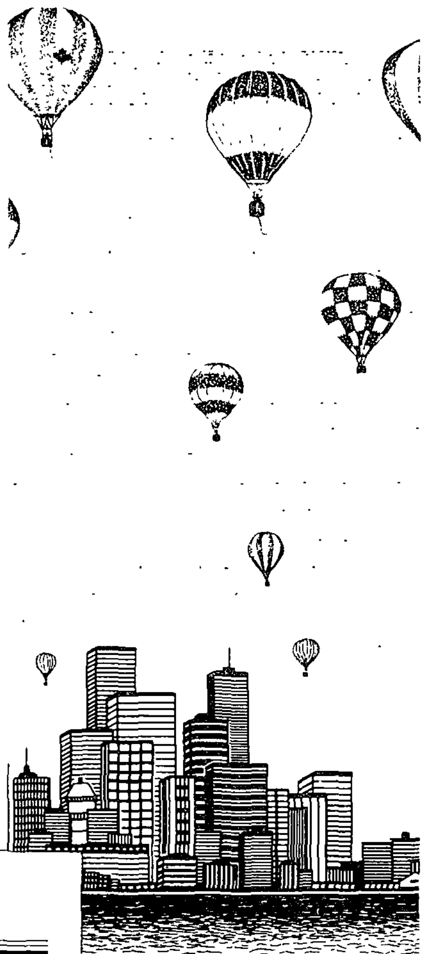

National Urban Air Quality Trends – 1978 to 1987

Report EPS 7/UP/3
May 1990

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Environment Canada Environnement Canada

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National Urban Air Quality Trends 1978-1987

by

Inventory Management Division
Regulatory Affairs and Program Integration Branch
Environmental Protection
Conservation and Protection
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Page vi Résumé

À la huitième ligne du premier paragraphe:

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- indice d'opacité, 1974 au lieu de
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acceptable et admissible au lieu de acceptable et tolérable

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Figure 9, should read:

1978 - 1987 instead of 1987 - 1987

Page 21 Table 7 Nitrogen Dioxide ...

Part (B) 24-hour Maximum, should read:

0 to 110* instead of 0 to 110**

Page 26 Table 8 Carbon Monoxide ...

Part (A) third line, should read:

13.1 to 17 *** instead of 13.1 to 17 **

Page 32 Table 9 Ozone ...

Part (B) second line, should read:

51 to 80** instead of 51 to 80*

Page 56 Table G Soiling Index ...

First number under "Total", should read:

53 instead of 3

Readers Comments

Comments regarding the content of this report should be addressed to:

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Ottawa, Ontario
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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 completeness criteria for the air quality data were brought in before 1974 for the 1974 data. Data availability for each contaminant are as follows:

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

In this report, monitoring data have been analyzed to determine national trends in average and peak concentrations of these contaminants on an annual basis for the last ten years (1978-1987). 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.

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. Les critères relatifs à l'état complet des données sur la qualité de l'air ont été établis avant 1974 et appliqués aux données de cette année-là. Voici les polluants pris en considération, ainsi que les dates à partir lesquelles 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 de souillure, 1974*

Dans le présent rapport, on a analysé les données de surveillance pour déterminer l'évolution des concentrations moyennes et de pointe de ces polluants à l'échelle nationale, sur une base annuelle, pour les dix dernières années (1978-1987). On a aussi comparé ces données aux objectifs nationaux afférents à la qualité de l'air ambiant, qui définissent trois niveaux de concentration maximale: souhaitable, acceptable et tolérable.

Les concentrations moyennes sont exprimées sous forme de moyennes arithmétiques, excepté 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, responsible for monitoring the quality of air, has undergone many refinements since its inception in 1970. Since the mid-seventies, 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 based on 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 to 1987 period show considerable improvements in ambient air quality as can be seen in the following tables:

Table S1 A Summary of Seven Pollutants Measured by NAPS Network

Pollutant	1987 Average Concentrations	Percent decline 1978-1987	Percent decline 1974-1987
Sulphur dioxide	5 ppb	50	61
Nitrogen dioxide	21 ppb	27	29
Carbon monoxide	1 ppm	33	58
Ozone	16 ppb	no change	NA
Total suspended particulate	48 $\mu g/m^3$	22	40
Particulate lead	0.1 $\mu g/m^3$	76	85
Coefficient of haze	0.28 COH	no change	26

NA - not available for 1974

It should be noted that the ozone levels recorded in Tables S1 and S2 came from 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.

Table S2 Attainment of the Acceptable (NAAQO) Level in 1974 and 1987

Pollutant	Annual objective 1974	Annual objective 1987	1-hour objective 1974	1-hour objective 1987	8-hour objective 1974	8-hour objective 1987	24-hour objective 1974	24-hour objective 1987
Sulphur dioxide	82	100	87	93	-	-	85	97
*Nitrogen dioxide	96	100	86	100	-	-	84	100
Carbon monoxide	-	-	97	100	71	94	-	-
*Ozone	50	43	18	45	-	-	-	-
Total Suspended	51	98	-	-	-	-	N/A	N/A

- no objective
* for NO_2 and O_3 the attainment rate is compared to 1977 and 1979 respectively

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, the average concentrations of the following pollutants for the 1978-1987 analysis period have shown significant improvement (at 99% confidence): sulphur dioxide, nitrogen dioxide, carbon monoxide, lead, and total suspended particulate. Coefficient of haze has shown a similar decline (at 95% confidence), while the ozone annual mean has not demonstrated any consistent trend.

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

Section 1

Introduction

1.1 Purpose and Scope

This is the seventh in a series of reports [1,2,3,4,5,6] on ambient air quality trends issued by Environment Canada. Its purpose is to report trends in the ambient air quality data collected through the National Air Pollution Surveillance (NAPS) Network[7] and to identify significant changes by statistical and other forms of analysis. This report covers the monitoring results for the 1978 to 1987 year period.

The NAPS program was initiated in January 1970 to provide a nation-wide data base for determining air quality in the major urban centres of Canada Effects on the urban environment as a consequence of changing industrial activity, fuel use patterns, population density, more extensive use of pollution control equipment, and other factors are documented in the trends reports. 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, and
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 which 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 dioxide (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 only reported annual means 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 in the United States Environmental Protection Agency (U.S. EPA) "Quality Assurance Handbook for Air Pollution Measurement Systems, Vol. 1". According to the 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 1987, 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 and the cities where monitoring instruments are located are shown in Figure 2. To emphasize the relationship of the allocation of monitoring stations with population, Figure 2 includes a population density map. The Class I Stations, their addresses and current status are listed in Table 1.

When the installation of Class I stations is completed, all air quality objective parameters and the coefficient of haze will be monitored. Most of these stations are located in downtown or major residential areas with a potential for poor air quality, which is consistent with the site selection criteria.

1.3 National Ambient Air Quality Objectives (NAAQOs)

Air quality objectives have been established as a guide in developing programs to reduce the damaging effects of air pollution[8]. These programs are designed to meet the following objectives:

1) assist in establishing priorities for reducing contaminant levels and the extent of pollution control needed,
2) provide a uniform yardstick 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 the effects of pollutants on: soil, water, vegetation, materials, animals, visibility, human health and personal comfort. 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. The desirable, acceptable and tolerable levels of the contaminants for the different averaging times in the present analysis are presented in Table 2. The effects of pollutants in the air quality objective ranges are presented in Table 3.

1.4 Analytical Methods

1.4.1 Pollutant Levels in Cities with Class I Stations

Cities with Class I stations were selected for this analysis because these stations monitor air quality trends and therefore offer a measure of consistency in the number of

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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.

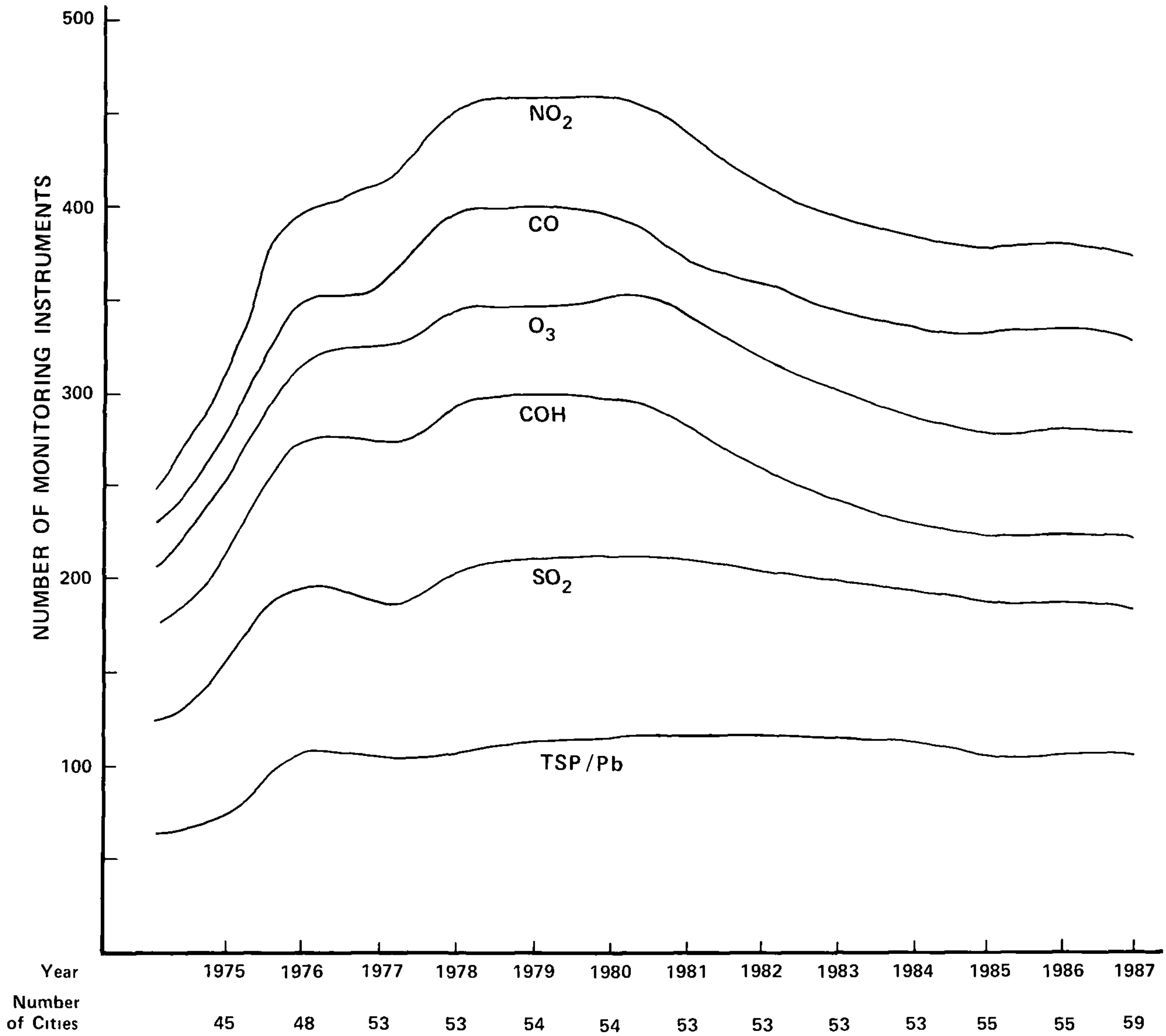
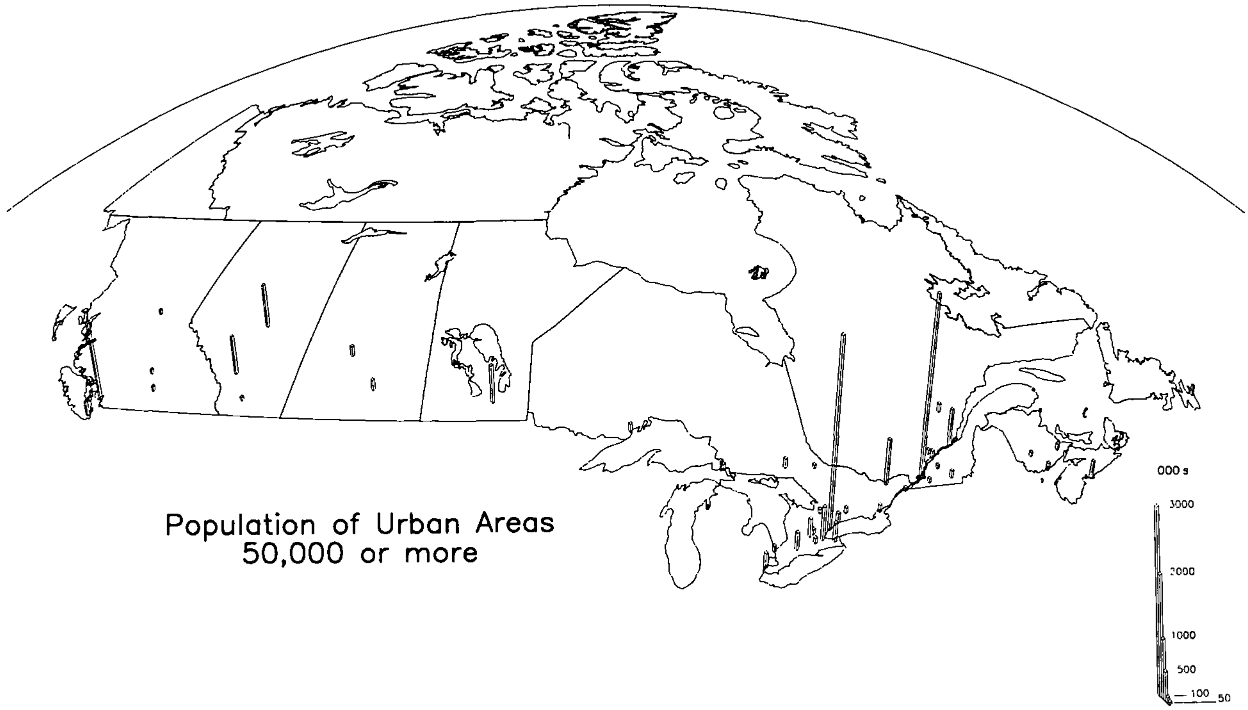


Figure 1 Profile of NAPS Network Instrumentation, 1974-1987

pollutants measured, the location of the site and the size of population, usually in excess of 250 000.

In this analysis, all available stations in the city were used to determine the city annual mean values for 1983 to 1987. 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 chosen (without a range) to approximate a city average pollutant level.

Pollutant 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.



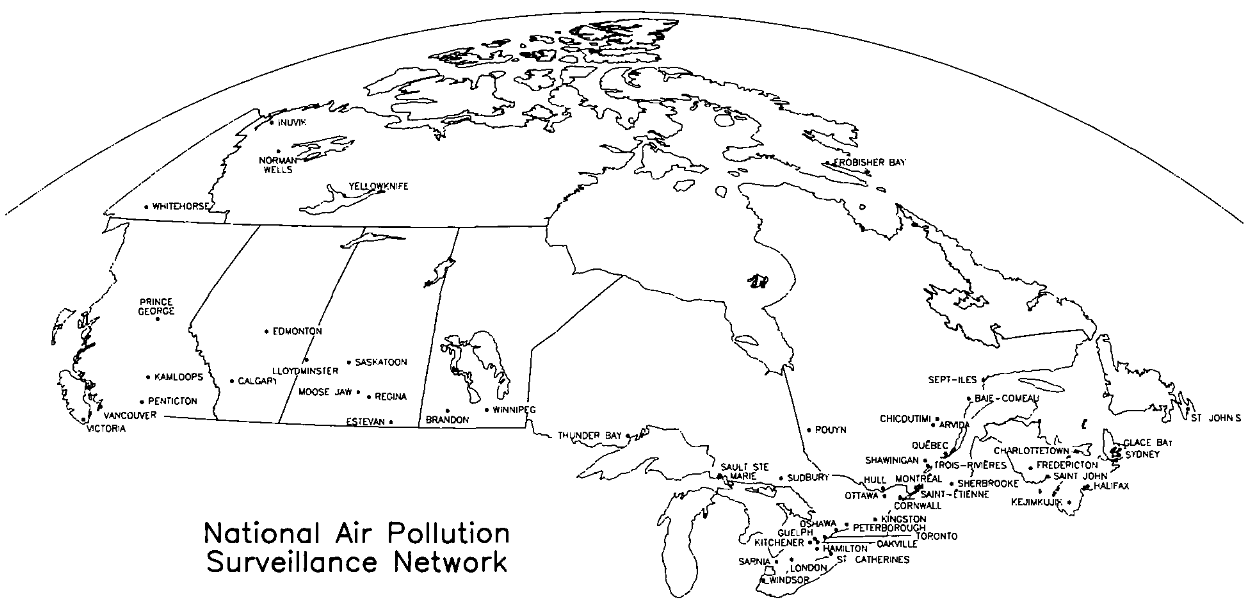


Figure 2 National Air Pollution Surveillance Network (March 1987)

Source: 1981 Census of Canada.

Maps produced by the Geocartographics Subdivision and the Environmental Statistics Unit, Statistics Canada, 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	50115C	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 Bréboeuf	no soiling index monitor
Ontario			
Ottawa	60101C	88 Slater Street	
	60104R	Rideau and Wurtemburg	
Windsor	60204C	471 University Avenue	
Toronto	60417C	26 Breadalbane Street	
	60403I	Evans and Arnold	
	60410R	Lawrence and Kennedy	
	60410R	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 Street	
	70118R	Jefferson and Scotia	
Saskatchewan			
Regina	80109C	1620 Albert Street	no soiling index monitor
Alberta			
Edmonton	90130C	10255-104th Street	no SO_2 analyzer
	90122R	127 St. and 29th Ave N.W	no SO_2 analyzer
Calgary	90227C	1611-4th Street S.W	high-volume sampler located at site 90204C
	90222R	39 St and 29th Ave N.W	no SO_2 analyzer
British Columbia			
Vancouver	00112C	Robson and Hornby	high-volume sampler located at site 00109C
	00106R	2294 West 10th Avenue	
	00108I	250 West 70th Avenue	no SO_2 analyzer
	00110R	E Hastings and Kensington	
	00111I	Rocky Pt. Park	
Victoria	00303C	1250 Quadra Street	

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 ppb	17 ppb
	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

Table 3 Pollutants and Their Effects*

National Ambient Air Quality Objective's Averaging Time	Carbon Monoxide CO (1-hour, 8-hour)	Nitrogen Dioxide NO_2 (1-hour)	Ozone O_3 (1-hour)	Sulphur Dioxide SO_2 (1-hour, 24-hour)	Suspended Particles (24-hour)
(Very Poor Range)	Increasing cardiovascular symptoms in non-smokers with heart disease Some visual impairment	Increasing sensitivity of patients with asthma and bronchitis	Light exercise produces effect in some patients with chronic pulmonary disease	Increasing sensitivity in patients with asthma and bronchitis	Increasing sensitivity on patients with asthma and bronchitis
Maximum Tolerable (Poor Range)	Increasing cardiovascular symptoms in smokers with heart disease	Odour and atmospheric discoloration Increasing bronchial reactivity in asthmatics	Decreasing performance by some athletes exercising heavily	Odourous Increasing vegetation damage and sensitivity	Visibility decreased Soiling evident
Maximum Acceptable (Fair Range)	No detectable impairment but blood chemistry changing	Odourous	Increasing injury to some species of vegetation	Increasing injury to species of vegetation	Decreasing visibility
0 - Maximum Desirable (Good Range)	No effects	No effects	No effects	No effects	No effects

In this example, City 2 and City 3 have the same five year average level for NO_2, although City 3 has a much greater 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, there was enough data available to establish a city average level of NO_2. 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 the average city pollutant level and its range will be used throughout this publication.

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 (Figure 4). 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 5% chance of falsely indicating a significant change.

The confidence intervals are calculated from an analysis of variance (ANOVA) of the concentration (mean or 98th percentile) of interest for each pollutant at each site across all the years of the study. In this analysis, the set of stations must be the same for all years in the study. This was achieved by using only stations that had valid data for at least 7 of the 10 years. Any missing values were filled in by making estimates. This system also explains 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. Data for the box plots was used as is with no stations removed and no missing values filled in An example of the plotting convention is shown in Figure 4. A more complete explanation of the method can be found in a previous report[5].Tukey's test results can provide comparisons at three levels to show:

1. changes in concentration levels from year to year at Class I and All Stations,
2. significant change (at 95% confidence) where confidence intervals do not overlap at either Class I Stations or All Stations, and
3 relative concentration levels between Class I and All Stations.

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 as presented in Table 4.

The 98th percentile of the hourly or the eight hour or 24 hour running average concentration corresponds to the 120th 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.

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

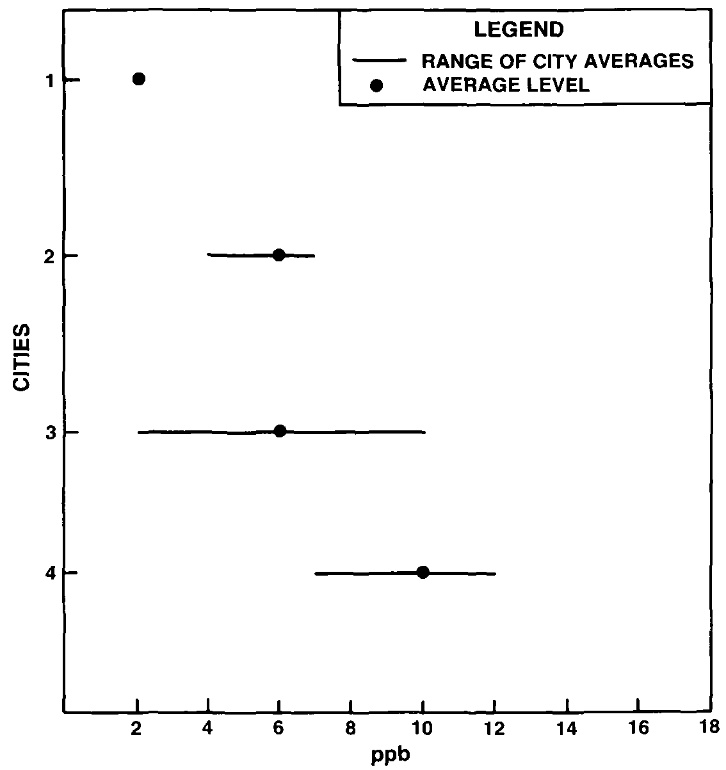


Figure 3 Sample of Plotting Method: for City Average Pollutant Levels

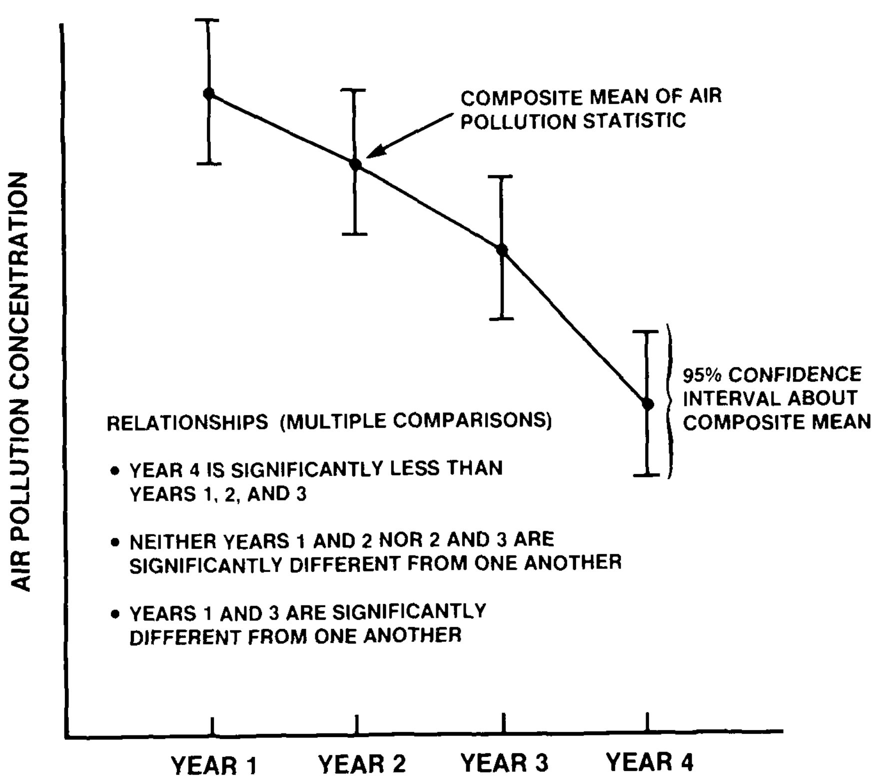


Figure 4 Plotting Convention for Tukey's Multiple Comparison Test [9]

Table 4 Linear Regression Analysis for Long-term Trends (1979-1987)

Pollutant	Indicator	10-year Average	Average Yearly Change
SO_2	Annual Mean	9.3 ppb	-0.63 **
TSP	Annual Mean	53 4 $\mu g/m^3$	-2.59 **
NO_2	Annual Mean	23.3 ppb	-0.38 **
COH	Annual Mean	0.28 COH	-0.004 *
Lead	Annual Mean	0.26 $\mu g/m^3$	-0.03 **
Ozone	Annual Mean	16.0 ppb	-0.003
Ozone	Peak Hourly	82.4 ppb	-2.6 **
CO	Annual Mean	1.3 ppm	-0.07 **
CO	Peak Hourly	4.5 ppm	-0.17 **

* significant at 95% confidence
** significant at 99% confidence

during pollution episodes occur under optimal weather conditions Unlike the 98th percentile it is more sensitive to yearly changes in (hot summer days) weather.

1.4.4 Box Plot Analysis

The box plot is a graphical technique used in exploratory data analysis to show the distribution of the annual means for "All Stations" calculated for the various 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 SP 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 percentiles), average (mean, median (50), and unfavorable (75 and 90 percentiles) stations, therefore, can be analyzed separately (see Appendix).

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

* All available stations were used in each year, 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

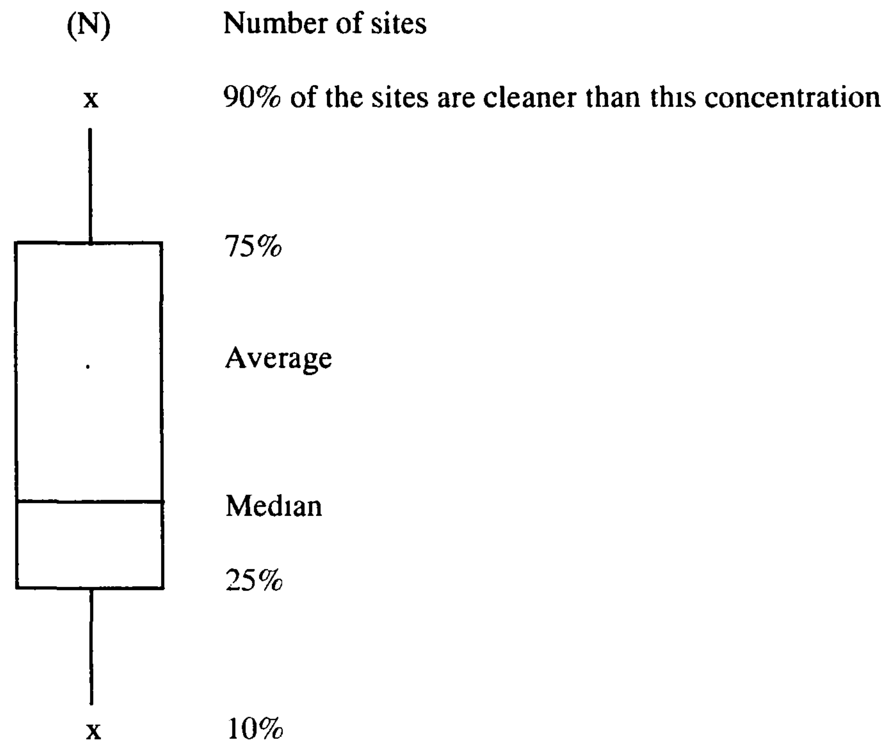


Figure 5 Concentration Box Plotting Levels

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 where the short-term air quality objectives (one-hour, eight-hour, 24-hour) are concerned. 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. Table 5 indicates that 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 60401C and 60416C (Table 5), approximately 4.0% of the readings at station 60416C exceed the desirable level, whereas 0.4% of the readings at the other station exceed the same level. This type of analysis tends to identify potential air quality problems at specific sites. Consequently, it 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)

Table 5 A Comparison of Station Readings for Carbon Monoxide

Station	Location	One-hour Average CO, 1981 >Desirable	>Acceptable	Total Readings
60401C	67 College Street	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 an Wilton St.	0	0	8299
60415R	Queensway W. and Hurontario	8	0	8607
60416C	381 Yonge Street	293	17	8481
60417C	26 Breadalbane	0	0	4297

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 nonferrous metals, and from the combustion of fuels like coal or heavy oil which may have a high sulphur content. Sulphur dioxide is a major pollutant that adversely affects health, vegetation and materials (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_2emissions 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.[10]

Figure 7 represents the SO_2 levels in sixteen selected urban centers across Canada. In most cases, the current levels are at the low end of the ranges shown in Figure 7. In terms of their five year composite averages, all limits are well within the desirable range of the annual air quality objectives. The only exception to this is Quebec City which is within the acceptable range.

2.1 Annual Means

The composite average of sulphur dioxide annual means recorded by the National Air Pollution Surveillance (NAPS) network decreased from 10 ppb in 1978 to 5 ppb in 1987 (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 are found in the Appendix. In the last five years, more than half of these stations have shown no change in annual mean concentrations.

Trends in composite annual mean values for All Stations and for Class I Stations with 95% confidence limits (derived using Tukey's test) are shown in Figure 9. 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 many significant differences (where confidence intervals do not overlap) between years, such as 1985 to 1987 and the years prior to 1982. 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 centers with an industrial SO_2 source, where higher SO_2 concentrations are expected.

In recent years, more than 90% of the monitoring stations (98% in 1987) have reported annual mean values within the maximum desirable objective level. Throughout the 1978 to 1987 year period there was a steady

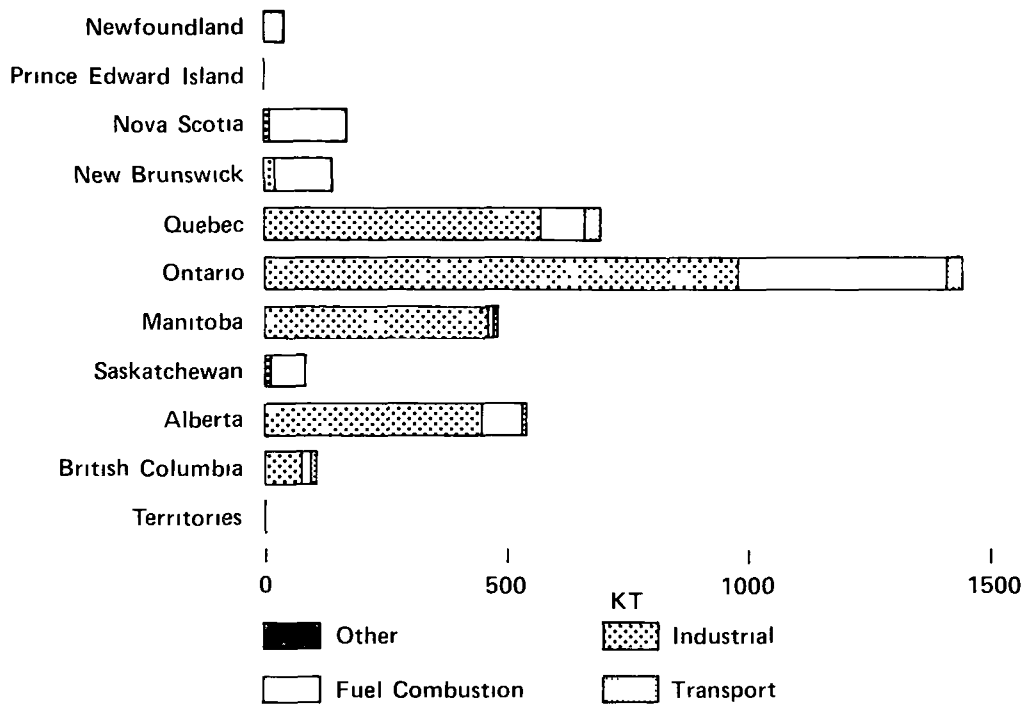


Figure 6 Sulphur Dioxide Emissions (x 10^3 tonnes) by Source Category and Province, 1985

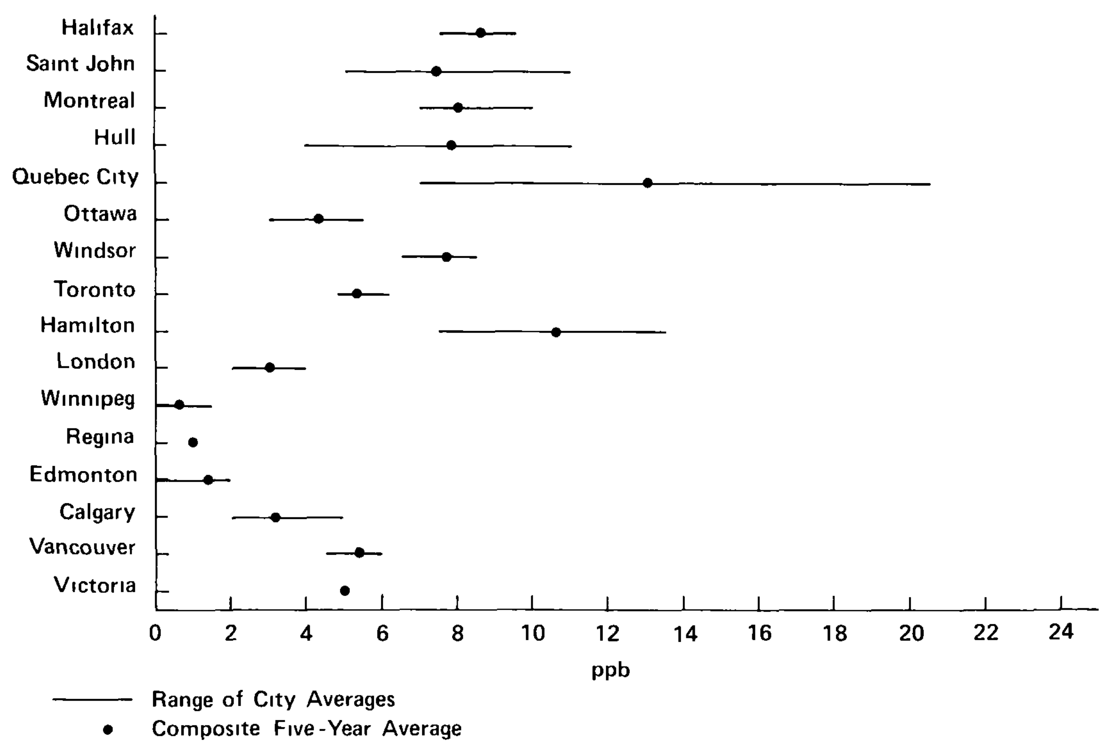


Figure 7 Annual Average Levels of Sulphur Dioxide in Selected Cities (parts per billion), 1983-1987

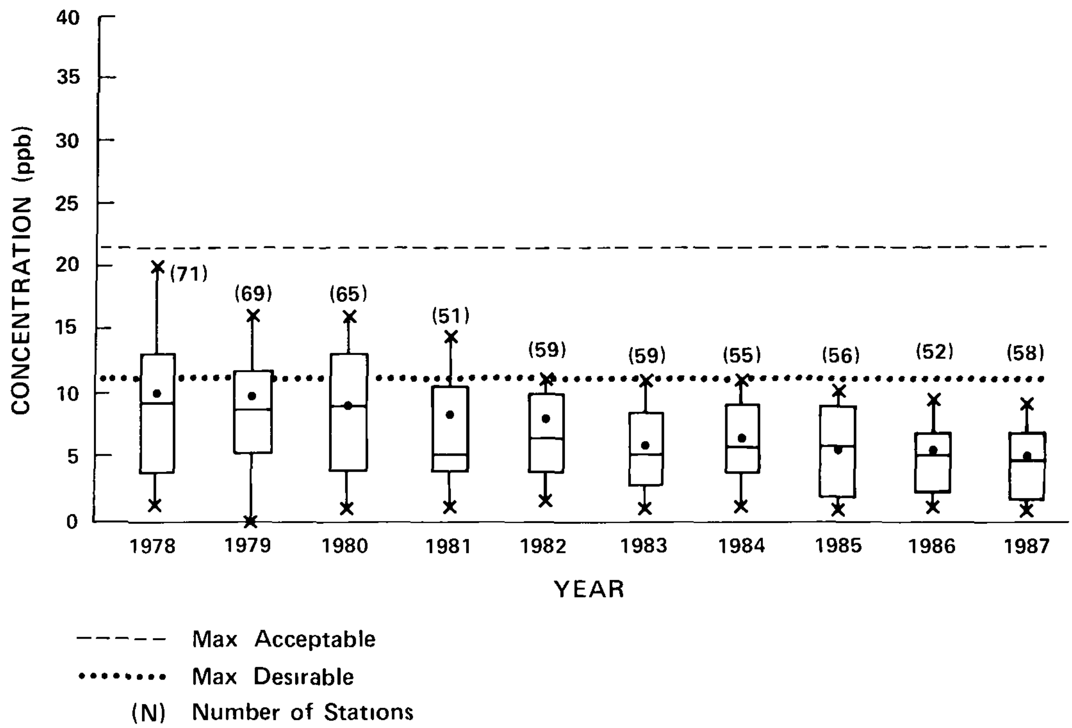


Figure 8 Sulphur Dioxide - Distribution of Station Annual Mean Data, 1978-1987

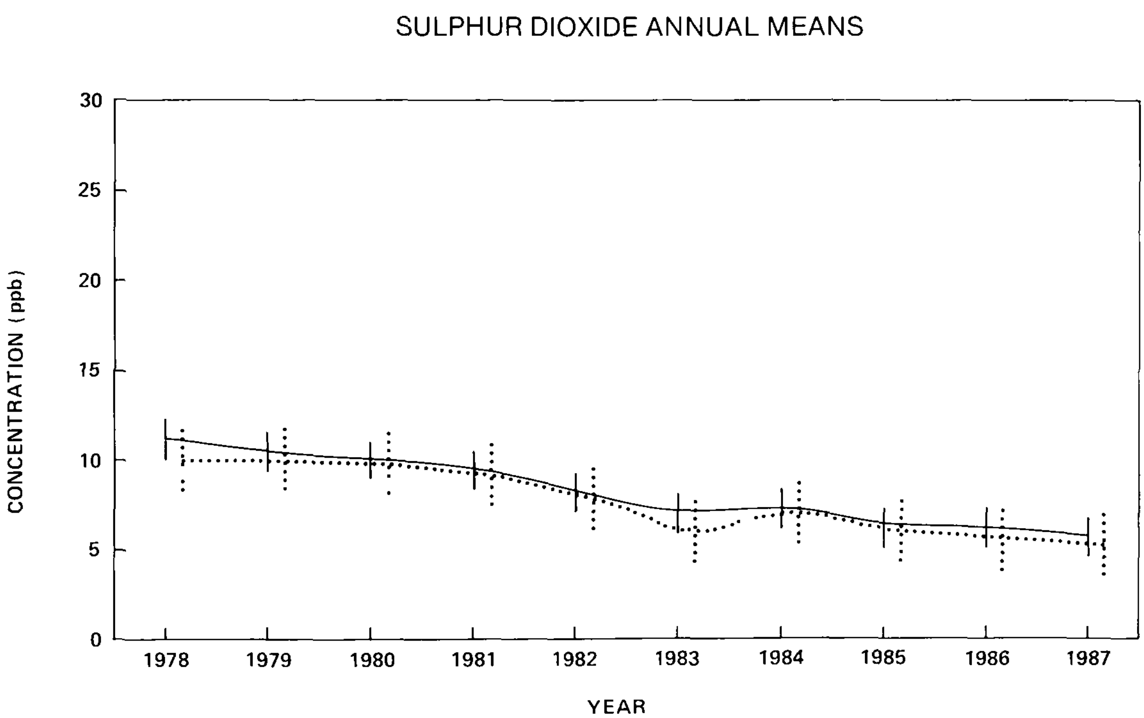


Figure 9 Trends in Sulphur Dioxide Annual Mean Values for All Stations (—) and Class I Stations (...) with 95% Confidence Limits, 1978-1987

increase in the number of sites that met the maximum desirable objective. The percentage of stations with readings in various ranges with respect to the annual NAAQOs for 1978 to 1987 are found in Table 6. The improvement achieved during the last four years is apparent since only one station has exceeded the acceptable level.

Overall, the annual mean values across the NAPS network compare favorably with the objectives, although some stations continue to register values in excess of the maximum acceptable level of 23 ppb. The stations with highest mean levels over the past eleven years are listed in Table H in the Appendix. From this table, the improvement at the worst sites is rather 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 to a level below the desirable level.

2.2 Short-term Concentrations

2.2.1 Twenty-four-hour Maximum Levels

During the 1978 to 1987 period the percentage of stations meeting the maximum desirable level of the National Ambient Air Quality Objectives have improved steadily from 42% to 80% of the stations. The maximum acceptable level was exceeded at 3% of the stations during the 1986 to 1987 period. However, this represents a significant improvement over the 15% of the stations that recorded SO_2 concentrations above the maximum acceptable level in 1979.

The maximum tolerable level was exceeded in the analysis period by about 1% of the network stations, with the exception of 1983 when three sites (4%) exceeded that level:

Table 6 Sulphur Dioxide - Percentage of Stations with Readings in Various Ranges with Respect to the National Ambient Air Quality Objectives (1978-1987)

Range (ppb)	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Annual Means										
0 to 11*	68	67	65	75	84	89	91	96	94	98
12 to 23**	25	29	34	23	14	9	9	4	4	2
>23	7	4	1	2	2	2	-	-	2	-
Stations	71	69	65	51	59	60	55	56	53	57
24-hour Maximum										
0 to 60*	42	41	57	49	59	65	63	62	78	80
61 to 110**	44	44	36	38	35	21	29	33	13	17
111 to 310***	13	15	6	12	4	10	8	5	2	3
>310	1	-	1	1	2	4	-	-	1	-
Stations	92	90	89	82	81	78	75	73	71	72
1-hour Maximum										
0 to 170*	61	62	74	55	64	73	67	73	77	77
171 to 340**	22	27	16	30	27	17	24	19	13	16
>340	17	11	11	15	9	10	9	8	10	7
Stations	92	89	88	82	81	78	75	73	71	74

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

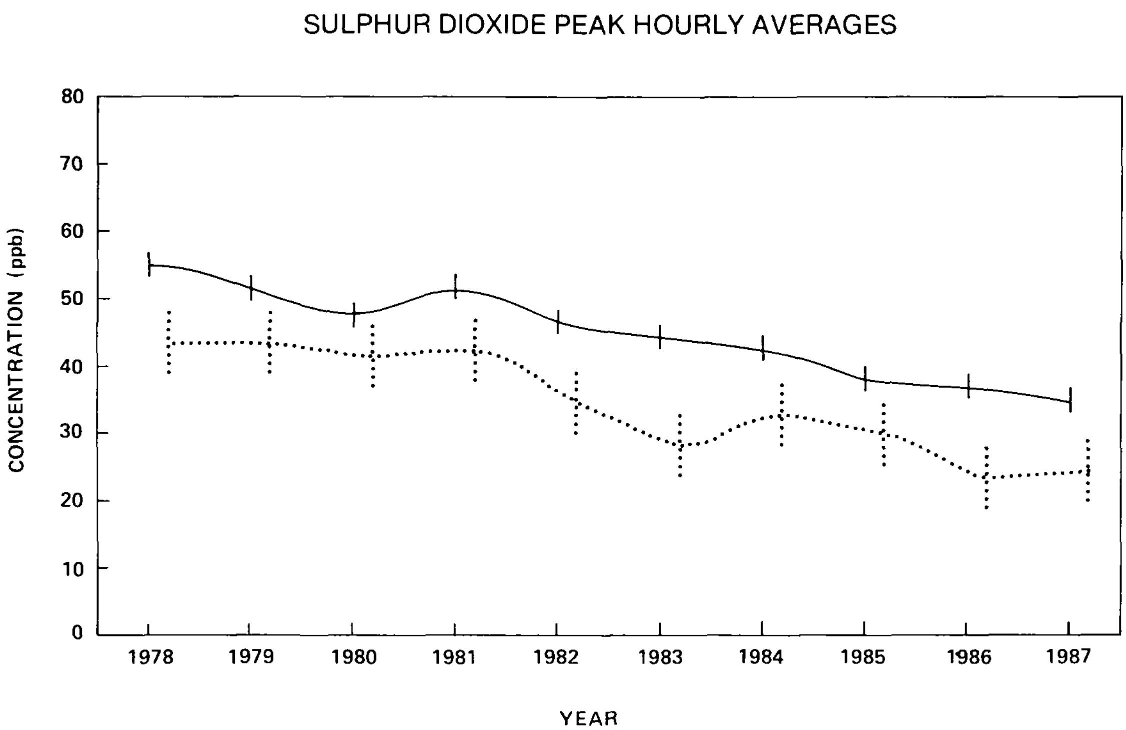
the Quebec City station 50303I, the Baie Comeau station 51301R, and the Rouyn, Noranda station 50610C. These three stations are located near industrial as well as residential, commercial, and institutional heating sources. It is important to note that a single-day exceedance can be influenced by meteorological factors such as a temperature inversion, wind speed and wind direction. Most stations register concentrations within the 24-hour acceptable range (i.e., 93% of the sites in 1980, and 97% in 1987). During the 1984 to 1987 period, all stations, but Quebec City station 50303I in 1986, met the maximum tolerable objective. This same period also represented an improvement in the percentage of stations meeting the maximum acceptable objective.

The plots representing the composite average of the 98th percentile concentrations show that there was a marked (95% confidence) improvement between 1978 to 1982 and the last two years at both the Class I and in All Stations.

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 1978 to 1987, with a decrease in the percentage of stations registering readings in excess of the maximum desirable level (Table 6) from the 40% range in 1978 to the 20% range in 1987. In 1978, 83% of the NAPS stations met the maximum acceptable level of 340 ppb, compared with 93% in 1987. Communities that experienced one-hour concentrations greater than the one-hour maximum acceptable level in 1987 were: Quebec, Rouyn, Shawinigan and Sudbury. Sudbury (980 ppb), and Rouyn (790 ppb) recorded the highest one-hour concentrations of SO_2 in 1987. Industrial point sources contribute significantly to ambient sulphur dioxide levels at these sites.

An important trend noted in previous reports (5,6) is the continued decline in the number of cities experiencing episodes of SO_2 levels in excess of the maximum desirable level. The plots of the 98th percentile concentration composite averages show many significant decreases (Figure 10). In the All Stations plot, a significant change (95% confidence) is indicated between the 1985 to 1987 period and all the previous years. With a greater emphasis on stack emissions control technology, SO_2 emissions should continue to decline.



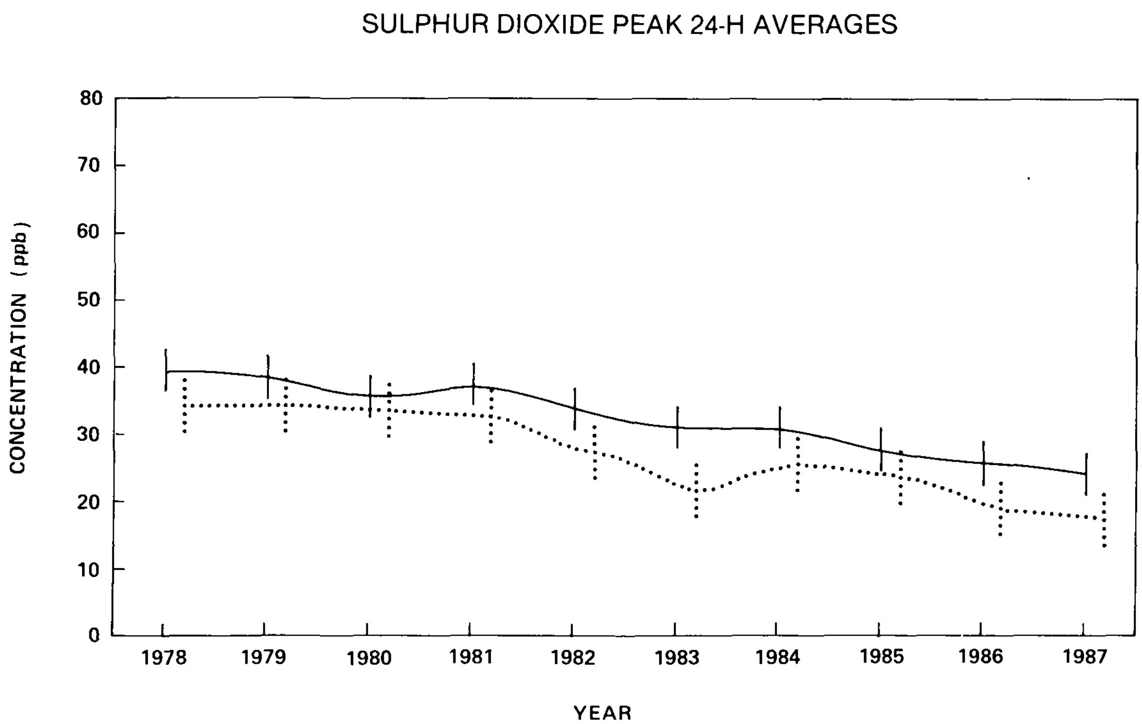


Figure 10 Composite Averages of Peak Sulphur Dioxide Concentrations with 95% Confidence Limits for Class I (...) and All Stations (—), 1978-1987

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 is produced 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 largely consists of cars and trucks. The next 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. The natural sources of NO_x emissions such as electrical discharges during storms, forest fires and bacterial action in soils are not shown in Figure 11.

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 1978 to 1987, the composite average of the network nitrogen dioxide annual means decreased from 29 ppb to 21 ppb (Figure 13). The number of stations indicating changes in

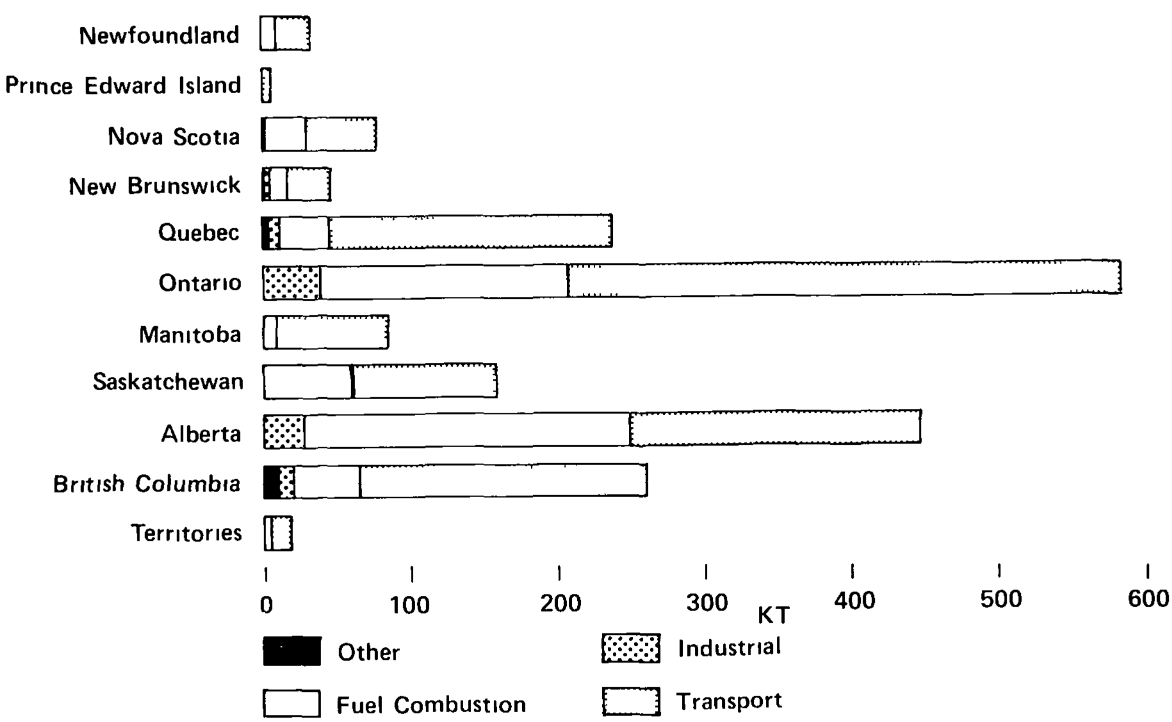


Figure 11 Emissions of Nitrogen Oxides by Source Category and by Province ($\times 10^3$ tonnes), 1985

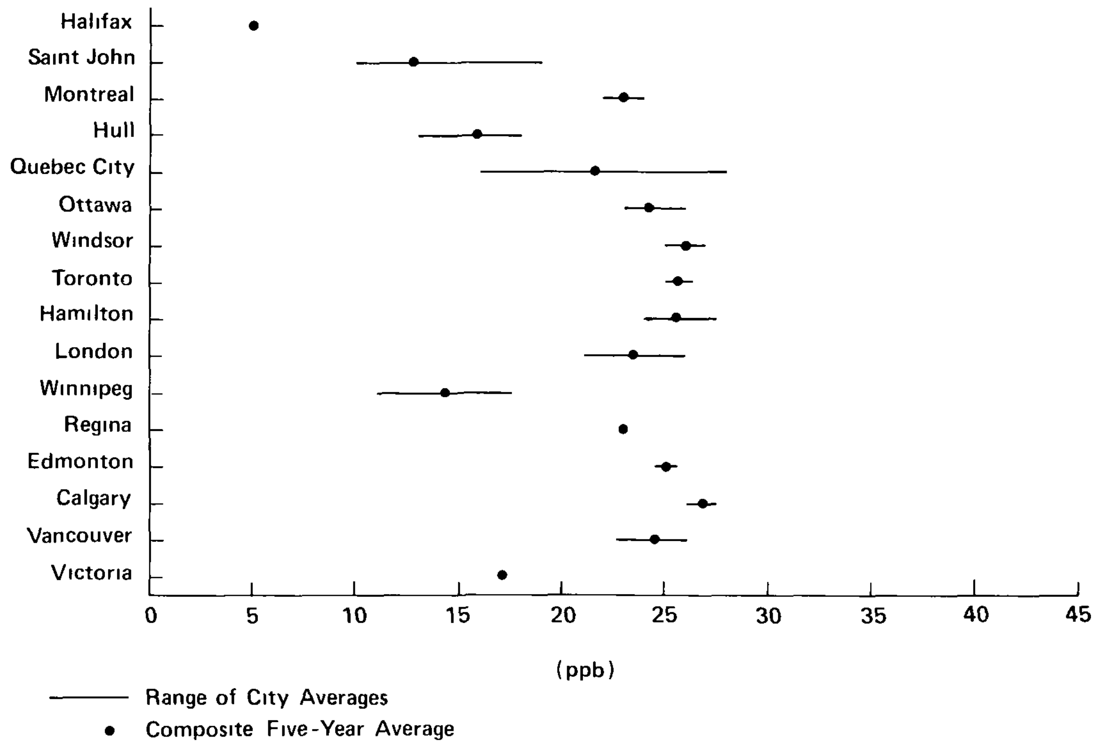


Figure 12 Nitrogen Dioxide Annual Average Levels in Selected Cities (parts per billion) 1983-1987

annual means are listed in the Appendix. These stations have valid annual mean data for pairs of consecutive years. In the past few years, more than half of the stations have shown no change. 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 are presented in Figure 14 for the 1978 to 1987 period. Both sets of stations show similar trends. However, measured concentrations at Class I Stations tend to be higher because they are located in the core of the city, where vehicle and fuel combustion sources are more concentrated.

In both Class I and All Stations, the 1985 to 1987 annual mean levels are significantly lower than 1978, indicating a real reduction in nitrogen dioxide levels. In the past two years, the mean levels have decreased slightly, but no significant changes have occurred since 1979.

The composite averages of station annual means for nitrogen dioxide remained within the desirable level between 1978 and 1987. Over this 10 year period, the annual mean levels have come down 27% by small increments (see the Appendix). As shown in Table 7, the number of stations meeting the maximum desirable level increased from 64% in 1978 to 87% in 1987. No individual station has registered readings in excess of the maximum acceptable level since 1977. The highest annual mean for nitrogen dioxide in 1987 occurred at a commercial (city centre) site in Calgary (34 ppb).

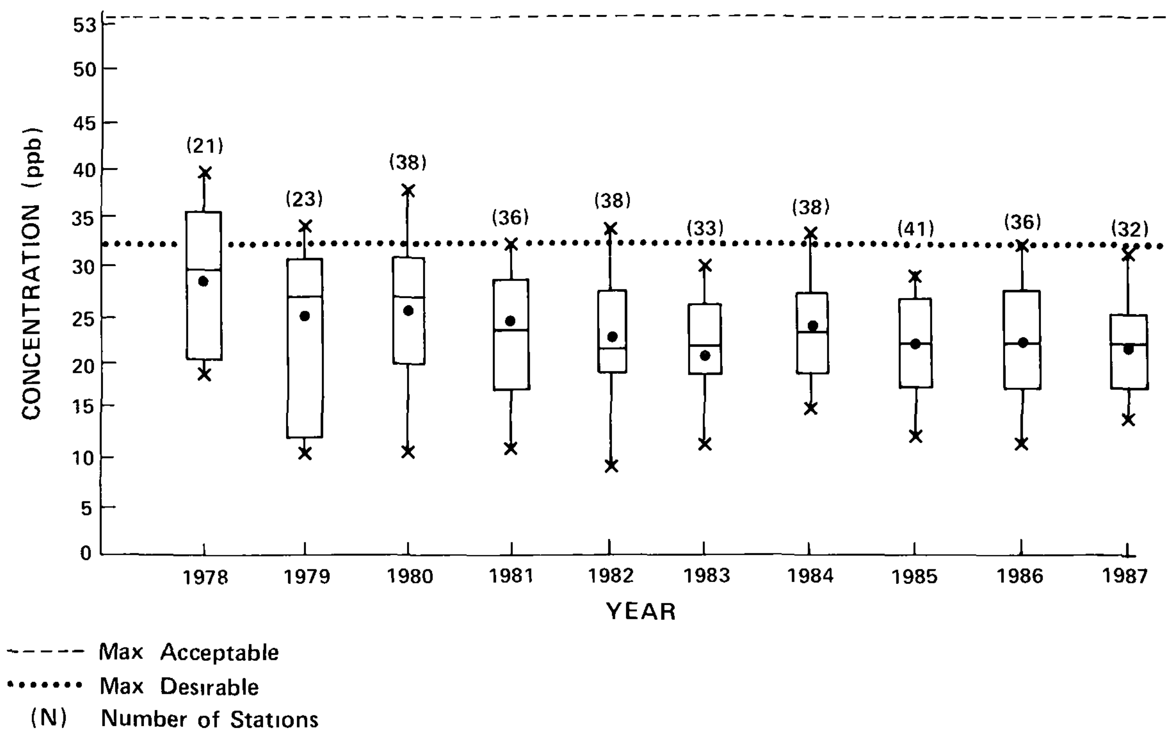


Figure 13 Nitrogen Dioxide - Distribution of Station Annual Mean Data, 1978-1987

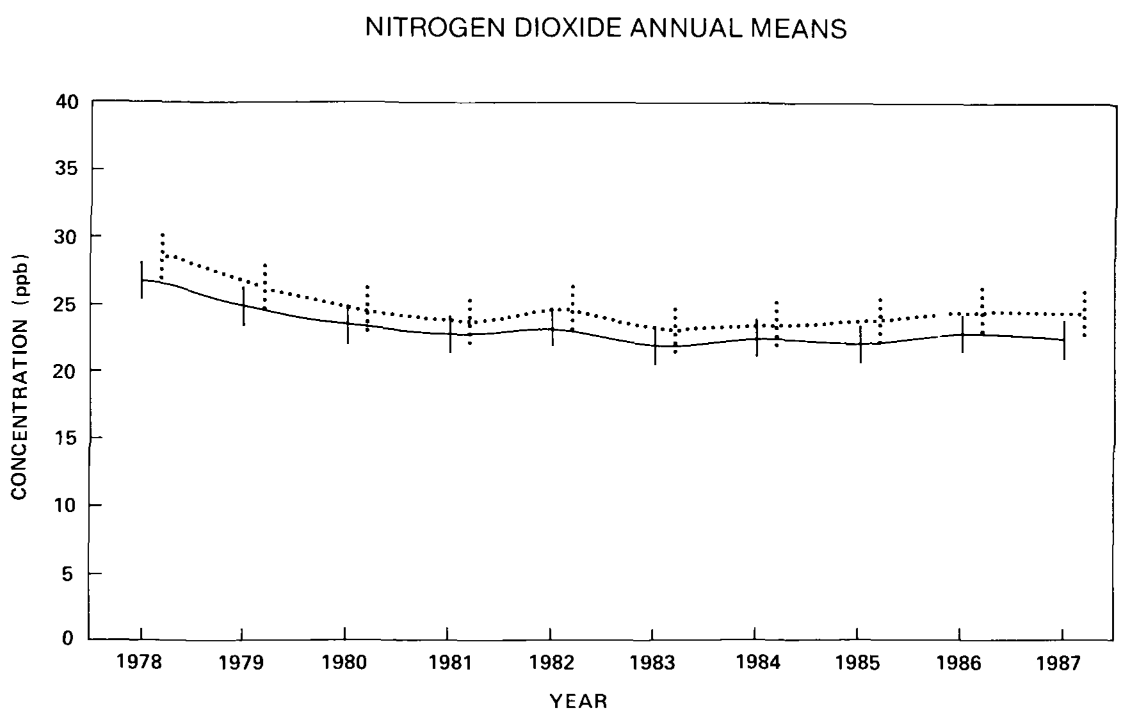


Figure 14 Trends in Nitrogen Dioxide Annual Mean Values for All Stations (—) and Class I (...) Stations with 95% Confidence Limits, 1978-1987

Table 7 Nitrogen Dioxide - Percentage of Stations in Various Ranges with Respect to the National Ambient Air Quality Objectives (1978-1987)

Range (ppb)	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
A) Annual Means										
0 to 32*	64	76	78	86	86	97	87	90	89	87
33 to 53**	36	24	22	14	14	3	13	10	11	13
>53	-	-	-	-	-	-	-	-	-	-
Stations	33	34	37	36	38	33	39	41	36	32
B) 24-hour Maximum										
0 to 110**	87	92	90	90	92	92	96	96	100	100
111 to 160**	13	8	10	8	8	8	4	4	-	-
>160	-	-	-	2	-	-	-	-	-	-
Stations	47	49	50	49	49	50	51	51	50	49
C) 1-hour Maximum										
0 to 210*	87	96	92	86	84	96	98	100	100	100
211 to 530**	13	2	8	14	16	4	2	-	-	-
>530	-	2	-	-	-	-	-	-	-	-
Stations	47	49	50	49	49	50	51	51	50	49

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

3.2 Short-term Concentrations

3.2.1 Twenty-four-hour Maximum Levels

The long-term trend in annual mean nitrogen dioxide levels is reflected by the fact that fewer stations have exceeded the 24-hour maximum acceptable level of 110 ppb (Table 7, part B). In 1978, 87% of the stations met the maximum acceptable level of 110 ppb, compared with 100% in the 1986 to 1987 period. For the past six years all stations have met the maximum tolerable 24-hour level of 160 ppb. From Figure 15, the general trend for Class I Stations and All Stations is equivalent; however, All Stations show a significant (95% confidence) decrease during the 1985 to 1987 period and the years prior to 1980.

3.2.2 One-hour Maximum Levels

The percentage of stations meeting the maximum acceptable one-hour level of 210 ppb was higher during the period from 1985 to 1987 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 (530 ppb) since 1979, and none did so prior to 1979.

The trend indicated by the composite average of the hourly 98th percentile concentrations

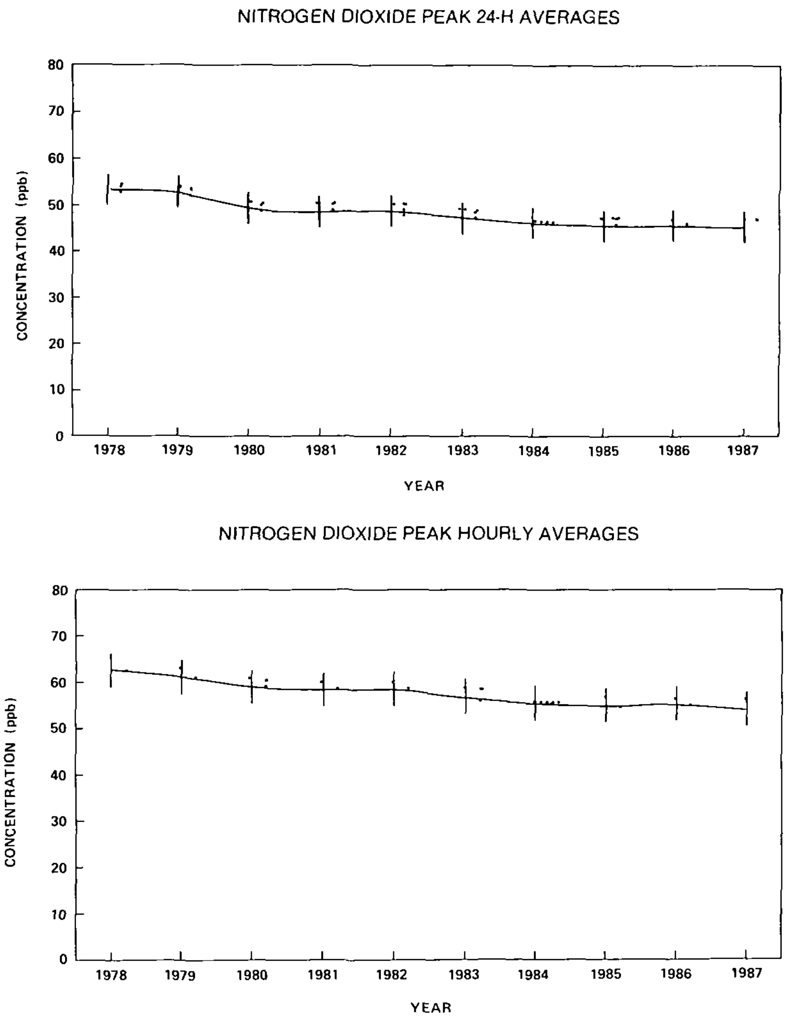


Figure 15 Composite Averages of Nitrogen Dioxide Concentrations with 95% Confidence Limits for Class I (...) and All Stations (—) 1978-1987

is shown in Figure 15. There was a significant (95% confidence) decrease between 1978 and 1987 in the All Stations plot. The Class I Stations plot does not show any significant differences; however, it is important to demonstrate that the general trend is the same.

Section 4

Carbon Monoxide

Carbon monoxide (CO) is a colourless, odorless, 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 that can be harmful even in small amounts when inhaled over a certain period of time; these periods are defined in the National Ambient Air Quality Objectives (see Tables 2 and 3).

Figure 16 represents 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 prime 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, the burning of wood waste by means of slash burning and wigwam burners is particularly prominent in the province of British Columbia.

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).

4.1 Annual Means

The composite average of CO annual means for the NAPS network decreased from 1.5 ppm in 1978 to a level of 1.0 ppm (Figure 18) in 1987. The higher concentrations (90th percentile) recorded at stations in more polluted areas, have decreased from a high of 3.2 ppm in 1979 to a level of 1.2 ppm in the past two years.

The number of stations indicating changes in annual mean data for carbon monoxide are listed in the Appendix. These stations have valid annual mean data for pairs of consecutive years. In the past five years, 70% of the paired stations have shown no change, and most of the stations that have changed registered decreases in CO levels. In fact, the annual mean has stabilized at 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, due to 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 All Stations being significantly lower in the 1986 to 1987 period than in 1983 (at 95% confidence) and the previous years. These decreases have been brought about by improvements at sites that commonly registered the highest values.

The highest reported station annual means in 1987, 3.3 ppm and 2.2 ppm, were recorded at commercial sites in Toronto and Vancouver.

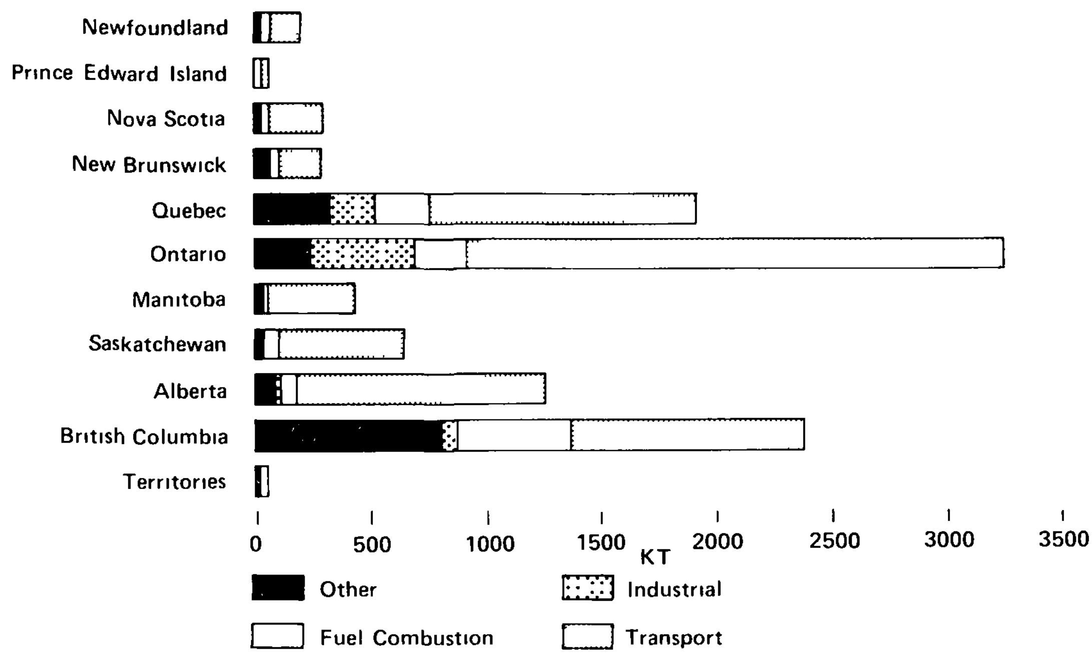


Figure 16 Emissions of Carbon Monoxide by Source Categories and by Province ($x\ 10^3$ tonnes), 1985

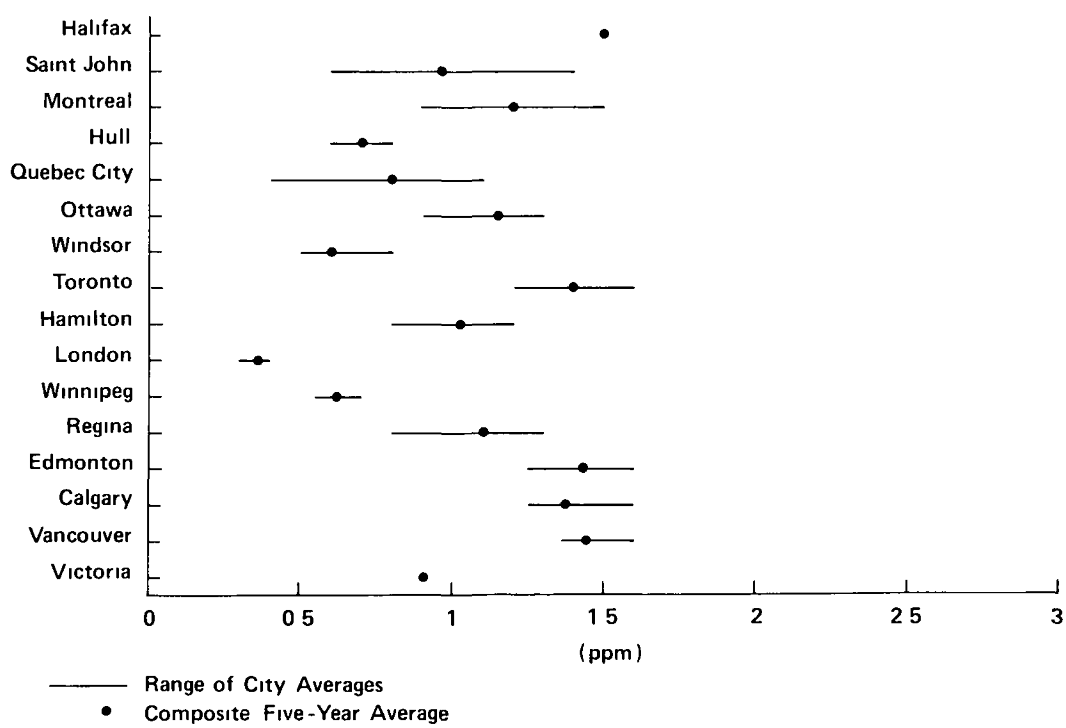
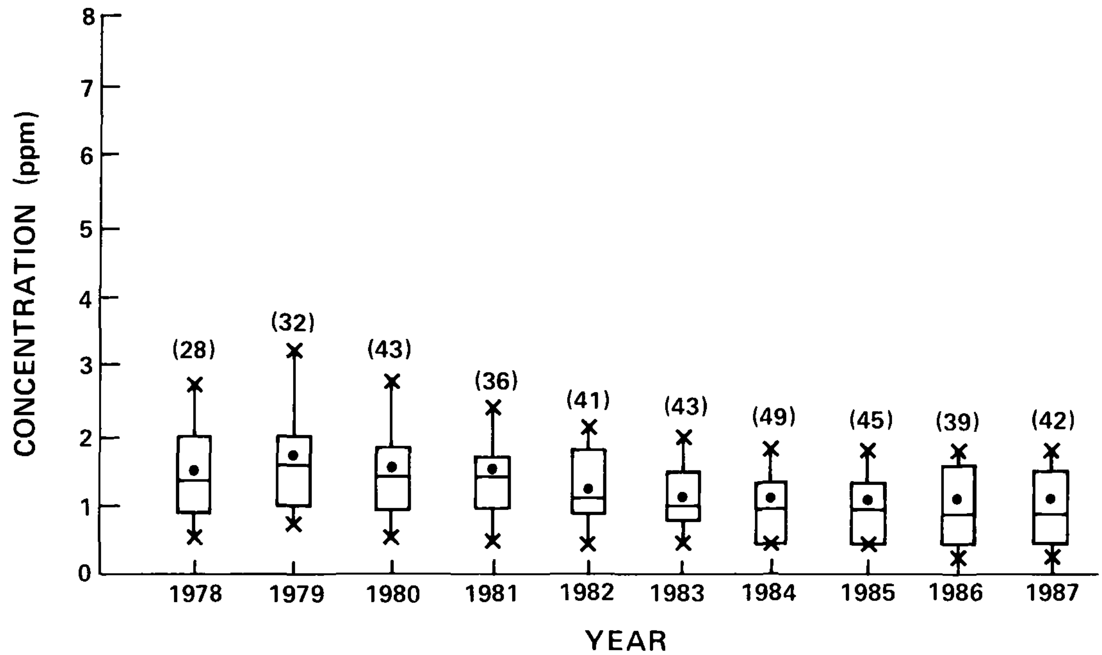


Figure 17 Carbon Monoxide Average Levels in Selected Cities (parts per million) 1983-1987



(N) Number of Stations

Figure 18 Carbon Monoxide - Distribution of Station Annual Mean Data, 1978-1987

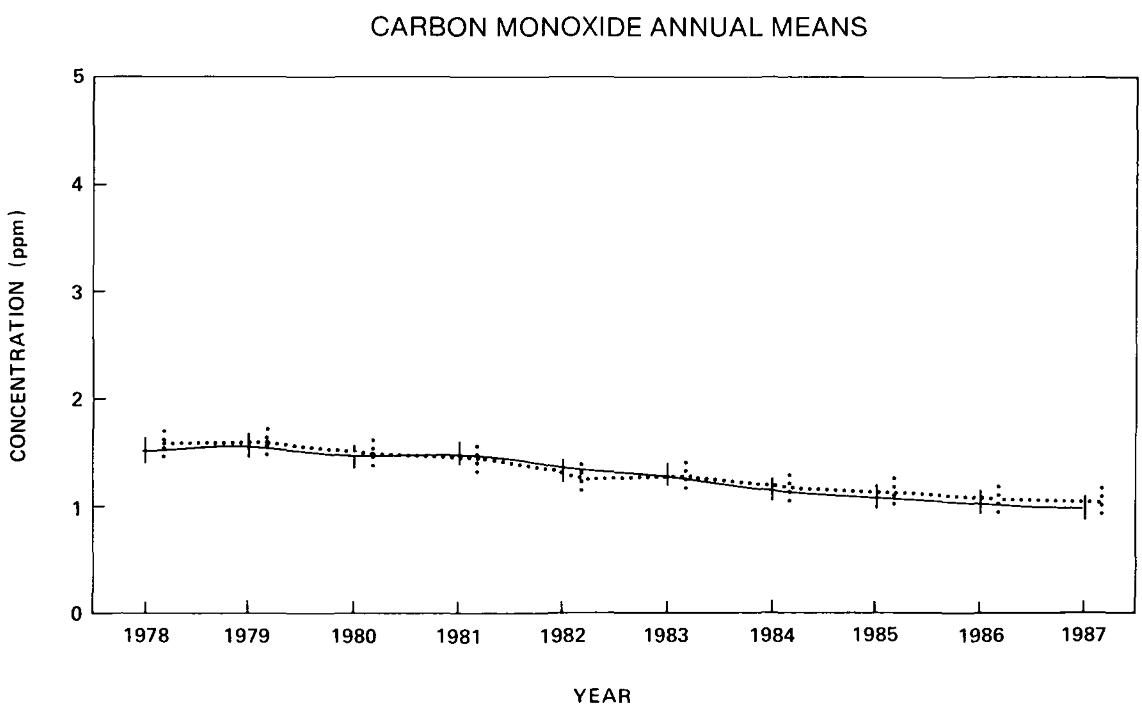


Figure 19 Trends in Carbon Monoxide Annual Mean Values for All Stations (—) and Class I Stations (...) with 95% Confidence Limits, 1978-1987

These levels as well as the number of stations that registered high CO readings have come down markedly in the 1980s. Since both stations are downtown sites located near major traffic arteries, this decrease probably reflects a general lowering of the individual car emission rate over the review period(11). From a "Summary Report, Canadian Energy Supply and Demand 1983 to 2005" there is evidence that in the 1979 to 1985 period the demand for heating fuel and gasoline was declining(12). These factors would also point to 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

The distribution of stations reporting average eight-hour readings, in the various ranges described by the National Ambient Air Quality Objectives from 1978 to 1987, are summarized in Table 8, part A. The percentage of stations meeting the eight-hour acceptable objective have remained in the 90% range. Previously, the percentage of stations meeting this standard ranged from 92% in 1978 to 86% in 1981 and 94% in 1987. The number of stations meeting the maximum acceptable level increased from 21% in 1978 to 49% in 1987 while the number of stations exceeding the tolerable level has not changed. The sites reporting a concentration in excess of 17 ppm (maximum tolerable level) in 1987 were Toronto station 60416C at 19 ppm and Edmonton station 90122R at 20 ppm.

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 1987 having a significantly lower composite average than 1982 and all previous years.

Table 8 Carbon Monoxide - Percentage of Stations with Readings in Various Ranges with Respect to National Ambient Air Quality Objectives (1978-1987)

Range (ppb)	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
A) 8-hour Maximum										
0 to 5 0*	21	18	23	13	15	25	24	36	43	49
5 1 to 13**	71	63	69	73	74	71	72	58	53	45
13 1 to 17**	6	14	4	12	6	-	2	4	2	2
>17	6	4	2	5	4	2	2	2	2	4
Stations	52	51	52	52	53	51	54	55	53	54
B) 1-hour Maximum										
0 to 210*	42	39	59	46	51	59	65	73	73	77
211 to 530**	56	55	38	46	42	37	39	33	27	21
>530	6	3	8	7	4	2	2	2	-	2
Stations	52	51	52	52	53	51	54	55	55	53

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

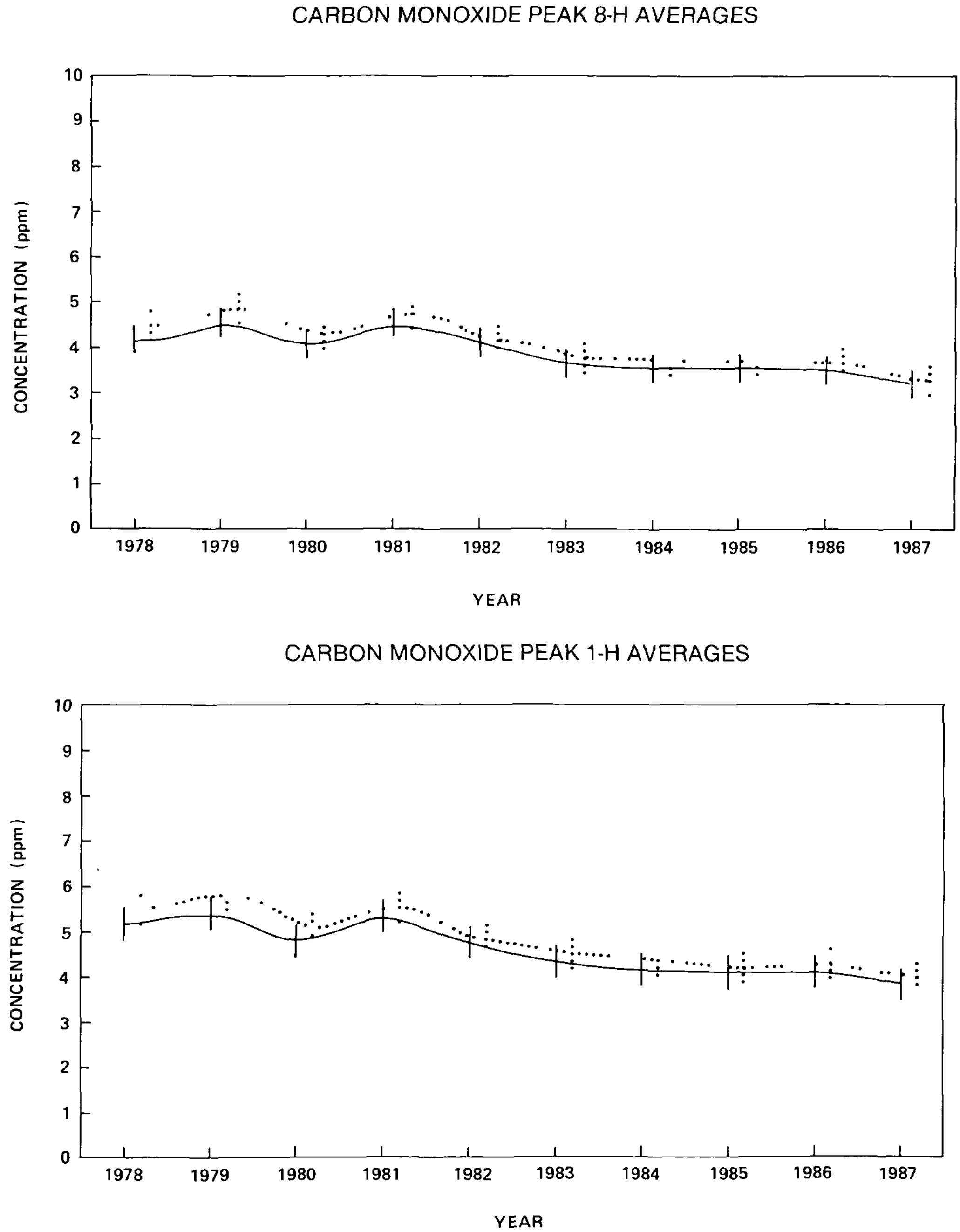


Figure 20 Composite Averages of Peak Carbon Monoxide Concentrations with 95% Confidence Limits for Class I (...) and All Stations (—), 1978-1987

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 have been decreasing over the years, with a rather sharp decrease occurring in 1980 and for the past two years (Table 8, part B). The number of stations with readings exceeding the maximum acceptable level have stabilized at 2% for the last five years from a high of 8% in 1980. Readings in excess of the maximum acceptable one-hour and eight-hour levels occurred at only one Toronto site in 1985, Station 60416C.

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 1987 levels being significantly lower than 1982 levels and those from previous years.

Ozone

Ozone is the principal species of several oxidizing gasses 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 that are energized by temperature and sunlight in a stagnant air mass. These conditions occur most frequently from late spring to early fall in most of the country.

Figure 21 displays the 1985 annual emission of VOC's by province and by source categories.

(1) The transportation category is the most prominent source of VOC contributing about one half of national emissions (Figure 21). The principal sources of VOC's in the transportation category are cars, trucks and other gasoline powered vehicles. (2) In the "other" category the most important sources are the gasoline distribution system, application of surface coatings (paints), general solvent use and dry cleaning. (3) Most of the industrial emissions come from petrochemical plants, plastic manufacturing and refineries. (4) For the fuel combustion category emissions the two most important sources are fuelwood and industrial fuel combustion.

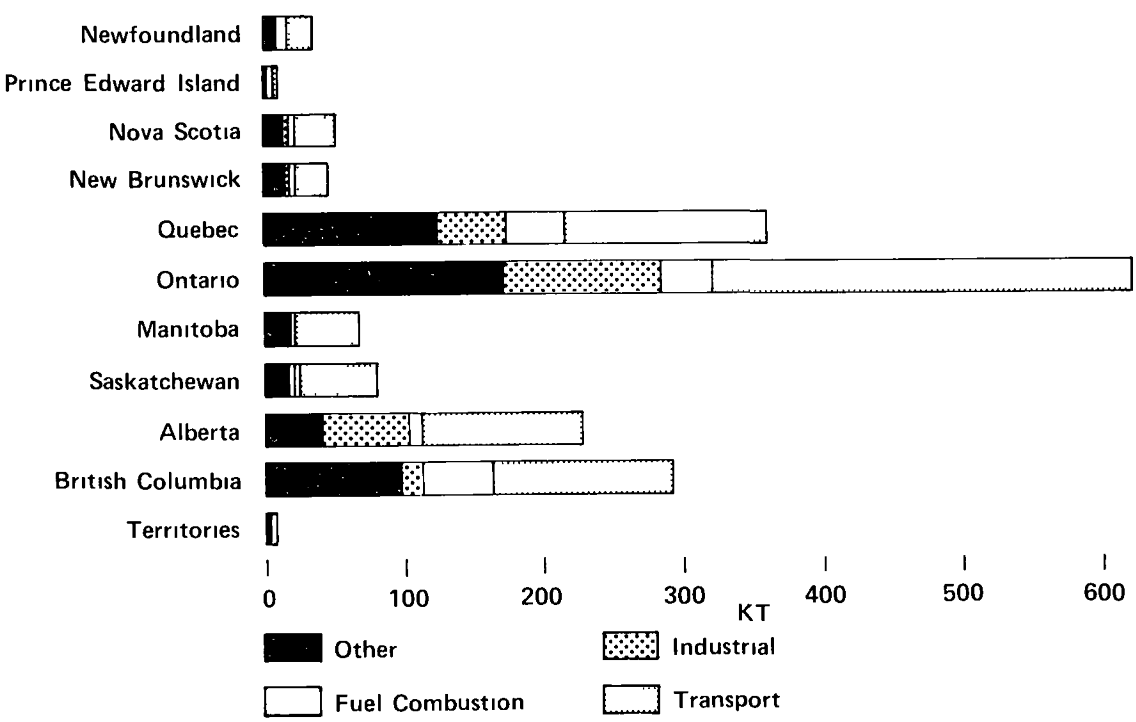


Figure 21 Emissions of Volatile Organic Compounds by Source Category and by Province (x 10^3 tonnes), 1985

According to the 1985 Inventory on Emissions of Common Air Contaminants Summary Table [10], fuel production, distribution and combustion accounts for well over half of the VOC's 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 [1]. With the absence of a common calibration procedure for ozone monitors across the NAPS network, it was found that the data was 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 reliable and consistent.

Figure 22 depicts averages of peak ozone levels for selected cities across Canada. The data set for six of the sixteen cities used for this analysis was incomplete therefore an average level was estimated with no range shown.

5.1 Annual Means

Annual ozone concentrations for the 1979 to 1987 period are presented in Figure 23. The composite average of ozone annual means for the NAPS network in 1987 was 16 ppb. Mean values for individual stations ranged from 4 ppb in Vancouver 00112C to 30 ppb in Fall River, N.S 30601R. Most station annual means in southern Ontario were in the 10 ppb to 24 ppb range. The number of stations indicating changes in annual mean ozone concentrations during the 1979 to 1987 period are listed in the Appendix. Stations with valid annual mean data for pairs of consecutive years were used in this analysis.

This analysis shows that more than half of the ozone sites do not change appreciably in any one year. In years when an increase in the number and severity of ozone episodes (days with ozone levels exceeding acceptable objective) was observed, only a third of the network stations registered an increase in the annual mean of more then one part per billion. The years 1983 and 1987 are an example of this phenomenon which is partially explained by meteorological conditions in certain parts of the country that favored ozone formation. The stability in the ozone annual mean statistic would suggest that levels at the cleaner sites (background) have not changed significantly during the analysis period (Figure 23).

The maximum acceptable annual mean level (NAAQO) for ozone is 15 ppb. As shown in Table 9, Part A, less than half of the monitoring sites met this objective. The sites exceeding this level were distributed across the network but were particularly dominant in southern Ontario. Over the past nine years the percentage of stations that have recorded readings which exceed the acceptable level are increasing to beyond the 60% range. A report on global climate changes produced at the Goddard Institute for Space Studies, New York* observed that the surface air temperature for the first seven years of the 1980's has shown measurable warming. A graph showing Annual Mean Global Temperature Change indicates peaks for 1980, 1983 and 1987 that correspond to a higher frequency of ozone episodes*. In fact the value for 1987 may not be a peak since preliminary ozone data for 1988 both in Canada and the

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

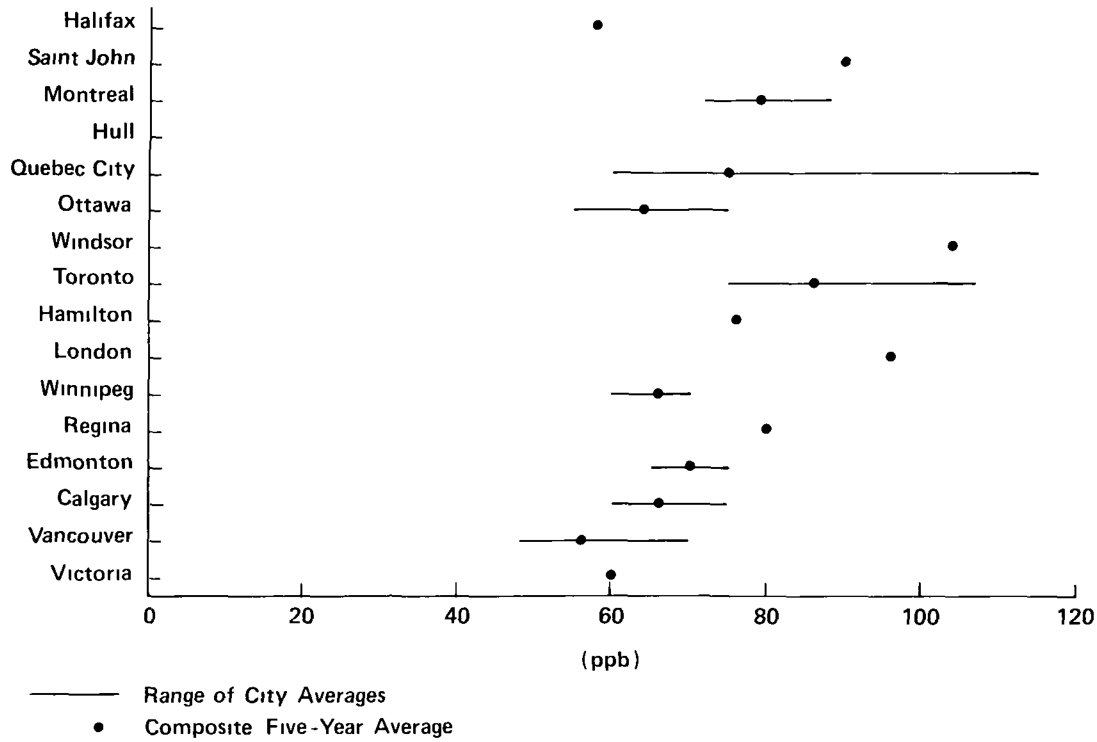


Figure 22 Average of Peak Hourly Ozone Levels in Selected Cities (parts per billion) 1983-1987

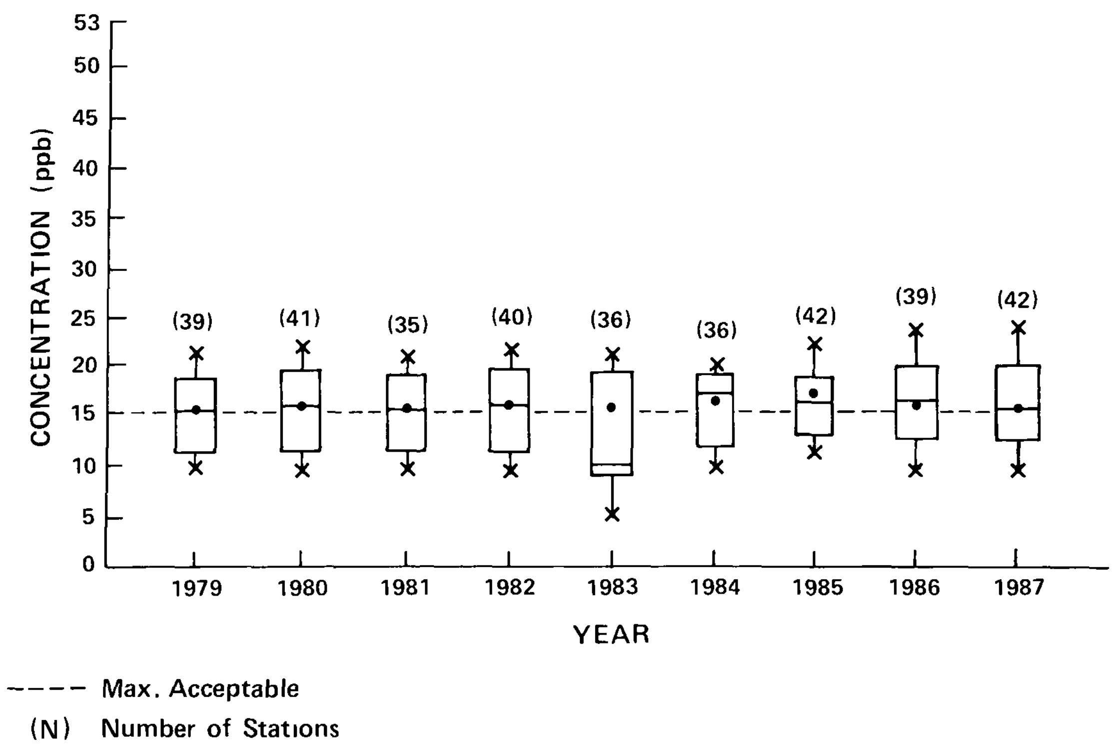


Figure 23 Ozone - Distribution of Annual Mean Data, 1979-1987

United States suggests even more incidents of high ozone levels.

5.2 One-hour Maximum Levels

A new indicator of peak one-hour ozone levels was selected for this report. The composite average of the 99.9th percentile provides more information about trends in extreme values (or ozone episodes) when the acceptable and tolerable air quality objectives are likely to be exceeded. It corresponds to the 9th highest concentration recorded at a station as compared to the 120th highest value for the 98th percentile. This indicator is more sensitive to yearly fluctuations in weather conditions. Cities that exceeded the NAAQO 1-h maximum acceptable level most often were found mainly in central Canada.

Figure 24 is a geographical presentation of the average number of days per year exceeding the hourly ozone air quality acceptable objective (NAAQO). From this figure it can be seen that four cities average more than ten days in the year, and nine more cities average five or more days when the acceptable level is exceeded for an hour or more. This is significant because most of the ozone damage occurs when the objectives are exceeded for an hour or more. The air quality objectives for ozone can found in Table 2, while Table 3 lists some of the adverse effects on vegetation and human health for the hourly objective.

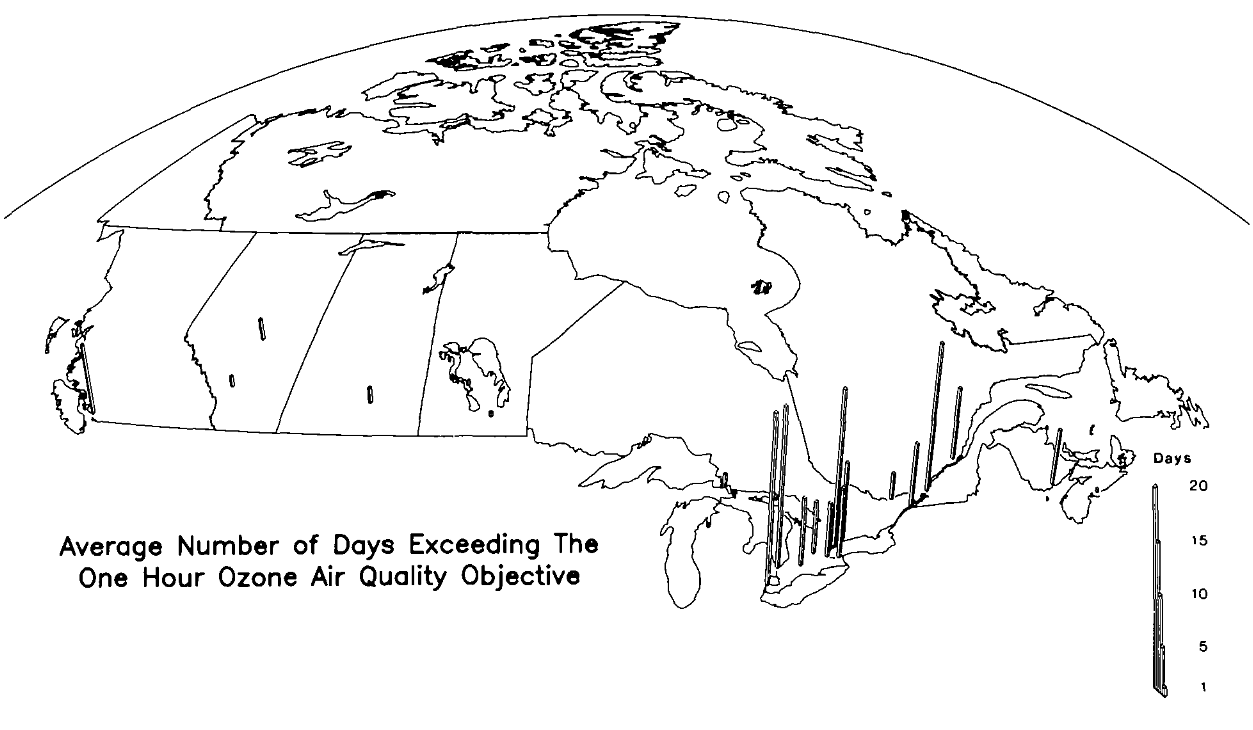


Figure 24 Average Number of Days Per Year Exceeding the Hourly Ozone Air Quality Acceptable Objective, 1982-1986

Source: 1981 Census of Canada

Maps produced by the Geocartographics Subdivision and the Environmental Statistics Unit, Statistics Canada, 1988.

Table 9 Ozone - Percentage of Stations with Readings in Various Ranges with Respect to National Ambient Air Quality Objectives (1979-1987)

Range (ppb)	1979	1980	1981	1982	1983	1984	1985	1986	1987
A) Annual Means									
0 to 15**	50	46	54	45	39	41	40	31	43
>15	50	54	46	55	61	59	60	69	57
No of Stations	38	41	35	40	36	34	41	39	42
B) 1-hour Maximum									
0 to 50*	2	4	6	4	--	4	4	13	13
51 to 80*	16	22	26	25	34	40	45	39	32
81 to 150***	62	68	58	69	58	52	47	46	52
>150	20	6	10	2	8	4	4	1	3
No. of Stations	45	50	50	49	50	52	51	56	60

* maximum desirable
** maximum acceptable
*** maximum tolerable

Table 9, part B, shows the percentage distribution of network stations according to the NAAQO hourly desirable, acceptable and tolerable objective ranges. In the past four years almost half of the stations exceeded the maximum acceptable hourly objective level at least once while the number of stations meeting the desirable level peaked at 13% for the last two years of the analysis period By contrast only 2% of the stations were able to meet the hourly desirable level in 1979.

The maximum tolerable objective was exceeded from a high of nine sites in 1979 to a single site in 1986. In the 1983 to 1987 period the tolerable objective was exceeded at the following cities: Montreal (1983, 1984, 1985), Toronto (1983), Oshawa (1983), Vancouver (1983), St. John (1984), Quebec (1985), Halifax (1986), Sarnia (1987) and Oakville (1987).

The trend in the peak hourly composite averages from 1979 to 1987 indicates a 20% decline, and linear regression analysis (table 4) demonstrates that this change is significant (99.9%). This trend is disrupted by higher values in 1983 and 1987 with a more frequent incidence of days with high ozone levels at eastern sites (Figure 24).

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 represents the lowest composite average value (1979 to 1987) and that 1987 is slightly higher. However, the ozone levels for both years are significantly (95%) lower than 1983, 1980 and 1979 respectively. For most years, the Class I average levels are below those for All Stations. This is likely due to higher nitrogen oxide (and hence scavenging) levels at downtown monitoring

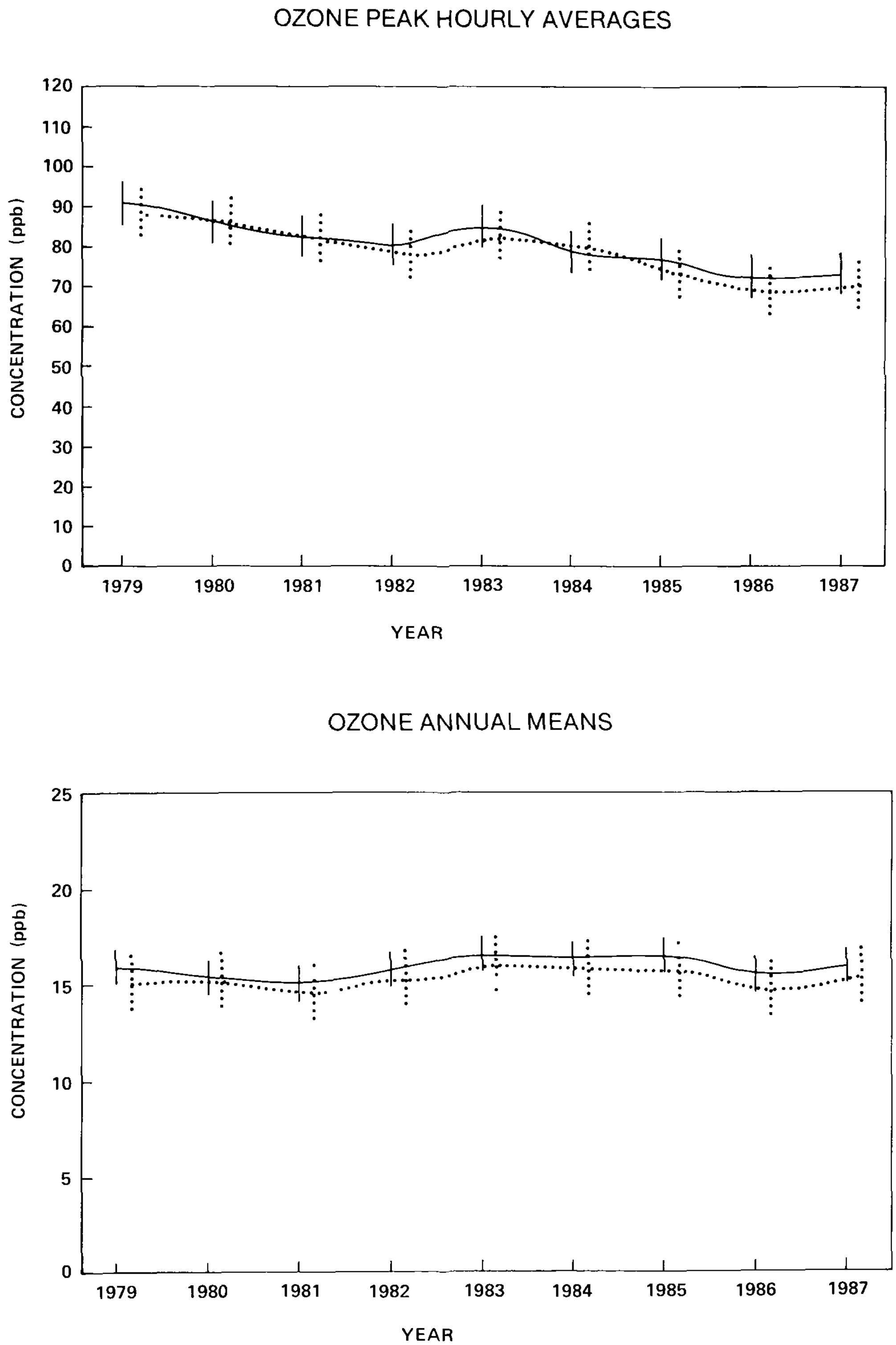


Figure 25 Trends in Ozone Annual Mean and Peak Hourly Concentrations for All Stations and Class I Stations, 1979-1987

sites where the Class I stations are located. It is interesting to note that the plot of peak hourly averages shows significant changes from 1979 to 1987 (Figure 25). By contrast the plot showing annual averages does not demonstrate significant change. This analysis suggests that there has been a significant decline in the severity of ozone episodes during the analysis period.

Section 6

Suspended Particulate

Total suspended particulate (TSP) is a general term applied to a wide variety of solid or liquid particles of a size and configuration such that they remain suspended in the air Particulates can be divided into two general size fractions; coarse and fine. The coarse fraction is composed of crystal materials while the fine fraction contains mostly soot and other combustion by-products. These combustion by-products can become involved in secondary (chemical) processes which can result in the formation of acids.

Particulate matter is the most commonly perceived form of air pollution, resulting in reduced visibility, soiling of materials and irritation of the respiratory tract. Particulate emissions from the most important man-made sources in Canada have been determined and are shown in Figure 26. The man-made sources of particulate matter arise from four main categories:

(1) Industrial emissions, accounting for 50% of the national suspended particulate matter arise from a variety of sources, including: iron ore mining and beneficiation, mining and rock quarrying operations and pulp and paper mills; (2) fuel combustion emissions, mainly from thermal power plants;

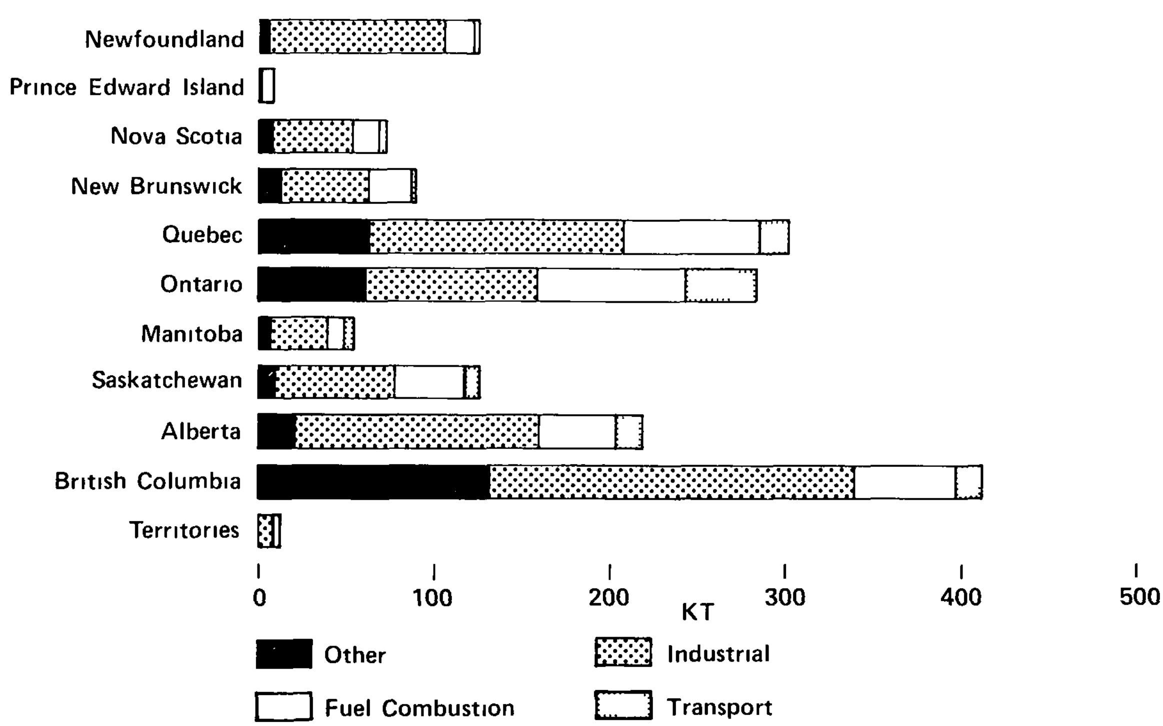


Figure 26 Emissions of Suspended Particulate Matter by Source Categories and by Province (x 10^3 tonnes), 1985

(3) transportation emissions that are chiefly produced from gasoline-powered motor vehicles; (4) other sources such as incineration and slash burning.

There are also natural sources of particulate matter that include dusting from storage piles and fields, pollens, sea spray and forest fires. Local weather conditions such as temperature, wind, precipitation and ground cover also affect particulate levels in cities; most importantly where the re-entrainment of dust from road traffic is concerned.

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 below 60 μg/m³. The only city to exceed this level was Hamilton which registered a maximum acceptable level of 70 μg/m³.

Suspended particulate National Ambient Air Quality Objectives are listed in Tables 2 and 3 for 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[13].

6. 1 Annual Geometric Means

The composite averages of the station annual geometric means have decreased approximately 20% between 1978 and 1987, and the annual mean value for 1987 is 48.0 μg/m³ (Figure 28 and the Appendix). 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 averages have come down in recent years to within the desirable range. The number of stations indicating changes in annual means greater than 4 μg/m³ from 1978 to 1987 can be found in the Appendix. These stations have valid annual mean data for pairs of consecutive years. Table E demonstrates that the higher annual mean in 1987 was the result of small increases at 42% of network sites.

The 10 year trend (Tukey's test) in the composite annual mean values for All Stations

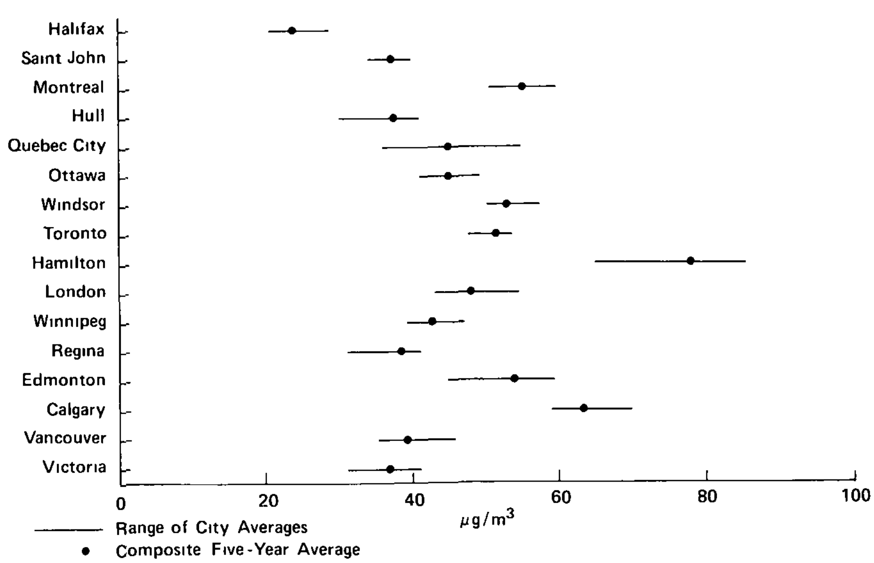


Figure 27 Total Suspended Particulate Levels in Selected Cities (micrograms per cubic metre), 1983-1987

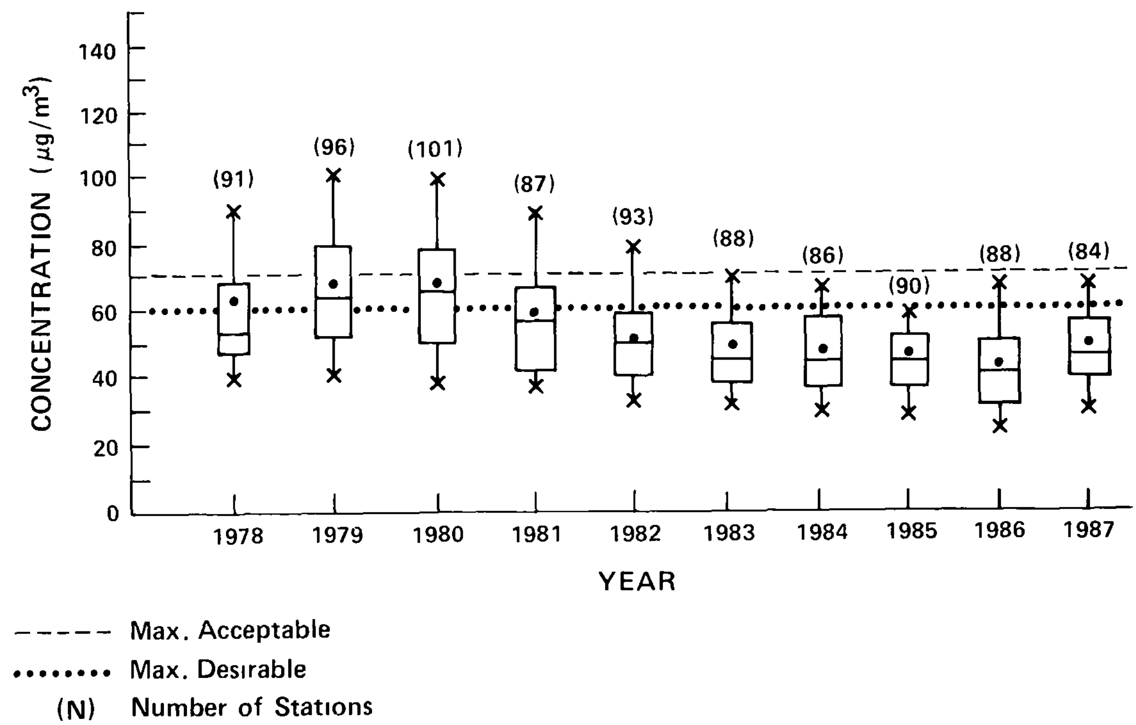


Figure 28 Suspended Particulate - Distribution of Station Annual Mean Data, 1978-1987

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 that 1985 was a significant (95% confidence) improvement over all the preceding years, while 1987, in turn represents a significant improvement over 1981 and all the years prior to it. From Figure 28, it is evident that the network annual means have been below the Annual Maximum Acceptable level (NAAQOs) since 1978.

There has been a general improvement across the country with respect to total suspended particulate levels. Within the past five years the 90th percentile annual means, representing the more polluted sites, are within the acceptable range (60-70$\mu g/m^3$) of the NAAQOs. The network annual mean levels have come down from 60 $\mu g/m^3$ to the upper 40 $\mu g/m^3$ range during the 1978 to 1987 period.

The rise in annual mean levels during the last two 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 decrease in particulate levels is the increasing percentage of stations that meet the desirable and acceptable levels. In 1985, only 2% of the stations

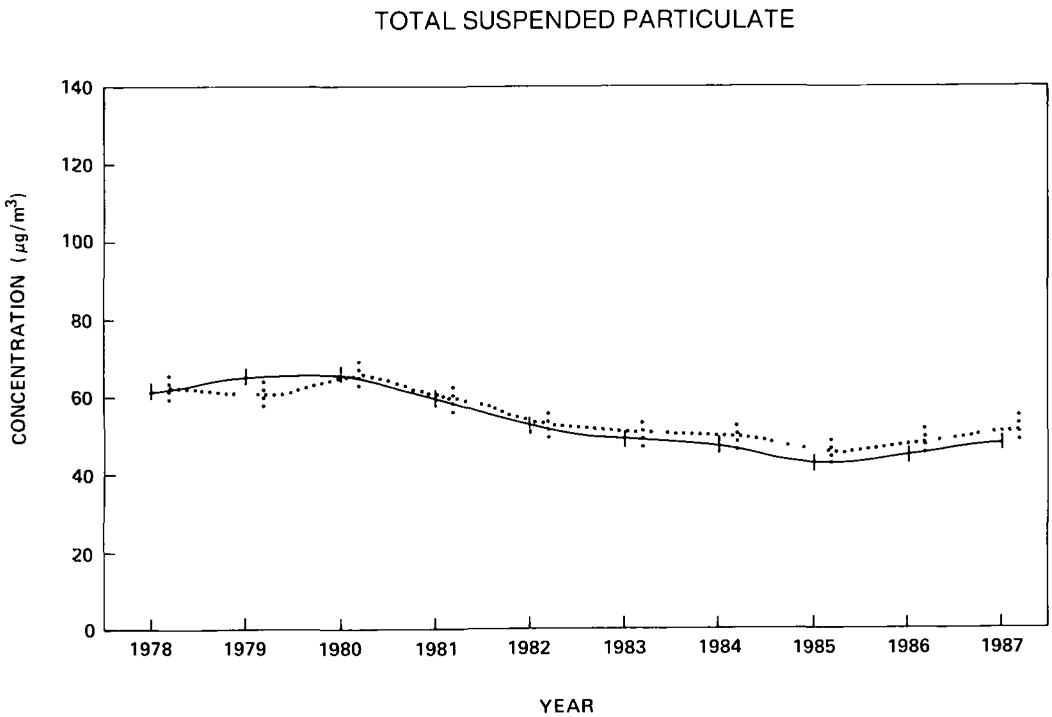


Figure 29 Trends in Suspended Particulate Annual Mean Values for All Stations (—) and Class I Stations (...) with 95% Confidence Limits, 1978-1987

Table 10 Total Suspended Particulate - Percentage of Stations in Various Ranges with Respect to the National Ambient Air Quality Objectives, 1978-1987

Range $\mu g/m^3$	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Annual Geometric Means										
0 to 60*	56	48	44	61	80	81	79	92	88	83
61 to 70**	17	18	22	21	8	9	12	6	4	9
>71	27	34	34	18	12	10	9	2	8	8
Stations	95	95	101	87	93	88	86	88	88	85

* desirable level
** acceptable level

exceeded the maximum acceptable TSP levels of 70 $\mu g/m^3$. Although the percentage of stations exceeding this standard increased to 8% by 1987, the results are still notably better than the 1979 to 1980 period when 34% of the stations failed to meet the maximum acceptable TSP objective. Similarly, the percentage of stations with annual means within the maximum desirable objective of 60 $\mu g/m^3$ increased from a low of 44% in 1980 to over 80% in 1986 and 1987

Stations reporting the highest annual means in 1987 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 near a construction site.

Lead

Lead is a heavy metal that may be hazardous to humans if it is ingested or inhaled; this fact has been recognized for a long time. It is particularly harmful to children under 10 years of age. Lead and lead compounds are present in the ambient air as a component 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. Clearly the industrial category is the major contributor of lead emissions to the environment. However, an Environment Canada report[14] shows a strong positive correlation between the transportation category 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[15]. As of 1987, vehicle emissions accounted for 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. This trend is expected to continue as leaded gasoline additives are phased out.

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 city five year averages. In

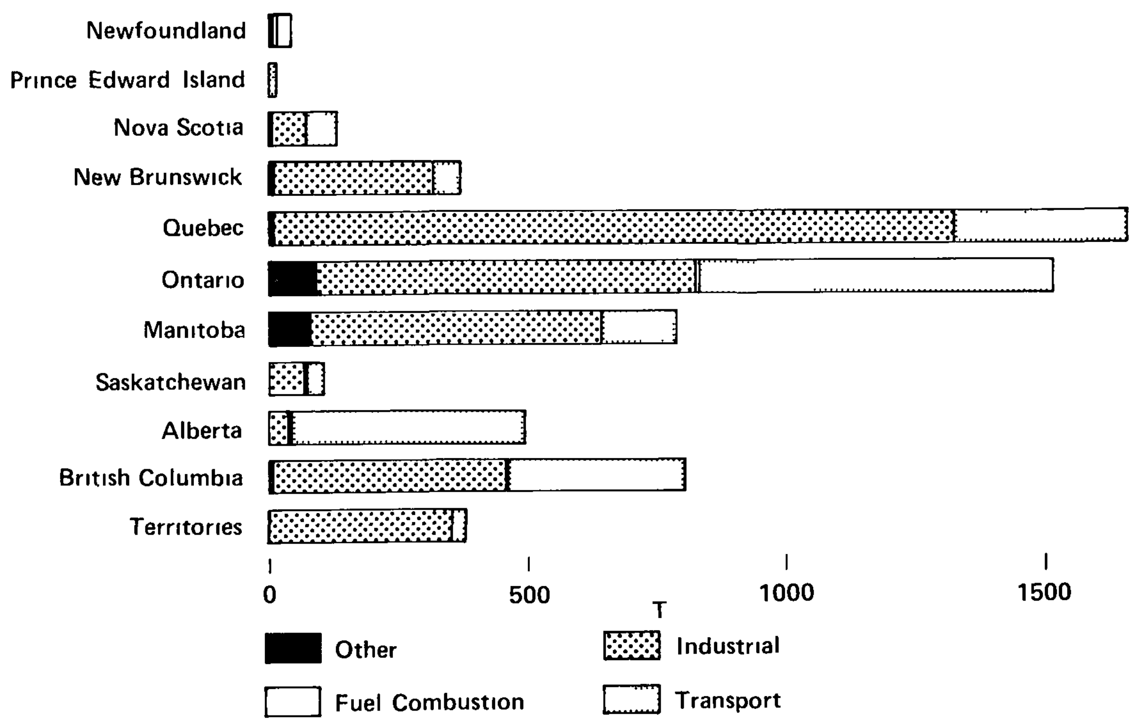


Figure 30 National Emissions of Lead by Source Category and by Province 1987 (tonnes)

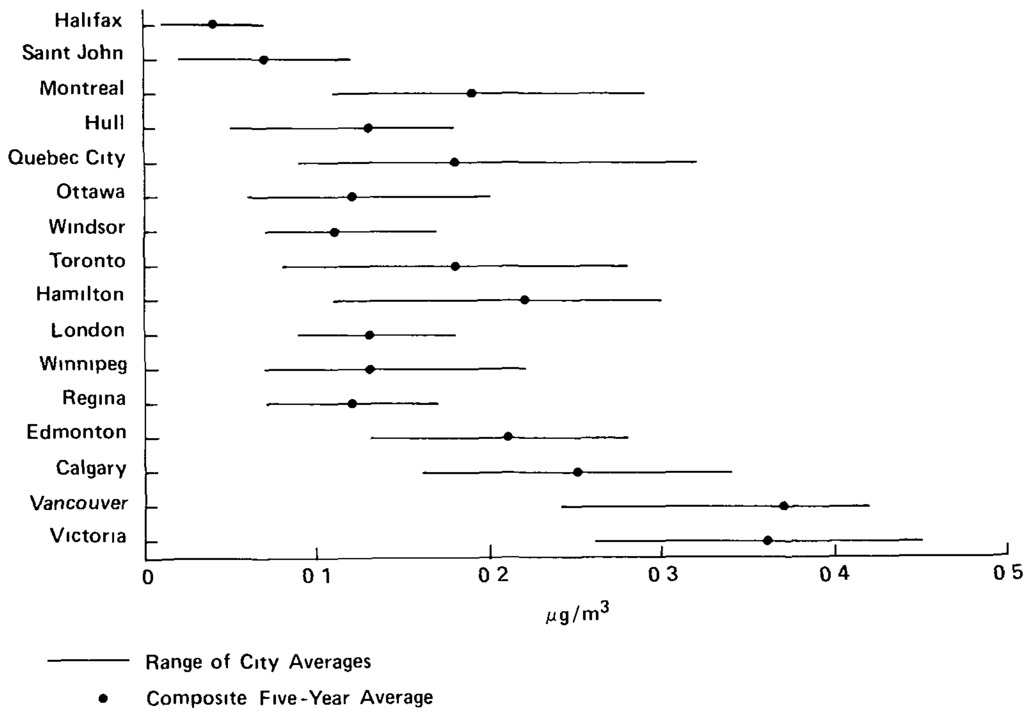


Figure 31 Annual Average Lead Levels in Selected Cities (µg/m^3), 1983-1987

Western Canada, the "older"* vehicle fleet would account for a greater use of leaded fuels. Table I, Appendix, shows dramatic decreases in lead levels at sites that measured the highest lead levels in the past. Also, noteworthy is the fact that the average and maximum levels in Central and Eastern Canada have come down 70% since 1983, while the decrease in lead levels for Western Canada was about 50% for the same period.

The composite average of the network annual mean lead concentrations decreased by about 76% between 1978 and 1987 (see Appendix and Figure 32). In fact, the annual average has come down 45% since 1985. 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 are listed in the Appendix. Stations showing decreases of greater than 0.04 µg/m^3 outnumbered stations showing no change, and these account for 52% of all lead monitoring sites

Composite average annual mean lead concentrations measured at selected stations (valid data for 7 to 10 years) in the NAPS network are shown in Figure 33. Class I Stations show higher levels than do All Stations, which is consistent with the fact that Class I Stations tend to be located in

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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 older than 10 years By contrast only 7% of the cars in Eastern Canada are older than 10 years Older cars also have higher emission rates of NO_x, HC and CO

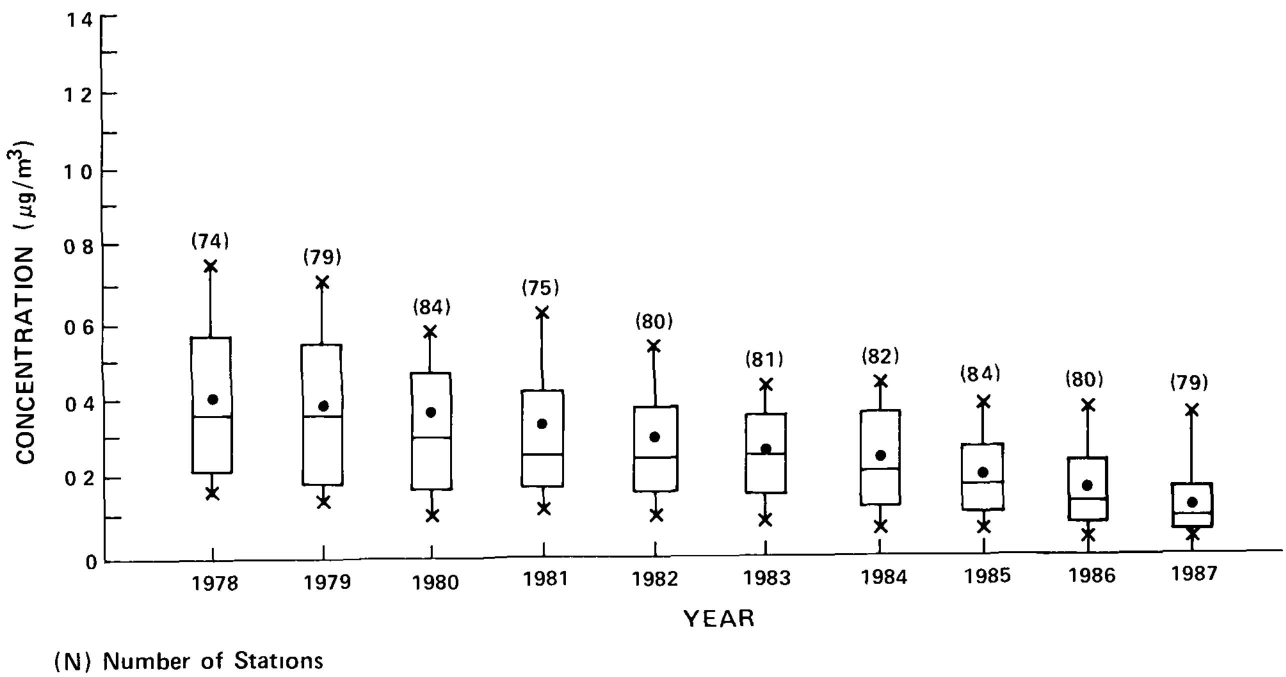

Figure 32 Lead - Distribution of Station Annual Mean Data, 1978-1987

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 continues to be somewhat higher than the overall average from 1978 to 1987. In Figure 33 the long-term change using Tukey's test is presented for All Stations (network) and there appears to be a significant decrease every few years. The most recent trend results indicate that 1987 is significantly lower than 1985 and all preceding years. As more and more automobiles use unleaded fuel the rate of this decreasing trend should become more pronounced as we approach background levels.

Historically the highest lead concentrations have occurred in cities. Station parameters, concentration levels, and traffic density for the highest lead sites for 1983 are compared to 1987 levels and are shown in the Appendix. 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.

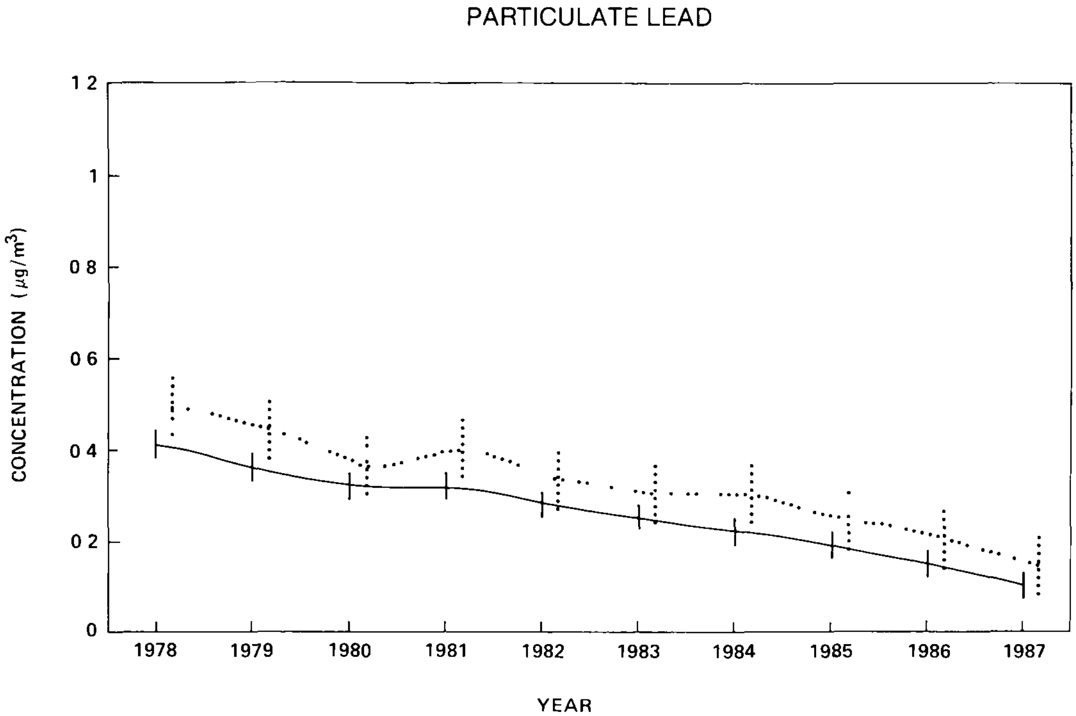

Figure 33 Trends in Lead Annual Mean Values for All Stations (—) and Class I Stations (...) with 95% Confidence Limits, 1978-1987

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 35 and the Appendix, the composite average of the station annual means has shown little change from 1978 to 1987. The soiling index peaked at 0.30 COH units during 1981 to 1982 but has since declined to 0.28 COH units in 1987, a change of about 6%. Reduced levels at the stations in traditionally more polluted sites accounted for most of the decrease in the average values.

Despite the small improvement in average soiling index levels, statistical analysis (linear regression) of changes for the 10 year period between 1978 to 1987 indicates a significant decrease in COH levels at 95% confidence.

Average levels of COH for selected cities are shown in Figure 34. Apart from three cities in southern Ontario, all five year averages fall within the 0.3 COH range The Appendix 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

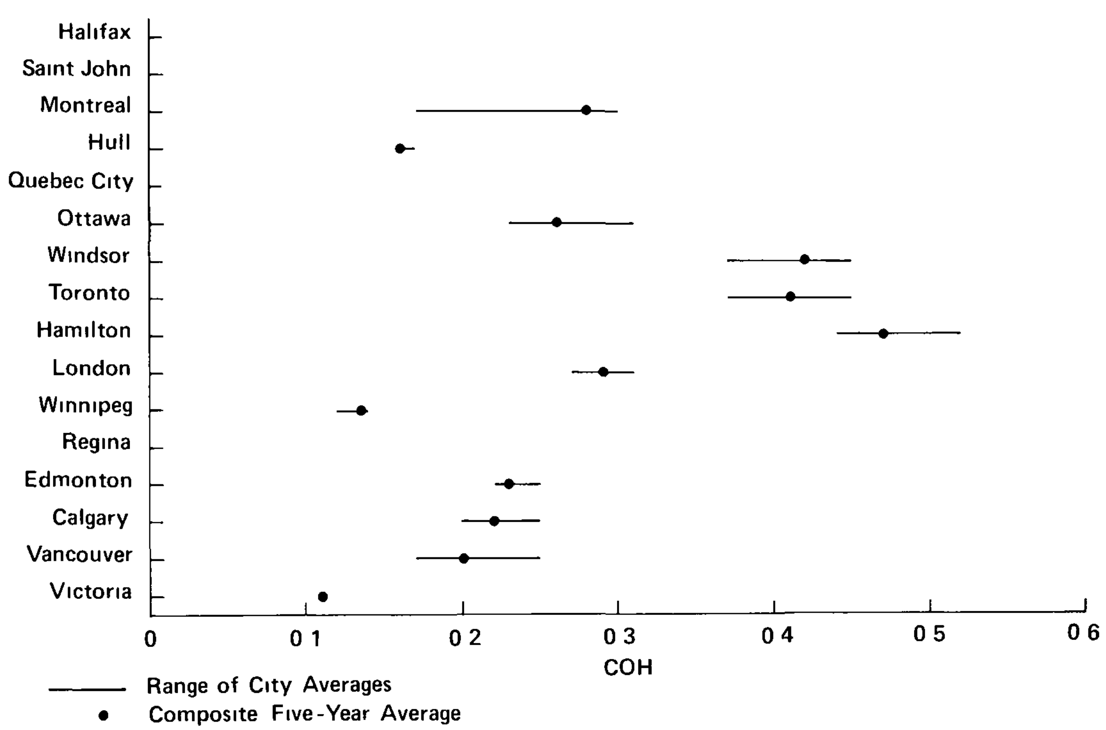

Figure 34 Coefficient of Haze Average Levels in Selected Cities in Canada

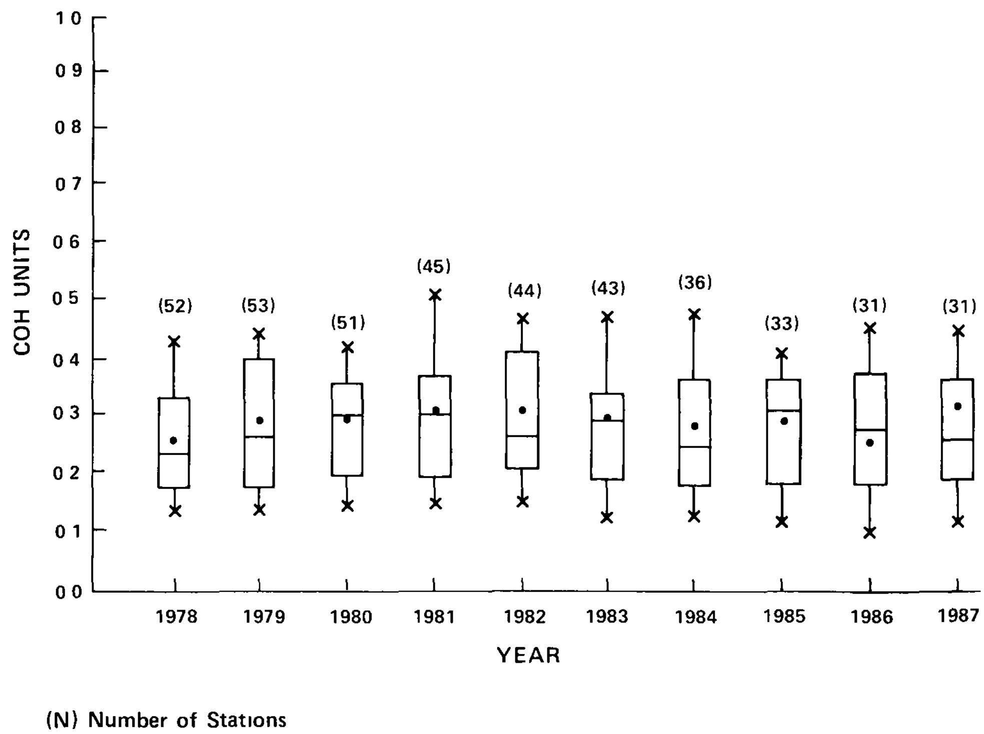

Figure 35 Soiling Index - Distribution of Station Annual Mean Data, 1978-1987

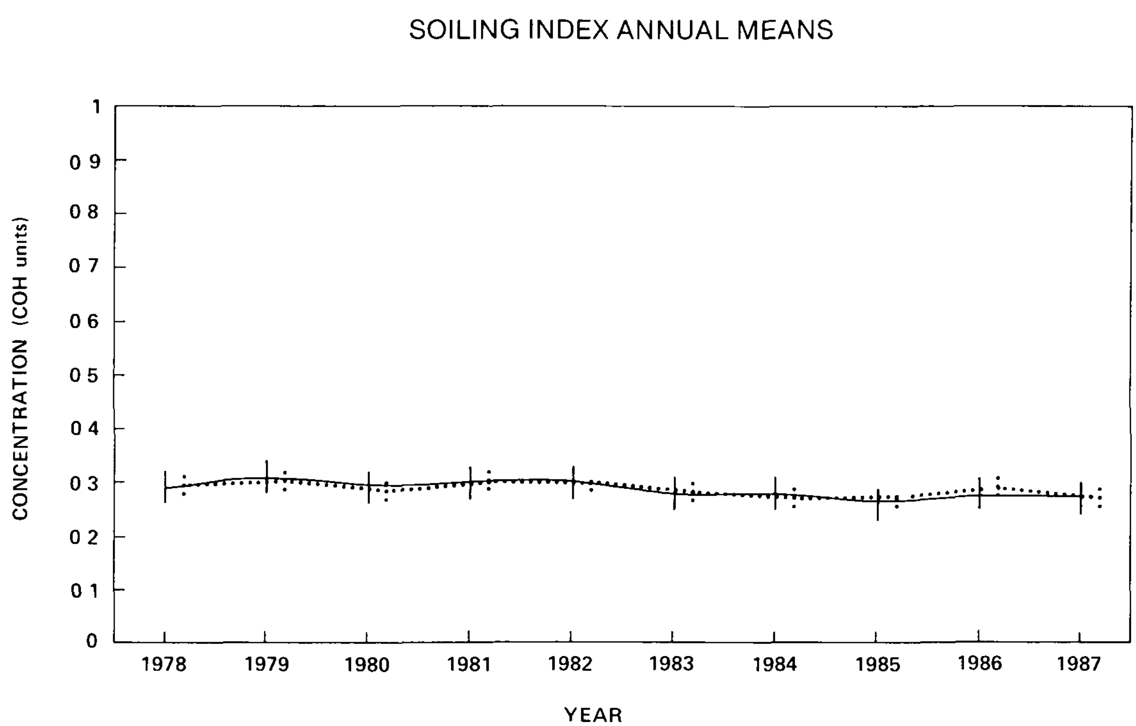

Figure 36 Trend in Soiling Index Annual Mean Values for All Stations (—) and Class I Stations (...) with 95% Confidence Limits, 1978-1987

soiling index have declined steadily from 53 sites in 1978 to 23 in 1987.

Long-term changes using Tukey's test in average annual mean soiling index values for Class I stations and for all NAPS network stations are shown in Figure 36. The trend lines for Class I Stations and All Stations almost coincide. However, the Class I Stations tend to have slightly higher index values than the All Stations do for the last few years; this is consistent with their central urban locations. 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 for stations in such cities as Montreal, Toronto, Hamilton, Windsor and Vancouver continues[2]. The Barton and Sanford station 60501C in Hamilton reported the highest annual mean in 1987 (0.55 COH units).

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APPENDIX

SUMMARY DATA - NATIONAL URBAN AIR QUALITY TRENDS 1978-1987

Table A Sulphur Dioxide - Number of Stations Indicating Changes in Annual Mean (1978-1987)

	Number of Stations			
Period	Decrease	Increase	No change*	Total
1978-79	14	7	38	59
1979-80	15	16	35	66
1980-81	11	5	25	41
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

* includes 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 (1978-1987)

	Number of Stations			
Period	Decrease	Increase	No change*	Total
1978-79	12	4	7	23
1979-80	15	6	10	31
1980-81	8	9	17	31
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

* includes stations having differences of 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 (1978-1987)

	Number of Stations			
Period	Decrease	Increase	No change*	Total
1978-79	9	10	13	32
1979-80	17	6	14	37
1980-81	5	8	19	32
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

* includes stations where differences were 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 (1979-1987)

	Number of Stations			
Period	Decrease	Increase	No change*	Total
1979-80	10	9	15	34
1980-81	13	4	15	32
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

* includes stations with 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 (1978-1987)

	Number of Stations			
Period	Decrease	Increase	No change*	Total
1978-79	14	40	31	85
1979-80	17	34	33	84
1980-81	42	4	28	74
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

* 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 (1978-1987)

	Number of Stations			
Period	Decrease	Increase	No change*	Total
1978-79	28	6	22	56
1979-80	30	6	33	69
1980-81	19	10	29	58
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

* 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 (1978-1987)

	Number of Stations			
Period	Decrease	Increase	No change*	Total
1978-79	18	20	15	3
1979-80	21	12	9	42
1980-81	4	16	17	37
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

* includes stations with differences greater 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 Statio Over the Past Eleven Years

		Annual means (ppb)										
City (Station)		1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Halifax	30116C	9	11	14	19	15	10	11	11	10	10	11
Quebec City	50303I	43	20	25	19	--	--	34	21	12	24	--
Shawinigan	512011	NM	26	--	15	17	12	--	12	10	23	17
Trois-Rivières	50801R	23	22	16	12	14	--	--	9	8	9	8
Arvida	50901R	--	20	15	20	20	15	16	17	9	9	8
Montreal	50104C	19	18	17	16	16	12	7	--	--	--	4
	50115C	NM	27	27	35	--	--	8	9	9	11	17
	50103R	21	28	19	--	23	20	14	10	18	13	8
Ottawa	60101C	13	15	13	11	10	11	5	9	9	--	--
Sudbury	60606C	23	13	11	13	10	8	8	10	10	9	9
	60602R	15	12	12	16	10	10	9	10	10	8	9
Sarnia	61004R	NM	17	17	13	14	12	10	9	11	8	7
Windsor	60204C	22	18	13	11	12	9	8	7	7	8	8
Cornwall	61204C	17	17	13	12	10	11	8	10	9	8	6
Hamilton	60501	23	16	17	13	10	14	14	15	9	8	9

-- insufficient data for calculation of a valid mean

Table I Monitoring Sites* with Highest Measured Lead Concentrations During 1983 to 1987

Station No	City	Address	Annual Geometric Mean (μg/m3) (1983)	(1987)	Maximum 24-h Conc (μg/m3) (1983)	(1987)	Sampler Height (m)	Distance to Nearest Roadway (m)	Nearest Major Roadway Volume (veh /day)
50109	Montreal	Duncan/Décarie	0 72	0 21	1 8	0 8	4	20	100 000
50601	Rouyn	Hotel de Ville	0 41	0 08	7 7	3 2	8	--	--
60403	Toronto	Evans/Arnold	0 46	0 18	1 7	0 6	2	120	150 000
60417	Toronto	Breadalbane	0 28	0 11	0 8	0 3	25	100	50 000
60501	Hamilton	Barton/Sanford	0 40	0 16	2 5	1 2	4	18	18 650
61501	Kitchener	Edna/Frederick	0 52	0 20	2 2	1 2	4 5		
90204	Calgary	316-7th Avenue	0 43	0 19	2 2	0 7	0 7	25	16 150
00104	Vancouver	27th/Ontario	0 50	0 33	1 8	1 1	18	200	10 800
00109	Vancouver	970 Burrard	0 56	0 24	1 9	1 1	4	20	21 200
00114	Vancouver	Mun Hall (Richmond)	0 46	0 17	2 1	0 8	15	100	29 000
00117	Vancouver	BCIT Burnaby	0 51	0 24	2 2	1 4	18	200	35 000
00303	Victoria	1250 Quadra	0 45	0.26	2 3	1 1	12	18	12 000

* only NAPS stations with complete data record included

Table J Summary Data - Urban Air Quality in Canada, 1974-1987

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
	1978	71	10	20	13	9	4	1
	1979	69	10	16	12	8	5	0
	1980	65	9	16	13	9	4	1
	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
NO_2 (ppb)	1978	33	29	40	35	29	20	18
	1979	34	26	34	31	27	19	12
	1980	38	25	37	31	23	19	11
	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	29	26	22	17	12
	1986	36	22	32	27	22	17	12
	1987	32	21	31	25	22	17	15
CO (ppm)	1974	18	2.4	5.0	3.0	2.2	1.2	0.7
	1978	40	1.5	2.8	2.0	1.3	0.8	0.5
	1979	42	1.7	3.2	2.0	1.5	1.0	0.8
	1980	43	1.5	2.8	1.8	1.4	0.9	0.6
	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

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)	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	07	05
	1984	36	16	20	19	17	12	10
	1985	42	17	23	19	16	13	11
	1986	39	16	23	20	17	13	10
	1987	42	16	23	20	16	13	9
SP ($\mu g/m^3$)	1974	59	78.6	121.0	96.0	70 0	53.0	43.0
	1978	91	61.4	92.0	68.0	53.0	44.0	36.0
	1979	96	66.0	99.0	78.0	60.0	50.0	38.0
	1980	101	67.0	99.0	77.0	64.0	50.0	40.0
	1981	87	58.6	80.0	66.0	56.0	42.0	37.0
	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
Lead ($\mu g/m^3$)	1974	58	0.68	1.22	0.97	0.53	0.26	0.15
	1978	74	0.42	0.75	0.57	0.36	0.23	0.14
	1979	79	0.39	0.72	0.55	0.36	0.21	0.12
	1980	84	0.34	0.60	0.47	0.30	0.17	0.10
	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
Soiling Index	1974	35	0.38	0.67	0.46	0.34	0.20	0.14
	1978	63	0.25	0.44	0.32	0.22	0.17	0.11
	1979	67	0.28	0.45	0.39	0.26	0.18	0.15
	1980	51	0.28	0.43	0.34	0.28	0.18	0.13
	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

Pollutant	Year	Number of Sites	Average of Annual Mean	Percentage of Sites with Annual Mean Lower than Given Values 90%	75%	50%	25%	10%
	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