Primary Environmental Indicators

1 Air Quality

Regulations designed to improve air quality target six main pollutants: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ground level ozone (O_3), carbon monoxide (CO), total suspended particulates (TSPs), and lead (Pb).[1] The primary synthetic sources of these pollutants are automobiles and industrial activity. These pollutants also occur naturally in the environment.

Two types of data are used to measure air quality: ambient concentrations and emissions estimates. Ambient concentrations are the actual measured amount of a pollutant in the air, usually reported in parts per million (ppm), parts per billion (ppb), or micrograms per cubic metre ($\mu g/m^3$). The National Air Pollution Surveillance (NAPS) network was established in 1969 to trace common air contaminants in Canada. In 1970, 43 monitoring instruments were tracking pollutant levels in 14 urban centers (Furmanczyk 1987: 2). In 1999, the network consisted of 252 stations in 153 cities across the country (Shelton 2001).[2]

Emissions estimates are calculations of the amount of a particular pollutant emitted by various sources over a given period. These calculations are based on many assumptions including the level of industrial activity, changes in technology, fuel-consumption rates, vehicle miles traveled, and other activities that cause air pollution. They do not include pollution caused or released by natural sources. Although emission estimates provide some useful information regarding air quality trends, they are less reliable indicators than ambient concentrations because they are estimates generated by models. In addition, frequent revisions in the calculation methods used to estimate emissions make comparisons between years less meaningful than comparisons of annual ambient levels.

In this section, each pollutant is described and compared to Canada's National Ambient Air Quality Objectives (NAAQOs) for the protection of human health and the environment. Canada has a three-tiered system of objectives that defines maximum desirable (strictest standard), acceptable, and tolerable levels of air pollution for periods of one year, 24 hours, eight hours, or one hour, depending on the pollutant. Standards are more stringent for longer time periods.[3] According to Environment Canada,

> [t]he 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 acceptable level is intended to provide adequate protection against adverse effects on humans, animals, vegetation, soil, water, materials, and visibility. 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. (Environment Canada 1999b)

Table 1.1 lists Canada's NAAQOs alongside the guidelines of the World Health Organization (WHO) and a corresponding description of the effects on human health and the environment for each category. When the strictest standard is met, there are no effects on human health or the environment.

For each pollutant discussed in the section, we provide a graph showing the average of the stations' annual means. The strictest annual health standard is included so readers can see instantly whether there are any health concerns associated with that level of pollution. To provide information about the variation found in individual stations' means, the tenth, fiftieth, and ninetieth percentiles (the box around the year's mean) is included. The top of the box illustrates the ninetieth percentile for the calculation, meaning that 90% of the stations have an annual mean equivalent to, or below, this level. Similarly, the lines in the middle of the box and the bottom of the box represent the fiftieth and tenth percentiles respectively. They show the levels for which 50% and 10% of the stations have an annual mean equivalent to or below.

It is important to realize that the number of stations monitoring each pollutant changes from year to year. Some stations are discontinued while others are added. Some stations do not provide enough data to determine a mean in some years. Generally, the number of stations has been increasing over time although there have been decreases in the number of stations tracking some pollutants. For instance, the national annual mean for lead has gone from being calculated by 113 stations in 1978 to just 32 stations in 1998. When fewer stations are used to calculate a mean, a single station with an usually large mean can more easily create the impression that the overall average has increased. The national annual mean for lead shows a spike in 1997 largely because one station, which is located near a re-opened lead mine in Quebec, had a mean that was 75 times larger than the national average from the previous year.

The percentage of stations with readings exceeding the NAAQOs short-term standards is also examined. This is calculated by dividing the number of stations with at least one reading above the NAAQOs by the total number of stations. In reading this data, it is important to understand that one reading above the standard may not be critical, considering that many stations have several thousand readings a year. Also a single day's exceedence can be influenced by meteorological factors such as temperature, sunlight, air pressure, humidity, wind, rain, and so on. Despite these limitations, the data provides a good complement to the annual data, illustrating changes in the number of stations meeting short-term concentration objectives.

City data for the major pollutants are also included in this section. Data from 13 cities, representing nine provinces, give readers a more comprehensive picture of air quality in Canada's major urban areas. To show trends for particular pollutants, the cities are grouped according to their metropolitan populations in three categories: large (Toronto, Montreal, Vancouver, and Ottawa-Hull), medium (Calgary, Edmonton, Quebec, and Winnipeg), and small (Hamilton, Halifax, Regina, St. John's, and Saint John). Some caution should be used when examining the data presented for the individual cities. For some cities in some years, the annual means for some pollutants was based on a single station's readings. The same information is grouped by city in tables, in order to give the reader a quick picture of what pollution trends are in individual cities.

Sulphur dioxide

Sulphur dioxide (SO_2) is a colourless gas that, in sufficient concentrations, has a pungent odour. There is concern about levels of SO_2 since it is a precursor to acid rain. Acid rain in sufficient concentrations can cause the acidification of lakes and streams, accelerate the corrosion of buildings and monuments, and impair visibility. As a result, in 1985 Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland created the Canadian Acid Rain Control Program, agreeing to cut total annual SO_2 emissions to 2.3 million tones by 1994 (Statistics Canada 1998: 44). They surpassed this target by 1993. In 1991, Canada signed the Canada/United States Air Quality Agreement for the reduction of SO_2 and NO_x emissions. Canada's obligations under this agreement include the establishment of a permanent national limit on SO_2 of 3.2 million tones by the year 2000 (USEPA 1995d: ES-1). Canada has met this obligation since 1992.

Although acid rain remains a topical concern, there is a debate among scientists whether acid rain does indeed damage forests and crops as well as endanger wildlife and human health. After 10 years of study, the United States National Acid Precipitation Assessment Program (NAPAP) concluded that acid rain has had little or no effect on wildlife, forests, crops, or human health (Bast, Hill, and Rue 1994: 74–81). In fact, it cites cases in which acid rain has had a positive effect on soil and lakes as it can enhance vital nutrients and reduce pH levels where alkalinity is a problem. There is also uncertainty about the natural acidic levels for different lakes. Chemist Edward Krug argues that some lakes are becoming more acidic because of less human influence. Whereas slash-and-burn timbering practices in the early 1900s resulted in uncontrolled erosion and, consequently, in large deposits of alkaline topsoil in nearby lakes, more sustainable forestry practices have reduced erosion and have allowed lakes to return to their natural acidic levels (Easterbrook 1995: 169).

Some Canadian scientists, however, estimate that even with full implementation of the Canada/United States Air Quality Agreement, close to 80 million hectares in south-eastern Canada will receive levels of acid rain that could have a negative effect on the environment.

They have estimated that a further 75% reduction in emissions in parts of eastern Canada and the United States is necessary to protect sensitive ecosystems in the area (Statistics Canada 1998: 45).

Trends for sulphur dioxide

The ambient annual national mean for SO_2 decreased by 61.4% between 1974 and 1999 (see figure 1.1). Since 1990, over 90% of the individual stations have reported annual means meeting Canada's strictest annual health standards.

During the period from 1977 to 1999, there were also significant reductions in the number of stations with readings exceeding the 1-hour and 24-hour objectives (see table 1.2). In 1999, 25.8% of stations failed to meet the 1-hour desirable objectives at least once, compared to 42.2% in 1977; 12.9% of stations exceeded the 1-hour acceptable level at least once, down from 19.3% in 1977; and, 14.5% of stations exceeded the 24-hour desirable level at least once while 3.2% and 1.6% of stations exceeded the acceptable and tolerable levels at least once. (Some stations may have had a single 1-hour reading that exceeded the desirable standard in that year. Considering there are 8,760 hours in a year, one reading may not be significant. Any station with at least one exceedance counts as a station in exceedance for the entire year.)

The city data shows similar trends to the national means. Nine of the 13 cities experienced declines in the ambient readings of SO_2. In many cases, the declines were dramatic. For example, SO_2 levels in Quebec City fell 94% between 1976 and 1999. In Montreal SO_2 levels declined by 77% between 1974 and 1999. Not every city experienced a decline. The annual means for Edmonton and Calgary showed increases relative to their levels in 1974. This may or may not represent an overall trend, however, since the increases are based on a single station's readings for each city for the majority of the years between 1974 and 1999. In 1999, all the cities had annual means that met the strictest annual health standard, "desirable." The large and medium cities were substantially below the desirable standard, though several of the smaller cities had higher means that were closer to just meeting the standard. (figures 1.2–1.4 and tables 1.7–1.19).

Emissions of sulphur dioxide in Canada fell 59.7% between 1970 and 1997 (figure 1.5). The increased use of control devices by industry has contributed to the decline in emissions. Improvements in the processes used, smelter closures, acid-plant adoption, the use of low-sulphur coal, the adoption of coal blending and washing procedures, and the conversion to cleaner fuels (e.g. natural gas and light oil) have also contributed to the decline (USEPA 1996a: 29). Emissions from mobile sources such as cars fell 8% between 1980 and 1997 while emissions from stationary sources such as power plants fell 43% over the same time period (OECD 1999: 2.2A). The main source of SO_x emissions, however, is industrial sources (figure 1.6).

Nitrogen dioxide

Nitrogen dioxide (NO_2) is a highly reactive gas that is readily formed through the combination of nitric oxide (NO) with oxygen. This reaction is typically a natural process, occurring through lightening, volcanic activity, bacterial action in the soil, and forest fires. Most of the nitrogen oxide compounds needed for this reaction however, originate from human activities. Nitrogen oxides (NO_x) are the sum total of NO, NO_2, and other oxides of nitrogen. The combustion of fossil fuels by automobiles, power plants, industry, and household activities all contribute to their concentrations in the environment.

Levels of NO_x in the environment are of concern since they combine with volatile organic compounds (VOCs) in the presence of sunlight to form ground-level ozone. This process contributes to the formation of urban smog. Nitrogen oxides also play a major role in atmospheric photochemical reactions that contribute to acid rain. Although the ambient levels of all nitrogen oxides are a concern, environmental agencies generally track NO_2 since NO is so readily converted to NO_2 in the environment. NO_2 is also the easiest to detect because of its presence in higher concentrations.

Trends for nitrogen dioxide

From 1974 to 1999, the Canadian annual mean decreased by 28%, from 21.3 ppb to 15.3 ppb (figure 1.7). Throughout this period, the annual mean has remained below the strictest annual health standard of 32 parts per billion (the "desirable" level). In addition, 90% of stations have been below the maximum acceptable level of 53 parts per billion over the entire time period. Since 1990, 90% of stations have been below the desirable levels. All stations have met this desirable target since 1992, with the exception of one exceedance in 1996 and one exceedance in 1999 (the acceptable standard was not breached in either case).

Trends in short-term concentrations similarly illustrate improvements in the concentration of nitrogen dioxide (table 1.3). In 1977, 13.6% of monitoring stations reported at least one reading that exceeded the 1-hour maximum acceptable level, and 15.9% had a reading that exceeded the 24-hour maximum acceptable level. By 1999, less than 1% of stations exceeded the 1-hour and 24-hour acceptable levels (there is no 1-hour or 24-hour desirable standard set for nitrogen dioxide so maximum acceptable level becomes the strictest standard).

City data shows similar trends since 1974. Most cities have had annual averages below the strictest standard since the early 1980s (see figures 1.8–1.10 and tables 1.7–1.19). Most cities, with the exception of Montreal and Halifax, had a decline in their annual average levels of NO_2. Hamilton experienced the biggest decline, 49%, between 1976 and 1999.

Emissions data for NO_x show a trend opposite to that of ambient levels. Canadian emissions increased 51.3% from 1970 to 1996 (figure 1.11). This increase in emissions of NO_x is puzzling in light of the reduction in ambient NO_2. When contemplating this discrepancy, it is important to recall that emissions data are estimates and ambient data are more reliable as they are actual measurements from the air.

The breakdown of sources for NO_x emissions shows that over half of the emissions came from transportation and another quarter came from industrial sources (figure 1.12).

Ground-level ozone

Ground-level ozone (O_3) is a colourless gas that is irritating to asthma sufferers. It is formed just above the earth's surface through the reaction of NO_x and volatile organic compounds (VOCs). Since this chemical reaction is facilitated by the presence of heat and sunlight, ozone is typically more of a concern during the summer months.

Since ozone is the main contributor to urban smog, regulators target emissions of VOCs to combat the problem. VOCs are a subgroup of hydrocarbons (HCs); they enter the atmosphere through evaporation of automotive fuel (from the fuel tanks of automobiles), paints, coatings, solvents, and consumer products such as lighter fluid and perfume. VOCs also occur naturally as a result of photosynthesis.

Increasing levels of ozone have led regulators to develop more stringent standards. In 1998, 12 Canadian Ministers of the Environment endorsed the Canada-Wide Agreement on Environmental Harmonization. This agreement included the development of Canada-wide standards for both ozone and particulate matter. The recommended standard for ozone was stipulated at 65 ppb averaged over 8 hours, to be achieved by 2010.

Much of the concern over ozone levels stems from a Canadian study examining NO_x and VOCs that states the current 1-hour maximum acceptable level for ozone does not fully protect human health. It also reports that there is "no discernible human health threshold for ground-level ozone," meaning that any improvement in ambient ozone levels is expected to have public health benefits (Environment Canada 1997a: 3).

Trends in ground-level ozone

The level of ambient ozone increased from 14.7 ppb to 23.7 ppb (61%) between 1974 and 1999 (figure 1.13). During this period, the Canadian mean (the average of the individual station means) has consistently been above the maximum acceptable level of 15 ppb, which is the strictest health standard since no targets for maximum desirable are set for ozone. In 1999, less than 10% of individual stations reported means below this level.

Data on the percentage of stations with readings exceeding short-term concentration objectives also suggests that ozone is increasingly becoming a concern (table 1.4). The percentage of stations reporting at least one reading in exceedence of the desirable standard has increased from 95% in 1977 to 99% in 1999. However, the percentage of stations exceeding the acceptable and tolerable limits has decreased at the same time from 78% to 58.4% and from 14.6% to zero respectively.

City data also reflects this trend. All cities examined had means in 1999 above the maximum acceptable level of 15 parts per billion—Vancouver was closest to meeting the standard with a level of 15.31 parts per billion (see figures 1.14–1.16 and tables 1.7–1.19). Most cities saw an increase in ground-level ozone between 1974 and 1999. The only exceptions were Hamilton and Halifax, where there was a slight decrease in ground-level ozone levels.

VOC emissions, which contribute to the formation of ground-level ozone, increased 27.1% between 1980 and 1997 (see figure 1.17). These emissions have remained relatively constant since 1985, however, showing that ambient ozone levels do not directly or predictably reflect VOC emissions. The main sources of VOC emissions in 1995 were industry and open sources (figure 1.18).

Carbon monoxide

When fuel and other substances containing carbon burn without sufficient oxygen, carbon monoxide (CO), a colourless, odourless gas is produced. Trace amounts of CO occur naturally in the atmosphere but most emissions come from automobiles. Levels of CO are of particular concern to monitoring organizations because of their effect upon human health: CO reduces the capacity of red blood cells to carry oxygen to body tissues. Since CO poisoning occurs as a result of short-term exposure, health guidelines do not include annual recommendations for ambient CO levels. However, 8-hour and 1-hour guidelines are available.

Trends for carbon monoxide

Annual ambient levels of CO have improved significantly in Canada over the past 25 years. Between 1974 and 1999, levels declined from 2.3 ppm to .55 ppm, a 76% reduction (figure 1.19). This decline has been reported at all stations. In 1974, the highest annual mean measured at an individual station was 5.1 ppm, whereas in 1999 it was 1.0 ppm. In 1999, 90% of stations reported annual means below 0.8 ppm.

The percentage of stations with readings exceeding NAAQOs levels has also seen improvements (see table 1.5). Whereas in 1977 68.8% of stations had at least one reading exceeding the 1-hour desirable level, in 1999, there were no stations that exceeded it. The number of stations with at least one reading exceeding the 8-hour desirable level also declined from 85.4% in 1977 to zero in 1999. There have been no exceedances in the 1-hour or 8-hour maximum acceptable levels since 1992.

City data shows very similar trends to the national annual means (figures 1.20–1.22 and tables 1.7–1.19). Every city, with the exception of Saint John, shows a reduction relative to 1974 levels. Most cities show considerable reductions, including Quebec (79.1%), Montreal (70.3%) and Vancouver (65.7%).

Carbon monoxide emissions declined 12.4% between 1970 and 1997 (figure 1.23). These reductions can partially be attributed to cleaner automobiles and more fuel-efficient industrial processes. To meet strict motor-vehicle regulations adopted in the early 1970s, exhaust-gas recycling systems (EGRS) were installed and some older vehicles were retired. This has led to vastly reduced emissions per vehicle. For example, North American cars built in 1993 emitted 90% less NO_x, 97% less hydrocarbons, and 96% less CO than cars built two decades earlier (Bast, Hill and Rue 1994: 111). There was also a reduction of 87.5% in CO emissions from incinerators between 1980 and 1995. In 1995, the two main sources of CO emissions were transportation (39.2%) and open sources (mainly forest fires) (figure 1.24).

Total suspended particulates

Suspended particulates are small pieces of dust, soot, dirt, ash, smoke, liquid vapour, or other matter in the atmosphere. Sources may include forest fires and volcanic ash as well as emissions from power plants, motor vehicles, and waste incineration, and dust from mining.

Particulates are an irritant to lung tissue and may aggravate existing respiratory problems and cardiovascular diseases. Once lodged in the lungs, certain particulates may contribute to the development of lung cancer. The smallest particulates pose the greatest threat to human health because they are able to reach the tiniest passages of the lungs. Canada's National Ambient Air Quality Objectives (NAAQOs) focus only on total suspended particulates. The Canada-Wide Agreement on Environmental Harmonization in 1998 led, however, to the development of a Canada-Wide standards for particulates smaller than 2.5 microns, known as $PM_{2.5}$. The recommended standard is 30 $\mu g/m^3$ averaged over 24 hours, to be achieved by 2010.

Trends for total suspended particulates

The ambient annual mean of total suspended particulates dropped 49.3% between 1974 and 1999 (figure 1.25). Since 1983, 90% of stations have reported annual means below the maximum acceptable level of 70 $\mu g/m^3$. Since 1990, 90% of the stations also met the maximum desirable level, 60 $\mu g/m^3$, with the exception of 1999, when the ninetieth percentile of stations was slightly over the desirable level. Despite these substantial reductions, a few stations continue to report annual means above the maximum acceptable level.[4]

The number of stations with readings above the short-term concentration standards also has decreased over the past two decades (table 1.6). In 1977, 81.7% of stations had readings exceeding the 24-hour maximum acceptable level. This number decreased to 37.8% of stations in 1997, though it has since crept back up to 51.9%. Similarly, in 1977, almost 10% of stations had at least one reading exceeding the tolerable level. This number declined to 2.7% of stations in 1997 but increased to 7.4% of stations in 1999.

Total suspended particulate levels in the cities were below the desirable annual level in 1999, with the exception of Hamilton. All the cities have witnessed improvements over the past 25 years in their particulate levels (figures 1.26–1.28 and tables 1.7–1.19).

Emissions estimates for total suspended particulates have swelled since 1985, though levels in 1996 were still 9.0% lower than estimated 1980 levels (figure 1.29). Most emissions of particulates originated from transportation (including 59.8% from road dust) in 1995 while 21.2% came from other open sources (figure 1.30).

Lead

Lead is a soft, dense, bluish-grey metal. Its high density, softness, low melting point, and resistance to corrosion make it of value in the production of piping, batteries, weights, gunshot, and crystal. Until recently, automobiles were the source of most lead emissions although small quantities of lead are naturally present in the environment. Lead is the most toxic of the main air pollutants. When it is ingested, it accumulates in the body's tissues. In high concentrations, it can cause damage to the nervous system and the brain, seizures, and behavioural disorders. In addition, recent evidence suggests that exposure to lead may be associated with hypertension and heart disease (USEPA 1995c: 2–6).

Because of lead's toxicity, environmental and health guidelines for lead are stricter than those for other air pollutants. Canada is committed to reducing levels as low as technologically feasible, although no explicit objectives have been set. The maximum set by the World Health Organization (WHO) for the protection of human health is 1.0 $\mu g/m^3$.

Trends for lead

The decline in ambient lead concentration is the greatest success story in the efforts to reduce air pollution. Ambient lead concentrations fell 94% in Canada between 1974 and 1998 (figure 1.31). Although the Canadian average has been below the WHO's standard throughout this period, it was not until 1982 that all individual stations reported means below the health standard.[5] Levels in Canada are currently so low that most stations have discontinued monitoring lead levels. In 1998, 32 stations reported ambient lead levels and only four stations recorded ambient levels for lead in 1999,[6] down from 113 stations in 1978. When fewer stations are used to calculate a mean, a single station with an usually large mean can more easily create the impression that the overall average has increased. The national annual mean for lead shows a spike in 1999 largely because one station, which is located near a re-opened lead mine in Quebec, had a mean that was 75 times larger than the national average from the previous year. City graphs display trends for lead very similar to trends in the national annual means (figure 1.32).

In Canada, emissions fell 73.9% from 1978 to 1995 and automobile emissions fell 87.8% from 1973 to 1988 (figure 1.33). Most of this reduction was due to the introduction of unleaded gasoline and the elimination of lead compounds in paints and coatings.

Table 1.1 National ambient air quality objectives

	Desirable	Acceptable	Tolerable	WHO
Sulphur Dioxide (ppb)				
1 hour	172	334	na	175
24 hours	57	115	306	44
Annual	11	23	na	17
Effects on Human Health and the Environment	no effect	increasing damage to sensitive species of vegetation	odorous, increasing damage and sensitivity exhibited in vegetation	
Nitrogen Dioxide (ppb)				
1 hour	na	213	532	110
24 hours	na	106	160	
Annual	32	53	na	21–26
Effects on Human Health and the Environment	no effect	odorous	odour and atmospheric discoloration; increasing reactivity among asthmatics	
Ground Level Ozone (ppb)				
1 hour	51	82	153	
24 hours	15	25	na	
Annual	na	15	na	
8 hours				60
Effects on Human Health and the Environment	no effect	increasing damage to some species of vegetation	decreasing performance by some athletes exercising heavily	
Suspended Particulate ($\mu g/m^3$)				
24 hours	na	120	400	
Annual	60	70	na	
Effects on Human Health and the Environment	no effect	decreasing visibility	visibility decreased, soiling through deposition, increasing sensitivity of patients with asthma and bronchitits	
Carbon Monoxide (ppm)				
1 hour	13	31	na	25
8 hours	5	13	17	10
Effects on Human Health and the Environment	no effect	no detectable impairment but blood chemistry is changing	increasing cardiovascular symptoms in smokers with heart disease	

Sources: Environment Canada 1999b; WHO 2001; Health Canada 2001.
Note: The WHO sets no guidelines for particulate matter because there is no evident threshold for effects on morbidity and mortality.

Table 1.2 Percentage of stations with readings exceeding sulphur dioxide standards

	1 hour objectives		24 hour objectives			Total number of stations
	> Desirable	> Acceptable	> Desirable	> Acceptable	> Tolerable	
1977	42.2	19.3	53.0	22.9	1.2	83
1982	35.8	8.6	40.7	6.2	2.5	81
1987	23.6	6.9	18.1	2.8	0.0	72
1992	22.1	10.4	18.2	3.9	0.0	77
1997	20.7	10.3	17.2	3.4	0.0	58
1999	25.8	12.9	14.5	3.2	1.6	62

Sources: data provided by Shelton 1999, 2001; calculations by authors.

Table 1.3 Percentage of stations with readings exceeding nitrogen dioxide standards

	1 hour objectives		24 hour objectives		Total number of stations
	> Acceptable	> Tolerable	> Acceptable	> Tolerable	
1977	13.6	0.0	15.9	0.0	44
1982	16.3	0.0	8.2	0.0	49
1987	0.0	0.0	2.0	2.0	49
1992	0.0	0.0	0.0	1.6	61
1997	0.0	0.0	0.0	0.0	78
1999	0.9	0.0	0.9	0.0	106

Source: data provided by Shelton 1999, 2001; calculations by authors.

Table 1.4 Percentage of stations with readings exceeding ozone standards

	1 hour objectives			Total number of stations
	> Desirable	> Acceptable	> Tolerable	
1977	95.1	78.0	14.6	41
1982	96.0	78.0	2.0	50
1987	93.4	54.1	3.3	61
1992	94.1	48.5	0.0	68
1997	97.9	56.7	0.0	141
1999	98.7	58.4	0.0	154

Source: data provided by Shelton 1999, 2001; calculations by authors.

Table 1.5 Percentage of stations with readings exceeding carbon monoxide standards

	1 hour objectives		8 hour objectives			Total number of stations
	> Desirable	> Acceptable	> Desirable	> Acceptable	> Tolerable	
1977	68.8	4.2	85.4	12.5	4.2	48
1982	50.0	7.7	88.5	11.5	5.8	52
1987	22.6	0.0	54.7	5.7	3.8	53
1992	7.1	0.0	35.7	0.0	0.0	56
1997	4.3	0.0	17.4	0.0	0.0	46
1999	0.0	0.0	0.0	0.0	0.0	51

Source: data provided by Shelton 1999, 2001; calculations by authors.

Table 1.6 Percentage of stations with readings exceeding total suspended particulate standards

	24 hour objectives		Total number of stations
	> Acceptable	> Tolerable	
1977	81.7	9.6	104
1982	66.1	2.8	109
1987	58.0	2.0	100
1992	46.1	0.0	89
1997	37.8	2.7	74
1999	51.9	7.4	54

Source: data provided by Shelton 1999, 2001; calculations by authors.

Table 1.7: Trends for specific pollutants, by city—Toronto, Ontario

	Level in 1974	Level in 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	14.7 ppb	5 ppb	−66%	11 ppb	yes
Nitrogen Dioxide	28.5 ppb	25 ppb	−12%	32 ppb	yes
Ground Level Ozone	20 ppb	21.8 ppb	9%	15 ppb	no
Suspended Particulate	70.7 μg/m^3	34 μg/m^3	−51.9%	60 μg/m^3	yes
Carbon Monoxide	2.6 ppm	0.8 ppm	−69.2%	5.2 μg/m^3	yes
Lead	1.09 μg/m^3	.02 μg/m^3 (1994)	−98%	1.0 μg/m^3 (WHO Standard)	yes

Source: Shelton 2001; calculations by the authors.

Table 1.8: Trends for specific pollutants, by city—Montreal, Quebec

	Level in 1974	Level in 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	18.8 ppb	4.3 ppb	−77%	11 ppb	yes
Nitrogen Dioxide	16 ppb	18.7 ppb	16.8%	32 ppb	yes
Ground Level Ozone	14.5 ppb	19.6 ppb	35%	15 ppb	no
Suspended Particulate	128 μg/m^3	38 μg/m^3	−70.3%	60 μg/m^3	yes
Carbon Monoxide	1.55 ppm	0.46 ppm	−70.3%	5.2 μg/m^3	yes
Lead	1.68 μg/m^3	.02 μg/m^3	−98.8%	1.0 μg/m^3 (WHO Standard)	yes

Source: Shelton 2001; calculations by the authors.

Table 1.9: Trends for specific pollutants, by city—Vancouver, British Columbia

	Level in 1974	Level in 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	9 ppb (1976)	3 ppb	−67%	11 ppb	yes
Nitrogen Dioxide	23.75 ppb (1978)	17.75 ppb	−25.3%	32 ppb	yes
Ground Level Ozone	13 ppb	15.31 ppb	17.8%	15 ppb	no
Suspended Particulate	56.6 μg/m^3	21 μg/m^3 (1998)	−62.8%	60 μg/m^3	yes
Carbon Monoxide	1.9 ppm	0.65 ppm	−65.7%	5.2 μg/m^3	yes
Lead	0.9 μg/m^3	.013 μg/m^3 (1994)	−98.5%	1.0 μg/m^3 (WHO Standard)	yes

Source: Shelton 2001; calculations by the authors.

Table 1.10: Trends for specific pollutants, by city—Ottawa, Ontario and Hull, Quebec

	Level in 1974	Level in 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	15.5 ppb	2.7 ppb	−83%	11 ppb	yes
Nitrogen Dioxide	20 ppb (1976)	12 ppb	−40%	32 ppb	yes
Ground Level Ozone	14 ppb (1976)	21.3 ppb	52%	15 ppb	no
Suspended Particulate	85 μg/m^3	31 μg/m^3	−63.5%	60 μg/m^3	yes
Carbon Monoxide	3.2 ppm	0.63 ppm	−80.3%	5.2 μg/m^3	yes
Lead	n/a	n/a	n/a	1.0 μg/m^3 (WHO Standard)	n/a

Source: Shelton 2001; calculations by the authors.

Table 1.11: Trends for specific pollutants, by city—Calgary, Alberta

	Level in 1974	Level in 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	2.5 ppb	3 ppb	20%	11 ppb	yes
Nitrogen Dioxide	31 ppb (1976)	23 ppb	−25.8%	32 ppb	yes
Ground Level Ozone	12 ppb	17.6 ppb	46.6%	15 ppb	no
Suspended Particulate	90.7 $\mu g/m^3$	54.7 $\mu g/m^3$	−39.6%	60 $\mu g/m^3$	yes
Carbon Monoxide	3 ppm	0.7 ppm	−76.6%	5.2 $\mu g/m^3$	yes
Lead	n/a	n/a	n/a	1.0 $\mu g/m^3$ (WHO Standard)	n/a

Source: Shelton 2001; calculations by the authors.

Table 1.12: Trends for specific pollutants, by city—Edmonton, Alberta

	Level in 1974	Level in 1999	Percentage Change	StriCtest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	0.3 ppb	3 ppb	90%	11 ppb	yes
Nitrogen Dioxide	39.5 ppb (1975)	21 ppb	−18.5%	32 ppb	yes
Ground Level Ozone	11 ppb	19.3 ppb	75.4%	15 ppb	no
Suspended Particulate	58.7 $\mu g/m^3$	43.7 $\mu g/m^3$	−25.5%	60 $\mu g/m^3$	yes
Carbon Monoxide	1.35 ppm	0.6 ppm	−55.5%	5.2 $\mu g/m^3$	yes
Lead	n/a	n/a	N/A	1.0 $\mu g/m^3$ (WHO Standard)	n/a

Source: Shelton 2001; calculations by the authors.

Table 1.13: Trends for specific pollutants, by city—Quebec City, Quebec

	Level In 1974	Level In 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	33 ppb (1976)	2 ppb	−94%	11 ppb	yes
Nitrogen Dioxide	20 ppb (1975)	12 ppb	−40%	32 ppb	yes
Ground Level Ozone	18 ppb (1975)	21 ppb	16.6%	15 ppb	no
Suspended Particulate	112 $\mu g/m^3$	30 $\mu g/m^3$	−73.2%	60 $\mu g/m^3$	yes
Carbon Monoxide	2.4 ppm (1975)	0.5 ppm	−79.1%	5.2 $\mu g/m^3$	yes
Lead	n/a	n/a	n/a	1.0 $\mu g/m^3$ (WHO Standard)	n/a

Source: Shelton 2001; calculations by the authors.

Table 1.14: Trends for specific pollutants, by city—Winnipeg, Manitoba

	Level in 1974	Level in 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	1.7 ppb (1975)	1 ppb (1991)	−41%	11 ppb	yes
Nitrogen Dioxide	16 ppb (1976)	15 ppb	−6.2%	32 ppb	yes
Ground Level Ozone	10 ppb (1975)	23 ppb	130%	15 ppb	no
Suspended Particulate	67 $\mu g/m^3$	33.5 $\mu g/m^3$ (1998)	−50%	60 $\mu g/m^3$	yes
Carbon Monoxide	1.15 ppm (1975)	0.45 ppm	−60.8%	5.2 $\mu g/m^3$	yes
Lead	n/a	n/a	n/a	1.0 $\mu g/m^3$ (WHO Standard)	n/a

Source: Shelton 2001; calculations by the authors.

Table 1.15: Trends for specific pollutants, by city—Hamilton, Ontario

	Level in 1974	Level in 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	18.5 ppb	7 ppb	–62%	11 ppb	yes
Nitrogen Dioxide	38.5 ppb (1976)	19.3 ppb	–49.8%	32 ppb	yes
Ground Level Ozone	22 ppb (1975)	21.3 ppb	–3.1%	15 ppb	no
Suspended Particulate	112.3 μg/m^3	75.7 μg/m^3	–32.5%	60 μg/m^3	no
Carbon Monoxide	1.9 ppm	1 ppm	–47.4%	5.2 μg/m^3	yes
Lead	n/a	n/a	n/a	1.0 μg/m^3 (WHO Standard)	n/a

Source: Shelton 2001; calculations by the authors.

Table 1.16: Trends for specific pollutants, by city—Halifax, Nova Scotia

	Level in 1974	Level in 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	8 ppb	10 ppb	25%	11 ppb	yes
Nitrogen Dioxide	7 ppb	21 ppb (1998)	20%	32 ppb	yes
Ground Level Ozone	27 ppb (1977)	25 ppb (1998)	–7.4%	15 ppb	no
Suspended Particulate	32.5 μg/m^3	16.7 μg/m^3	–48.6%	60 μg/m^3	yes
Carbon Monoxide	.75 ppm (1977)	0.6 ppm (1998)	–20%	5.2 μg/m^3	yes
Lead	0.192 μg/m^3	.005 μg/m^3 (1994)	–97.3%	1.0 μg/m^3 (WHO Standard)	yes

Source: Shelton 2001; calculations by the authors.

Table 1.17: Trends for specific pollutants, by city—Regina, Saskatchewan

	Level in 1974	Level in 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	0 ppb	0 ppb	0%	11 ppb	yes
Nitrogen Dioxide	23 ppb (1985)	12 ppb	–47.8%	32 ppb	yes
Ground Level Ozone	19 ppb (1979)	20 ppb	5.2%	15 ppb	no
Suspended Particulate	54 μg/m^3	26 μg/m^3 (1998)	–51.8%	60 μg/m^3	yes
Carbon Monoxide	0.8 ppm (1979)	0.6 ppm	–25%	5.2 μg/m^3	yes
Lead	n/a	n/a	n/a	1.0 μg/m^3 (WHO Standard)	n/a

Source: Shelton 2001; calculations by the authors.

Table 1.18: Trends for specific pollutants, by city—St. John's, Newfoundland

	Level in 1974	Level in 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	8 ppb (1977)	4 ppb	–50%	11 ppb	yes
Nitrogen Dioxide	15 ppb (1990)	7 ppb	–53%	32 ppb	yes
Ground Level Ozone	20 ppb (1991)	23 ppb	15%	15 ppb	no
Suspended Particulate	50 μg/m^3 (1976)	21 μg/m^3 (1998)	–58%	60 μg/m^3	yes
Carbon Monoxide	0.7 ppm (1984)	0.4 ppm	–42.8%	5.2 μg/m^3	yes
Lead	n/a	n/a	n/a	1.0 μg/m^3 (WHO Standard)	n/a

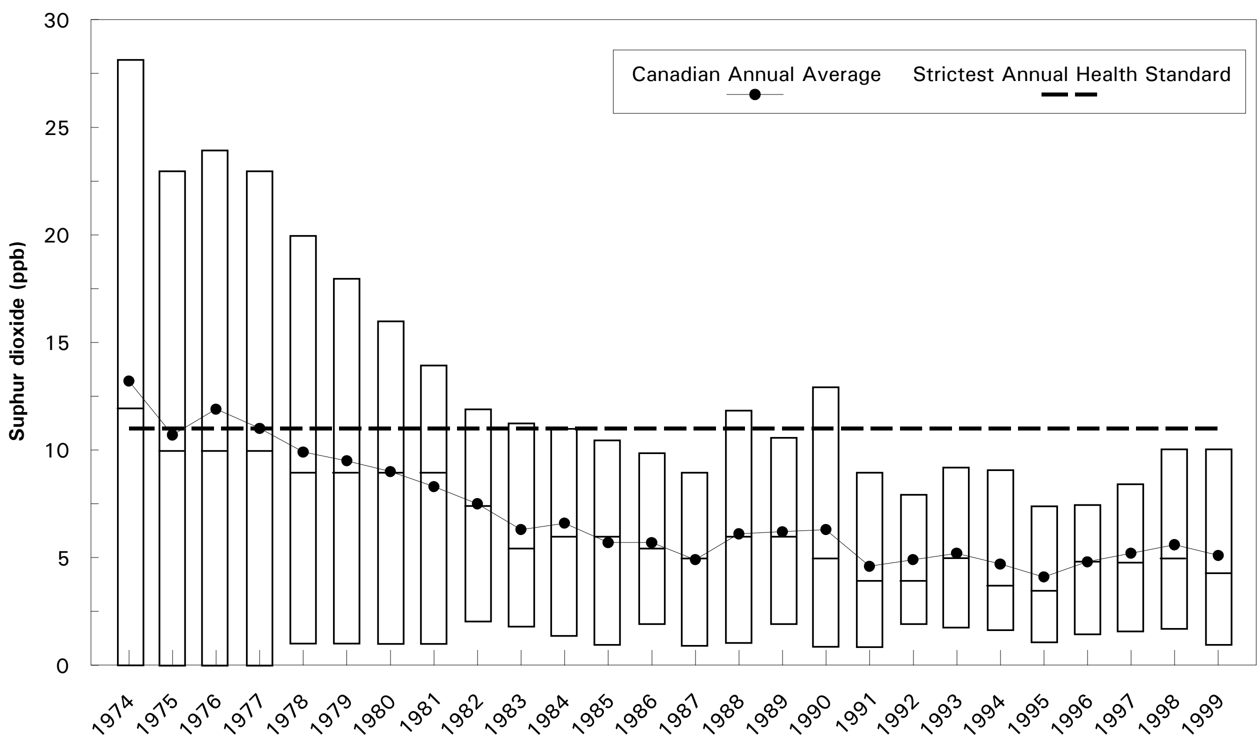
Source: Shelton 2001; calculations by the authors.

Table 1.19: Trends for specific pollutants, by city—Saint John, New Brunswick

	Level in 1974	Level in 1999	Percentage Change	Strictest Annual Health Standard	Meeting Strictest Standards
Sulphur Dioxide	22 ppb	9 ppb	−59%	11 ppb	yes
Nitrogen Dioxide	16 ppb (1981)	11 ppb	−31.3%	32 ppb	yes
Ground Level Ozone	25 ppb (1980)	24 ppb	4%	15 ppb	no
Suspended Particulate	60 μg/m^3	26 μg/m^3	−56.6%	60 μg/m^3	yes
Carbon Monoxide	0.7 ppm (1980)	1 ppm	42.8%	5.2 μg/m^3	yes
Lead	n/a	n/a	n/a	1.0 μg/m^3 (WHO Standard)	n/a

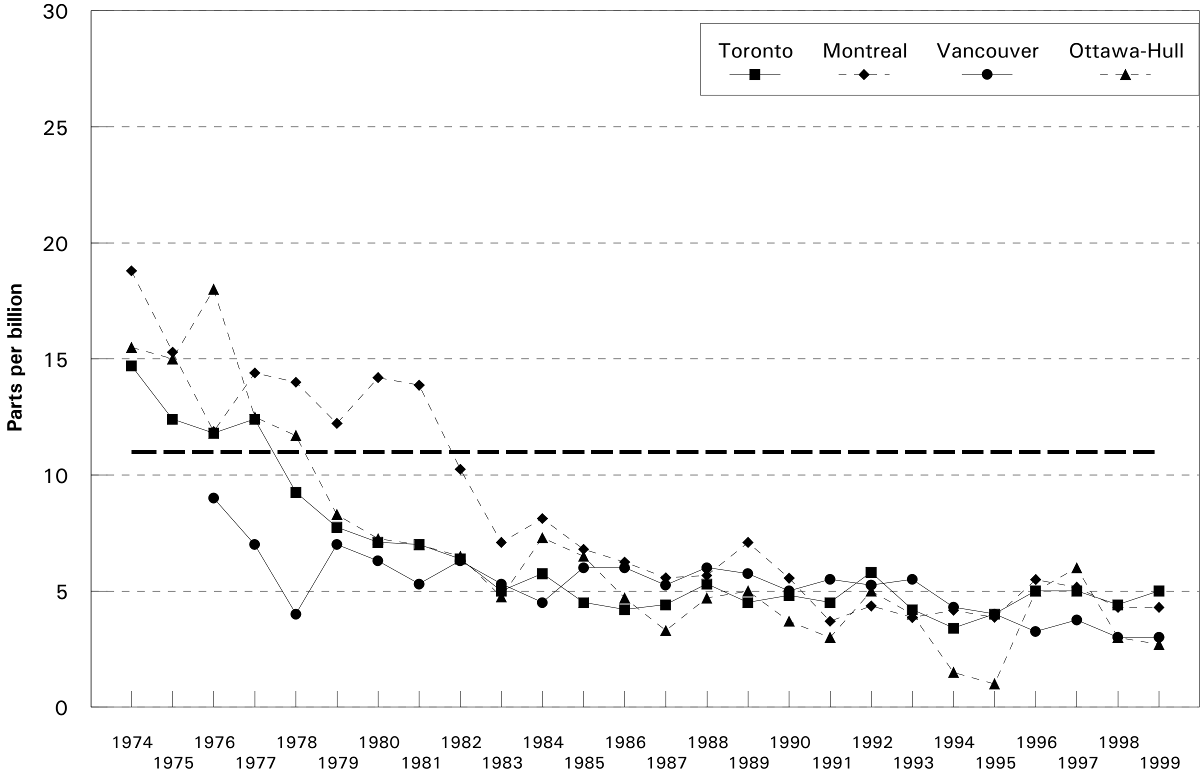
Source: Shelton 2001; calculations by the authors.

Figure 1.1: Ambient levels of sulphur dioxide (ppb)



Source: Shelton 1999, 2001; calculations by authors.

Figure 1.2: Sulphur dioxide—large cities, 1974–1999

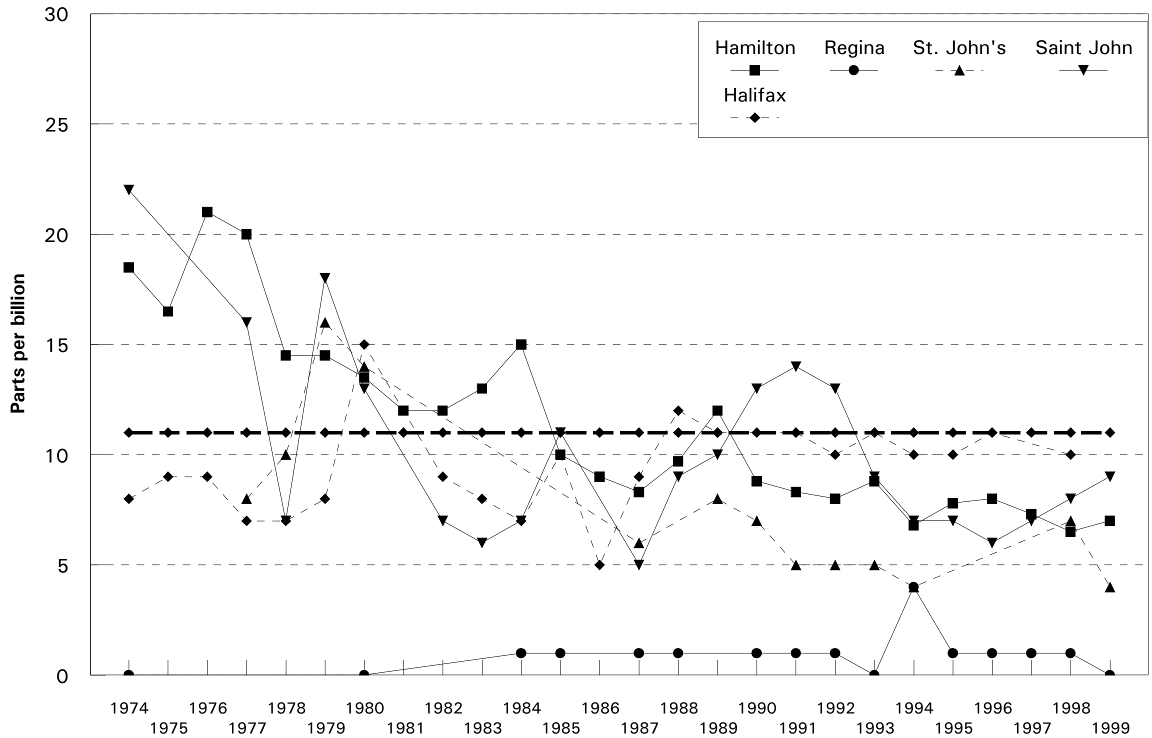


Source: Shelton 2001; calculations by authors. Data for Ottawa-Hull are reported by only one monitoring station for the years 1976, and 1995 through 1997.

Figure 1.3: Sulphur dioxide—medium cities, 1974–1999

Source: Shelton 2001; calculations by authors. Data for Edmonton are reported by only one monitoring station for the years 1981 to 1999. Data for Quebec are single station readings 1987, 1989, 1993, 1994, and 1997 to 1999. Data for Winnipeg are single station readings in 1977 and 1979.

Figure 1.4: Sulphur dioxide—small cities, 1974–1999

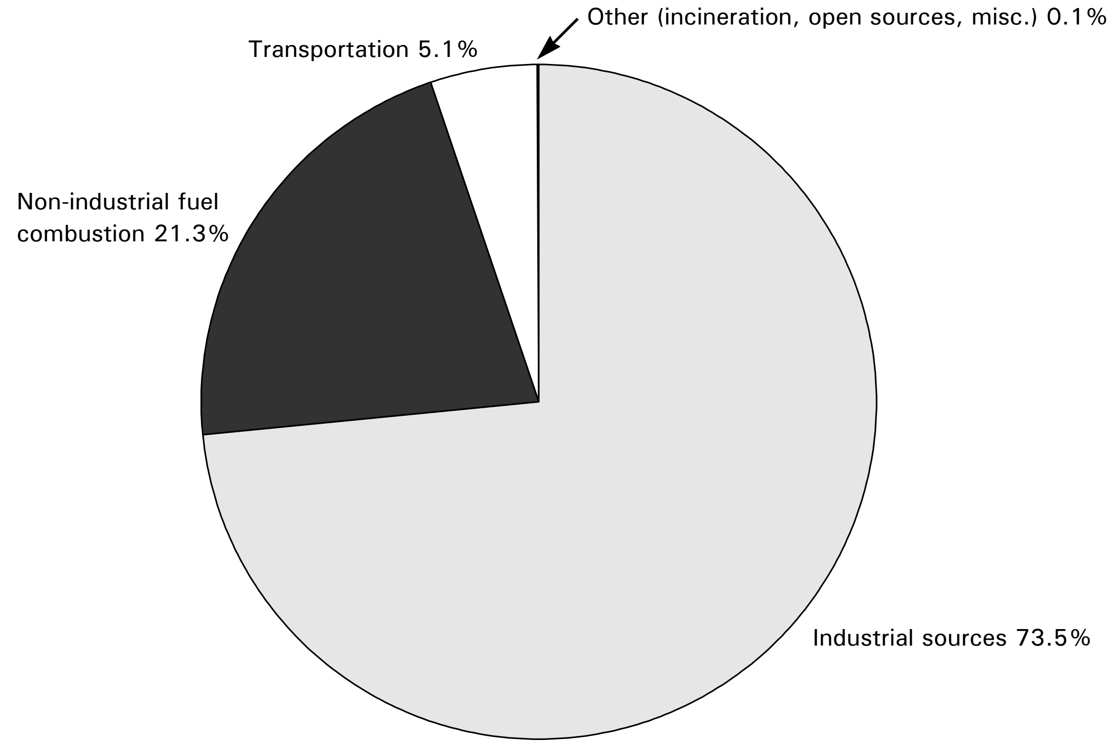


Source: Shelton 2001; calculations by authors. All data for St. John's are reported by only one monitoring station. Data for Hamilton are from a single station in 1984.

Figure 1.5: Sulphur dioxide (SO_2) emissions estimates

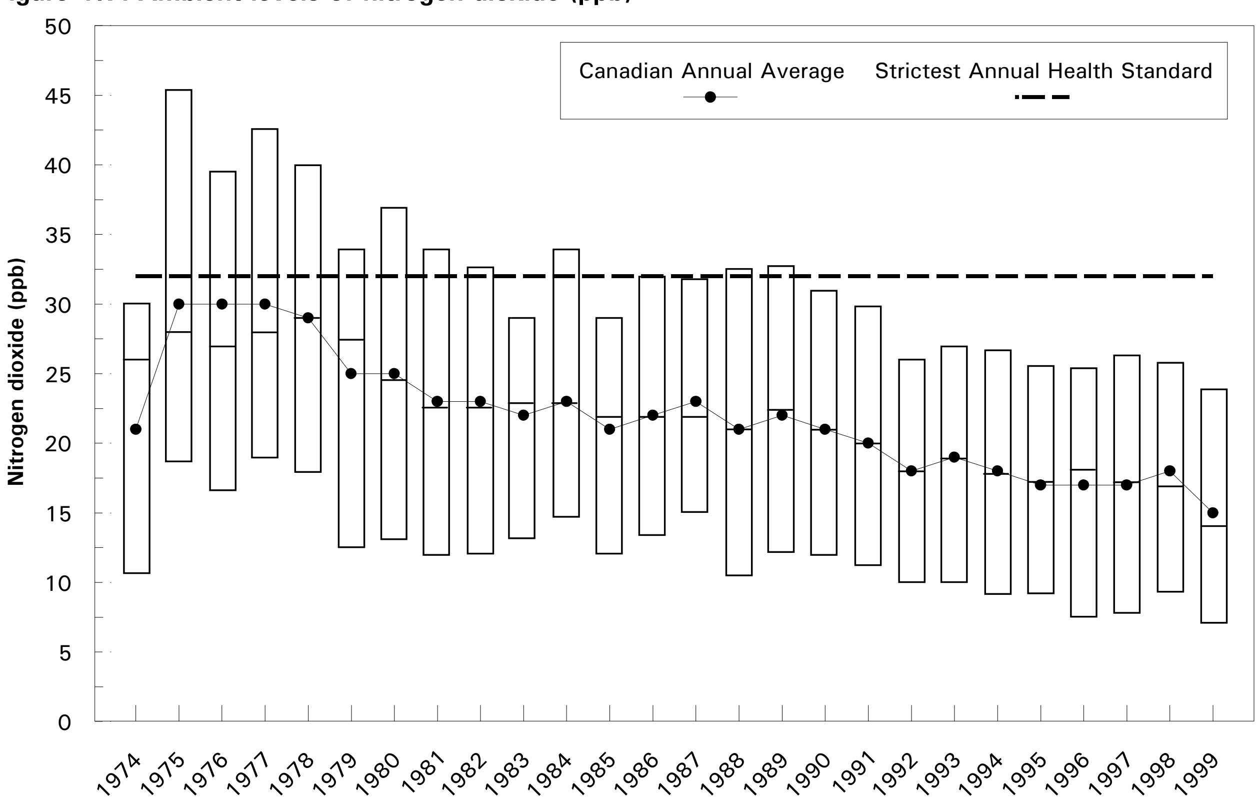
Source: OECD 1999

Figure 1.6: Sulphur oxide (SO_x) by source, 1995



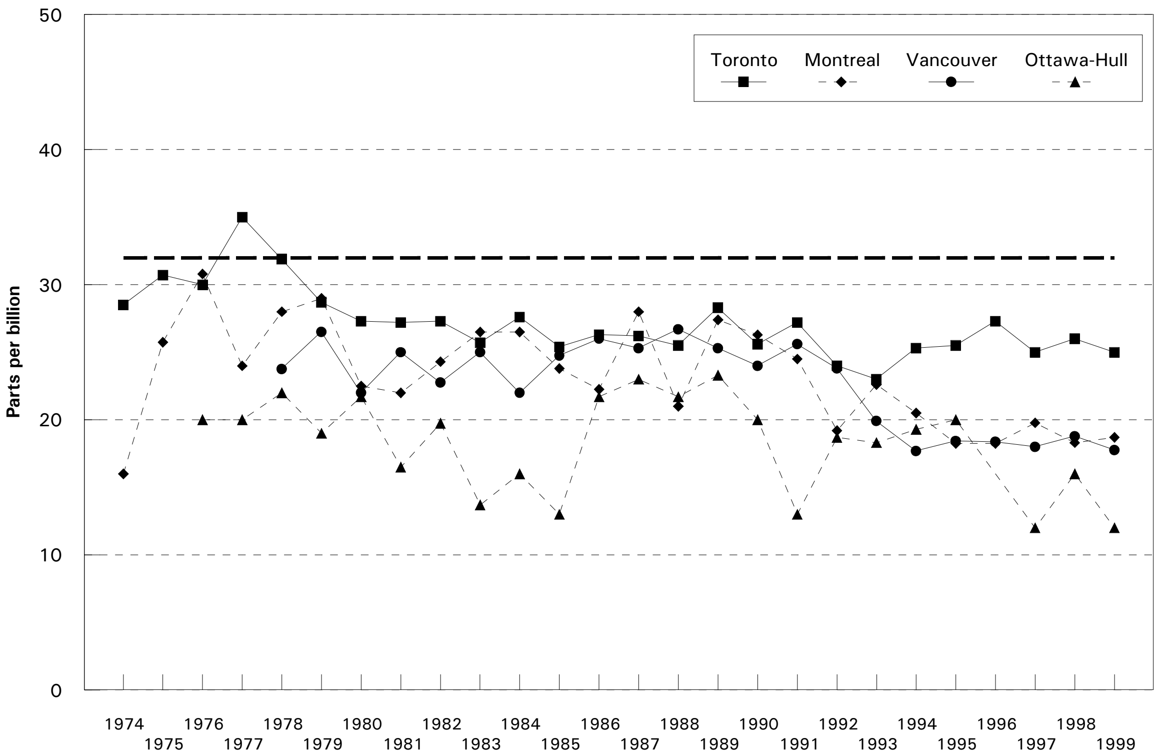
Source: Environment Canada 1998a. Note that data do not include natural sources.

Figure 1.7: Ambient levels of nitrogen dioxide (ppb)



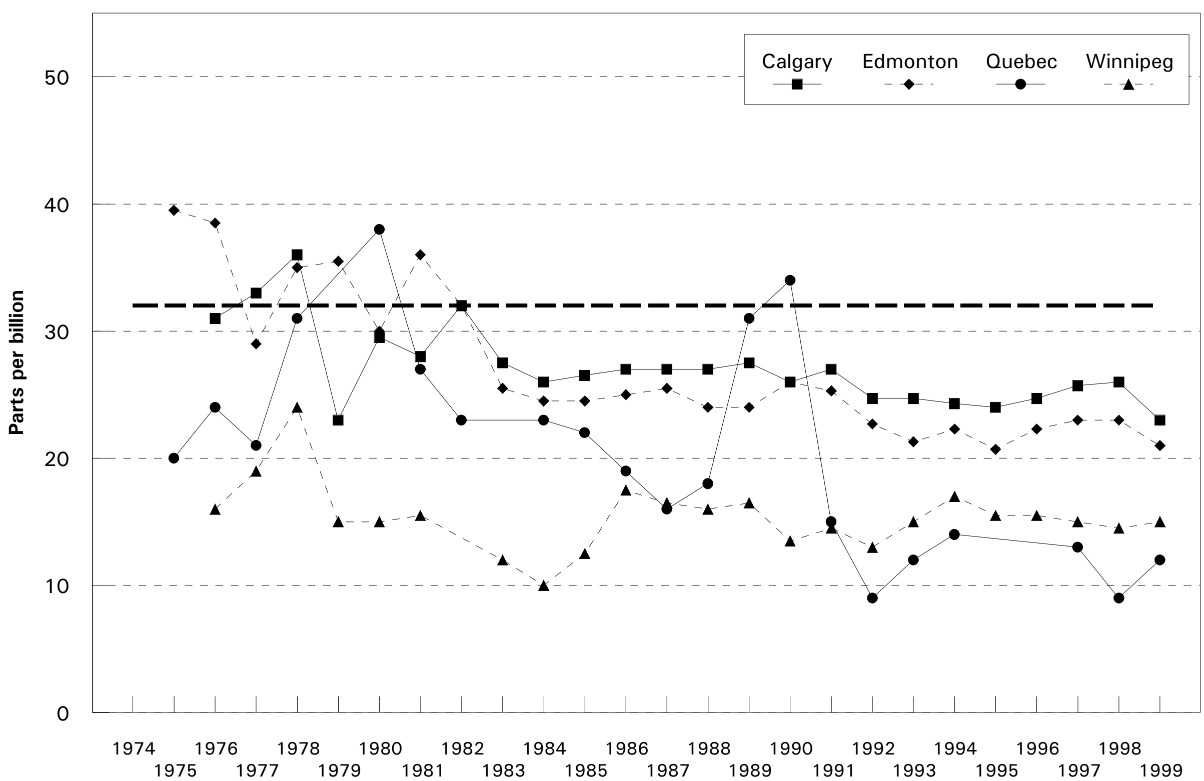
Source: Shelton 1999; 2001.

Figure 1.8: Nitrogen dioxide—large cities, 1974–1999



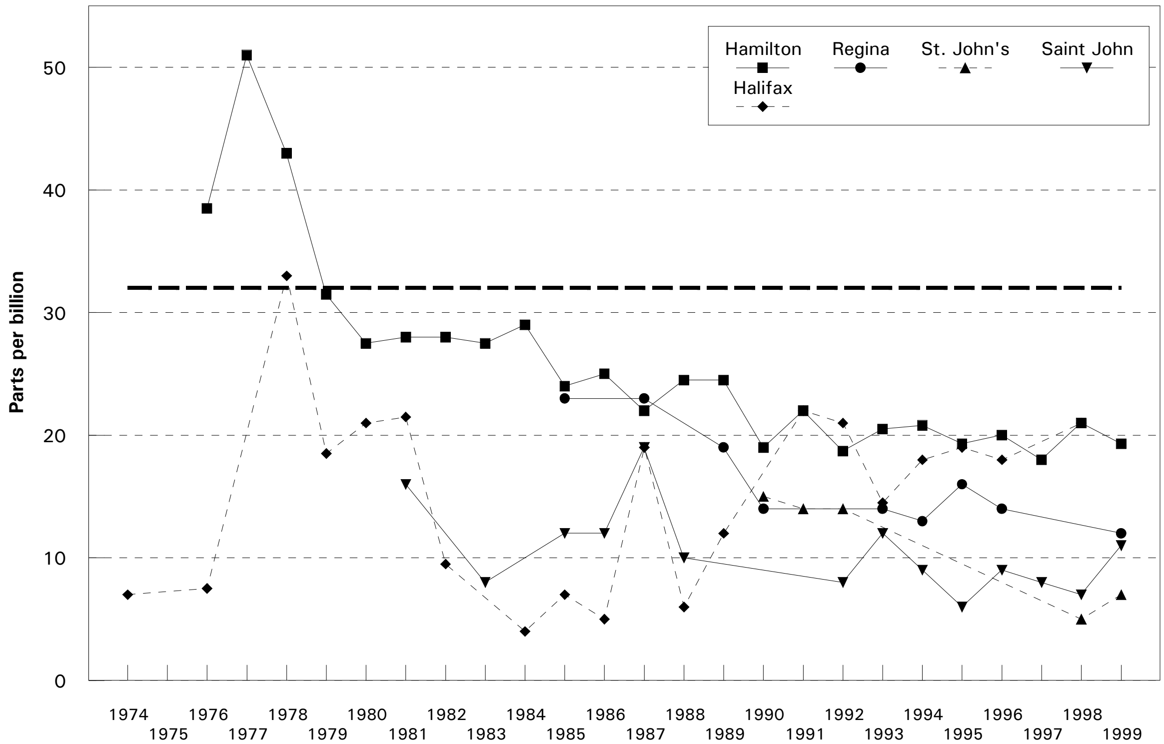
Source: Shelton 2001; calculations by authors. Data for Ottawa-Hull are reported by only one monitoring station in 1976, 1977, 1991, and 1997. Data for Montreal are from a single station in 1975.

Figure 1.9: Nitrogen dioxide—medium cities, 1974–1999



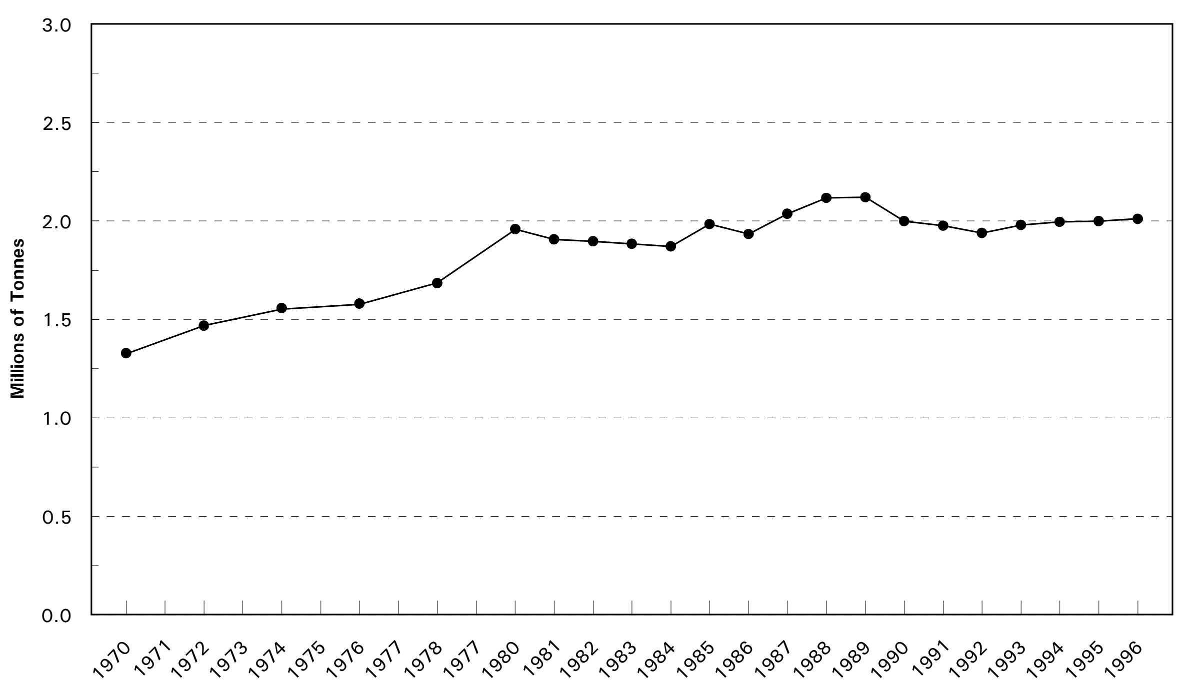
Source: Shelton 1999; 2001. Note: data for Winnipeg are reported by only one monitoring station in 1976, 1977, 1979, 1983, 1992 and 1994. Data for Quebec are single station readings from 1975 to 1990, and 1998. Data for Calgary are single station readings in 1976 and 1979.

Figure 1.10: Nitrogen dioxide—small cities, 1974–1999



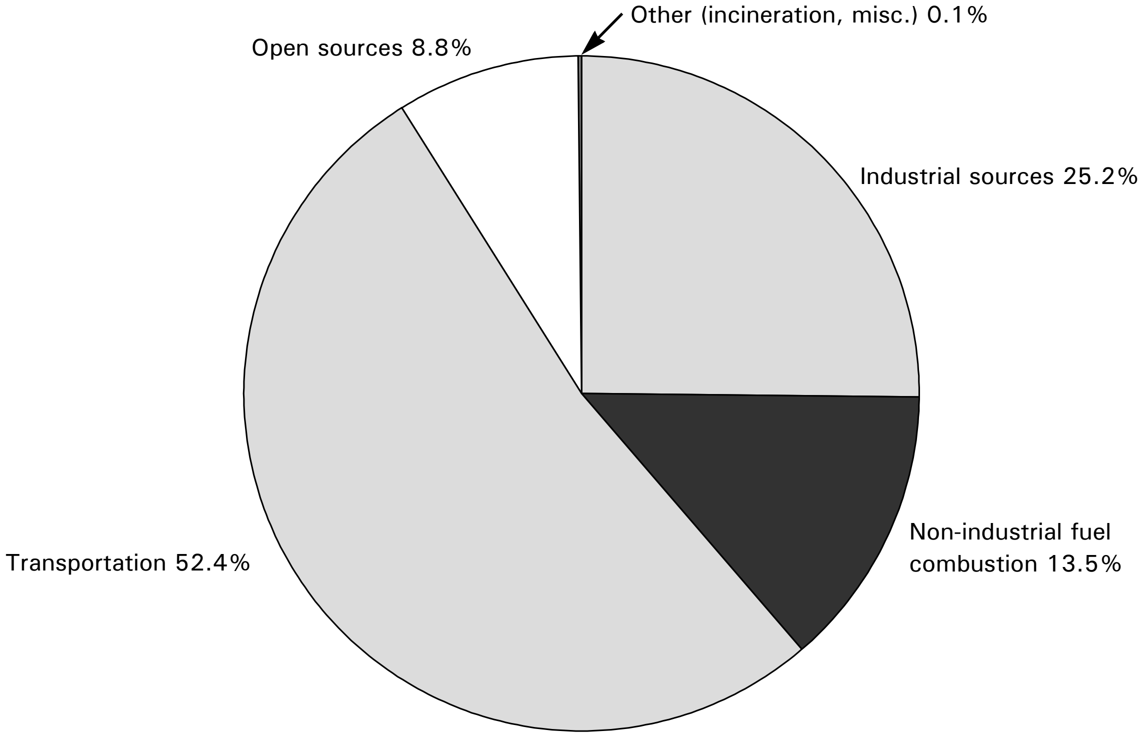
Source: Shelton 1999; 2001. All data for St. John's are reported by only one monitoring station. Data for Halifax are single station readings in 1974, 1978, from 1984 to 1988, 1991, 1992, 1994 to 1996, and 1998. Data for Regina are single station readings in 1985, 1987, 1989, 1990, 1993 to 1996, and 1999. Data for Saint John are single station readings in 1981, 1983, 1985 to 1987, 1995, and 1999. Data for Hamilton are single station readings in 1984 and 1987.

Figure 1.11: Nitrogen oxide emissions estimates



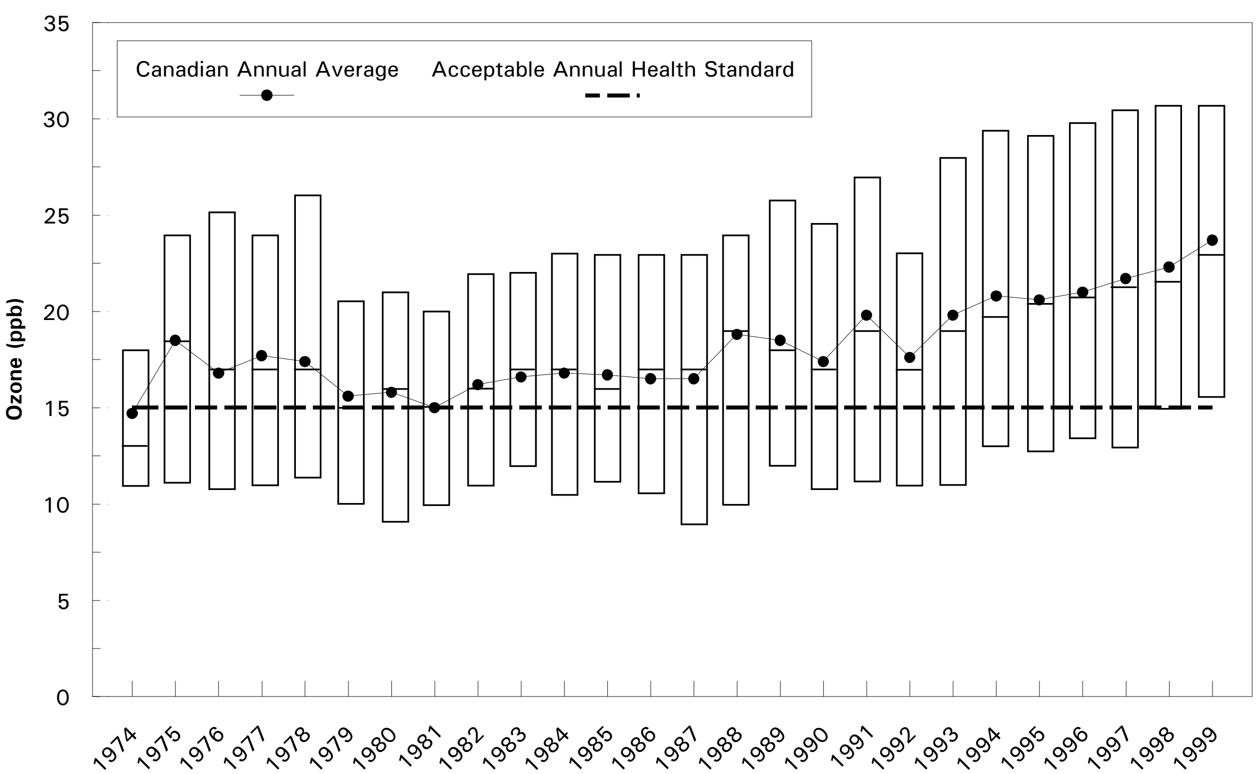
Source: OECD 1999.

Figure 1.12: Nitrogen oxide emissions, by source, 1995



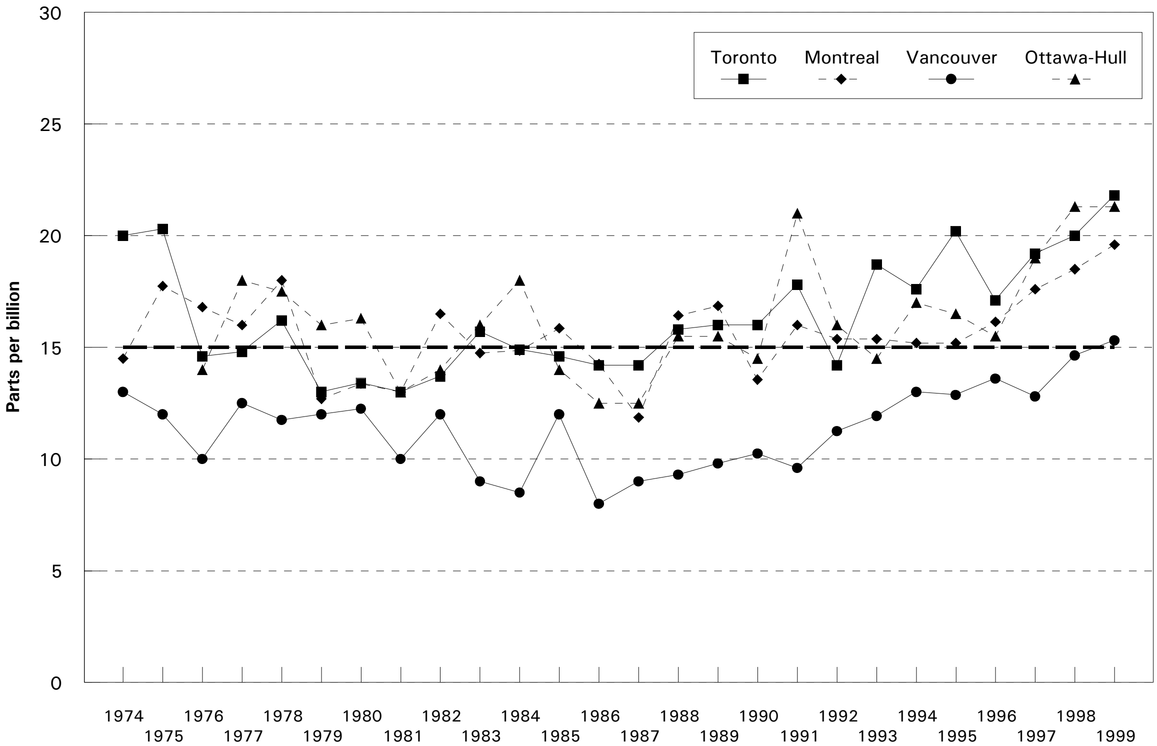
Source: Environment Canada 1998a; please note that data do not include natural sources.

Figure 1.13: Ambient levels of ground-level ozone (ppb)



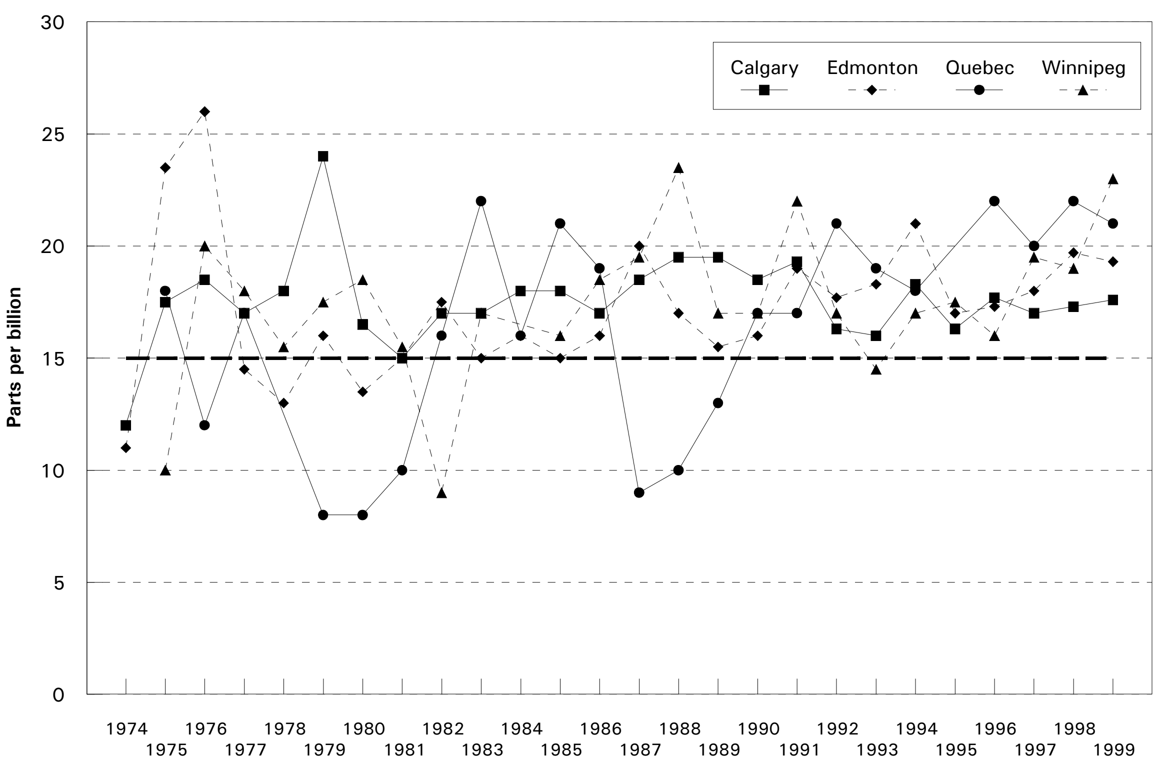
Source: Shelton 1999, 2001; calculations by authors.

Figure 1.14: Ozone—large cities, 1974–1999



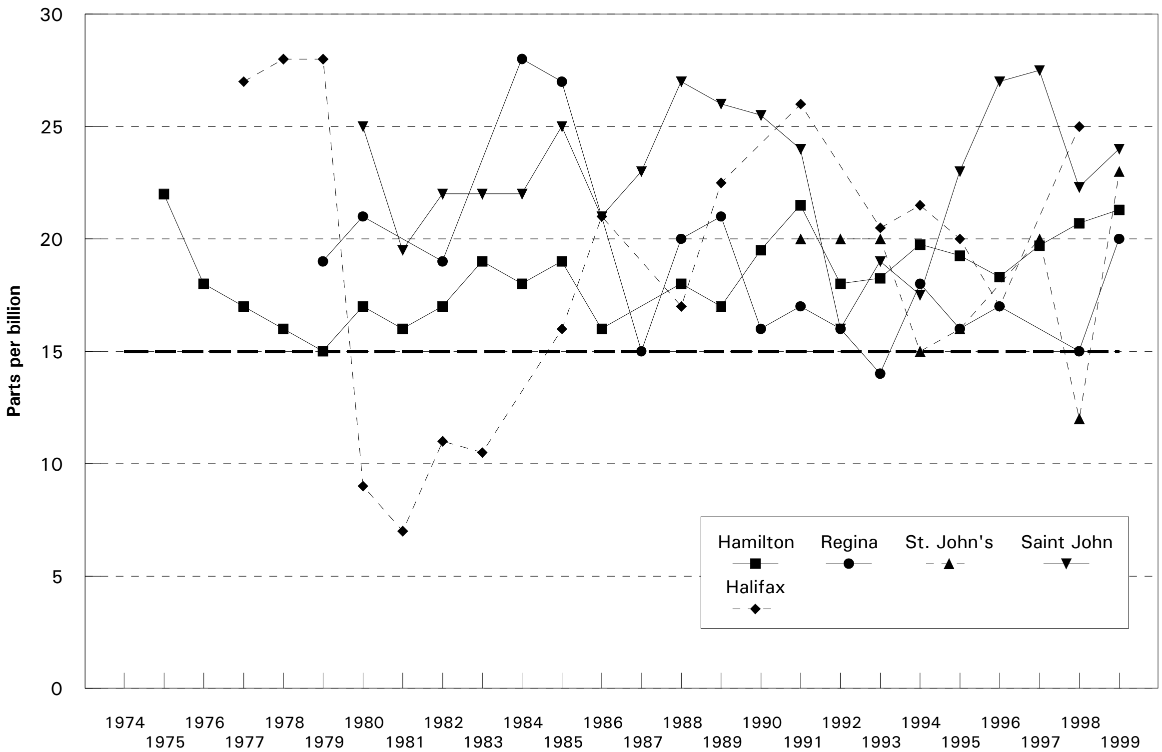
Source: Shelton 2001; calculations by authors. Data for Ottawa-Hull are reported by only one monitoring station in 1984 and 1991. Data for Toronto are from a single station in 1974.

Figure 1.15: Ozone—medium cities, 1974–1999



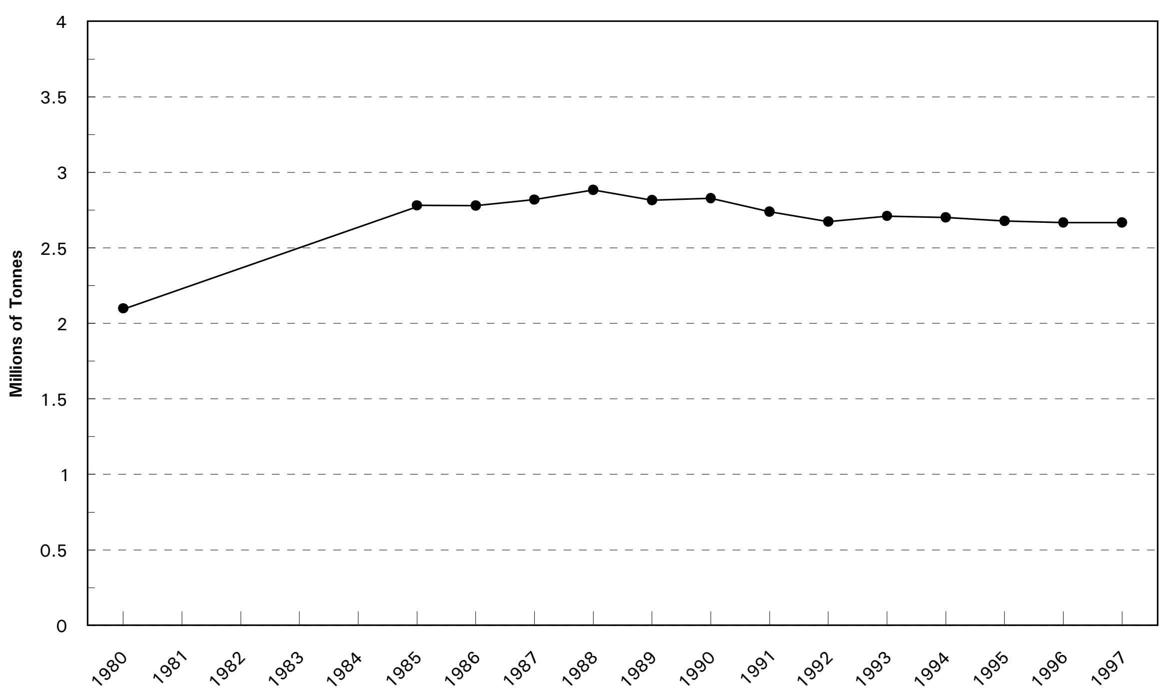
Source: Shelton 2001; calculations by authors. Data for Quebec are reported by only one monitoring station from 1975 to 1980, 1983, 1987, 1989, 1996, and 1998. Data for Winnipeg are single station readings in 1975, 1982, 1983, 1989 to 1991, 1994, and 1999. Data for Calgary are single station readings in 1974 and 1979. Data for Edmonton are from a single station in 1974.

Figure 1.16: Ozone—small cities, 1974–1999



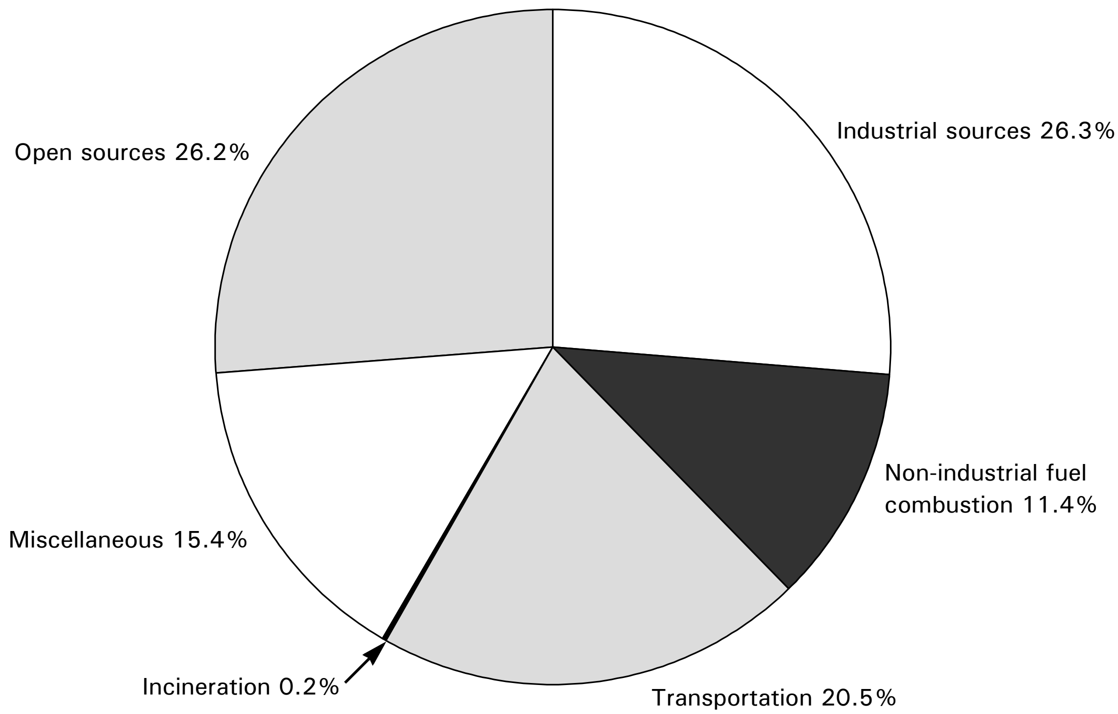
Source: Shelton 2001; calculations by authors. Data for Hamilton are reported by only one monitoring station from 1975 to 1989. All data for Regina and St. John's are single station readings. Data for Halifax are single station readings from 1977 to 1982, and in 1985, 1986, 1988, 1991, and 1996. Data for Saint John are from a single station in 1983, 1984, 1986, 1991, 1992, and 1995.

Figure 1.17: Volatile organic compounds emissions estimates



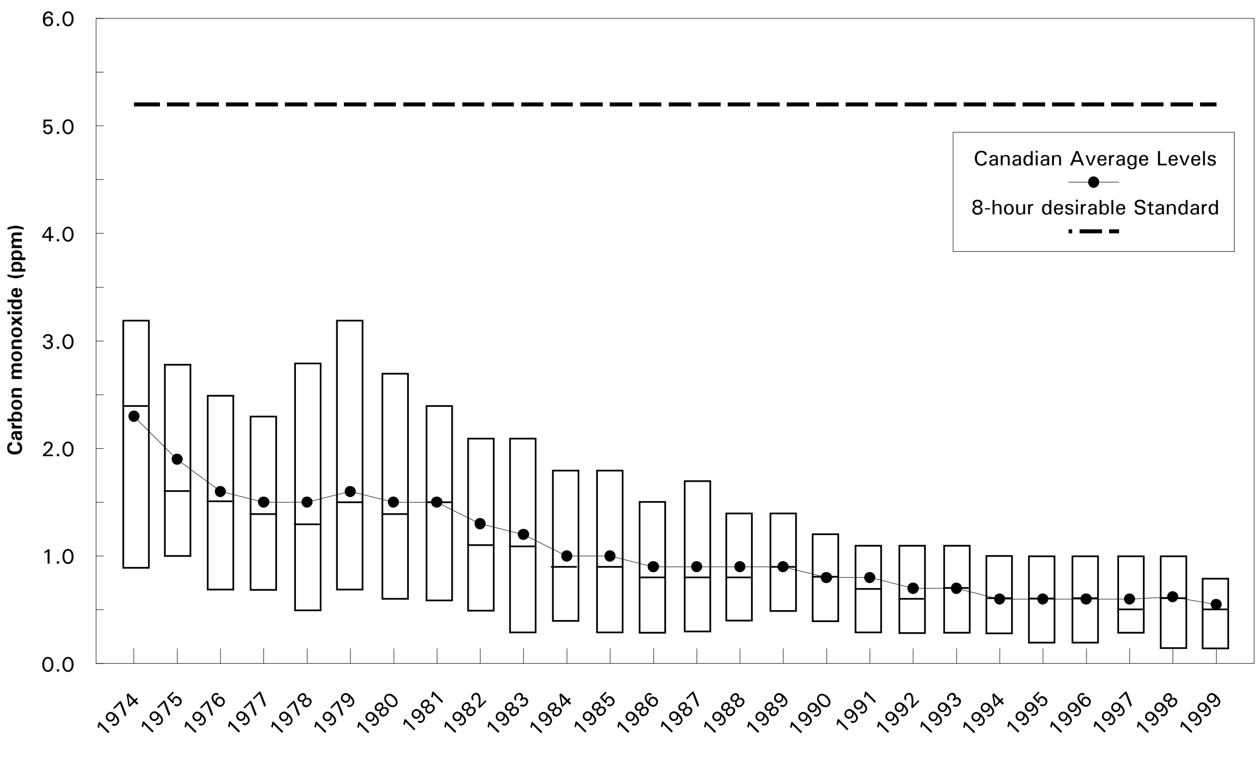
Source: OECD 1999

Figure 1.18: Volatile organic compounds emissions, by source, 1995



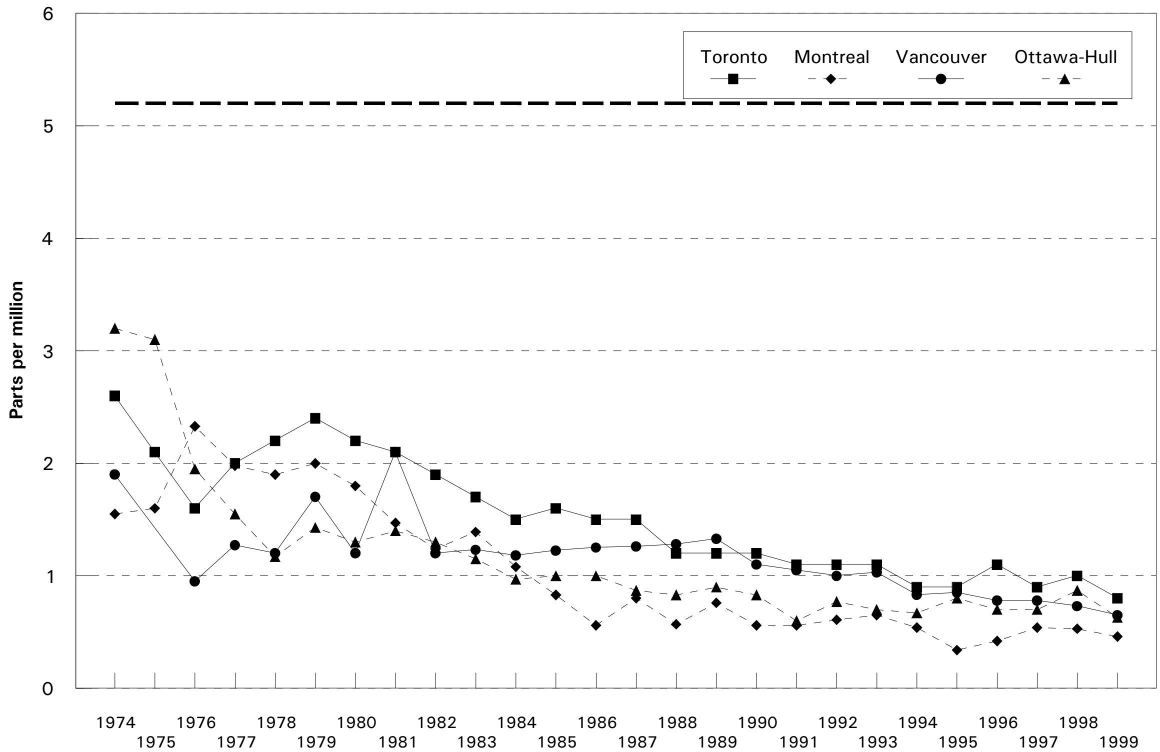
Source: Environment Canada 1998a. Data do not include natural sources.

Figure 1.19: Ambient levels of carbon monoxide (ppm)



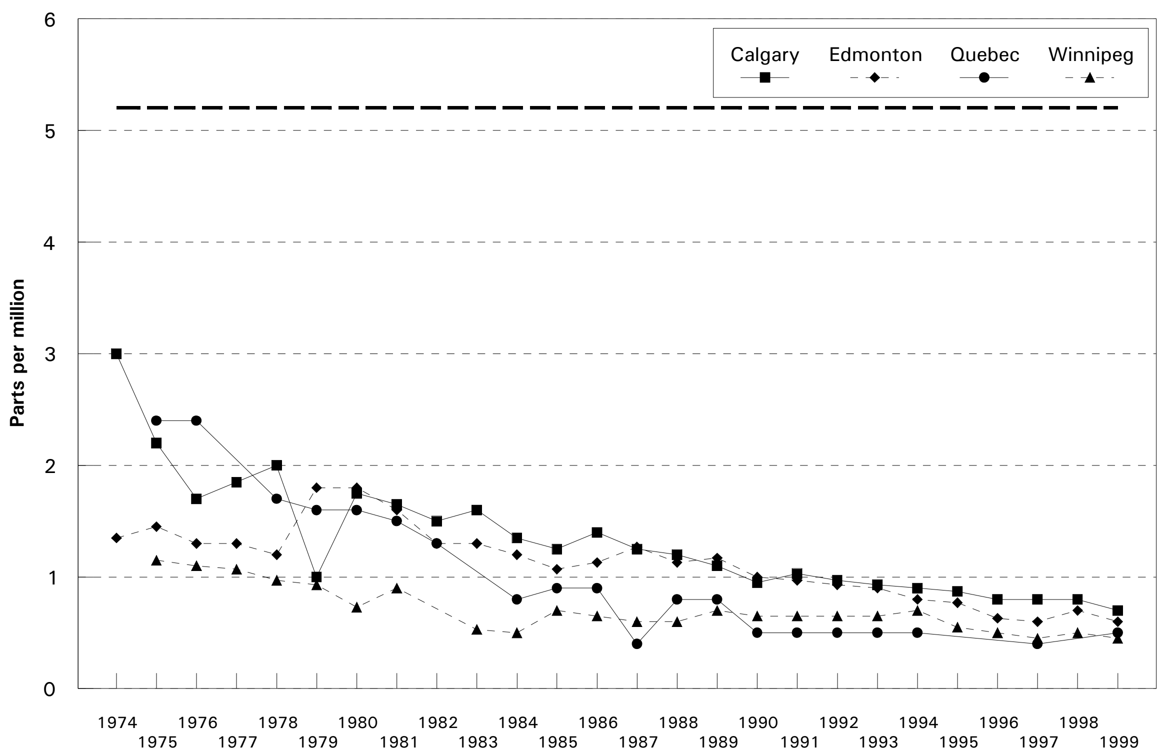
Source: Shelton 1999, 2001; calculations by authors.

Figure 1.20: Carbon monoxide—large cities, 1975–1999



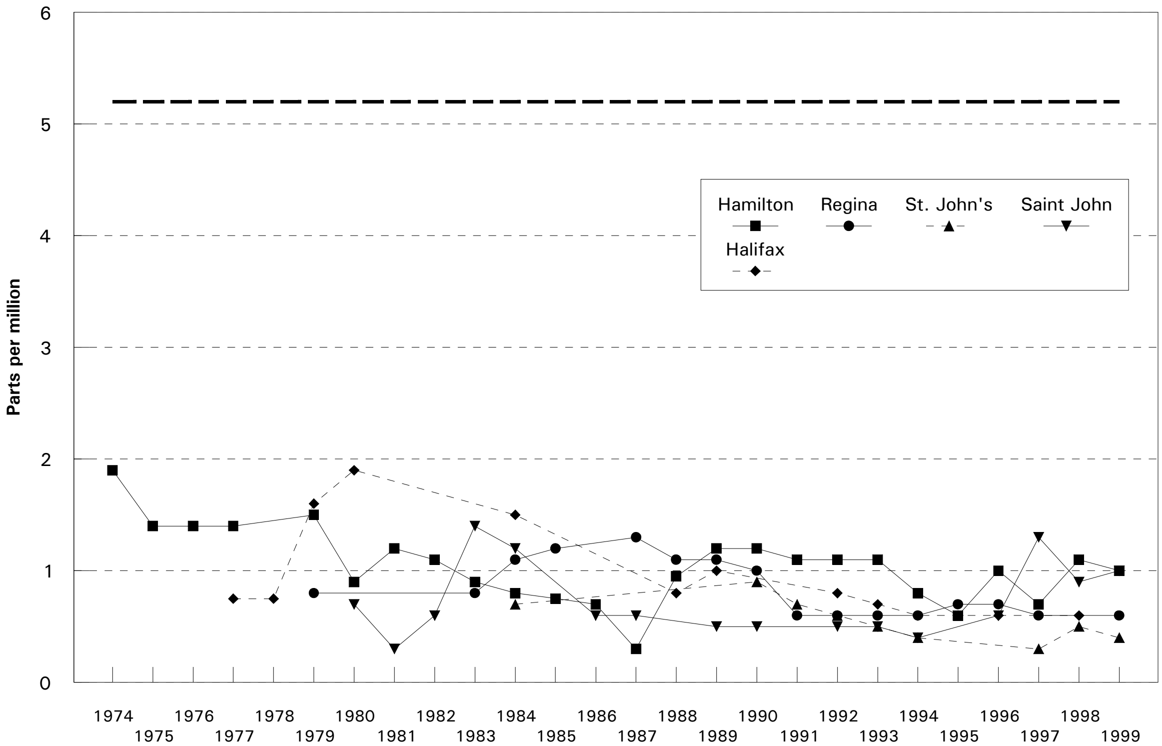
Source: Shelton 2001; calculations by authors. Data for Toronto and for Ottawa-Hull are single station readings in 1974 and 1975.

Figure 1.21: Carbon monoxide—medium cities, 1974–1999



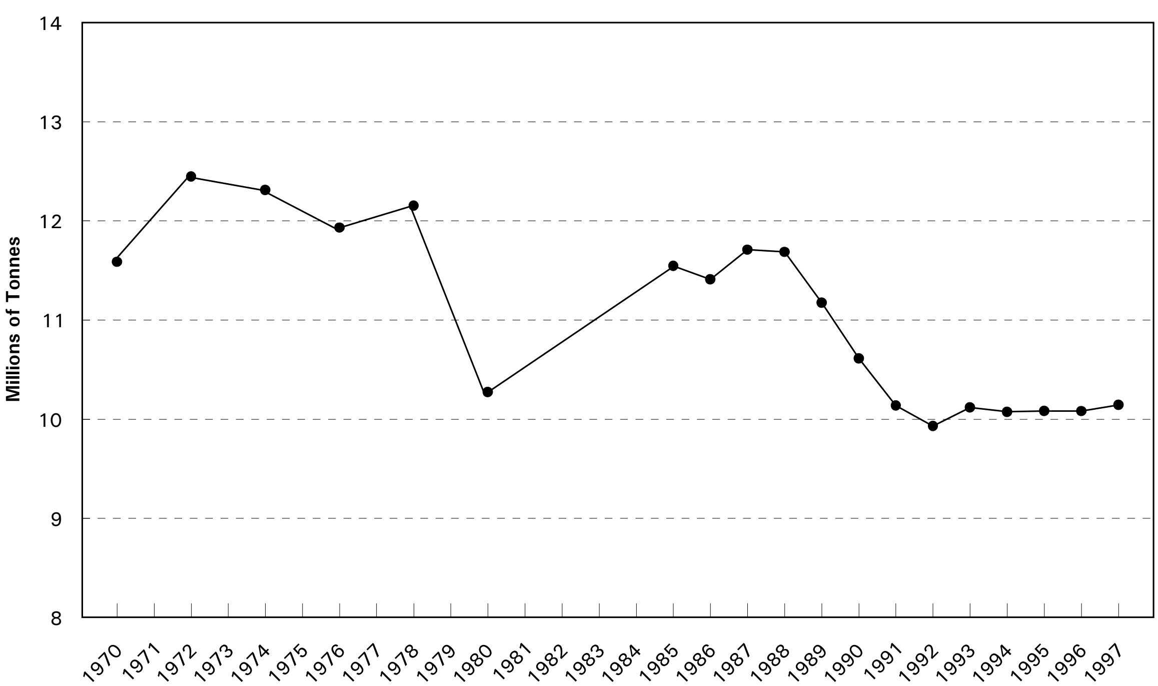
Source: Shelton 2001; calculations by authors. Data for Calgary are reported by only one monitoring station in 1974 and 1979. Data for Winnipeg are single station readings in 1981 and 1994, and all data for Quebec are single station readings.

Figure 1.22: Carbon monoxide—small cities, 1974–1999



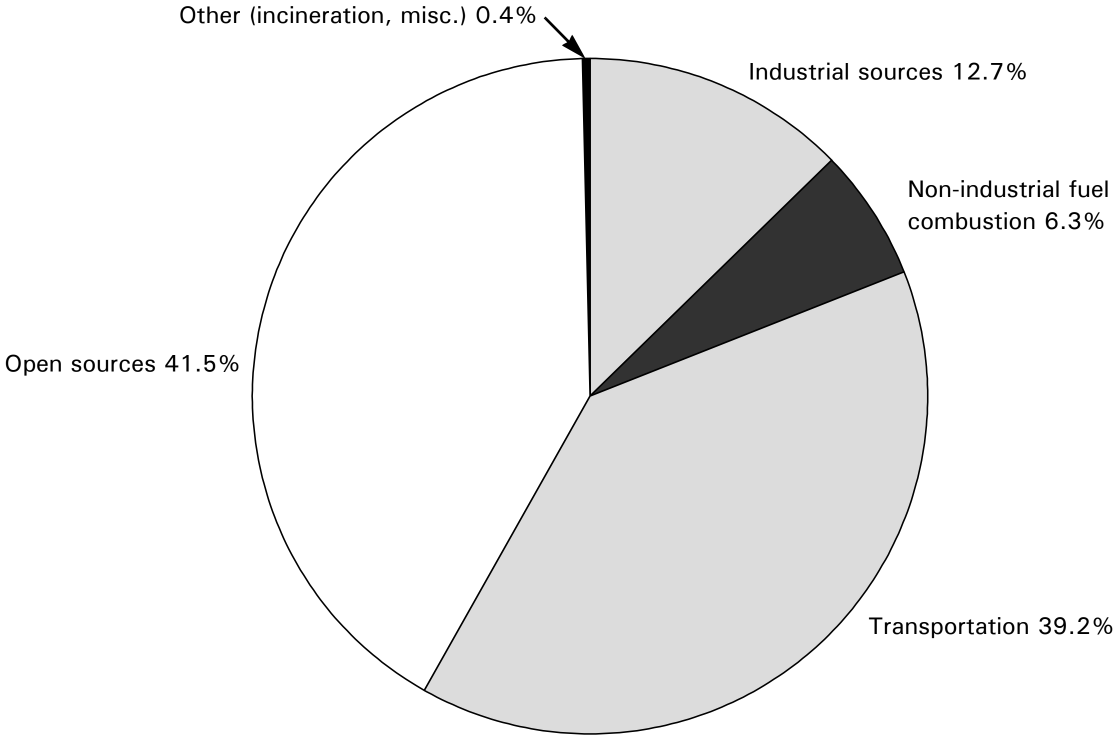
Source: Shelton 2001; calculations by authors. Data for Hamilton are reported by only one monitoring station from 1974 to 1984, 1987, and 1989 to 1999. Data for Halifax are from a single station in 1979, 1980, 1984, 1988, 1989, 1992, and 1993 to 1998. All data for Regina, St. John's, and Saint John are single station readings.

Figure 1.23: Carbon monoxide emission estimates



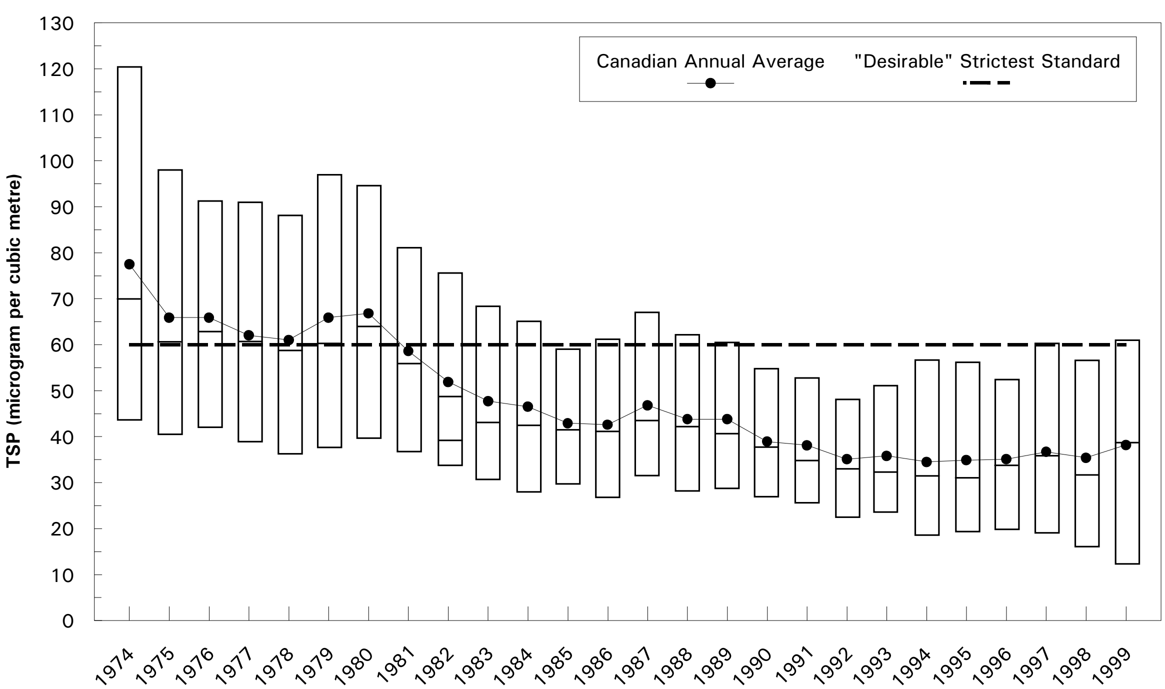
Source: OECD 1999

Figure 1.24: Carbon monoxide emissions, by source, 1995



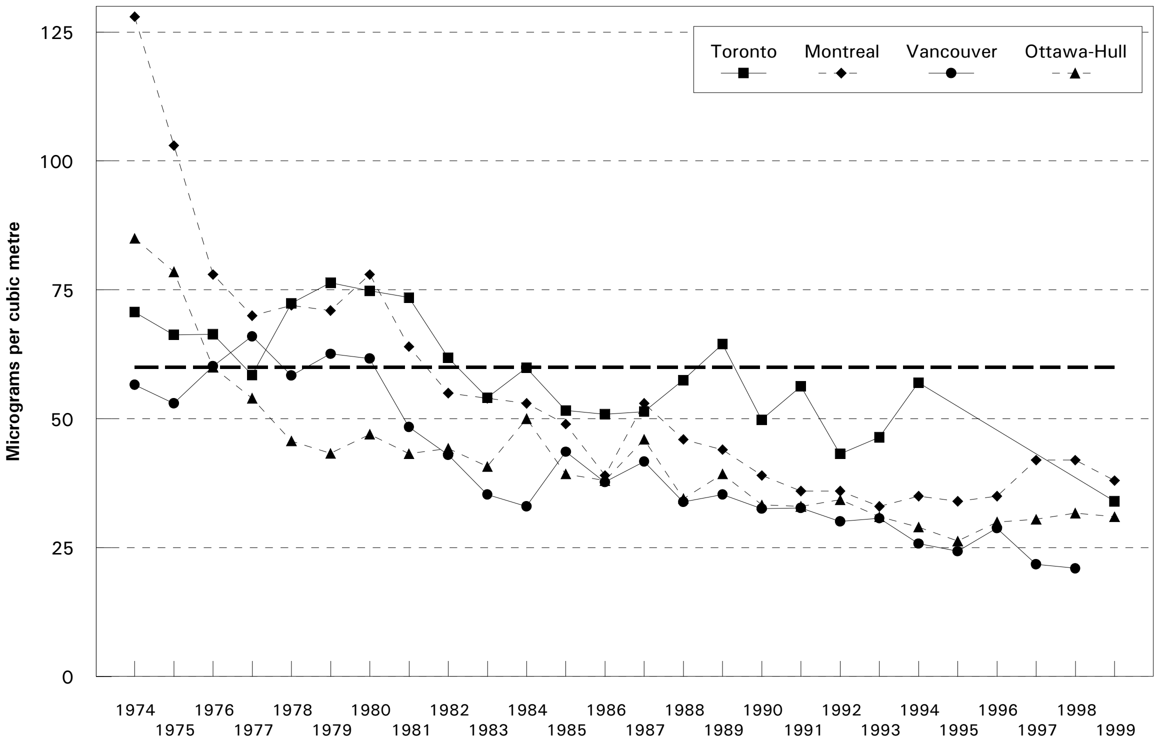
Source: Environment Canada 1998a; please note that data do not include natural sources.

Figure 1.25: Ambient levels of total suspended particulates (μg/m³)



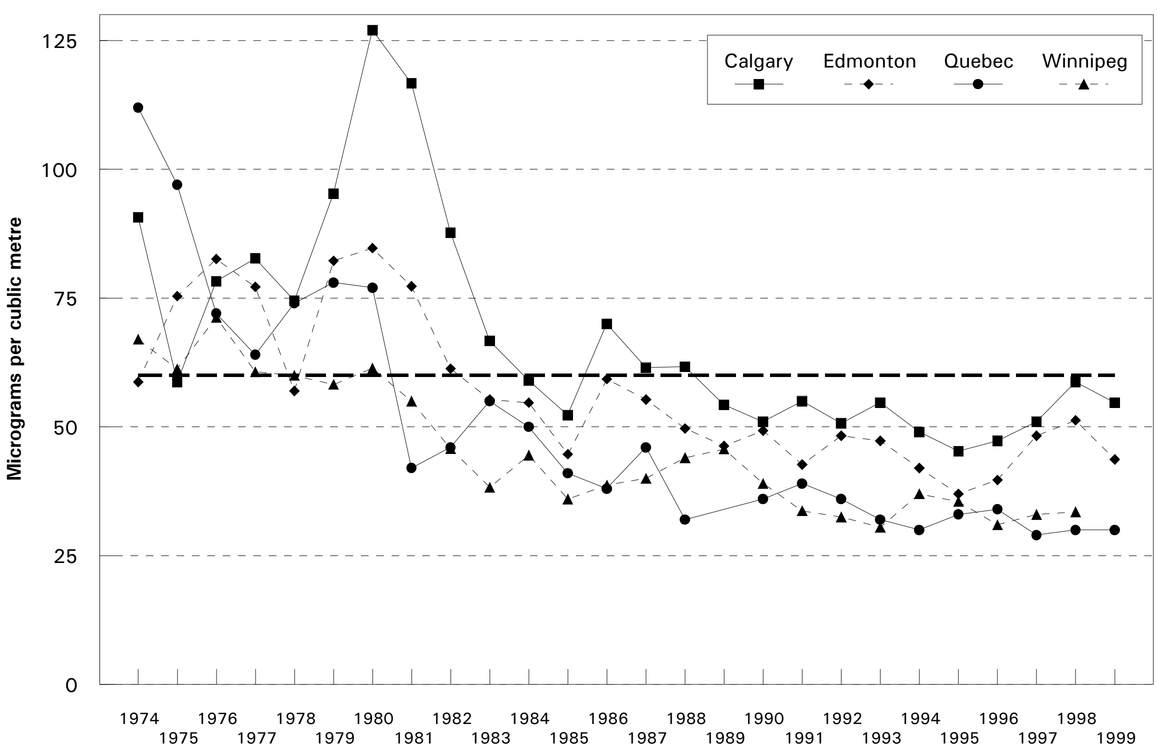
Source: Shelton 1999, 2000; calculations by authors.

Figure 1.26: Total suspended particulates—large cites, 1974–1999



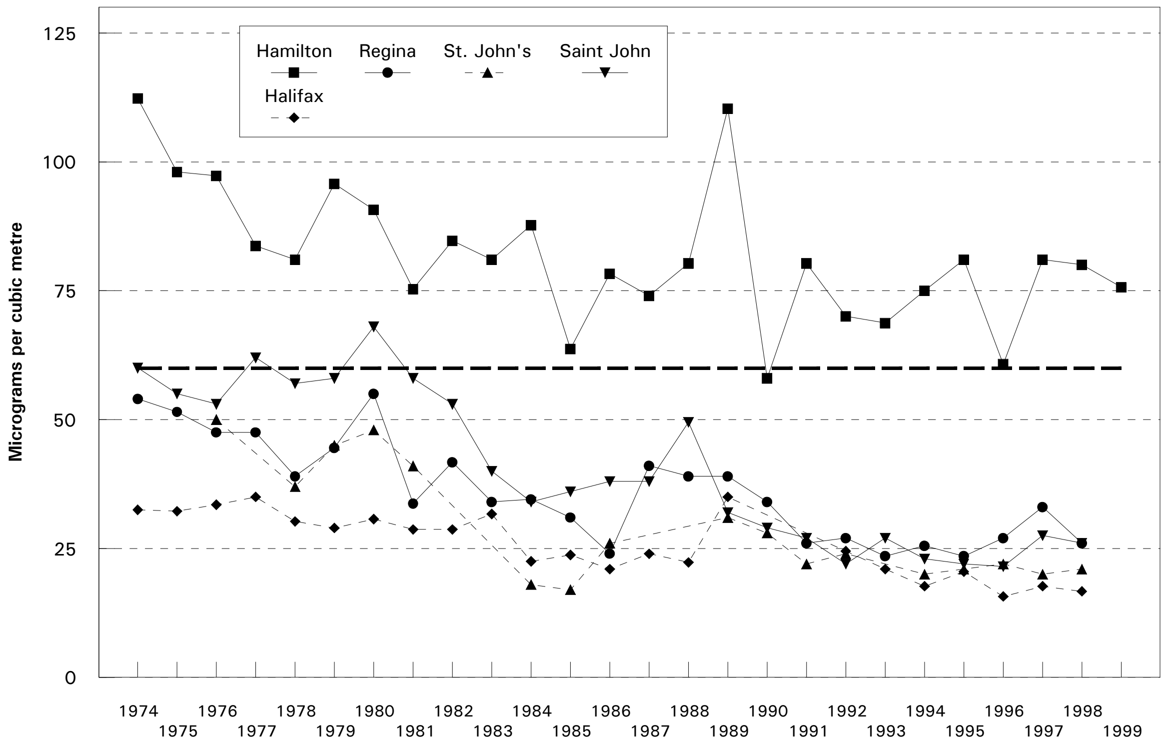
Source: Shelton 2001; calculations by authors. Data for Toronto are single station readings in 1994 and 1999, and for Ottawa-Hull are single station readings in 1976 and 1999.

Figure 1.27: Total suspended particulates—medium cites, 1974–1999



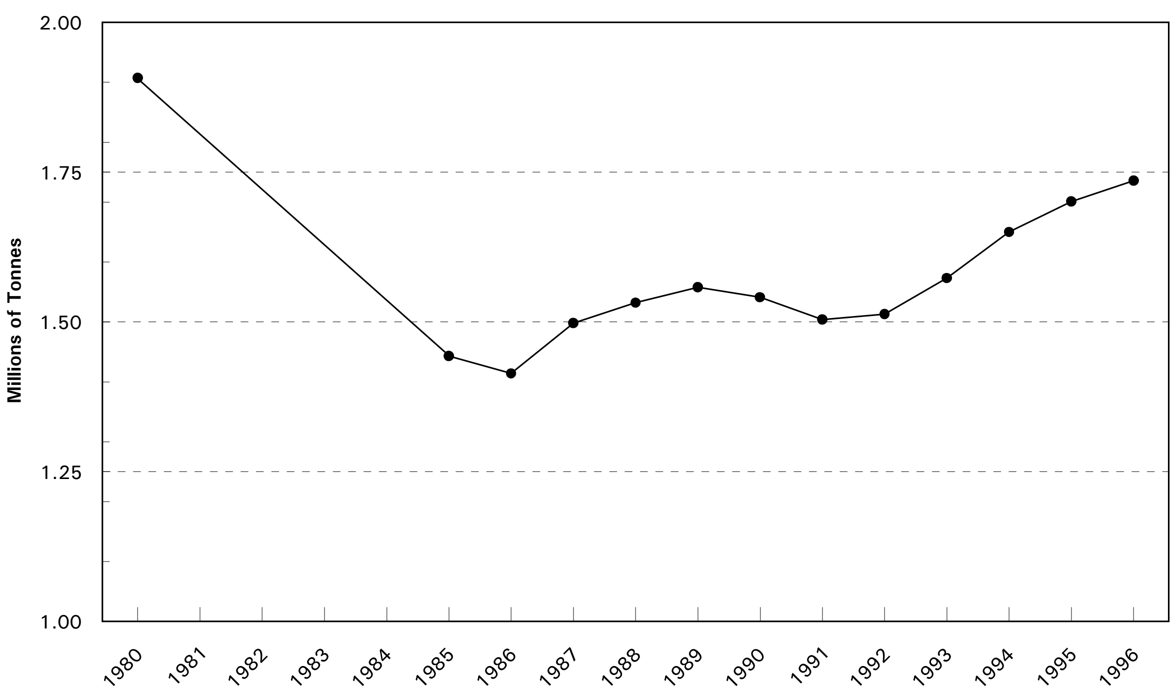
Source: Shelton 2001; calculations by authors. Data for Winnipeg are reported by only one monitoring station in 1994. Data for Quebec are single station readings in 1981 and 1988.

Figure 1.28: Total suspended particulates—small cites, 1974–1999



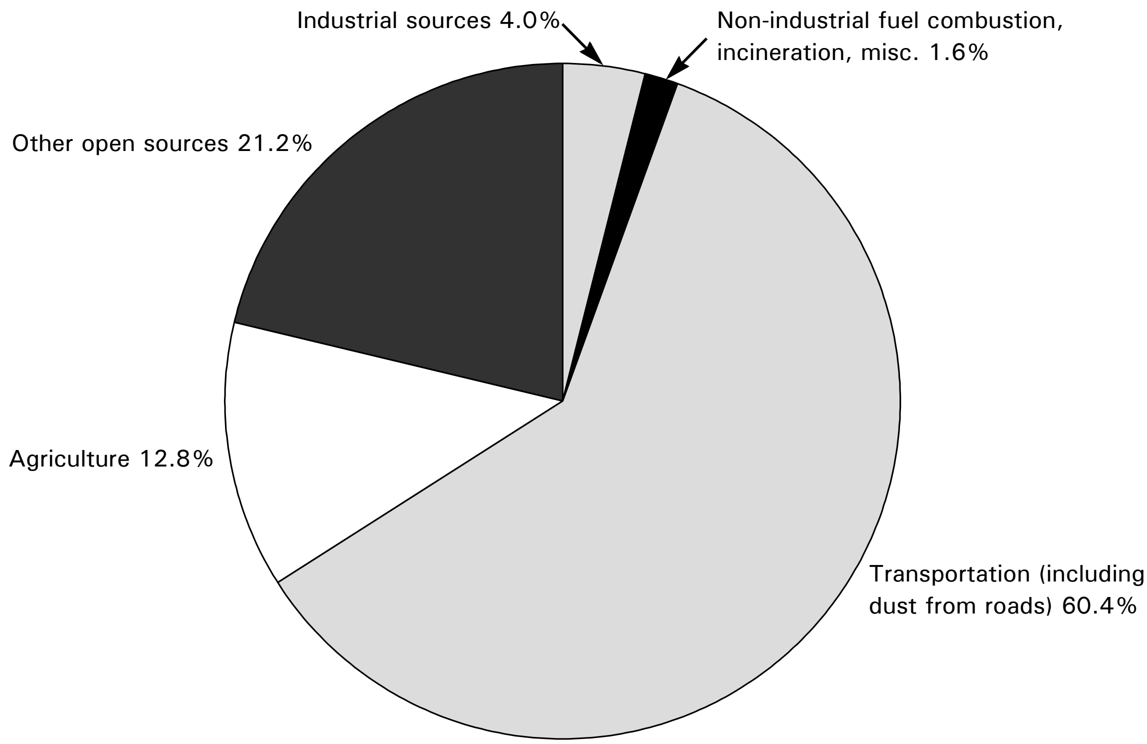
Source: Shelton 2001; calculations by authors. Data are reported by only a single monitoring station for Hamilton in 1975, and for Halifax in 1989. Data for Saint John are single station readings from 1974 to 1987, and in 1990. Data for Regina are from a single station in 1986, 1989, and 1997. All data for St. John's are single station readings.

Figure 1.29: Total suspended particulate emission estimates



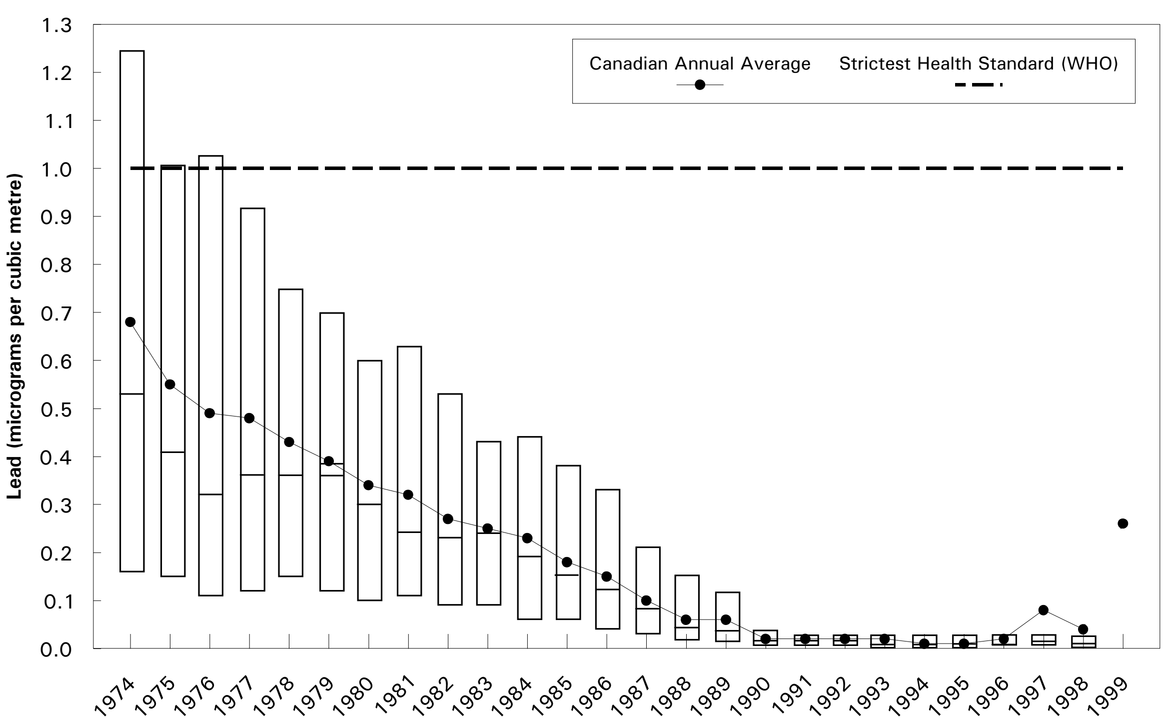
Source: OECD 1999.

Figure 1.30: Total suspended particulate emissions, by source, 1995



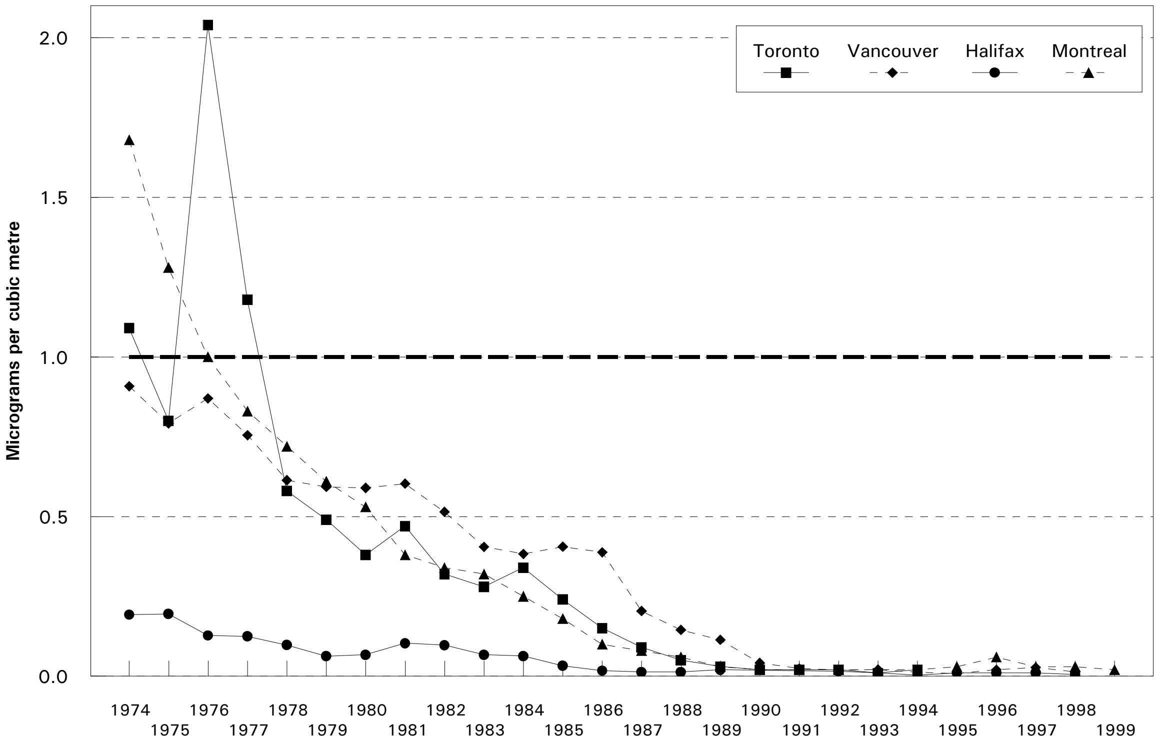
Source: Environment Canada 1998a; please note that data do not include natural sources.

Figure 1.31: Ambient levels of lead (μg/m³)



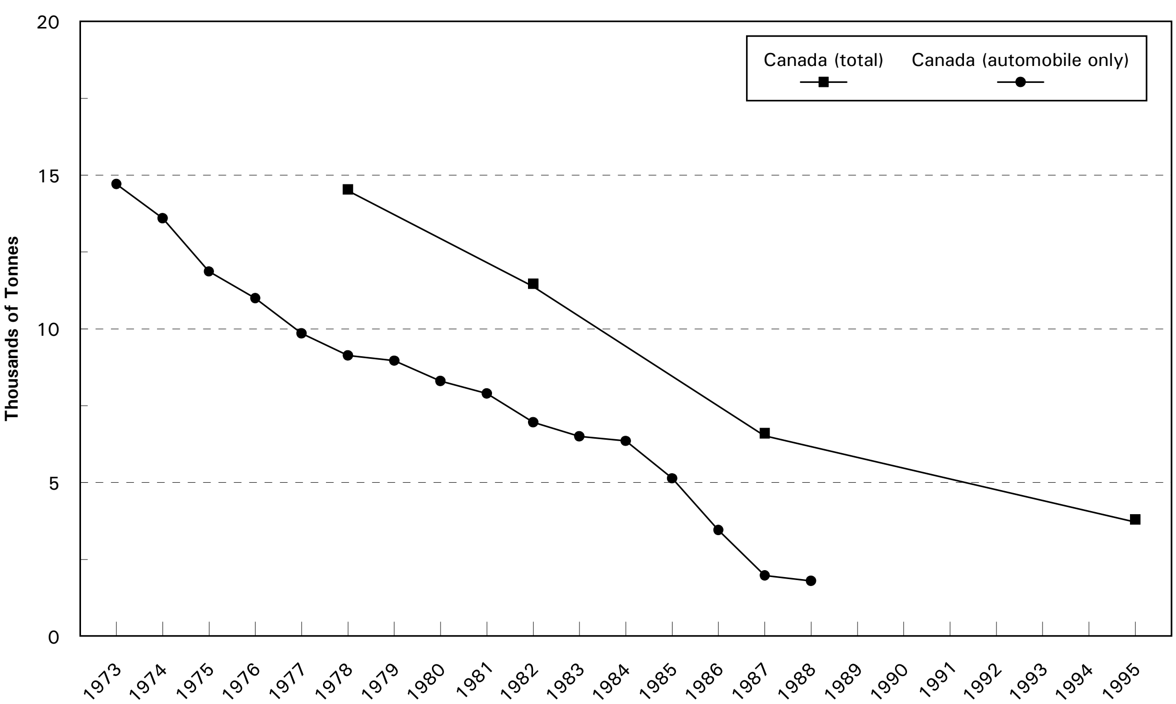
Source: Shelton 1999, 2001; calculations by authors. Note that, in 1999, only four stations were used to calculate the annual mean (there were 32 in 1998 and 67 in 1994). The spike in 1999 is caused by one station located near a lead mine.

Figure 1.32: Lead—selected cities, 1974–1999



Source: Shelton 2001; calculations by authors. Data are single station readings for Toronto in 1976, Halifax in 1989, and Montreal in 1996.

Figure 1.33: Lead emissions estimates



Source: OECD 1999