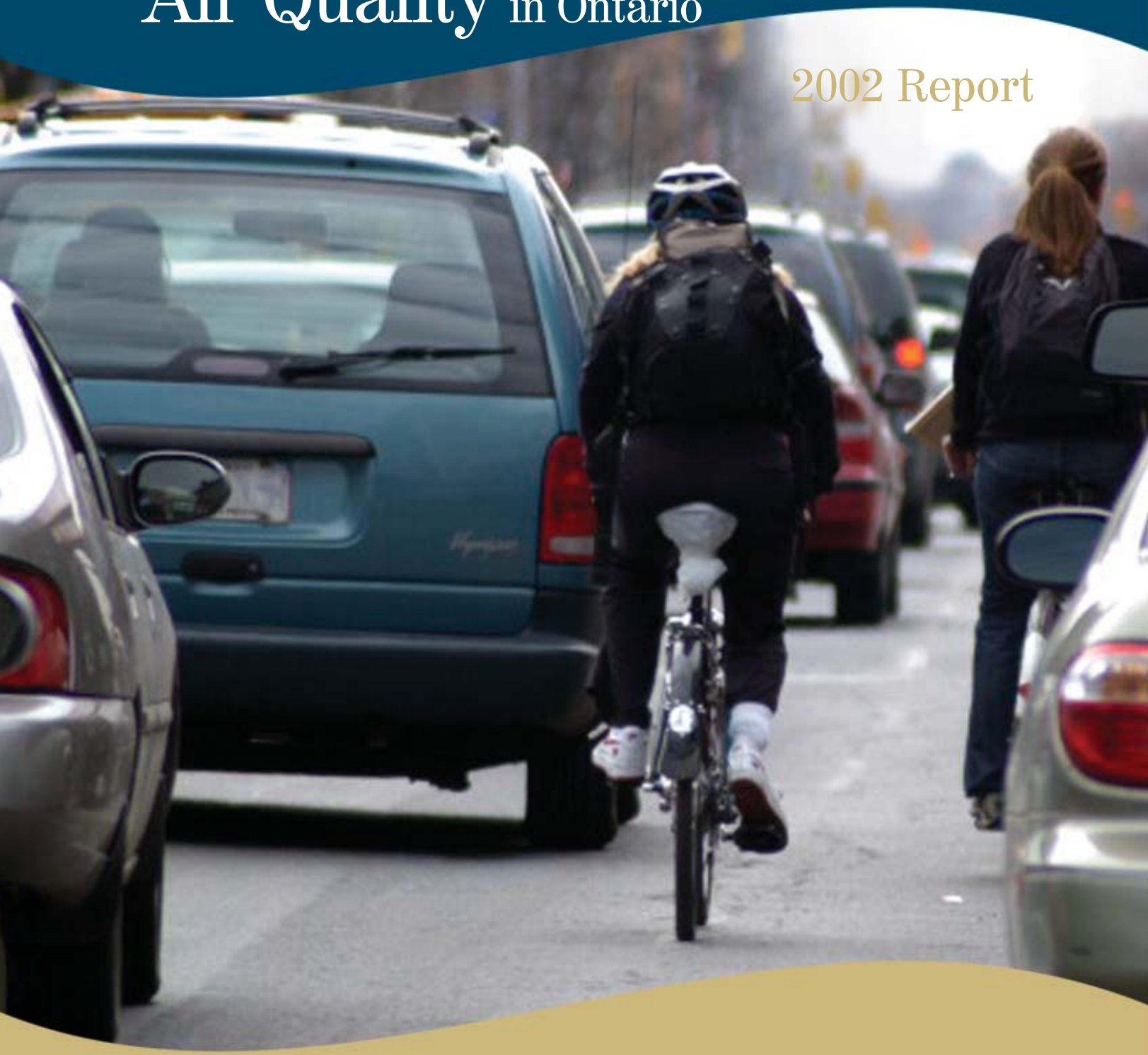
Air Quality in Ontario

2002 Report



Ontario

Acknowledgements

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Foreword

During the 32 years following the first edition of this report in 1971, there has been consistent improvement in the state of air quality in Ontario despite significant increases in population, economic activity and vehicle-kilometres travelled.

Encouraging as this is, a great deal of work remains to be done. The Ontario government is directing increased emphasis on two key components of smog, ozone and $PM_{2.5}$, which recent scientific evidence suggests have significant health effects.

Data analysis strongly indicates that neighbouring U.S. states – namely Ohio, Illinois and Michigan – are significant contributors to elevated levels of ozone and $PM_{2.5}$ in southern Ontario. The contributions from long-range transport and transboundary movement of these pollutants needs further assessment. Continued monitoring is required to evaluate trends and determine the effectiveness of emission reduction and abatement strategies.

Ontario has continued to review and expand its existing air monitoring network by deploying real-time monitors, namely the Tapered Element Oscillating Microbalance (TEOM), for the measurement of $PM_{2.5}$. In 1996, there was only one $PM_{2.5}$ monitor in the network. In 2002, there were 26 TEOMs measuring $PM_{2.5}$ in real-time across the province. The continued collection and assessment of such data will allow for improvements to the reporting of important air quality information to all Ontarians.

2002 Report Findings

- The 2002 air quality report marks 32 years of reporting on the state of air quality in Ontario. This report summarizes province-wide monitoring of air quality.
- Data collected during the last 32 years for carbon monoxide (CO), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) continue to show an improving trend toward cleaner air.
  - CO concentrations decreased by 87 per cent from 1971 to 2002.
  - SO_2 concentrations decreased by 84 per cent from 1971 to 2002.
  - NO_2 concentrations decreased by 23 per cent from 1975 to 2002.
- There has been no significant change in measured levels of carbon monoxide, sulphur dioxide and nitrogen dioxide ambient concentrations over the 10-year period of 1993 to 2002.
- In 2002, Ontario's Ambient Air Quality Criteria (AAQC) for ozone was exceeded at 39 of 40 ambient air monitoring stations on at least one occasion. Thunder Bay was the only site that did not record any hours of ozone above 80 ppb in 2002.
- The annual one-hour maximum concentration of ozone has decreased from 1980 to 2002. However, there was an increasing trend in ozone mean concentrations during the same 23-year period.
- In August 2002, Ontario became the first province in Canada to incorporate $PM_{2.5}$ into its Air Quality Index (AQI). The addition of $PM_{2.5}$ in the AQI system allows better representation and reporting of ambient air quality, and smog advisories.
- In 2002, unusually warm and dry weather contributed to the greatest number of smog advisory days (27) since the inception of the provincial Smog Advisory program in 1993.
- All of the smog episodes (due to ozone and/or $PM_{2.5}$) in 2002 occurred during the traditional summer smog season, May to September. There were no smog episodes outside of the traditional summer smog season.
- Data analysis strongly indicates that neighbouring U.S. states – namely Ohio, Illinois and Michigan – continue to be significant contributors to elevated ozone and $PM_{2.5}$ in southern Ontario during the smog season.
- Air quality in 10 cities (five from Ontario, and five from the United States) located in the Great Lakes Basin area was compared. Overall, the air quality of Ontario cities was generally cleaner, for the parameters measured, than that of the American cities.
- Levels of selected toxic volatile organic compounds (VOCs) in 2002 continued to remain below existing provincial criteria.

Table of Contents

Foreword ii

2002 Report Findings iii

Chapter 1 Overview 1

Chapter 2 Ground-Level Ozone 3

Chapter 3 Fine Particulate Matter 11

Chapter 4 Other Criteria Contaminants 16

Chapter 5 Air Quality Index, Smog Alerts and 2002 Smog Episodes 27

Chapter 6 Air Toxics – Selected VOCs 37

Glossary 42

Abbreviations 46

References 48

List of Figures

Figure 2.1 Ontario VOC Emissions by Sector 4

Figure 2.2 Geographical Distribution of Number of One-Hour Ozone Exceedances across Ontario (2002) 5

Figure 2.3 10-Year Trend for Ozone Exceedance Days and "Hot" Days in Ontario (1993-2002) 6

Figure 2.4 Trend of Ozone One-Hour Maximum Concentrations in Ontario (1980-2002) 7

Figure 2.5 Trend of Ozone Seasonal Means at Sites Across Ontario (1980-2002) 8

Figure 2.6 Trend of Ozone Annual Means for Urban and Rural Ontario (1990-2002) 8

Figure 2.7 Trend of Ozone Monthly Means in Southern and Northern Ontario (1990-2002) 9

Figure 2.8 Ozone Levels at Selected Sites Across Ontario (2002) 9

Figure 2.9 Selected Sites in the Great Lakes Basin Area 10

Figure 2.10 Range of Ozone One-Hour Maximum Concentrations in the Great Lakes Basin Area (1993-2002) 10

Figure 3.1 Ontario $PM_{2.5}$ Emissions by Sector. 12

Figure 3.2 Annual Statistics for 24-Hour $PM_{2.5}$ (2002) 13

Figure 3.3 Seasonal Distribution of $PM_{2.5}$ at Sites Across Ontario (2002) 13

Figure 3.4 $PM_{2.5}$ Levels in Selected Cities Across Ontario (2002) 14

Figure 3.5 $PM_{2.5}$ Annual Means in the Great Lakes Basin Area (2001 and 2002) 15

Figure 4.1 Ontario Nitrogen Oxides Emissions by Sector. 17

Figure 4.2 Nitrogen Dioxide Annual Means Across Ontario (2002) 18

Figure 4.3 Trend of Nitrogen Dioxide Annual Means in Ontario (1975-2002) 19

Figure 4.4 Range of Nitrogen Dioxide Annual Means in the Great Lakes Basin Area (1993-2002) 19

Figure 4.5 Ontario Carbon Monoxide Emissions by Sector 20

Figure 4.6 Geographical Distribution of Carbon Monoxide One-Hour Maximum Concentrations Across Ontario (2002) 21

Figure 4.7 Trend of Carbon Monoxide One-Hour and Eight-Hour Maximums in Ontario (1993-2002) 22

Figure 4.8 Trend of Vehicle-Kilometres Travelled in Ontario (1993-2002) 22

Figure 4.9 Range of Carbon Monoxide One-Hour Maximum Concentrations in the Great Lakes Basin Area (1993-2002) 22

Figure 4.10 Ontario Sulphur Dioxide Emissions by Sector 23

Figure 4.11 Sulphur Dioxide Annual Means Across Ontario (2002) 24

Figure 4.12 32-Year Trend of Sulphur Dioxide Concentrations in Ontario (1971-2002) 24

Figure 4.13 Range of Sulphur Dioxide Annual Means in the Great Lakes Basin Area (1993-2002) 26

Figure 4.14 Total Reduced Sulphur Compounds Annual Means in Ontario (1993-2002) 26

Figure 5.1 Air Quality Index Monitoring Sites in Ontario (2002) 28

Figure 5.2 Air Quality Index Summary (2002) 31

Figure 5.3 Summary of Smog Advisories Issued (1995-2002) 32

Figure 5.4 Generalized Synoptic Weather Pattern over Southern Ontario Conducive to Elevated Pollutant Levels 33

Figure 5.5 AQI Readings at Windsor West (September 9, 2002) 35

Figure 5.6 AQI Readings at Downtown Toronto (September 9, 2002) 36

Figure 6.1 Locations of Ambient VOC Monitoring Sites across Ontario (2002) 39

Figure 6.2 Trend of Benzene, Toluene and O-xylene Concentrations in Ontario (1993-2002) 40

Figure 6.3 Trend of 1,1,1-Trichloroethane,Carbon Tetrachloride and Dichloromethane Concentrations in Ontario (1993-2002) 41

List of Tables

Table 1.1 Linkages between Air Pollutants and Air Issues 2

Table 5.1 Air Quality Index Pollutants and their Impacts 29

Table 5.2 Air Quality Index Summary (2002) 30

Chapter 1 Overview

This report focuses on air concentrations based on measurements of pollutants in the ambient outdoor air to determine the state of air quality in the province of Ontario.

Air pollution is of concern to many people who live in Ontario. Average air pollution levels in Ontario during the past 32 years have decreased, but smog remains a concern, especially in southern Ontario. Air pollution comes from various sources, including stationary sources such as factories, power plants and smelters; mobile sources such as cars, buses, trucks, planes, ships (marine vessels) and trains; and finally, natural sources such as forest fires, windblown dust and biogenic emissions from vegetation.

Many pollutants, including those that are associated with smog (ozone and fine particulate matter), remain in the atmosphere for long periods of time. These air pollutants and/or their precursors are generated both locally and regionally, and carried hundreds of kilometres by winds from province to province and country to country, affecting areas far removed from the source of the pollution.

This report focuses on air concentrations based on measurements of pollutants in the ambient outdoor air to determine the state of air quality in the province of Ontario.

The Ontario Ministry of the Environment collects continuous air quality data at more than 80 monitoring sites across the province. These data are used to determine the state of air quality in Ontario and help develop abatement programs to reduce the burden of air pollutants, address key air issues and assess the efficacy of policies and programs. Ambient air monitoring in Ontario provides information on the actual concentrations of selected pollutants in communities across Ontario. Table 1.1 shows the relationship between monitored air pollutants and current air issues.

For the past 32 years, the Ministry of the Environment has been monitoring air quality across Ontario and using this information to:

- inform the public about outdoor ambient air quality;
- assess Ontario's air quality and evaluate long-term trends;
- identify areas where criteria are exceeded and identify the origins of pollutants;
- provide the basis for air policy/program development;

- provide quantitative measurements to enable abatement of specific sources;
- determine the significance of pollutants from U.S. sources and their effects on Ontario;
- provide air quality researchers with data to link environmental and human health effects to air quality; and
- since 1993, provide smog advisories for public health protection.

This report, the 32nd in a series, summarizes the state of ambient air quality in Ontario during 2002 and examines trends over time. It covers the measured levels of seven contaminants: ozone (O_3), fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), total reduced sulphur (TRS) compounds, and ambient mercury (Hg) in Ontario. An overview of the air quality of 10 cities in the Great Lakes Basin area is also provided in the report. The report also summarizes the results from the Air Quality Index (AQI) and Smog Alert programs and briefly examines smog episodes in 2002. Results for a selected number of volatile organic compounds (VOCs) are also reviewed.

The main focus of the 2002 publication is to report on the state of Ontario's ambient air quality. As in the past, the data for the source monitoring sites will be presented in a separate appendix document, along with the ambient data. Ontario continues to benefit from one of the most comprehensive air monitoring systems in North America. The network is designed to measure continuous air quality at more than 80 monitoring sites across the province and undergoes regular maintenance to ensure a high standard of quality. With these data, we can make informed decisions about what needs to be done to protect and improve our air quality. ■

Ontario's comprehensive air monitoring system is designed to measure continuous air quality at more than 80 monitoring sites across the province and undergoes regular maintenance to ensure a high standard of quality.

Table 1.1: Linkages between Air Pollutants and Air Issues

Pollutant	Smog	Acid Deposition	Odour	Visibility/Soiling	Local vs. Regional
Ozone	Yes	Yes	No	No	Regional
Sulphur Dioxide	Yes	Yes	No	Yes	Local & Regional
Carbon Monoxide	Yes	No	No	No	Local
Nitrogen Oxides	Yes	Yes	No	Yes	Local & Regional
Volatile Organic Compounds	Yes	No	Yes	No	Local & Regional
Particles	Yes	Yes	Yes	Yes	Local & Regional
Total Reduced Sulphur Compounds	No	No	Yes	No	Local

Chapter 2 Ground-Level Ozone

Changing weather patterns contribute to short-term and year-to-year differences in ozone concentrations. In Ontario, elevated concentrations of ground-level ozone are generally recorded on hot, sunny days from May to September, between noon and early evening.

Ground-level ozone (O_3) is a gas formed when nitrogen oxides (NO_X) and volatile organic compounds (VOCs) react in the presence of sunlight. While ozone at ground-level is a major environmental and health concern, the naturally occurring ozone in the stratosphere shields the earth from harmful ultraviolet radiation.

The formation and transport of ground-level ozone are strongly dependent on meteorological conditions. Changing weather patterns contribute to short-term and year-to-year differences in ozone concentrations. In Ontario, elevated concentrations of ground-level ozone are generally recorded on hot, sunny days from May to September, between noon and early evening.

Characteristics, sources and effects

Ozone is a colourless, odourless gas at ambient concentrations, and is a major component of smog. Ground-level ozone is not emitted directly into the atmosphere. Ozone results from chemical reactions between VOCs and NO_X in the presence of sunlight.

Figure 2.1 shows 2001 estimates of Ontario's VOC emissions from human activity by sector. Transportation sectors accounted for approximately 29 per cent of VOC emissions during 2001. The use of general solvents was the second largest source of 2001 VOC emissions, accounting for approximately 24 per cent.

Ozone irritates the respiratory tract and eyes. Exposure to ozone in sensitive people can result in chest tightness, coughing and wheezing. Children active outdoors during the summer, when ozone levels are highest, are particularly at risk of such effects. Other groups at risk include individuals with pre-existing respiratory disorders, such as asthma and chronic obstructive lung disease. Ground-level ozone is linked to increased hospital admissions and premature deaths. Ozone also causes agricultural crop loss each year in Ontario and visible leaf damage in many crops, garden plants and trees.

Monitoring results for 2002

Ground-level ozone was monitored at 42 ambient locations during 2002. Of these, 38 sites (30 urban and eight rural) had sufficient

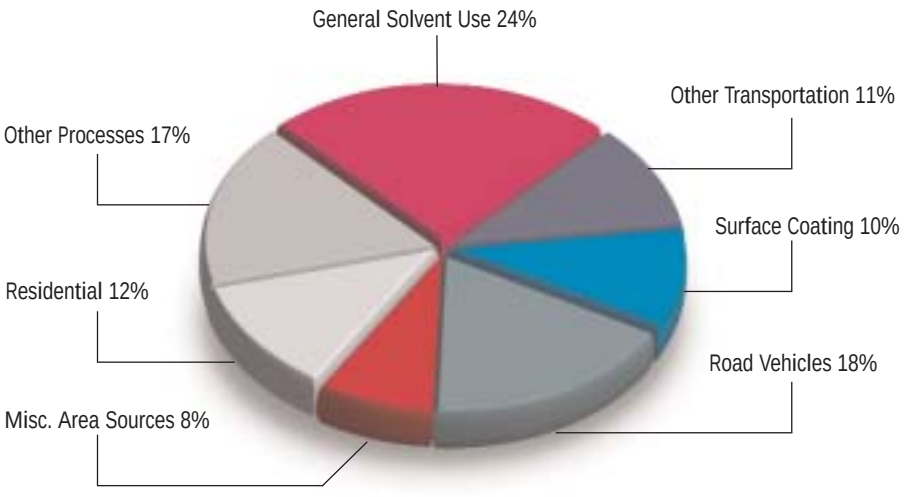
data for the analysis presented. The highest annual mean was 34.7 parts per billion (ppb), measured at Tiverton, a rural site on the eastern shore of Lake Huron, while the lowest annual mean was 20.2 ppb measured at the Windsor West and Etobicoke South sites. Generally, ozone is lower in urban areas because it is removed by reaction with nitric oxide emitted locally by vehicles and other combustion sources.

Among urban sites in 2002, Windsor West recorded the highest one-hour concentration (127 ppb), and the greatest number of instances (164 hours) when ozone was above Ontario's one-hour ambient air quality criterion (AAQC) of 80 ppb. Newmarket recorded the highest annual urban mean (31.4 ppb). At rural sites, Tiverton measured the highest one-hour concentration (136 ppb), while Long Point had the most number of instances (276 hours) above the provincial one-hour AAQC, followed closely by Port Stanley (273 hours).

Ground-level ozone continues to exceed its provincial criterion across the province. In 2002, Ontario's one-hour AAQC for ozone was exceeded at 39 of 40 ambient air monitoring stations on at least one occasion. Thunder Bay was the only site that did not record any hours of ozone above 80 ppb in 2002.

Figure 2.2 shows the geographical distribution of the number of hours of elevated ozone concentrations across Ontario. The significance of transboundary flow is reflected in the relatively higher levels found at rural sites in the southwestern part of the province along the northern shore of Lake Erie. An area of elevated ozone levels to the north and east of Toronto is also evident and could be attributed to both the long-range transport of pollutants into Ontario from the U.S. and the local emissions from Toronto and its surrounding areas.

Figure 2.1: Ontario VOC Emissions by Sector
(Emissions From Human Activity, 2001 Estimates)



Note: Emission data are a combination of reported and projected emission estimates that may be revised with updated source/sector information or emission estimation methodologies as they become available.

In general, ozone levels in southern Ontario decrease from southwest to northeast. More than 50 per cent of provincial ozone levels during widespread smog episodes are due to long-range transport of ozone and its precursors from neighbouring U.S. states. This U.S. contribution is expected to be much higher (as much as 90 per cent) in Ontario cities and towns on the northern shores of Lake Erie, the eastern shores of Lake Huron and in the extreme southwest near the U.S. border.

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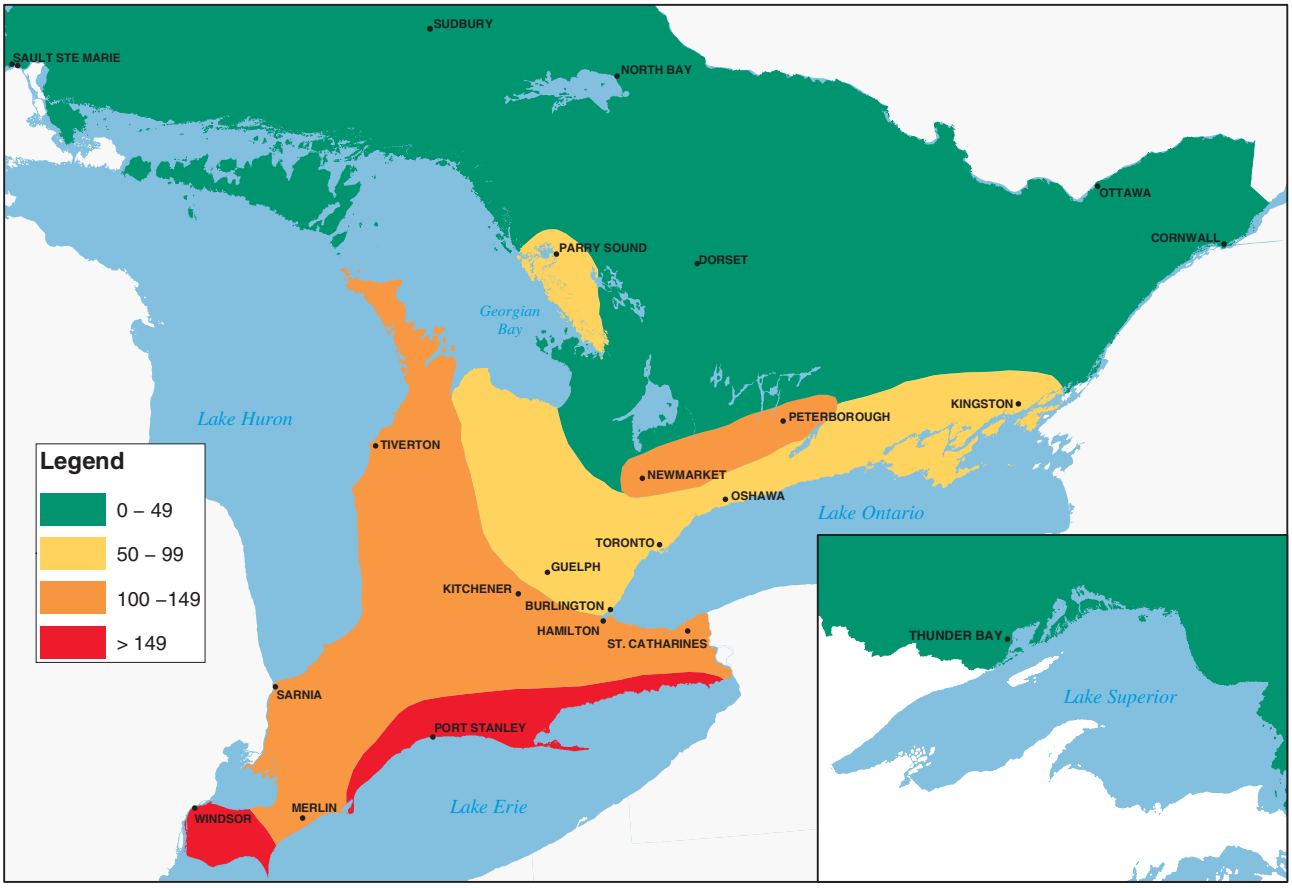
Trends

Interpretation of the 10-year ambient ozone trend is complicated by meteorology and emission changes that can vary from year to year. For example, ozone levels are strongly influenced by weather. Figure 2.3 shows the distribution of the province-wide ozone exceedance days (at least one hour > 80 ppb) and the number of hot days (those days with

Figure 2.2: Geographical Distribution of Number of One-Hour Ozone Exceedances Across Ontario (2002)

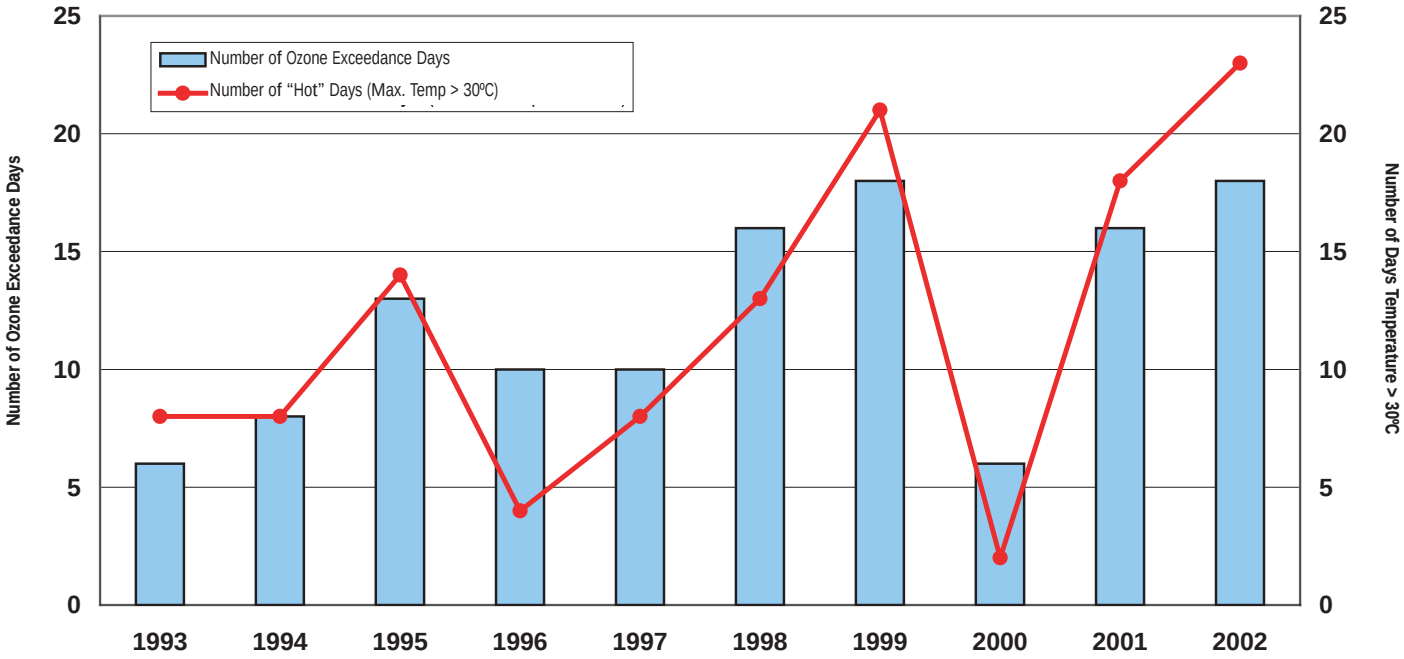


maximum air temperatures greater than 30°C) from 1993 to 2002. The high number of ozone exceedance days in 1999 and 2002 can be attributed to the high number of "hot" days which are favourable to the formation and transport of ozone, whereas the low numbers of exceedance days in 2000 reflect conditions less conducive to the production of ground-level ozone.

The annual one-hour maximum concentration of ozone is shown for 1980 to 2002, in Figure 2.4. For the 23-year period, the annual one-hour maximum concentration ranges from 97 to 156 ppb, with the highest recorded in 1988. Overall, the trend line shows random fluctuations but a decreasing trend in annual one-hour maximum concentration of ozone from 1980 to 2002 is evident.

The trend of the ozone seasonal means (summer and winter) for the 17 (12 urban and five rural) long-term ozone sites for the period 1980 to 2002 is shown in Figure 2.5. It shows that there has been an increasing trend in the ozone seasonal means during the 23-year period. The ozone summer means have increased by approximately 23 per cent and the winter means by approximately 27 per cent over the 23-year period. The increase of the summer mean is significantly dependent on meteorological factors and the long-range transport of ozone and its precursors from the U.S, whereas the increase of

Figure 2.3: 10 Year Trend for Ozone Exceedance Days and 'Hot' Days in Ontario (1993 – 2002)



Note: Based on 21 ozone sites operated over 10 years;
"Hot" days based on eight meteorological sites operated over 10 years;
An ozone exceedance day has at least one hour > 80ppb.

the winter mean indicates an increase in background concentrations of ozone throughout Ontario. This increase in background ozone is similarly found in other areas across North America.

The trend of ozone annual means for urban and rural sites in Ontario for 1990 to 2002 is shown in Figure 2.6. It shows that the ozone annual mean concentrations for urban cities in southern Ontario are consistently about 5 ppb less than those of urban cities in northern Ontario and about 11 ppb less than those in rural Ontario. The destruction of ozone by nitrogen oxides, substantially present in urban areas, is the reason for the lower ozone concentrations in southern Ontario.

In Figure 2.7, the ozone monthly means are compared in southern and northern Ontario for 1990 to 2002. The ozone monthly mean concentrations are higher in northern Ontario during the cooler months of the year. For the month of February, ozone mean concentrations in the north are 10 ppb greater than those observed in the south. Among the possible scientific explanations are: since local emissions of nitrogen oxides are lower in the north, there is less removal of ozone than in southern urban areas. Also, during late winter and early spring, there is greater potential for stratospheric ozone to be mixed into the troposphere in northern Ontario. During the summer months, ozone and its precursors are transported into southern Ontario from the mid-western U.S. causing ozone levels to rise in southern Ontario.

Ozone and the Canada-wide Standard (CWS)

Comprehensive reporting on progress toward meeting the CWS for ozone commences in 2006.

In 2000, the Canadian Council of Ministers of the Environment (CCME) developed a Canada-wide Standard (CWS) for ozone as a result of the pollutant's adverse effects on human health and the environment. As referenced in the *Guidance Document on Achievement Determination*, the CWS for ozone is 65 ppb, eight-hour running average time, based on the fourth highest annual ambient measurement averaged over three consecutive years. Jurisdictions are required to meet the CWS by 2010 and commence reporting on the achievement of the CWS for ozone by 2011. However, comprehensive reporting on progress toward meeting the CWS for ozone commences in 2006, therefore the following discussion and analysis focuses on the examination of the fourth highest annual ambient ozone measurements across Ontario for 2002.

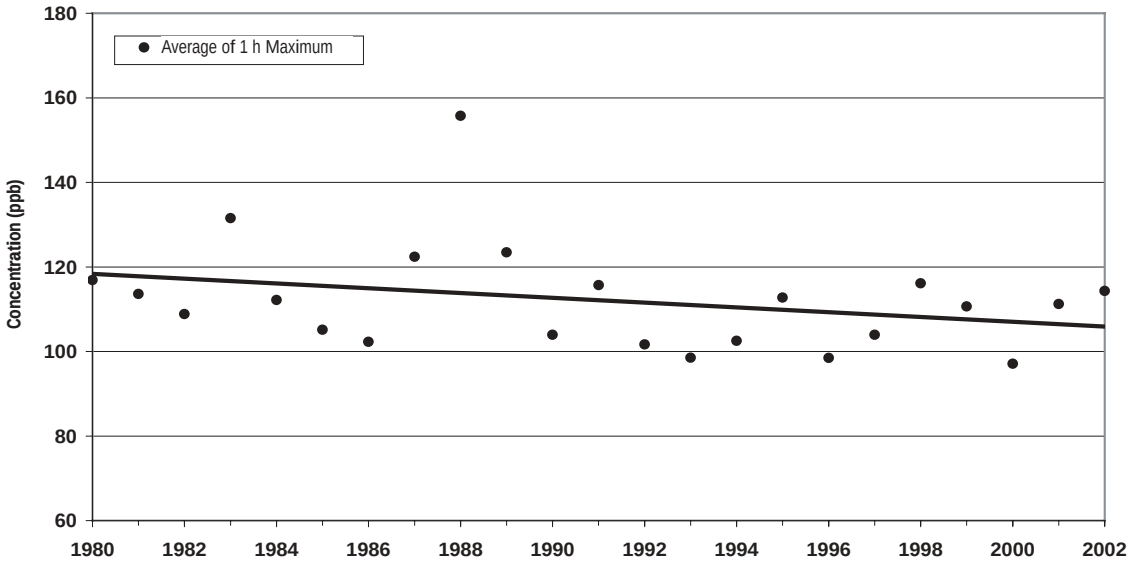
Figure 2.8 displays the fourth highest ozone eight-hour daily maximum for selected sites across Ontario in 2002. All of the sites exceeded 65 ppb, with the exception of Thunder Bay where the fourth highest ozone eight-hour daily maximum was 59 ppb.

Great Lakes Basin perspective

There were a total of 10 cities selected within the Great Lakes Basin area for this study as illustrated in Figure 2.9. The selected cities include five from Ontario and five from the United States. The Ontario cities are Toronto, Hamilton, London, Windsor and Thunder Bay, and those in the United States include Chicago, Detroit, Milwaukee, Cleveland and Buffalo.

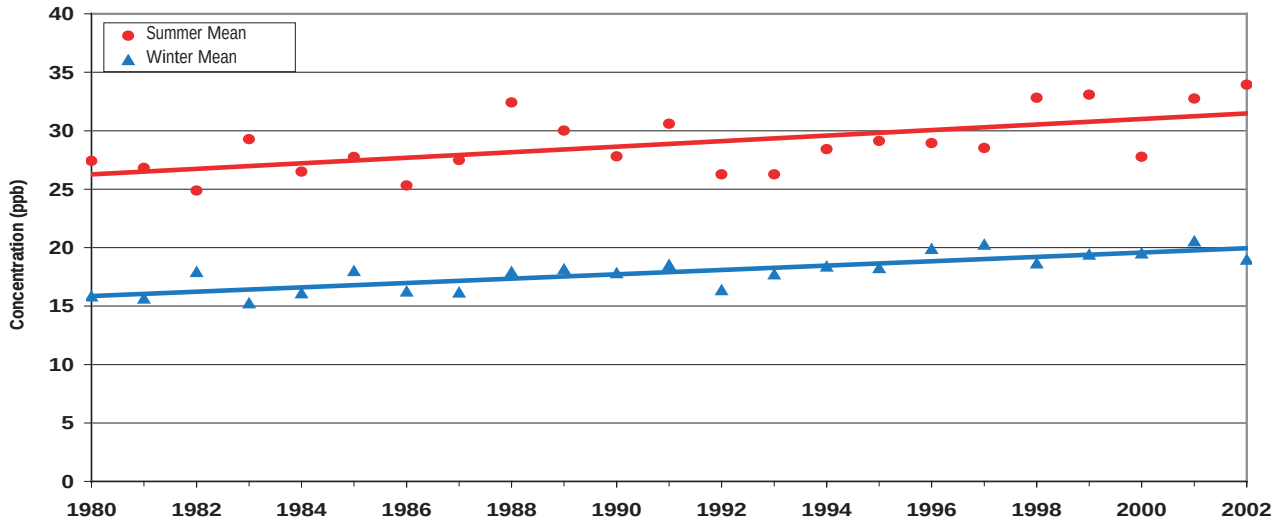
In 2002, the highest O_3 one-hour maximum concentration was recorded for Detroit with a reported value of 140 ppb. Chicago and Milwaukee followed with concentrations of 136 ppb and 132 ppb respectively. Of the Ontario cities studied, Windsor recorded the

Figure 2.4: Trend of Ozone One-Hour Maximum Concentrations in Ontario (1980 – 2002)



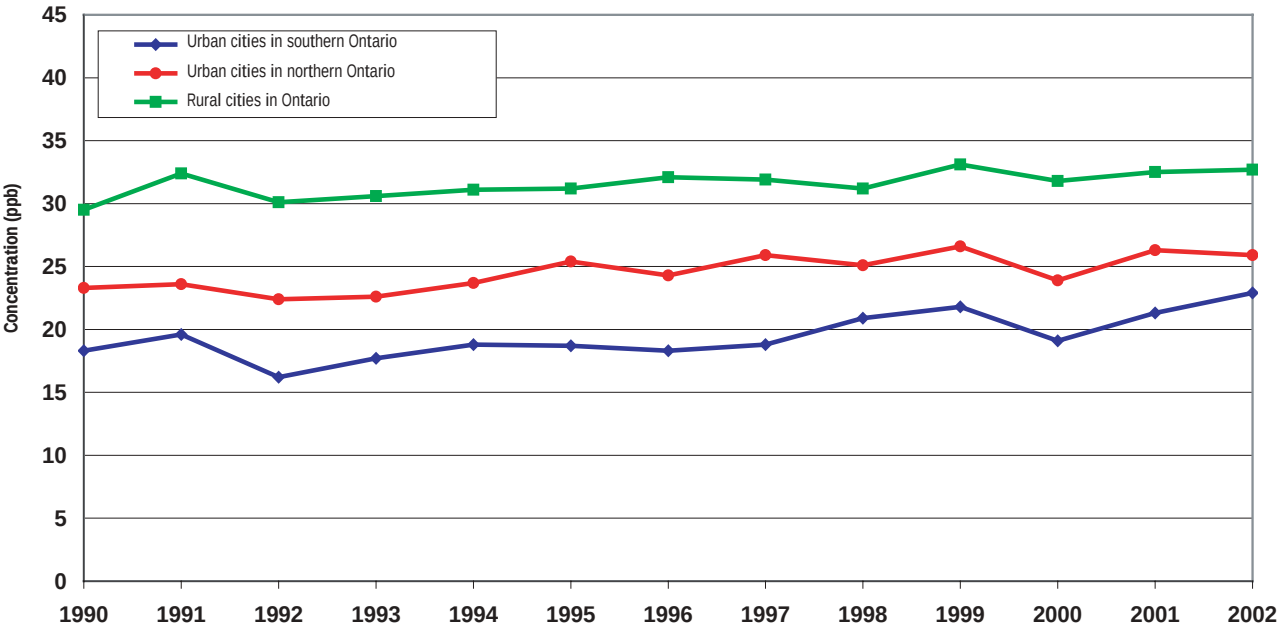
Note: Based on data from 17 ozone sites operated over 23 years.

Figure 2.5: Trend of Ozone Seasonal Means at Sites Across Ontario (1980 – 2002)



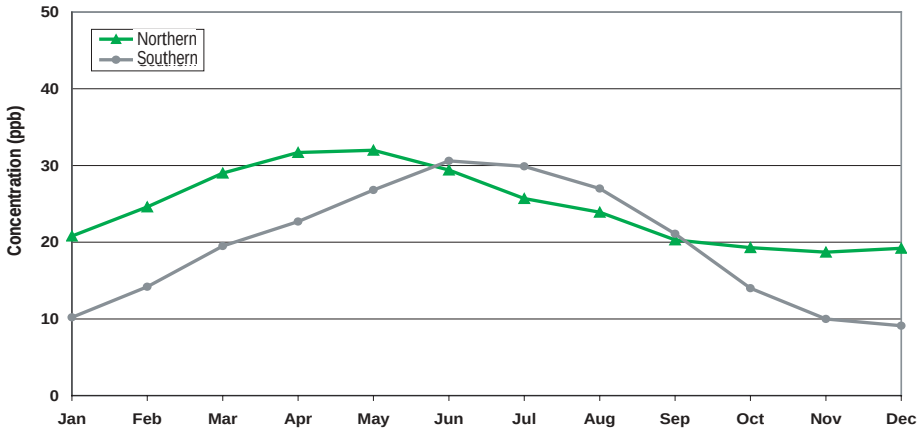
Note: Based on data from 17 ozone sites operated over 23 years;
Seasonal definitions – Summer (May to September); Winter (January to April, October to December).

Figure 2.6: Trend of Ozone Annual Means for Urban and Rural Ontario (1990 – 2002)



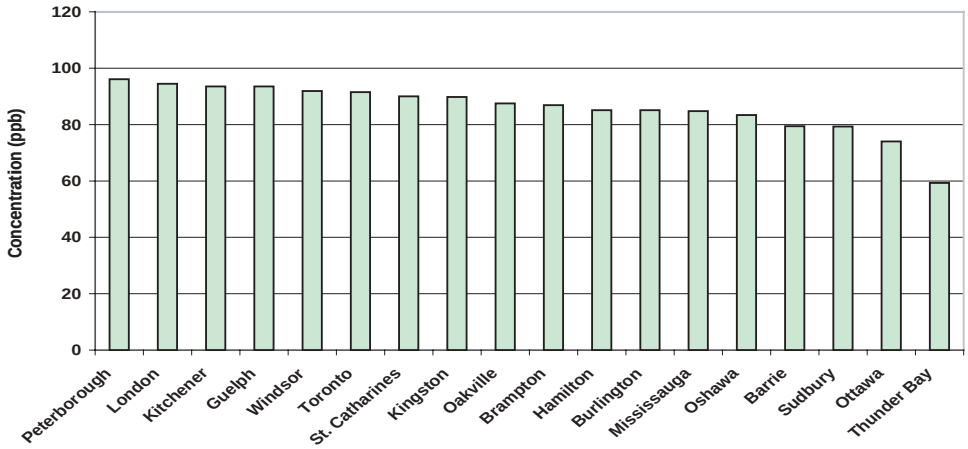
Note: Urban cities in southern Ontario – Windsor, London, Hamilton, Toronto;
Urban cities in northern Ontario – Thunder Bay, Sault Ste. Marie, Sudbury, North Bay;
Rural cities in Ontario – Merlin, Simcoe, Long Point, Tiverton.

Figure 2.7: Trend of Ozone Monthly Means in Southern and Northern Ontario (1990 – 2002)



Note: Northern – Thunder Bay, Sault Ste. Marie, Sudbury, North Bay;
Southern – Windsor, London, Hamilton, Toronto.

Figure 2.8: Ozone Levels at Selected Sites Across Ontario
4th Highest Ozone 8-Hour Daily Maximum (2002)



Note: Displayed sites are selected based on future requirements for Canada-wide Standard (CWS) reporting.

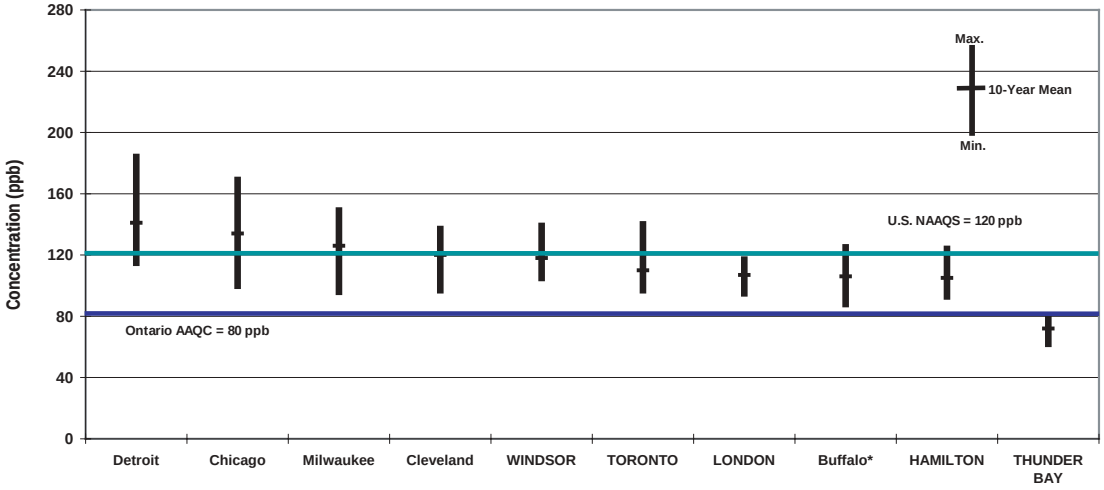
highest O_3 one-hour maximum concentration of 127 ppb. Thunder Bay reported the lowest O_3 one-hour maximum concentration of 78 ppb and was the only site that did not exceed either the U.S. National Ambient Air Quality Standard (NAAQS) or the Ontario AAQC. Toronto recorded the second lowest concentration for year 2002 when compared with the other nine cities examined. In 2002, the U.S. NAAQS of 120 ppb was exceeded by seven of the Great Lakes cities considered, while the Ontario AAQC of 80 ppb was exceeded by nine cities.

The 10-year (1993-2002) range of O_3 one-hour maximum concentrations for the 10 cities of interest is illustrated in Figure 2.10. Concentrations monitored in Detroit had the highest values over the past decade, followed by Chicago and Milwaukee. Windsor, due to its close proximity to Detroit, and subsequent impact of transboundary pollution, is depicted as the city with the highest O_3 one-hour maximum concentrations in Ontario. Thunder Bay was observed to have the lowest levels of all the Great Lakes cities examined without any exceedances over the last decade. ■

Figure 2.9: Selected Sites in the Great Lakes Basin Area

Note: Populations of the cities studied in the Great Lakes Basin Area range from 121,000 (Thunder Bay) to 7.4 million (Chicago)

Figure 2.10: Range of Ozone One-Hour Maximum Concentrations in the Great Lakes Basin Area (1993 – 2002)



Note: Ontario cities are in CAPITALS.
*Buffalo ozone data based on Amherst monitoring site.

Chapter 3 Fine Particulate Matter

Particulate matter is the general term used to describe a mixture of microscopic solid particles in the air. Particulate matter is characterized according to size – mainly because of the different health effects associated with particles of different diameters. Fine particulate matter refers to particles that are 2.5 microns in diameter and less. Also known as $PM_{2.5}$ or respirable particles, fine particulate matter penetrates the respiratory system further than larger particles.

Particles originate from many different stationary and mobile sources, as well as from natural sources. They may be emitted directly from a source or formed in the atmosphere by the transformation of gaseous emissions. This chapter discusses the ambient monitoring results from the $PM_{2.5}$ monitoring network.

Characteristics, sources and effects

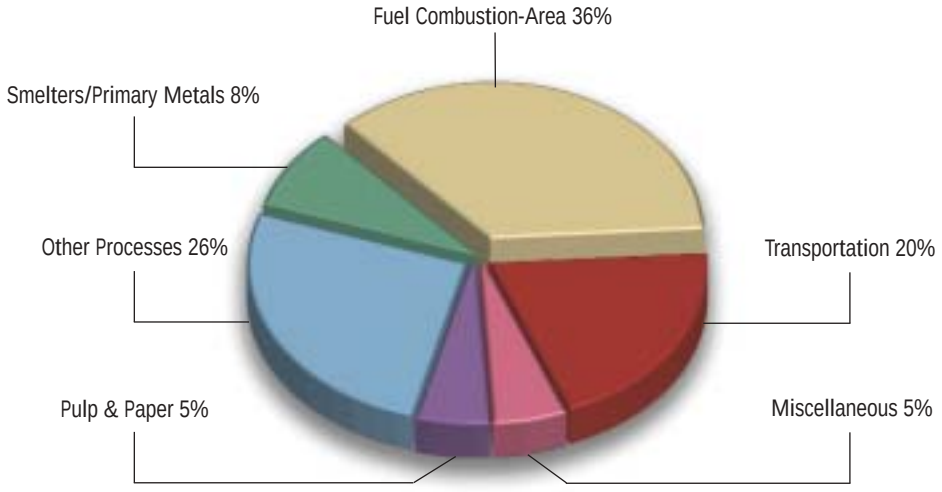
Particulate matter includes aerosols, smoke, fumes, dust, fly ash and pollen. Its composition varies with origin, monitoring location, time of year, and atmospheric conditions. Fine particulate matter is primarily formed indirectly through a series of complex chemical reactions in the atmosphere and directly through fuel combustion (e.g. motor vehicles, power generation, industrial facilities, residential fireplaces and wood stoves, agricultural burning and forest fires). Significant amounts of $PM_{2.5}$ and its precursors are carried into Ontario from the U.S. During periods of widespread elevated levels of $PM_{2.5}$, it is estimated that more than 50 per cent of the pollutant in Ontario comes from the U.S. The U.S. contribution to $PM_{2.5}$ concentrations in border cities is estimated to be as high as 90 per cent.

Figure 3.1 shows 2001 estimates of Ontario's $PM_{2.5}$ emissions from area/point/mobile sources. Fuel combustion accounted for approximately 36 per cent of $PM_{2.5}$ emissions during 2001.

The greatest effect on health is from particles 2.5 microns or less in diameter. Exposure to $PM_{2.5}$ is associated with hospital admissions and several serious health

effects, including premature death. People with asthma, cardiovascular or lung disease, as well as children and elderly people, are considered to be the most sensitive to the effects of $PM_{2.5}$. Adverse health effects have been associated with exposure to $PM_{2.5}$ during both short periods, such as a day, and longer periods of a year or more. Fine particulate matter is also responsible for environmental impacts such as corrosion, soiling, damage to vegetation and reduced visibility.

Figure 3.1: Ontario $PM_{2.5}$ Emissions by Sector
(Emissions From Area/Point/Mobile Sources, 2001 Estimates)



Note: 1. Emissions from open sources (such as construction activity, agricultural activity, road dust) are not included; Emissions from open sources from the smelters are not available.

2. Emission data are a combination of reported and projected emission estimates that may be revised with updated source/sector information or emission estimation methodologies as they become available.

Monitoring results in 2002

In 2002, continuous monitoring for $PM_{2.5}$ was conducted at 26 ambient monitoring locations; 22 sites had sufficient data for the analysis presented here. The annual mean concentrations ranged from 6.2 micrograms per cubic metre (µg/m^3) in Thunder Bay to a maximum of 13.0 µg/m^3 in downtown Hamilton. The highest 24-hour average (71.8 µg/m^3) was recorded on July 6, 2002 at the Peterborough site, closely followed by Ottawa which recorded a 24-hour average of 70.4 µg/m^3 that very same day (Figure 3.2). These extremely elevated concentrations were a result of a $PM_{2.5}$ episode due to the Quebec forest fires in early July and affected several sites across the province as discussed under Smog Episodes in Chapter 5. The provincial ambient average for $PM_{2.5}$ during 2002 was 8.7 µg/m^3.

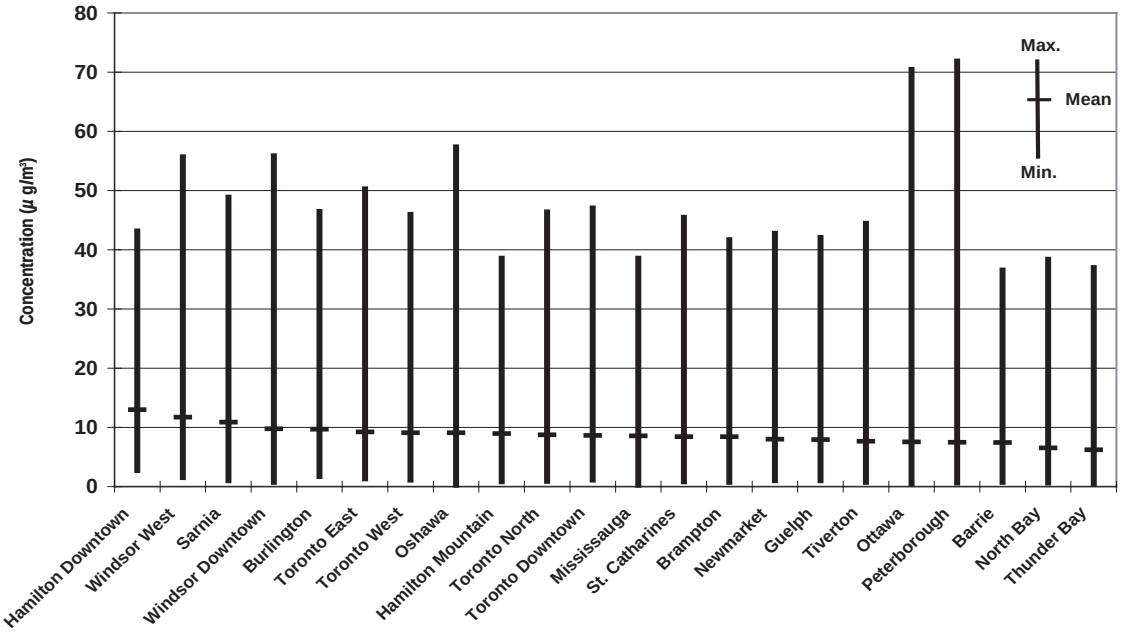
The seasonal variability of $PM_{2.5}$ is more distinct when comparing the summer/winter 98th percentiles for the 22 ambient sites during 2002 (Figure 3.3). The 98th percentile values recorded in the summer months are much greater than the 98th percentile values in the winter months. The air monitoring site in downtown Toronto recorded the highest 98th percentile (43.5 µg/m^3) during the summer months and the Windsor West site recorded the highest 98th percentile (23.7 µg/m^3) during the winter months. The lowest 98th percentiles were recorded at North Bay (25.6 µg/m^3) during the summer and Tiverton (11.2 µg/m^3), a rural site on the eastern shore of Lake Huron, during the winter.

$PM_{2.5}$ and the Canada-wide Standard (CWS)

In 2000, the Canadian Council of Ministers of the Environment (CCME) developed a Canada-wide Standard (CWS) for $PM_{2.5}$ as a result of the pollutant's adverse effects on human health and the environment. As referenced in the *Guidance Document on Achievement Determination*, the CWS for $PM_{2.5}$ is 30 µg/m^3, 24-hour averaging time, based on the 98th percentile ambient measurement annually averaged over three consecutive years. Jurisdictions are required to meet

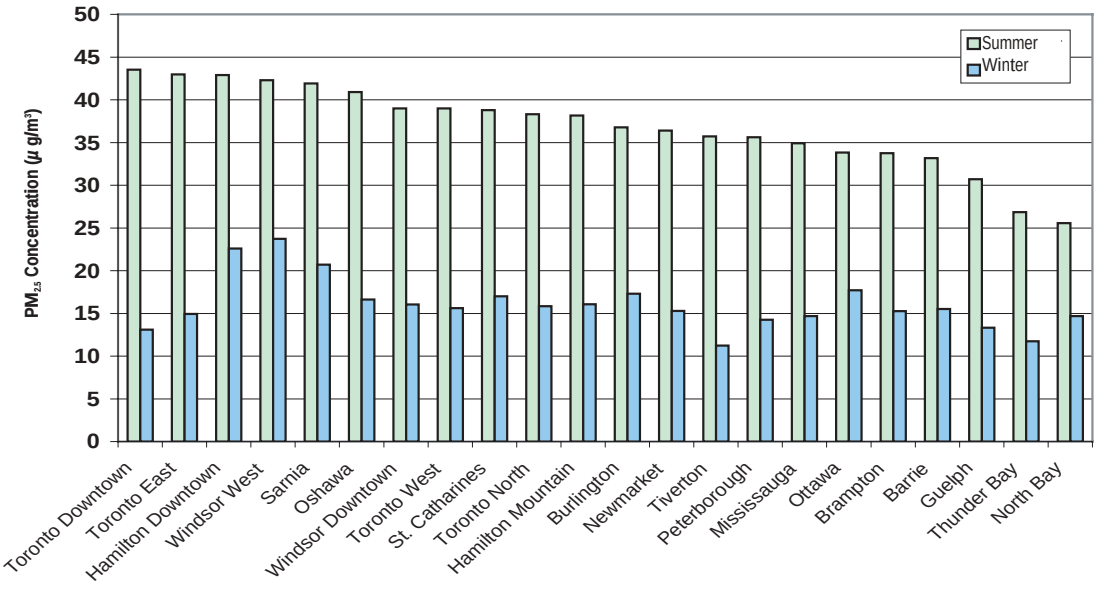
In 2000, the Canadian Council of Ministers of the Environment (CCME) developed a Canada-Wide Standard (CWS) for $PM_{2.5}$ as a result of the pollutant's adverse effects on human health and the environment.

Figure 3.2: Annual Statistics for 24-Hour $PM_{2.5}$ (2002)



Note: $PM_{2.5}$ concentrations are measured by TEOM (Tapered Element Oscillating Microbalance).

Figure 3.3: Seasonal Distribution of $PM_{2.5}$ at Sites Across Ontario (2002)



Note: $PM_{2.5}$ concentrations are measured by TEOM (Tapered Element Oscillating Microbalance);
98th percentile calculated per season based on daily average;
Seasonal definitions – Summer (May to September); Winter (January to April, October to December).

the CWS by 2010 and commence reporting on the achievement of the CWS for $PM_{2.5}$ by year 2011. However, comprehensive reporting on progress toward meeting the CWS for $PM_{2.5}$ commences in 2006, hence, the following discussion and analysis mainly focus on the examination of $PM_{2.5}$ 98th percentiles across Ontario.

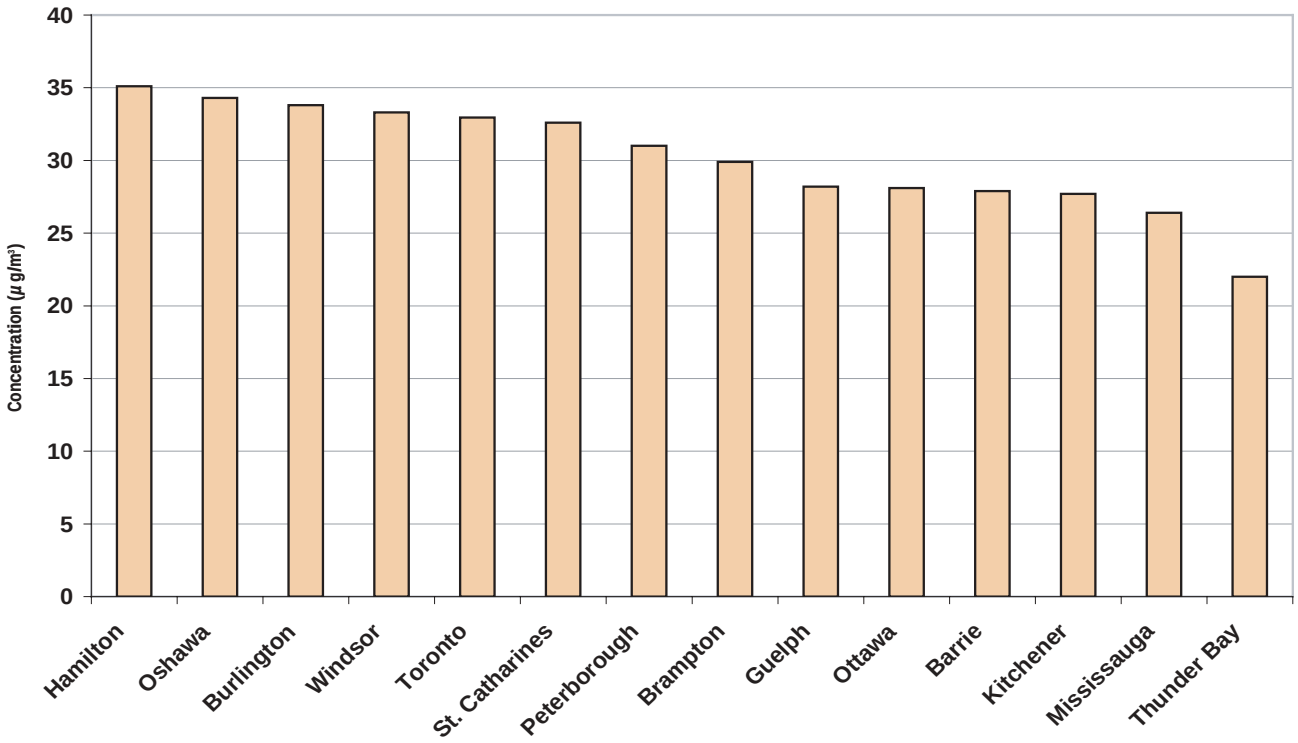
Figure 3.4 displays the 98th percentile $PM_{2.5}$ daily average for selected sites across Ontario in 2002. The 98th percentiles ranged from 22.0 µg/m^3 in Thunder Bay to 35.1 µg/m^3 at the Hamilton site. Seven of the 14 ambient sites exceeded 30 µg/m^3.

Great Lakes Basin perspective

Figure 3.5 displays $PM_{2.5}$ annual means for 10 selected cities in the Great Lakes Basin area (see Figure 2.9) for the years 2001 and 2002. Cleveland exhibited the highest annual mean $PM_{2.5}$ concentrations for both 2001 and 2002 at 17.1 µg/m^3 and 16.0 µg/m^3 respectively. On the lower end of the scale is Thunder Bay with a concentration of 6.2 µg/m^3 for year 2002, and Toronto at 8.9 µg/m^3 for both 2001 and 2002.

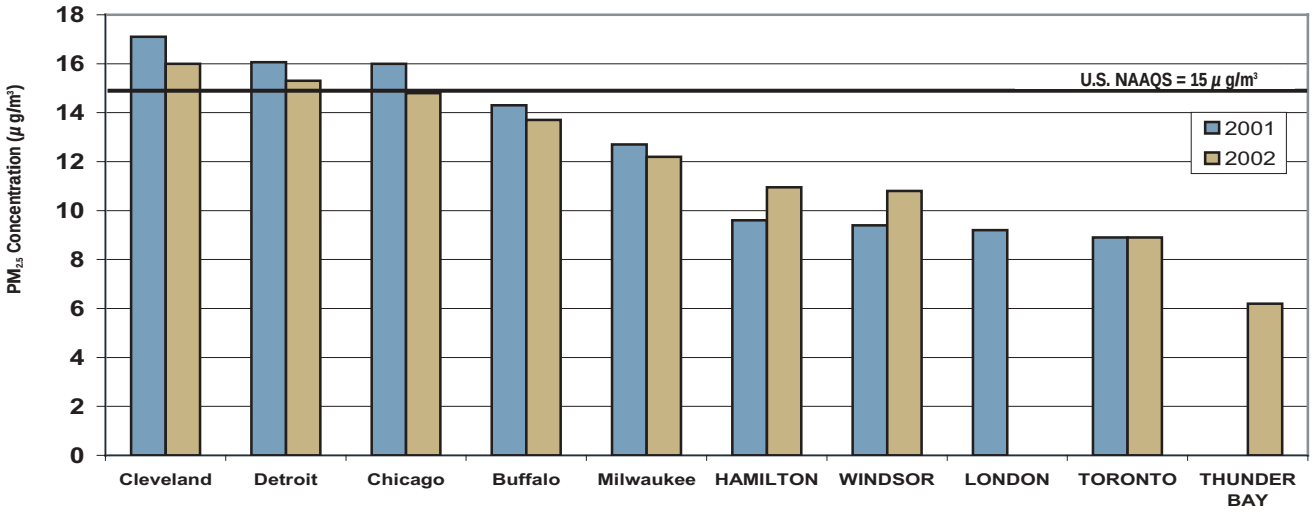
The analyzed U.S. cities reported annual mean concentrations higher than those of the Ontario cities. Cleveland and Detroit exceeded the U.S. annual NAAQS of 15 µg/m^3 during 2002. All Canadian cities recorded annual means well below the U.S. standards. ■

Figure 3.4: $PM_{2.5}$ Levels in Selected Cities Across Ontario
98th Percentile $PM_{2.5}$ Daily Average (2002)



Note: $PM_{2.5}$ concentrations are measured by TEOM (Tapered Element Oscillating Microbalance);
Displayed sites are selected based on future requirements for Canada-wide Standard (CWS) reporting.

Figure 3.5: $PM_{2.5}$ Annual Means in the Great Lakes Basin Area (2001 and 2002)



Note: Ontario cities in CAPITALS.

2001 – Data not available for Thunder Bay; 2002 – Data not available for London.

$PM_{2.5}$ concentrations are measured by the following method(s):

Cleveland – RAAS Sequential

Detroit – FRM and TEOM

Chicago – FRM

Buffalo – TEOM

Milwaukee – FRM Partisol and TEOM

Hamilton, Windsor, London, Toronto and Thunder Bay – TEOM

Other Criteria Contaminants

Chapter 4

Characteristics, sources and effects of nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), total reduced sulphur (TRS) compounds and mercury (Hg) are discussed in this chapter, as well as their ambient concentrations during 2002 and trends over time from a regional and Great Lakes Basin perspective (where applicable). The 2001 annual emission estimates are also discussed.

Nitrogen dioxide plays a major role in atmospheric reactions that produce ground-level ozone, a major component of smog.

Nitrogen Dioxide

Characteristics, sources and effects

Nitrogen dioxide (NO_2) is a reddish-brown gas with a pungent and irritating odour, which transforms in the air to form gaseous nitric acid and organic nitrates. It also plays a major role in atmospheric reactions that produce ground-level ozone, a major component of smog. Nitrogen dioxide is also a precursor to nitrates, which contribute to levels of fine particulate matter in the atmosphere.

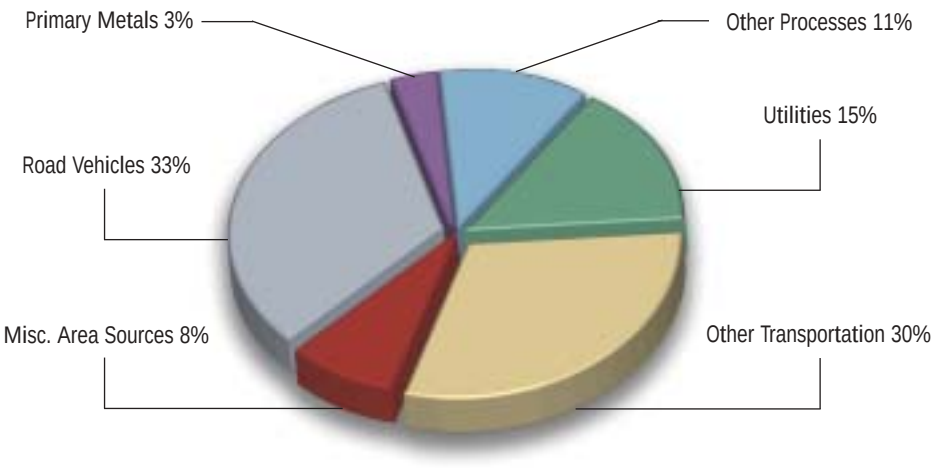
All combustion in air produces nitrogen oxides (NO_X), of which NO_2 is a major component. Natural sources of NO_X include lightning and the aerobic activity of soil bacteria. Approximately 63 per cent of NO_X in Ontario in 2001 were emitted from the transportation sector (Figure 4.1). A large part of the remaining 37 per cent of NO_X emissions came from fossil fuel power generation, primary metal production and incineration.

Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infection. People with asthma and bronchitis have increased sensitivity. Nitrogen dioxide chemically transforms into nitric acid in the atmosphere and, when deposited, contributes to lake acidification. Nitric acid can also corrode metals, fade fabrics, degrade rubber, and damage trees and crops.

Monitoring results for 2002

Monitoring for NO_2 was conducted at 31 ambient locations in 2002; 23 sites provided sufficient data for the analysis presented here. Nitrogen dioxide annual means across Ontario are displayed in Figure 4.2. The Etobicoke South site, located

Figure 4.1: Ontario Nitrogen Oxides Emissions by Sector
(Emissions From Human Activity, 2001 Estimates)



Note: Emission data are a combination of reported and projected emission estimates that may be revised with updated source/sector information or emission estimation methodologies as they become available.

in a heavily industrialized and traffic-influenced area of Toronto, recorded the highest annual mean (26.1 ppb) during 2002. Typically, the highest NO_2 means are recorded in larger urbanized areas, such as the Greater Toronto Area (GTA) and the Golden Horseshoe area of southern Ontario. The Etobicoke South air station also recorded the highest 24-hour concentration (63 ppb) and the highest one-hour concentration (110 ppb) in 2002. During 2002, Ontario's 24-hour criterion of 100 ppb and one-hour criterion of 200 ppb for NO_2 were not exceeded at any of the 23 monitoring locations.

Trends

Provincial average ambient NO_2 concentrations show a decreasing trend for the period 1975 to 2002 (Figure 4.3). Average concentrations in 2002 were 23 per cent lower than the levels recorded in 1975.

Great Lakes Basin perspective

Of the selected cities displayed in Figure 2.9 in the Great Lakes Basin area, the highest composite NO_2 annual means were recorded for Chicago and Toronto with reported values of 24 ppb and 22 ppb respectively, for 2002. The lowest composite annual mean of 12 ppb was reported in Thunder Bay. Throughout 2002, no cities examined in this Great Lakes Basin analysis exceeded the U.S. NAAQS of 53 ppb.

The 10-year range of composite NO_2 annual means for the 10 cities in the Great Lakes Basin is illustrated in Figure 4.4. Similar to the monitoring results for 2002, Chicago and Toronto exhibited the highest range of NO_2 annual means for the years 1993 to 2002. Large urban centres such as Chicago and Toronto typically experience higher NO_2 levels due to population density and increased motor vehicle emissions. Thunder Bay is at the lower end of the scale, and is the city with the lowest composite annual means over the past decade.

Carbon Monoxide

Characteristics, sources and effects

Carbon monoxide (CO) is a colourless, odourless, tasteless and, at high concentrations, a poisonous gas. This gas can enter the bloodstream and reduce oxygen delivery to the organs and tissues. People with heart disease are particularly sensitive. Exposure to high CO levels is linked with the impairment of vision, work capacity, learning ability and performance of complex tasks.

Carbon monoxide is produced primarily by the incomplete combustion of fossil fuels. The transportation sector accounted for 85 per cent of all CO emissions from human activity in Ontario during 2001 (Figure 4.5).

Monitoring results for 2002

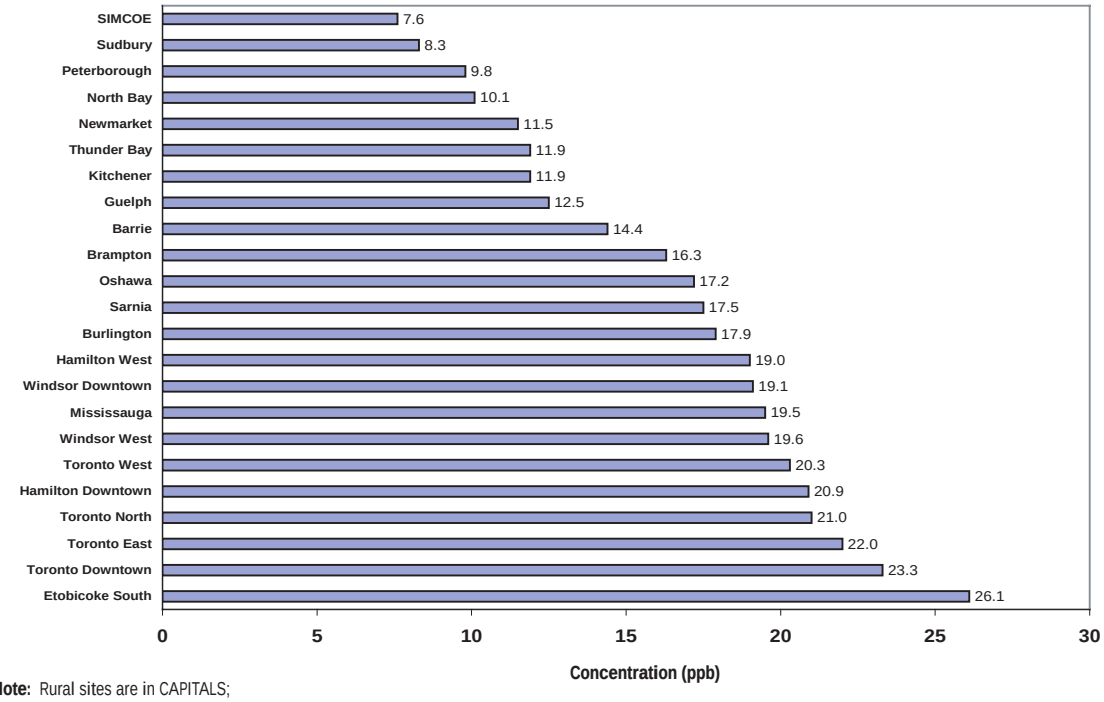
Monitoring for CO was conducted at 20 ambient locations in 2002; 17 sites provided sufficient data for the analysis presented here. In 2002, the highest annual mean was 0.89 parts per million (ppm), recorded at the Etobicoke South site. The highest one-hour maximum CO value (6.0 ppm) was measured at the Mississauga site (Figure 4.6), located near a high-traffic density corridor. This site also recorded the highest eight-hour maximum value (3.7 ppm). Typically, the highest CO concentrations are recorded in larger urban centres as a result of vehicle emissions. Ontario's one-hour (30 ppm) and eight-hour (13 ppm) ambient air quality criteria for CO have not been exceeded at any of the monitoring sites in Ontario since 1991.

Trends

The trends in provincial averaged one-hour and eight-hour maximum CO concentrations for 1993 to 2002 are shown in Figure 4.7. Ambient CO concentrations, as measured by the composite average of the one and eight-hour maximums, decreased by 55 per cent over this 10-year period. The CO composite annual mean in 2002 was 29 per cent less than the corresponding 1993 composite mean. These reductions in ambient CO levels have occurred despite a 17 per cent increase in vehicle-kilometres travelled over the same 10-year period (Figure 4.8). Carbon monoxide concentrations also decreased by 87 per cent from 1971 to 2002.

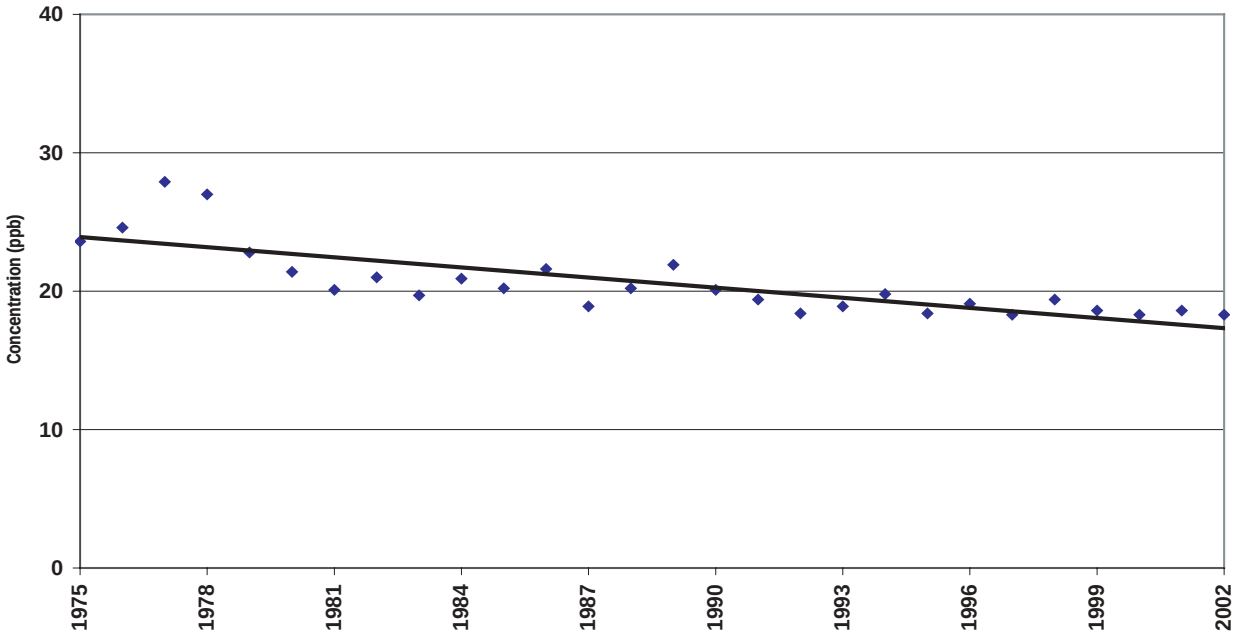
Reductions in ambient CO levels have occurred despite a 17 per cent increase in vehicle-kilometres travelled over the same 10-year period.

Figure 4.2: Nitrogen Dioxide Annual Means Across Ontario (2002)



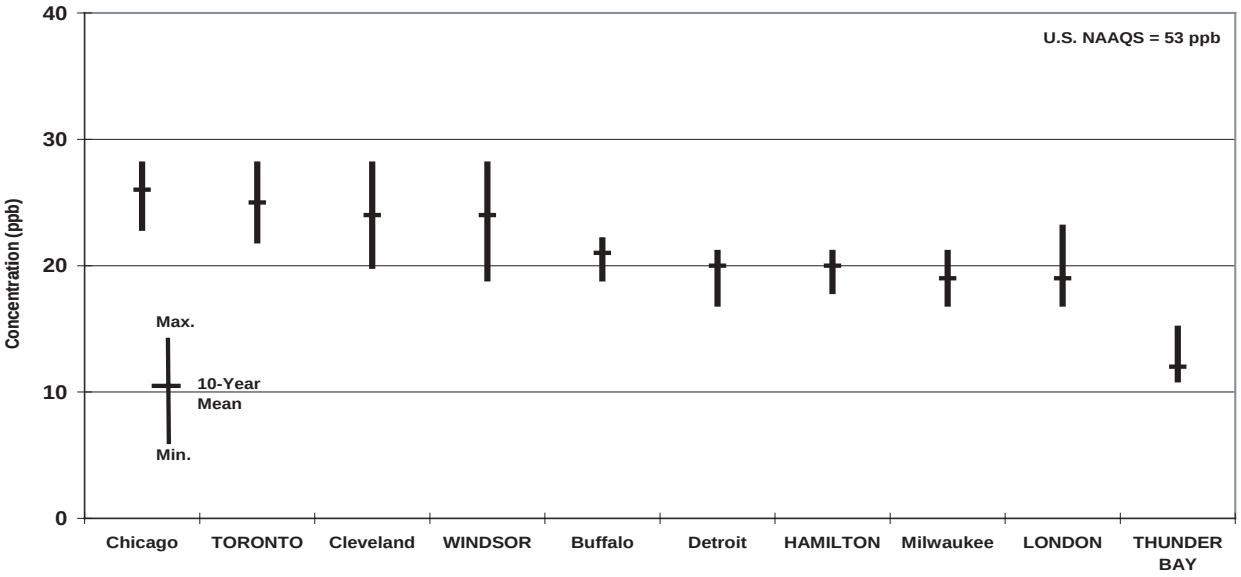
Note: Rural sites are in CAPITALS;
Data collected from ambient sites.

Figure 4.3: Trend of Nitrogen Dioxide Annual Means in Ontario (1975 – 2002)



Note: Annual composite mean based on 14 ambient sites operated over 28 years.

Figure 4.4: Range of Nitrogen Dioxide Annual Means in the Great Lakes Basin Area (1993 – 2002)



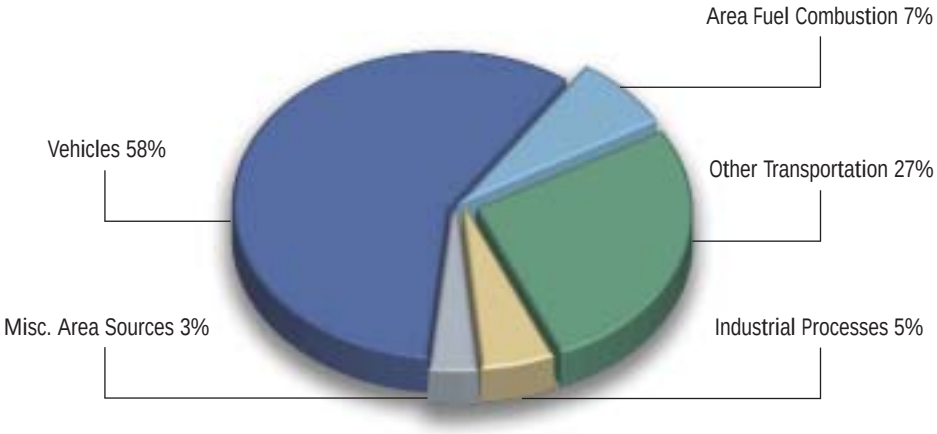
Note: Ontario cities are in CAPITALS.

Great Lakes Basin perspective

London recorded the lowest CO one-hour maximum concentration of 2.27 ppm for the year 2002 for the 10 cities (see Figure 2.9) compared in the Great Lakes Basin area. Cleveland and Detroit reported the highest values with concentrations of 10.30 ppm and 5.80 ppm, respectively. No exceedances of the Ontario AAQC of 30 ppm or the U.S. NAAQS of 35 ppm were made by any of the cities examined in 2002.

The range of CO one-hour maximum concentrations for years 1993 through 2002 is displayed in Figure 4.9. Cleveland and Detroit are represented at the higher end of the scale, with Cleveland recording one value that exceeded the Ontario AAQC of 30 ppm. Following Detroit are Toronto and Hamilton. London reported the lowest one-hour maximum concentration over the past decade. Larger urban centres frequently encounter higher levels of CO where concentrations are strongly influenced by local vehicle emissions.

Figure 4.5: Ontario Carbon Monoxide Emissions by Sector
(Emissions From Human Activity, 2001 Estimates)



Note: Emission data are a combination of reported and projected emission estimates that may be revised with updated source/sector information or emission estimation methodologies as they become available.

Sulphur Dioxide

Characteristics, sources and effects

Sulphur dioxide (SO_2) is a colourless gas that smells like burnt matches. Sulphur dioxide can also be oxidized to form sulphuric acid aerosols. Further, sulphur dioxide is a precursor to sulphates, which are one of the main components of fine particulate matter in the atmosphere.

Approximately 69 per cent of the SO_2 emitted in Ontario in 2001 came from smelters and utilities (Figure 4.1). Other industrial sources of SO_2 include iron and steel mills, petroleum refineries, and pulp and paper mills. Lesser sources include transportation, residential, commercial and industrial space heating. The highest concentrations of SO_2 historically have been recorded in the vicinity of large, industrial facilities.

Health effects caused by exposure to high levels of SO_2 include breathing problems, respiratory illness, changes in the lung's defences, and worsening respiratory and cardiovascular disease. People with asthma, chronic lung disease or heart disease are the most sensitive to SO_2. Sulphur dioxide also damages trees and crops. Sulphur dioxide and NO_2 are the main precursors of acid rain, which contributes to the acidification of lakes and streams, accelerated corrosion of buildings, and reduced visibility. Sulphur dioxide also causes the formation of microscopic acid aerosols, which have serious health implications and contribute to climate change.

Monitoring results for 2002

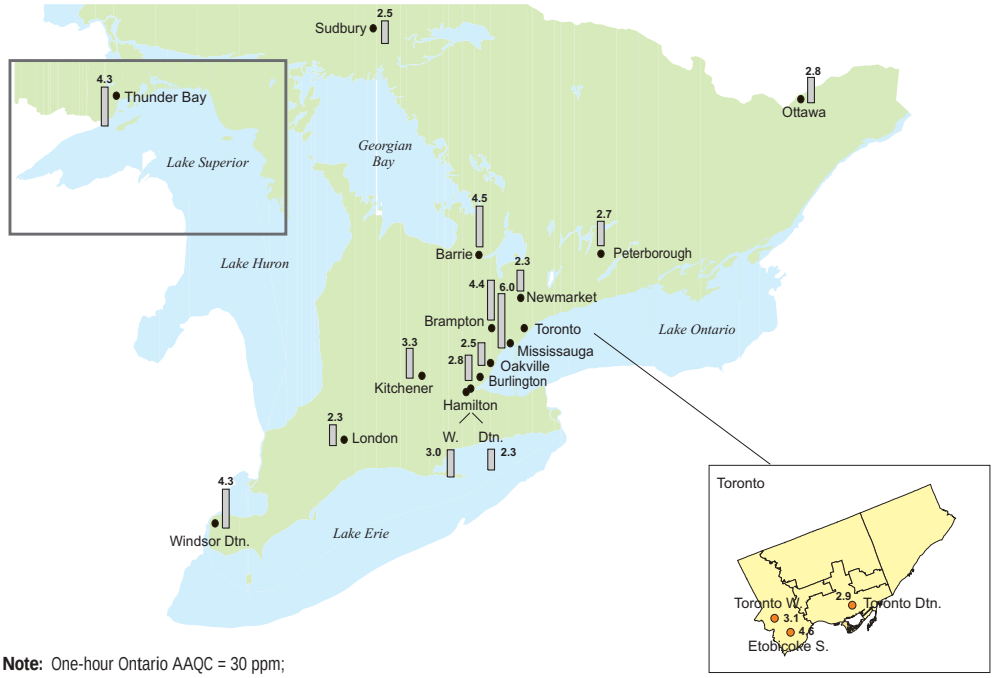
Sulphur dioxide was monitored at 26 ambient locations in 2002; 23 sites provided sufficient data for the analysis presented here. Sarnia recorded the highest annual mean (10.4 ppb) and 24-hour maximum concentration (93 ppb) during 2002. The provincial 24-hour criterion (100 ppb) for SO_2 was not exceeded at any ambient sites in 2002. The Sudbury site located at Science North, recorded the highest one-hour concentration (334 ppb). In 2002, Sarnia and Sudbury were the only ambient sites to record an exceedance of the SO_2 one-hour criterion of 250 ppb.

Figure 4.11 shows the SO_2 annual means at ambient sites across Ontario. Sarnia and the Windsor West site recorded the highest annual mean in 2002. The annual levels across the province ranged from a low of 0.5 ppb in Thunder Bay to a high of 10.4 ppb in Sarnia. The annual criterion of 20 ppb for SO_2 was not exceeded at any site in Ontario during 2002.

Trends

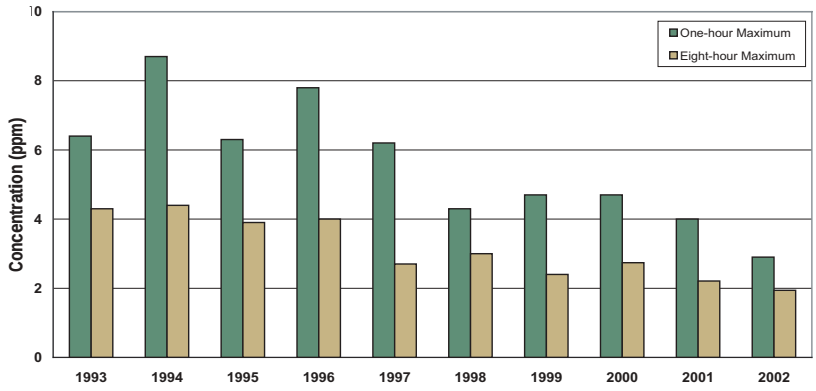
Over the long-term, average ambient SO_2 concentrations in the province decreased by 84 per cent from 1971 to 2002. (Figure 4.12). Regulations 346 and 350, control orders on smelting operations, and the Countdown Acid Rain program, resulted in significant decreases of SO_2 emissions in the early 1990s. In 1998, Algoma Steel Inc. closed down its operation in Wawa, Ontario, resulting in a reduction of SO_2 emissions from 1998 onwards. The introduction of low-sulphur diesel fuel in the late 1990s also resulted in a decrease in sulphur dioxide emissions from the transportation sector. Over the 10-year period from 1993 to 2002, ambient sulphur dioxide concentrations decreased by 20 per cent.

Figure 4.6: Geographical Distribution of Carbon Monoxide One-Hour Maximum Concentrations Across Ontario (2002)



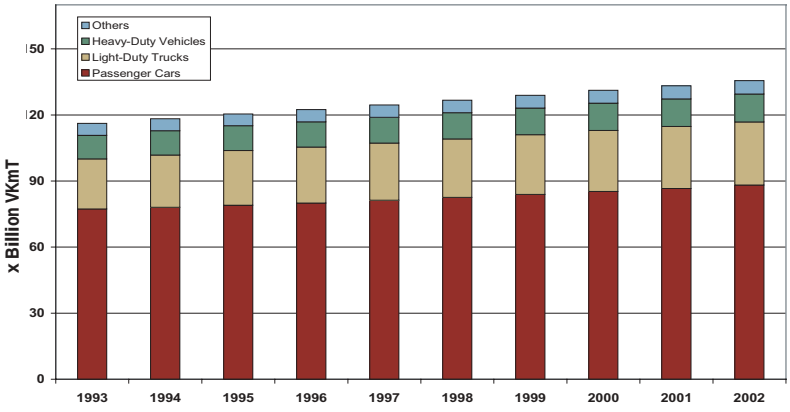
Note: One-hour Ontario AAQC = 30 ppm;
Carbon monoxide concentrations are reported in parts per million (ppm).

Figure 4.7: Trend of Carbon Monoxide One-Hour and Eight-Hour Maximums in Ontario (1993 – 2002)



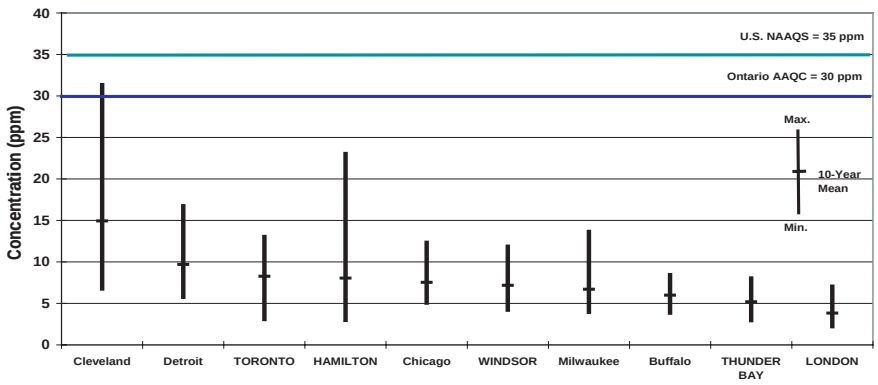
Note: Data is based on 9 ambient CO sites operated over 10 years;
Ontario's one-hour AAQC = 30 ppm;
Ontario's eight-hour AAQC = 13 ppm.

Figure 4.8: Trend of Vehicle-Kilometres Travelled in Ontario (1993 – 2002)



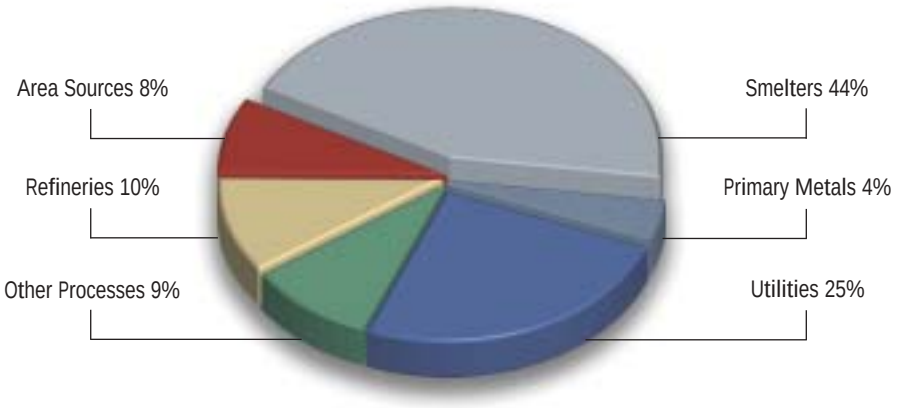
Note: Based on Ontario MOBILE 5C model input parameters obtained from Environment Canada;
VKmT represents vehicle-kilometres travelled.

Figure 4.9: Range of Carbon Monoxide One-Hour Maximum Concentrations in the Great Lakes Basin Area (1993 – 2002)



Note: Ontario cities are in CAPITALS.

Figure 4.10: Ontario Sulphur Dioxide Emissions by Sector
(Emissions From Human Activity, 2001 Estimates)



Note: Emission data are a combination of reported and projected emission estimates that may be revised with updated source/sector information or emission estimation methodologies as they become available.

Total Reduced Sulphur Compounds

Characteristics, sources and effects

Total reduced sulphur (TRS) compounds produce an offensive odour similar to rotten eggs or decomposed cabbage. Industrial sources of TRS compounds include the steel industry, pulp and paper mills, crude oil refineries and sewage treatment facilities. Natural sources include swamps, bogs and marshes.

Total reduced sulphur compounds are not normally considered a health hazard. They are, however, a primary cause of nuisance odours at some locations in the province.

Great Lakes Basin perspective

Of the selected cities displayed in Figure 2.9 of the Great Lakes Basin area, the highest composite SO_2 annual mean for 2002 was reported for Windsor at 6.8 ppb, followed by Buffalo at 6.0 ppb. Thunder Bay recorded the lowest composite annual mean of 0.5 ppb. All cities examined in the Great Lakes Basin were below the Ontario annual AAQC of 20 ppb and the U.S. annual NAAQS of 30 ppb.

Figure 4.13 illustrates the range of SO_2 annual means for the years 1993 through 2002. Cleveland recorded the highest composite SO_2 annual means over the past decade, followed by Windsor and Buffalo. Thunder Bay is the city with the lowest composite annual mean over the last decade when compared with the remaining nine cities examined.

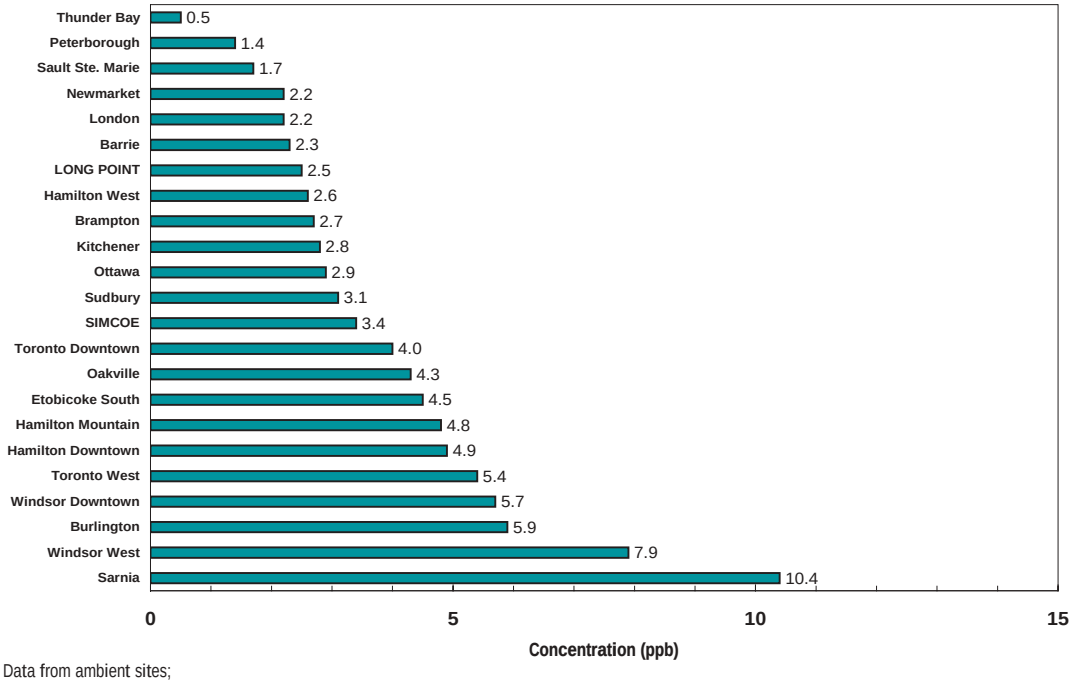
Monitoring results for 2002

Monitoring for TRS compounds was conducted at nine ambient locations in 2002. The highest TRS mean (2.1 ppb) was recorded at the Windsor West air monitoring site which is impacted by emissions from industrial sources in Detroit, Michigan. This is also where the greatest number of hours (66) above the AAQC of 27 ppb was recorded. The maximum one-hour TRS concentration (147 ppb) was also measured in Windsor.

Trends

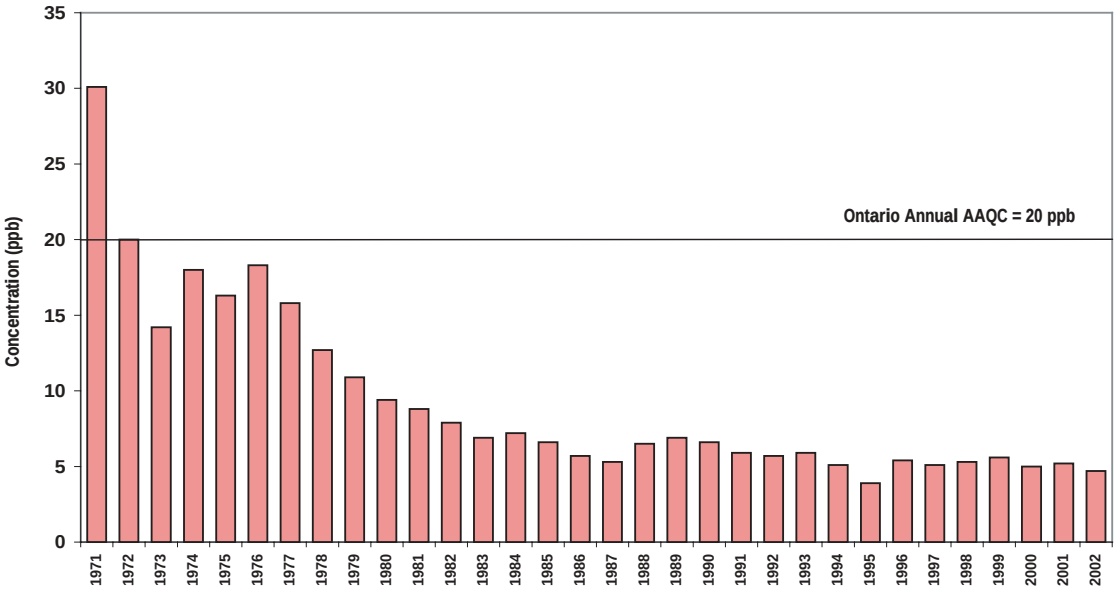
Provincial TRS annual mean concentrations at ambient monitoring sites from 1993 to 2002 are displayed in Figure 4.14. A trend is not apparent in the provincial means of ambient TRS levels shown over the last decade.

Figure 4.11: Sulphur Dioxide Annual Means Across Ontario (2002)



Note: Data from ambient sites;
Rural sites are in CAPITALS;
Ontario annual AAQC for sulphur dioxide is 20 ppb.

Figure 4.12: 32-Year Trend of Sulphur Dioxide Concentrations in Ontario (1971 – 2002)



Note: Annual composite mean based on 10 ambient SO_2 sites operated over 32 years.

Mercury

Characteristics, sources and effects

The accumulation of mercury in the aquatic food chain results in relatively high levels of mercury in fish that may be consumed by humans.

Mercury (Hg) is unique, as it is the only metal that is a liquid at room temperature. It is probably best known as the silver liquid in thermometers.

Mercury is of concern as an environmental contaminant because of its ability to accumulate in living organisms, potentially reaching concentrations that could pose a hazard to health in humans and wildlife. The accumulation of mercury in the aquatic food chain results in relatively high levels of mercury in fish that may be consumed by humans. Although mercury has been recognized as an environmental pollutant for decades, relatively limited monitoring has taken place to assess the behaviour of mercury in the atmosphere.

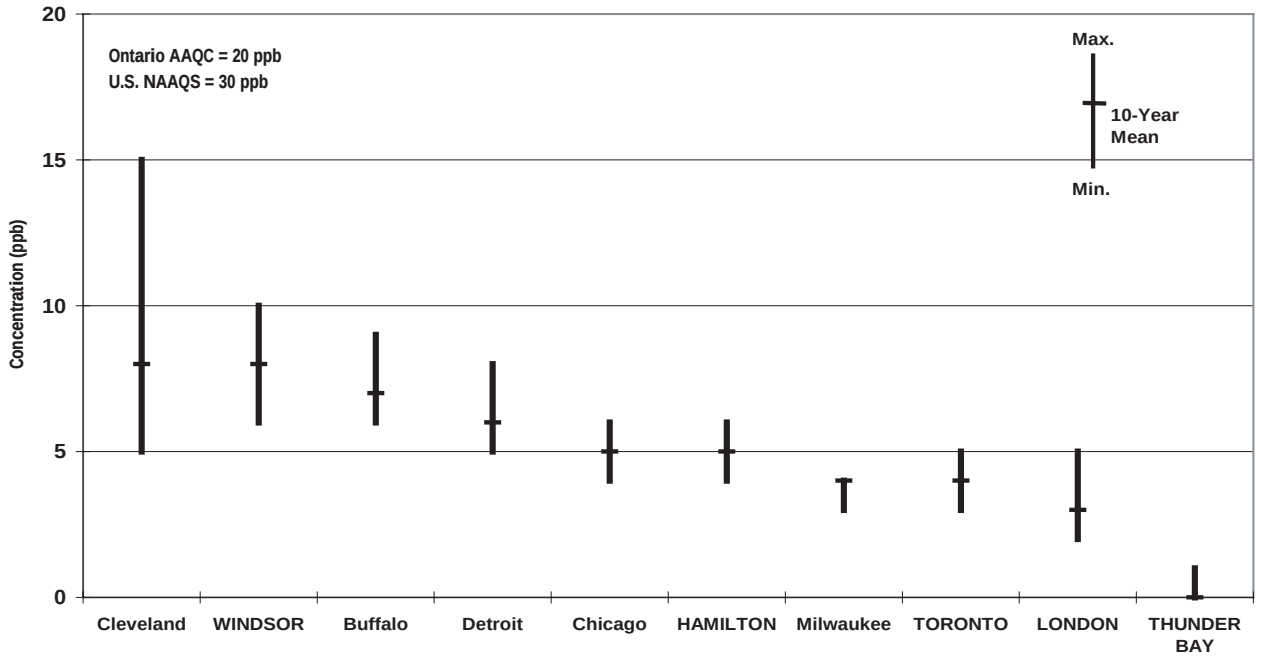
Mercury sources include incinerators and coal and oil-fired power generating stations. Mercury also occurs naturally in the environment as mercuric sulphide.

Potential health effects resulting from exposure to mercury include leukemia and other cancers, reproductive and developmental effects, such as impaired development in newborn and young children, and damage to the pulmonary system. Effects of mercury on the aquatic ecosystem are of particular concern as levels bio-accumulate in animals at the top of the food chain resulting in exposure many times higher than directly from water or air.

Monitoring results for 2002

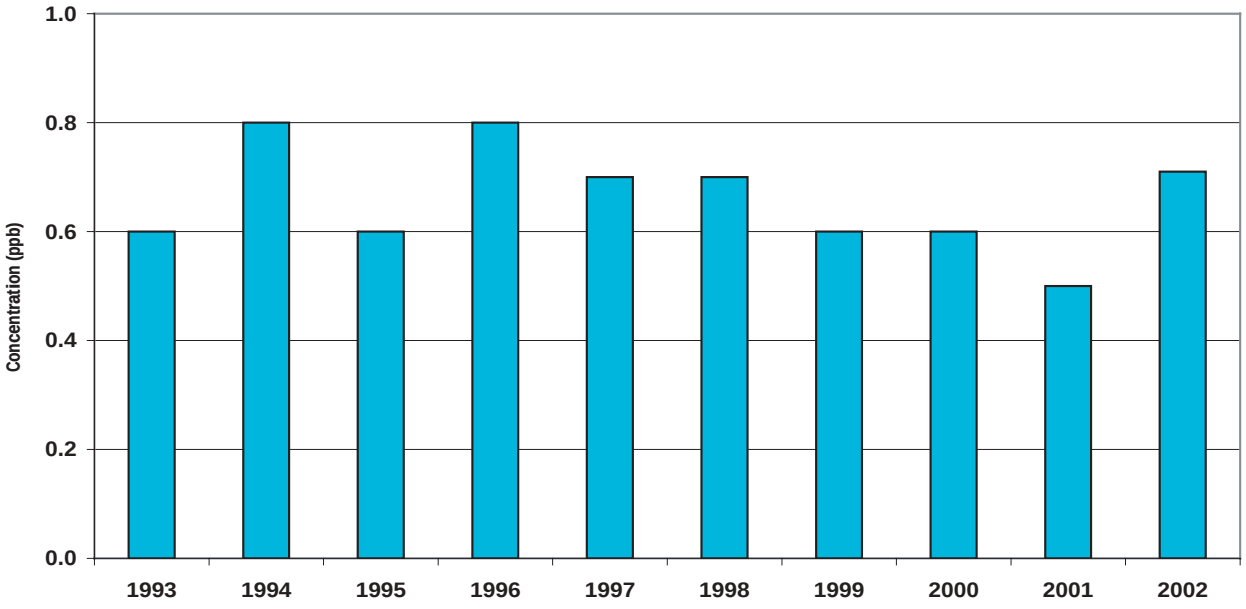
Continuous air monitoring for elemental mercury is relatively new to Ontario's provincial air monitoring network. Monitoring for mercury began in 2000 at two locations – Toronto West and Mississauga, however in 2002, Mississauga was the only site with sufficient data for presentation. During 2002, the maximum one-hour Hg reading at Mississauga was 26 nanograms per cubic metre (ng/m^3), which was well below the provincial one-hour guideline of 5,000 ng/m^3. The ambient annual mean concentration of mercury in Mississauga was 1.91 ng/m^3, which is considered a typical value for urban sites in North America. ■

Figure 4.13: Range of Sulphur Dioxide Annual Means in the Great Lakes Basin Area (1993 – 2002)



Note: Ontario cities are in CAPITALS.

Figure 4.14: Total Reduced Sulphur Compounds Annual Means in Ontario (1993 – 2002)



Note: Annual composite mean based on 10 ambient total reduced sulphur sites operated over 10 years.

Chapter 5 Air Quality Index, Smog Alerts and 2002 Smog Episodes

Air Quality Indices (AQI)

The Ministry of the Environment operates an extensive network of air quality monitoring sites across the province. In 2002, 36 of these sites, located in 23 urban centres and seven rural areas, formed the basis of the Air Quality Index (AQI) network. The Air Quality Office of the Environmental Monitoring and Reporting Branch continually obtains data for several criteria pollutants from these 36 sites.

The AQI network, shown in Figure 5.1, provides the public with real-time air quality information from across the province. The AQI is based on pollutants that have adverse effects on human health and the environment. The pollutants are ozone (O_3), fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), and total reduced sulphur (TRS) compounds. At the end of each hour, the concentration of each pollutant measured at a particular site is converted into a number ranging from 1 upwards using a common scale or index. The calculated number for each pollutant is called a sub-index.

At a given site, the highest sub-index for any given hour becomes the AQI. The lower the index, the better the air quality. The index values, corresponding categories and potential health and environmental effects, are shown in Table 5.1.

If the AQI value is below 32, the air quality is categorized as good. For AQI values in the 32–49 range (moderate category) there may be some adverse effects on very sensitive people. For index values in the 50–99 range (poor category), the air quality may have adverse effects on sensitive members of human and animal populations, and may cause significant damage to vegetation and property. With an AQI value of 100 or more (very poor category), the air quality may have adverse effects for a large proportion of those exposed.

Computed air quality indices, or AQI values, and air quality forecasts are released daily to the public and news media at set intervals. The public can access the index values by calling the ministry's automatic telephone answering device (ATAD), English recording: 1-800-387-7768, or in Toronto, 416-246-0411, and French recording: 1-800-221-8852. The AQI values can also be obtained from the ministry's Web site: *www.airqualityontario.com*. Air quality forecasts, based on regional meteorological conditions and current pollution levels in Ontario and bordering U.S. states, are also provided daily on this Web site.

The new fine particulate matter ($PM_{2.5}$) sub-index and implications

During August 2002, the province of Ontario replaced the outdated suspended particles (SP) sub-index with the new $PM_{2.5}$ sub-index. The $PM_{2.5}$ sub-index provides a more accurate representation of Ontario's air and allows the public to make better decisions to protect their health. For 2002, re-computed AQI readings that included the $PM_{2.5}$ sub-index indicated good air quality just under 90 per cent of the time. As well, data show that a two-fold to three-fold increase in the number of hours the AQI exceeded 49 over that of previous years. Very poor AQI readings (due to $PM_{2.5}$) were recorded for the first time at a number of AQI sites in 2002 and were associated with smoke from forest fires in Quebec, which invaded southern and eastern Ontario on July 6 and 7, 2002.

Table 5.2 shows the percentage distribution of hourly AQI values for the 36 monitoring sites by the AQI descriptive category and the pollutant responsible for the AQI above 49. On average the AQI sites in 2002 reported air quality in the good and very good categories approximately 89 per cent of the time.

The $PM_{2.5}$ sub-index provides a more accurate representation of Ontario's air and allows the public to make better decisions to protect their health.

Figure 5.1: Air Quality Index Monitoring Sites in Ontario (2002)

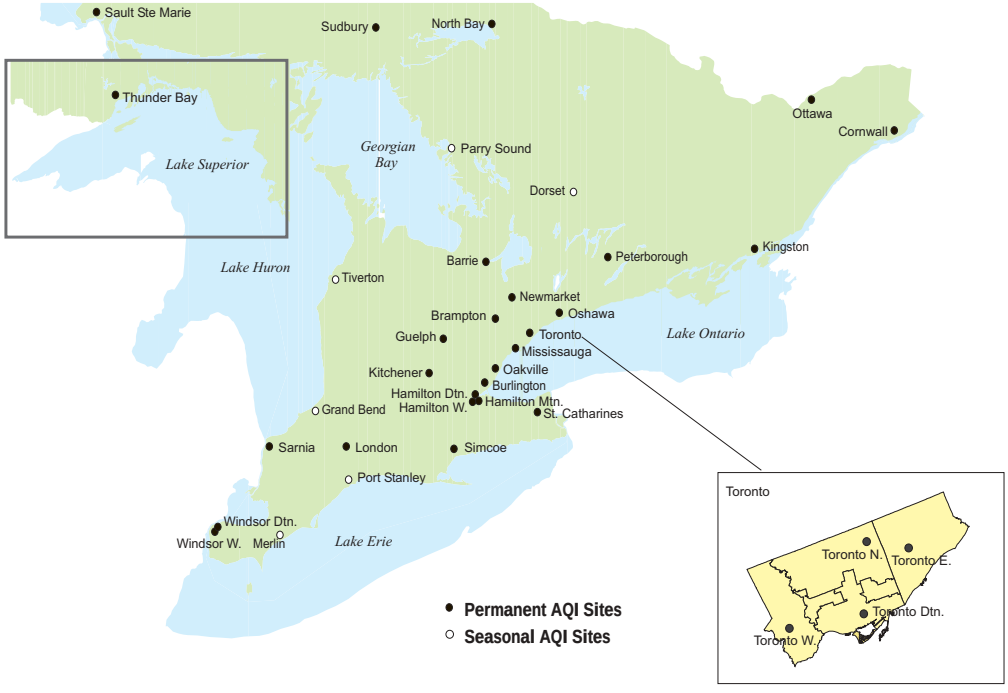


Table 5.1: Air Quality Index Pollutants and their Impacts

Index	Category	Ozone (O_3)	Fine Particulate Matter ($PM_{2.5}$)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)	Sulphur Dioxide (SO_2)	Total Reduced Sulphur (TRS) Compounds
1–15	Very good	No known harmful effects	Sensitive populations may want to exercise caution	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects
16–31	Good	No known harmful effects	Sensitive populations may want to exercise caution	Slight odour	No known harmful effects	Damages some vegetation in combination with ozone	Slight odour
32–49	Moderate	Respiratory irritation in sensitive people during vigorous exercise; people with heart/lung disorders at some risk; damages very sensitive plants	People with respiratory disease at some risk	Odour	Blood chemistry changes, but no noticeable impairment	Damages some vegetation	Odour
50–99	Poor	Sensitive people may experience irritation when breathing and possible lung damage when physically active; people with heart/lung disorders at greater risk; damages some plants	People with respiratory disease should limit prolonged exertion; general population at some risk	Air smells and looks brown. Some increase in bronchial reactivity in people with asthma	Increased symptoms in smokers with heart disease	Odorous; increasing vegetation damage	Strong odour
100–over	Very poor	Serious respiratory effects, even during light physical activity; people with heart/lung disorders at high risk; more vegetation damage	Serious respiratory effects even during light physical activity; people with heart disease, the elderly and children at high risk; increased risk for general population	Increasing sensitivity for people with asthma and bronchitis	Increasing symptoms in non-smokers with heart diseases; blurred vision; some clumsiness	Increasing sensitivity for people with asthma and bronchitis	Severe odour; some people may experience nausea and headaches

Table 5.2: Air Quality Index Summary (2002)

Station ID	City/Town	Percentage of Valid Hours AQI in Range					Valid Hours	Percentage of Valid Hours Pollutant Responsible for AQI > 49						No. of Days At Least 1h AQI > 49
		Very Good	Good	Moderate	Poor	Very Poor								
		0-15	16-31	32-49	50-99	100+		O_3	$PM_{2.5}$	NO_2	CO	SO_2	TRS	
12008	Windsor Downtown	51.3	35.3	10.5	2.9	0	7338	2.0	< 1	0	0	0	x	30
12016	Windsor West	48.2	32.8	14.6	4.4	0	7292	2.2	1.4	0	x	0	0.7	47
13021	Merlin	47.7	40.5	9.6	2.1	0	6200	2.1	x	x	x	x	x	23
14064	Sarnia	34.3	48.6	14.6	2.6	0	7204	1.5	1.1	0	0	0	0	29
15020	Grand Bend	36.9	53.1	8.1	1.9	0	7034	1.9	x	x	x	x	x	22
15025	London	57.2	33.1	8.1	1.7	0	7226	1.7	x	0	0	0	x	21
16015	Port Stanley	26.3	50.2	17.4	6.1	0	4894	5.5	< 1	x	x	x	x	37
18007	Tiverton	20.1	64.5	13.5	1.9	0	6596	1.8	< 1	x	x	x	x	21
22071	Simcoe	27.5	56.3	14.0	2.3	0	8003	2.3	x	0	x	0	x	27
26060	Kitchener	40.6	46.7	11.2	1.5	0	7388	1.4	< 1	0	0	0	x	17
27067	St. Catharines	51.3	35.2	11.5	2.0	0	7392	1.3	< 1	0	0	0	x	24
28028	Guelph	32.7	56.6	9.5	1.3	0	8457	1.1	< 1	0	x	x	x	19
29000	Hamilton Downtown	44.5	39.7	13.9	1.8	0	7418	< 1	1.0	0	0	0	0	21
29114	Hamilton Mountain	42.1	43.3	12.7	1.9	0	7254	1.6	< 1	0	x	0	0	22
29118	Hamilton West	64.6	29.2	5.8	< 1	0	7339	< 1	x	0	0	0	0	10
31103	Toronto Downtown	47.1	42.1	9.1	1.6	< 1*	8738	< 1	1.0	0	0	0	x	24
33003	Toronto East	49.7	39.7	9.1	1.4	< 1*	8743	< 1	1.0	0	x	x	x	22
34020	Toronto North	41.6	46.7	10.1	1.5	< 1*	8722	1.1	< 1	0	x	x	x	23
35003	Toronto West	54.7	34.4	9.5	1.4	< 1*	8691	< 1	< 1	0	0	0	x	22
44008	Burlington	39.5	47.8	11.1	1.6	0	8693	< 1	< 1	0	0	0	x	30
44015	Oakville	52.6	38.1	8.2	1.1	0	7194	1.1	x	0	0	0	0	18
45025	Oshawa	39.4	50.1	8.8	1.7	< 1*	8664	< 1	1.3	0	x	x	x	24
46089	Brampton	37.5	52.3	9.2	1.0	< 1*	8742	< 1	< 1	0	0	0	x	16
46110	Mississauga	46.9	42.9	9.1	1.1	< 1*	8592	< 1	< 1	0	0	0	x	22
47045	Barrie	37.6	52.8	9.0	< 1	< 1*	8701	< 1	< 1	0	0	0	x	13
48006	Newmarket	25.3	61.8	11.2	1.7	< 1*	8739	1.3	< 1	0	0	0	x	26
49005	Parry Sound	26.9	57.1	14.8	1.1	0	4715	1.1	x	x	x	x	x	9
49010	Dorset	24.6	65.0	9.9	< 1	0	7951	< 1	< 1	0	x	x	x	9
51001	Ottawa	40.2	52.2	7.1	< 1	< 1*	8078	< 1	< 1	0	0	0	x	5
52020	Kingston	55.1	37.9	6.0	< 1	0	7404	< 1	x	x	x	x	x	16
56051	Cornwall	47.8	46.5	5.5	< 1	0	7114	< 1	x	x	x	0	0	3
59006	Peterborough	29.2	60.5	8.7	1.5	< 1*	8719	1.2	< 1	0	0	0	x	26
63200	Thunder Bay	43.1	52.4	4.0	< 1	< 1**	7396	0	< 1	0	0	0	0	8
71068	Sault Ste. Marie	34.8	55.6	8.3	1.3	0	7281	< 1	1.3	0	x	0	0	21
75010	North Bay	34.5	58.1	7.0	< 1	0	8717	< 1	< 1	0	x	x	x	6
77203	Sudbury	33.3	61.7	4.9	< 1	0	8569	< 1	x	0	0	0	0	4

* very poor hour(s) was a result of a $PM_{2.5}$ episode due to the Quebec forest fires on July 6 and 7, 2002.

** very poor hour(s) was a result of a $PM_{2.5}$ episode due to a local forest fire on June 6 and 7, 2002.

x - Pollutant not measured

Figure 5.2: Air Quality Index Summary (2002)

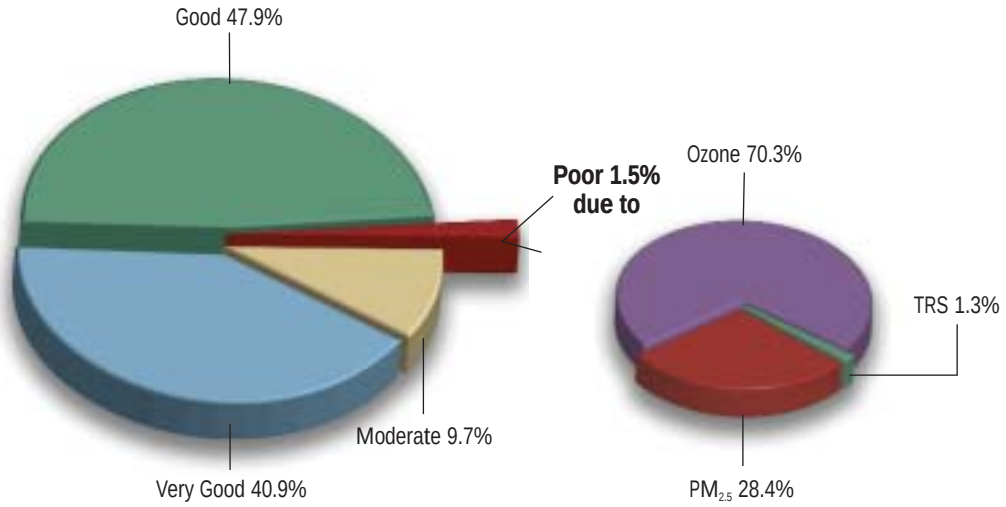


Figure 5.2 shows the composite pie diagrams of the percentages of very good, good, moderate and poor air quality recorded at sites across the province. The pie diagram on the left shows category percentages. The diagram on the right breaks down the poor air quality slice into percentages of pollutants associated with the AQI above 49. Ozone accounted for 70.3 per cent of the number of poor air quality hours recorded during 2002 at the AQI sites and $PM_{2.5}$ accounted for 28.4 per cent. Total reduced sulphur compounds accounted for 1.3 per cent of the poor air quality values.

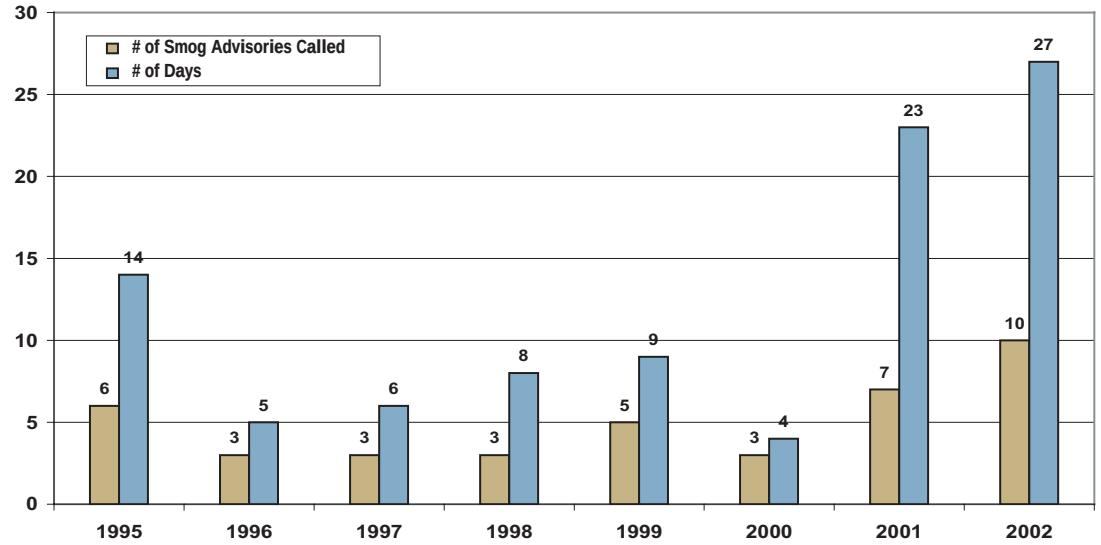
Air Pollution Index (API)

The Air Pollution Index (API) continues to be the basis of an alert and control system to warn of deteriorating air quality. The Ontario Environmental Protection Act (1971) authorizes the Minister of the Environment to order any source not essential to public health or safety to curtail or cease its operations when air pollution levels occur that may be injurious to health. The API is derived from 24-hour running averages of SO_2 and SP as measured by the co-efficient of haze (COH).

If the API reaches a value of 32 (designated as an Air Advisory Level) and adverse atmospheric conditions are expected for at least six hours, owners of sources of air pollution may be ordered to make preparations for curtailment of such operations. The First Air Pollution Alert Level is reached if the index reaches 50. A second alert is issued at an API of 75 and further curtailment may be ordered. The Air Pollution Episode Level occurs at an API of 100, and owners of all sources not essential to public safety may be ordered to cease operations.

In 2002, the advisory level was not reached at any of the API sites across the province. This was also true for 1998 to 2001. The last time the API reached the advisory level was in 1997; a reading of 34 was recorded at the Windsor West site. The last time the First Alert Level was reached in the province was in 1984 when an API level of 50 was recorded at the Toronto Downtown site.

Figure 5.3: Summary of Smog Advisories Issued (1995 – 2002)



Smog alert program

The ministry began issuing smog advisories in 1993 under the Air Quality Advisory program. The program was revised in 1995, and then expanded to the Smog Alert program in 2000. The program is a joint effort between the Ontario Ministry of the Environment and Environment Canada. Smog advisories are issued to the public when widespread, elevated and persistent ground-level ozone concentrations and/or $PM_{2.5}$ (AQI in poor category) are forecast to occur within the next 24 hours. The smog advisory program covers southern, eastern and central Ontario where ozone levels typically exceed the one-hour AAQC of 80 ppb and $PM_{2.5}$ levels are most likely to exceed the 45 µg/m^3 three hour running average.

Air quality initiative and enhanced smog alert program

As mentioned earlier, on May 1, 2000, Ontario's enhanced Smog Alert and Air Quality Index (AQI) program was implemented. This enhanced program provides Ontarians with improved reporting through comprehensive and timely air quality readings and forecasts.

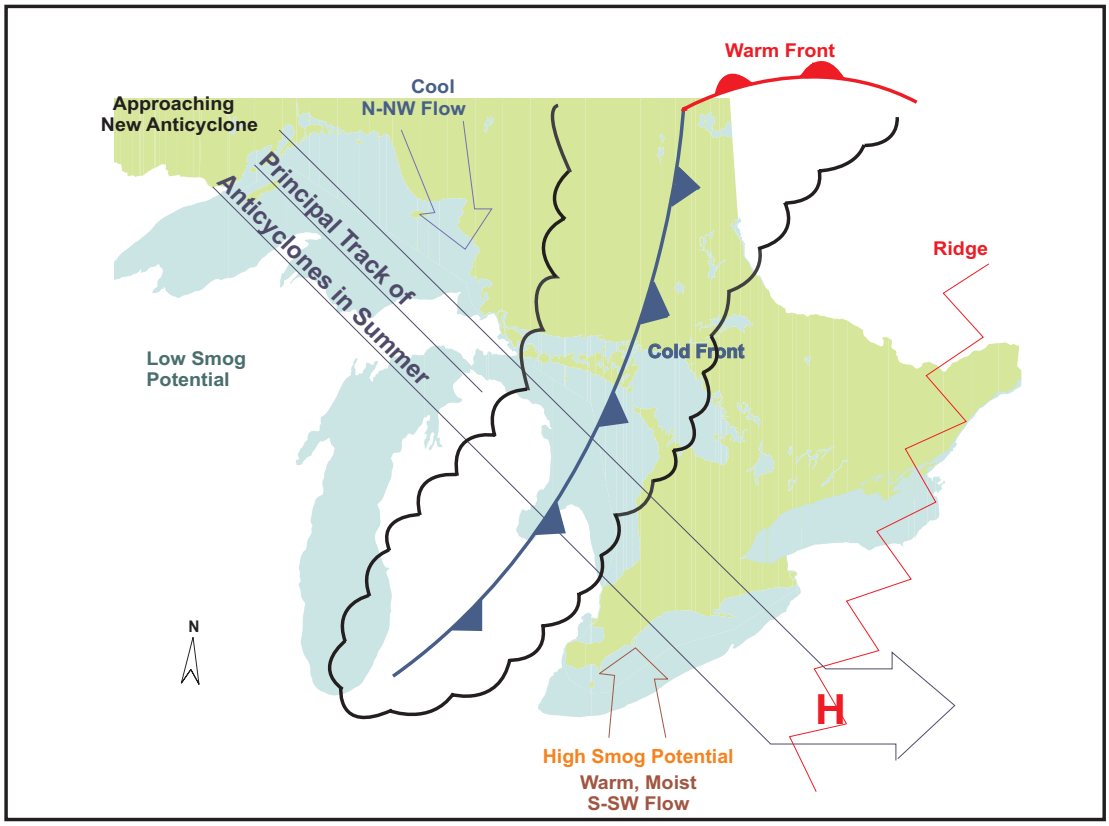
The air quality Ontario initiative includes:

- A two-level air quality forecast that provides a three-day outlook known as a smog watch, in addition to the current 24-hour smog advisory;
- A Smog Watch is called when there is a 50 per cent chance that a smog day is forecast within the next three days;
- A Smog Advisory is called when there is a strong likelihood that a smog day is forecast within the next 24 hours;
- If widespread, elevated smog levels occur without warning and weather conditions conducive to the persistence of such levels are forecast to continue for at least six hours, then a smog advisory is issued immediately;
- A public Web site, *www.airqualityontario.com*, where current AQI readings, smog forecasts and other air quality information are available;

- Direct e-mails of smog alerts to anyone who subscribes to the ministry's smog alert network at the above Web site;
- An increase in the number of AQI sites to include rural Ontario impacted by trans-boundary smog; and
- Toll-free numbers by which anyone at anytime can get updated information on the air quality (1-800-387-7768 in English and 1-800-221-8852 in French).

For the 2002 smog season, Ontarians experienced the greatest number of smog advisory days since the inception of the Smog Advisory program (Figure 5.3). Compared to 2001, the number of smog advisory days in 2002 increased in southwestern Ontario (e.g. 23 to 25 in Windsor) and actually decreased in central and eastern Ontario (e.g. 10 to 3 in Sudbury and 14 to 6 in Ottawa). The high number of smog advisory days was mainly attributed to a large number of hot days (23) recorded in the province during 2002 and also to meteorological conditions favourable for the production of ozone and $PM_{2.5}$, and subsequent transboundary flow of polluted air into Ontario. Improved science and the enhancement of the smog alert program also affected the number of advisories issued. In contrast, the summer of 2000, which was cool and wet with only two hot days, had four smog advisory days for the province as a whole.

Figure 5.4: Generalized Synoptic Weather Pattern Over Southern Ontario Conducive to Elevated Pollutant Levels



Co-operative activities with Michigan

Since May 2000, during the smog season from May to September, air quality and meteorological discussions between Michigan and Ontario meteorologists are held twice per week or more frequently if there is potential for a smog advisory in Ontario or an ozone action day in Michigan. Although ozone action days in Michigan and smog advisories in Ontario are not linked to the same air quality standards, the weather conditions conducive to high levels of smog are often common to both airsheds.

2002 smog episodes

Smog episodes in Ontario are often a part of a regional weather condition that prevails over much of northeastern North America. For southern Ontario, it is a significant transboundary problem. Elevated levels of ozone and $PM_{2.5}$ are often due to weather patterns that affect the lower Great Lakes region. Figure 5.4 illustrates a generalized summer synoptic weather pattern over southern Ontario during high smog conditions. This results in the long-range transport of smog pollutants from neighbouring U.S. industrial and urbanized states during warm south to southwesterly air flow conditions.

Hot and dry conditions and the issuance of a record-breaking number of smog advisory days characterized the summer of 2002 across southern Ontario. Following normal temperatures in May for southern Ontario, temperatures for the core summer months (June, July and August) were generally warmer than normal. Most of the hot days in southern Ontario were recorded during the month of July. September temperatures were slightly warmer than normal in southwestern Ontario and near normal for the rest of southern Ontario. While precipitation in May was greater than normal, the Great Lakes/St. Lawrence climate region experienced less precipitation than normal for the summer.

There were 10 smog advisories for Ontario, covering 27 days in 2002. The advisories issued often covered large geographical areas and were of varying duration, from a one-day event on July 18, 2002 to a five-day event during the period August 10 to August 14. Of the 10 smog advisories issued, five were of two days or less. The first official smog advisory of the season was a two-day event, issued for June 9 and June 10. The last or tenth smog advisory of the season was issued for the period September 7 to 10 inclusive. This four-day event was the latest in the year that the ministry issued a smog advisory since the inception of the smog advisory program in 1993.

Following the addition of $PM_{2.5}$ to the AQI system on August 23, 2002, one major smog episode occurred: the four-day event from September 7 to 10. On September 7, a smog advisory was issued for southwestern Ontario as hot, sunny conditions with light southerly winds were expected to dominate the region resulting in elevated smog levels. The one-hour ozone criterion of 80 ppb was exceeded at seven AQI sites, mainly in the southwestern part of the province. The highest level, a one-hour value of 101 ppb, occurred at Port Stanley on the northern shores of Lake Erie. On September 8, elevated ozone levels became widespread encompassing 28 AQI sites in southern Ontario, across the GTA, downwind of Toronto, and over central Ontario. Maximum one-hour ozone levels were typically in the range 90 to 110 ppb, and the peak hourly ozone reading was 125 ppb recorded at Sarnia. Elevated ozone levels continued on September 9 and expanded to cover eastern Ontario. The one-hour ozone criterion was

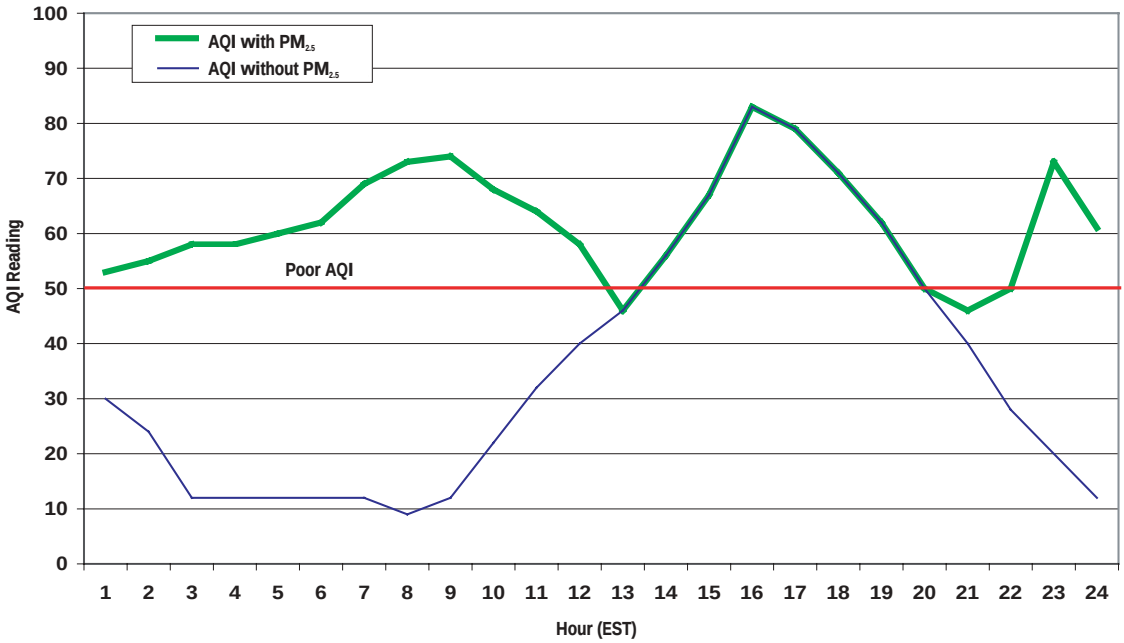
Hot and dry conditions and the issuance of a record-breaking number of smog advisory days characterized the summer of 2002 across southern Ontario.

exceeded at 33 of the 36 AQI sites with maximum one-hour ozone levels typically in the range 95 to 115 ppb. The peak hourly ozone reading on September 9 was 127 ppb, and this occurred at Windsor West. The smog episode came to an end the night of September 10 as a cold front moved southeastward across the region and pushed the polluted air out of the province. Fifteen sites exceeded the Ontario AAQC for ozone and the peak one-hour ozone level of 107 ppb was recorded at Port Stanley at this time.

The 24-hour $PM_{2.5}$ levels in the southwestern part of the province were in the 20 to 25 µg/m^3 range on September 7, increasing to 20 to 40 µg/m^3 across southern Ontario on September 8, and 30 to 50 µg/m^3 on September 9. On September 10, fine particulate matter levels across southern Ontario were in the 25 to 40 µg/m^3 range. This example confirms once again that both ozone and $PM_{2.5}$ levels are often elevated simultaneously during multi-day, summer smog episodes.

The AQI readings for Windsor West and downtown Toronto on September 9 are depicted in Figures 5.5 and 5.6, respectively. Ozone levels tend to have a strong diurnal pattern, often peaking in the afternoon/evening. However, $PM_{2.5}$ levels show small variations throughout the day, with a small peak in the morning rush hour period and a small depression in the afternoon as the air near the ground becomes well mixed under strong daytime heating. Without $PM_{2.5}$ in the AQI system, very good to good air quality would have been reported throughout the morning of September 9 in both Windsor and

Figure 5.5: AQI Readings at Windsor West (September 9, 2002)

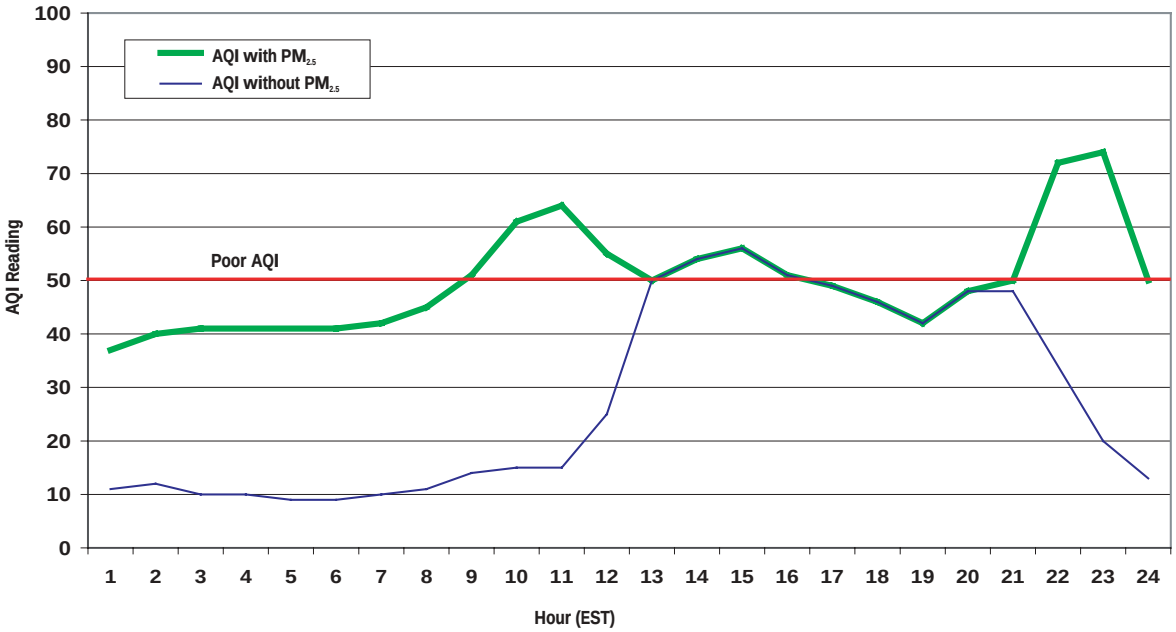


Toronto. Thus, the addition of $PM_{2.5}$ in the AQI system is allowing for better representation and reporting of ambient air quality. For this particular episode, smog levels remained elevated throughout the entire day.

The addition of $PM_{2.5}$ to the AQI system will also allow the ministry to capture and report on some of the rarer natural smog events such as elevated $PM_{2.5}$ concentrations from forest fires. For example, the unique northern Quebec forest fires in the summer of 2002 impacted vast areas of eastern North America including southern Ontario, some 900 km south, on July 6 and 7. Air quality readings of $PM_{2.5}$ during this smog episode were in the "very poor" range at a number of sites across southern and eastern Ontario, including the GTA, Peterborough and Ottawa.

For 2002, all the smog episodes (due to ozone and/or $PM_{2.5}$) occurred during the traditional summer smog season, May to September. There were no smog episodes outside of the traditional summer smog season. ■

Figure 5.6: AQI Readings at Downtown Toronto (September 9, 2002)



Chapter 6 Air Toxics – Selected VOCs

Characteristics, sources and effects

Certain volatile organic compounds (VOCs) warrant special concern because they play an important role in the formation of ground-level ozone and $PM_{2.5}$. Volatile organic compounds that contribute to the formation of ozone typically have a short life span in the atmosphere. In contrast, VOCs that are least reactive to ozone formation are capable of being transported very long distances and do not break down in the troposphere.

Volatile organic compounds are emitted into the atmosphere from a variety of anthropogenic sources, including vehicles, fossil fuel combustion, steel-making, petroleum refining, fuel-refilling, industrial and residential solvent use, paint application, manufacturing of synthetic materials (e.g. plastics, carpets), food processing, agricultural activities and wood processing and burning. Specialized, non-routine monitoring and analytical techniques are required to measure VOCs because they are usually present in the atmosphere in a gaseous form at ultra-trace concentrations.

VOC monitoring

Volatile organic compound samples are collected by automatically drawing ambient air into empty stainless steel canisters over a 24-hour period (midnight to midnight), following the National Air Pollution Surveillance (NAPS) sampling schedule (every sixth day) for urban sites. Volatile organic compound samples at rural sites are usually collected every three days from 12:00 to 16:00 EST. Concentrations for 143 selected VOCs are reported for each sample. The list of 143 selected VOCs and their statistics appear in the separate Appendix document.

For purposes of this report, data from 1993 to 2002 for eight ambient monitoring stations (Windsor, Sarnia, Longwoods, Hamilton, Simcoe, Egbert, Stouffville and Ottawa) are included in this discussion. The monitoring sites described in this report are displayed in Figure 6.1. Data from these sites are provided by Environment Canada as part of a co-operative federal-provincial program under NAPS.

Benzene, toluene and *o*-xylene

Benzene is a volatile aromatic hydrocarbon, primarily used in the production of plastics and other chemical products. Large quantities of benzene are obtained from petroleum, either by direct extraction from certain types of crude oils or by chemical treatment of gasoline. Benzene is classified as a human carcinogen.

Toluene is an aromatic hydrocarbon that is used to make chemicals, explosives, dyes and many other compounds. It is used as a solvent for inks, paints, lacquers, resins, cleaners, glues and adhesives. Toluene is found in gasoline and aviation fuel. Studies reveal that toluene affects the central nervous system of humans and animals; however, there is little evidence to classify it as a carcinogen.

Like benzene and toluene, *o*-xylene is an aromatic hydrocarbon. It is released directly into the atmosphere by manufacturers of motor vehicles and equipment, manufacturers of metal cans and shipping containers, and oil refining. Sources of *o*-xylene, as a result of human activity, include oil refining, motor vehicles, wood-burning stoves and fireplaces, whereas natural sources include coal tar, oil, forest fires and plant volatiles. *O*-xylene affects the central nervous system as a depressant. It has not been classified as a carcinogen.

Motor vehicle exhaust is the major source of benzene, toluene and *o*-xylene in Ontario. These compounds are very reactive in forming ground-level ozone and $PM_{2.5}$. Figure 6.2 shows trends of benzene, toluene, and *o*-xylene for the period from 1993 to 2002. All three VOCs show a decreasing trend over the 10-year period. The most significant decline was in *o*-xylene where the annual composite mean decreased by 63 per cent when comparing 1993 to 2002.

1,1,1-trichloroethane, carbon tetrachloride and dichloromethane

Hydrocarbons that add or substitute one or more atoms of chlorine, bromine, fluorine or iodine, are halogenated compounds, such as 1,1,1-trichloroethane, carbon tetrachloride and dichloromethane. 1,1,1-trichloroethane is a colourless liquid with a sweet odour that evaporates quickly into a vapour. It is found in many common products such as glue, paint, industrial degreasers and aerosol sprays. Carbon tetrachloride is also a clear liquid but it is most often found as a colourless gas. It has a strong aromatic odour that can be detected at low levels. Carbon tetrachloride is produced for use in the manufacturing of refrigerants and propellants for aerosols. Dichloromethane, another colourless liquid with a sweet odour, is most commonly used as a paint remover. It is also used as a solvent and cleaning agent, a fumigant for strawberries and grains, and to extract substances from produce.

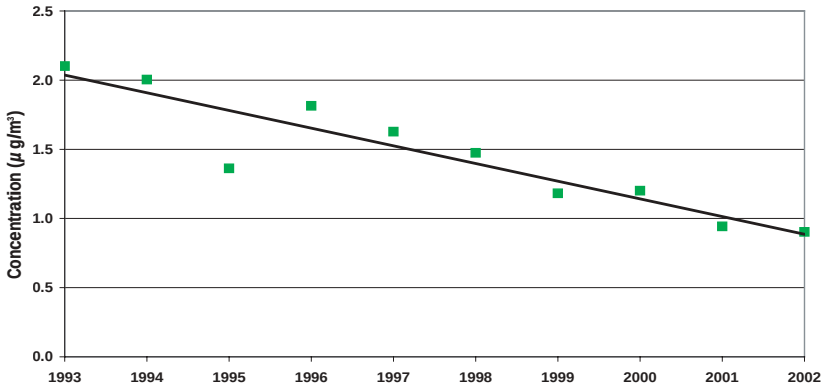
Figure 6.3 shows trends in 1,1,1-trichloroethane from 1994 to 2002, and carbon tetrachloride and dichloromethane for the period from 1993 to 2002. All three halogenated compounds show a decreasing trend over the multi-year periods. ■

Figure 6.1: Locations of Ambient VOC Monitoring Sites Across Ontario (2002)

Note: Data from these sites are provided by Environment Canada as part of the NAPS program.

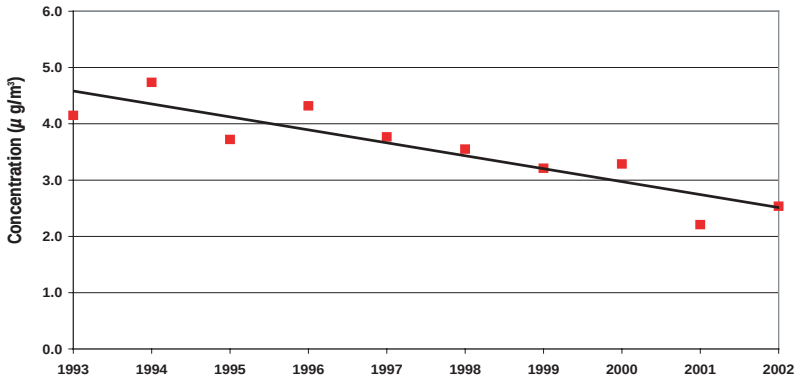
Figure 6.2: Trend of Benzene, Toluene and *O*-xylene Concentrations in Ontario (1993 – 2002)

a) Benzene



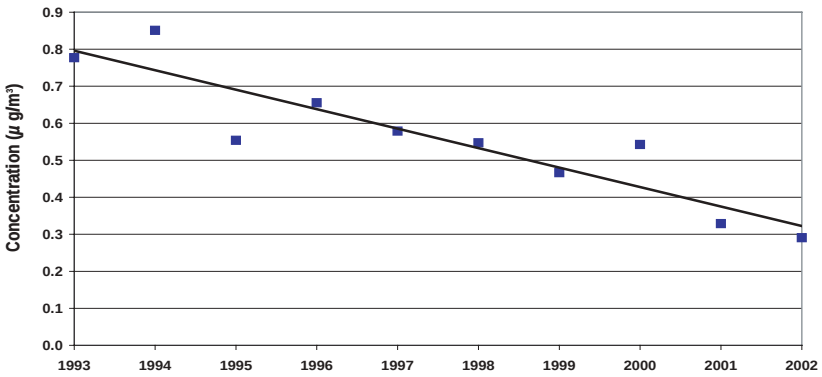
Note: Annual composite mean based on eight sites over ten years; data from these sites are provided by Environment Canada as part of the NAPS program.

b) Toluene



Note: Annual composite mean based on eight sites over ten years; data from these sites are provided by Environment Canada as part of the NAPS program.

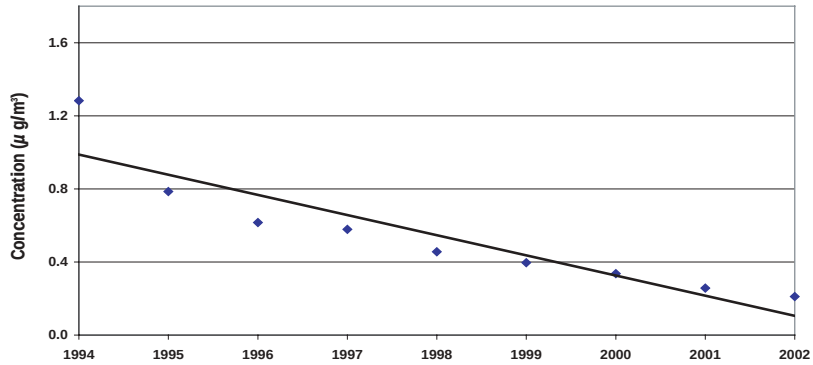
c) *O*-xylene



Note: Annual composite mean based on eight sites over ten years; data from these sites are provided by Environment Canada as part of the NAPS program.

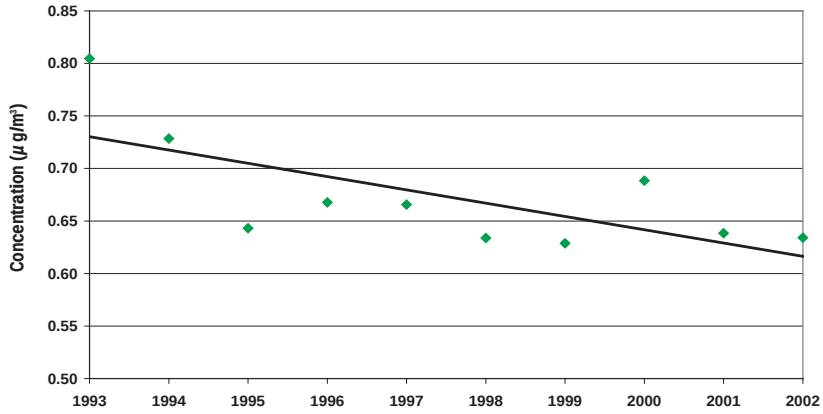
Figure 6.3: Trend of 1,1,1-Trichloroethane, Carbon Tetrachloride and Dichloromethane Concentrations in Ontario (1993 – 2002)*

a) 1,1,1-Trichloroethane



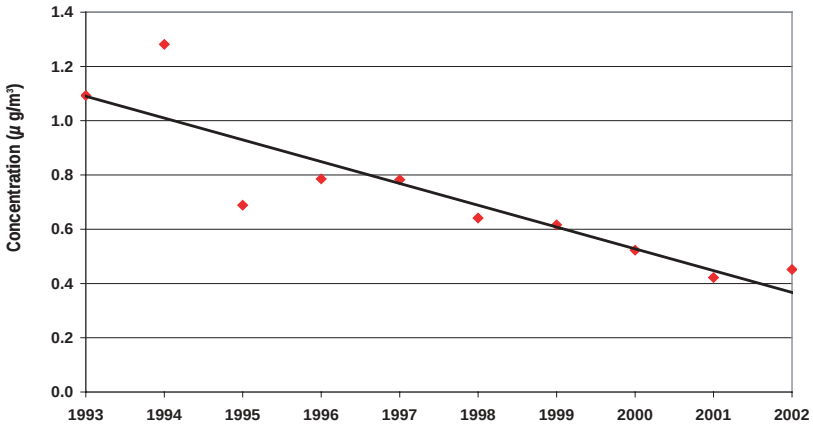
Note: Annual composite mean based on eight sites over ten years; data from these sites are provided by Environment Canada as part of the NAPS program.

b) Carbon Tetrachloride



Note: Annual composite mean based on eight sites over ten years; data from these sites are provided by Environment Canada as part of the NAPS program.

c) Dichloromethane



Note: Annual composite mean based on eight sites over ten years; data from these sites are provided by Environment Canada as part of the NAPS program.

** Data for 1,1,1-Trichloroethane is only available from 1994 to 2002.*

Glossary

Acidic deposition refers to deposition of a variety of acidic pollutants (acids or acid-forming substances such as sulphates and nitrates) on biota or land or in waters of the Earth's surface.

Air Quality Index real-time information system that provides the public with an indication of air quality in cities and towns across Ontario.

AQI station continuous monitoring station used to inform the public of air quality levels on a real-time basis; station reports on criteria pollutants.

Air Pollution Index basis of Ontario's alert and control system to warn of deteriorating air quality; derived from 24-hour running averages of sulphur dioxide and suspended particles.

Airshed a geographical region of influence or spatial extent of the air pollution burden.

Ambient air outdoor or open air.

Aromatic hydrocarbon a compound where the double-bond carbon atoms occur in a ring-type pattern

Carbon monoxide a colourless, odourless, tasteless and at high concentrations, a poisonous gas.

Carcinogen an agent that incites carcinoma (cancer) or other malignancy.

Continuous pollutant contaminant for which a continuous record exists; effectively, pollutants that have hourly data (maximum 8,760 values per year except leap year – i.e. 2000 where maximum values for the year are 8,784).

Continuous station — where pollutants are measured on a real-time basis and data determined hourly (for example ozone, sulphur dioxide).

Criterion — maximum concentration or level (based on potential effects) of contaminant that is desirable or considered acceptable in ambient air.

Detection limit — minimum concentration of a contaminant that can be determined.

Exceedance — violation of the pollutant levels permitted by environmental protection criteria.

Fine Particulate Matter — particles smaller than about 2.5 microns in diameter, which arise mainly from condensation of hot vapours and chemically-driven gas-to-particle conversion processes; also referred to as $PM_{2.5}$. These are fine enough to penetrate deep into the lungs and have the greatest effects on health.

Fossil fuels — natural gas, petroleum, coal and any form of solid, liquid or gaseous fuel derived from such materials for the purpose of generating heat.

Geometric mean — statistic of a data set calculated by taking the nth root of the product of all (n) values in a data set. Provides a better indication than arithmetic mean of the central tendency for a small data set with extreme values.

Global warming — long-term rise in the average temperature of the Earth; principally due to an increase in the build-up of carbon dioxide and other gases.

Ground-level ozone — colourless gas formed from chemical reactions between nitrogen oxides and hydrocarbons in the presence of sunlight near the Earth's surface.

Inhalable particles represent up to 60 per cent of the total suspended particulate matter; composed of both coarse (diameter 2.6 to 10.0 microns) and fine (diameter < 2.5 microns) particles; also referred to as PM_{10}.

Micron a millionth of a metre.

Median middle value of a set of numbers arranged in order of magnitude.

Nitrogen dioxide a reddish-brown gas with a pungent and irritating odour.

Ozone episode day a day on which widespread (hundreds of kilometres) elevated ozone levels (greater than 80 ppb maximum hourly concentration) occur simultaneously.

Particulate matter refers to all airborne finely divided solid or liquid material with an aerodynamic diameter smaller than 100 microns.

Percentile value percentage of the data set that lies below the stated value; if the 70 percentile value is 0.10 ppm, then 70 per cent of the data are equal to or below 0.10 ppm.

Photochemical oxidant air pollutants formed by the action of sunlight on oxides of nitrogen and VOCs.

Photochemical smog see *smog*.

Photochemical reaction chemical reaction influenced or initiated by light, particularly ultraviolet light.

Primary pollutant contaminant emitted directly to the atmosphere.

Secondary pollutant contaminant formed from other pollutants in the atmosphere.

Smog	a contraction of smoke and fog; colloquial term used for photochemical smog, which includes ozone and other contaminants; tends to be a brownish haze.
Smog advisory	smog advisories are issued to the public when there is a strong likelihood that widespread, elevated and persistent smog levels are expected.
Stratosphere	atmosphere 10 to 40 kilometres above the Earth's surface.
Stratospheric ozone	ozone formed in the stratosphere from the conversion of oxygen molecules by solar radiation; ozone found there absorbs much ultraviolet radiation and prevents it from reaching the Earth.
Sulphur dioxide	a colourless gas that smells like burnt matches.
Suspended particles	suspended particulate matter most likely to reach the lungs (diameter less than 25 microns).
Toxic deposition	absorption or adsorption of a toxic pollutant at ground, vegetative or surface levels.
Toxic pollutant	substance that can cause cancer, genetic mutations, organ damage, changes to the nervous system, or even physiological harm as a result of prolonged exposure, even to relatively small amounts.
Troposphere	atmospheric layer extending about 10 kilometres above the Earth's surface.

Abbreviations

AAQC	Ambient Air Quality Criteria (Ontario)
API	Air Pollution Index
AQI	Air Quality Index
ATAD	Automatic Telephone Answering Device
CCME	Canadian Council of Ministers of the Environment
CO	carbon monoxide
COH	coefficient of haze reported as SP
CWS	Canada-Wide Standard
EC	Environment Canada
EMRB	Environmental Monitoring and Reporting Branch
EST	Eastern Standard Time
GTA	Greater Toronto Area
Hg	mercury
MOE	Ministry of the Environment
NAAQS	National Ambient Air Quality Standard (U.S.)
NO	nitric oxide
NO_2	nitrogen dioxide
NO_X	nitrogen oxides
O_3	ozone
$PM_{2.5}$	fine particulate matter

SO_2	sulphur dioxide
SP	suspended particles
TEOM	Tapered Element Oscillating Microbalance
TRS	total reduced sulphur
US EPA	United States Environmental Protection Agency
VOCs	volatile organic compounds
kg	kilogram
ng/m^3	nanograms (of contaminant) per cubic metre (of air)
µg/m^3	micrograms (of contaminant) per cubic metre (of air)
ppb	parts (of contaminant) per billion (parts of air)
ppm	parts (of contaminant) per million (parts of air)

References

1. Benzene, Microsoft® Encarta® Online Encyclopedia, 2001, *http://encarta.msn.com*.
2. Brook, J.R., Dann,T. and Burnett, R.T., 1997: *The Relationship Among TSP, PM_{10}, $PM_{2.5}$ and Inorganic Constituents of Atmospheric Particulate Matter at Multiple Canadian Locations*. Journal of Air and Waste Management Association, Vol 46, pp. 2–18.
3. Burnett, R.T., Dales, R.E., Krewski, D., Vincent, R., Dann, T., and Brook, J.R., 1995: *Associations Between Ambient Particulate Sulphate and Admissions to Ontario Hospitals for Cardiac and Respiratory Diseases*. American Journal of Epidemiology, Vol 142, pp. 15–22.
4. Canadian Council of Ministers of the Environment, 2002. *Guidance Document on Achievement Determination: Canada-Wide Standards for Particulate Matter and Ozone.*
5. Environment Ontario, 2003. Air Quality in Ontario 2001 – *A Concise Report on the State of Air Quality in the Province of Ontario.*
6. Environment Ontario, 2003. *Air Quality in Ontario 2001 – Appendix*.
7. Fraser, D., Yap, D., Fudge, D., Misra, P.K. and Kiely, P. 1995. *A Preliminary Analysis of Recent Trends in Ground-Level Ozone Concentrations in Southern Ontario.* Presented at the 88th Air and Waste Management Association Annual Conference, San Antonio, Texas, June 1995.
8. Fraser, D., Yap, D., Kiely, P., De Brou, G., and *Dong, W. 1997. Daily and Continuous Monitoring of $PM_{10}/PM_{2.5}$ in Ontario.* Presented at the 90th Air and Waste Management Association Annual Conference, Toronto, Ontario, June 1997.
9. Fraser, D., Yap, D., Kiely, P. and Mignacca, D. 1991. *Analysis of Persistent Ozone Episodes in Southern Ontario 1980–1991*. Technology Transfer Conference, Toronto, 1991. Proceedings AP14, pp. 222–227.
10. Lin, C.C.-Y., Jacob, D.J., Munger, J.W., and Fiore, A.M. 2000. *Increasing Background Ozone in Surface Air Over the United States*. Geophysical Research Letters, Vol. 27 (21), pp. 3465–3468.
11. Lioy, P. et al., 1991. *Assessing Human Exposure to Airborne Pollutants*. Environmental Science and Technology, Vol. 25, pp. 1360.
12. Lipfert, F.W. and Hammerstrom, T. 1992. *Temporal Patterns in Air Pollution and Hospital Admissions*. Environmental Research, Vol. 59, pp. 374–399.
13. Lippmann, M. 1991. *Health Effects of Tropospheric Ozone*. Environmental Science and Technology, Vol. 25, No. 12, pp. 1954–1962.
14. Pengelly, L.D., Silverman, F. and Goldsmith, C.H. 1992. *Health Effects of Air Pollution Assessed Using Ontario Health Survey Data*. Urban Air Group, McMaster University.
15. *Rethinking the Ozone Problem in Urban and Regional Air Pollution*. National Academy Press, Washington, D.C., 1991.
16. *Toxic Air Pollution Handbook*. 1994. Edited by David R. Patrick. A&WMA.
17. Toluene. Canadian Centre for Occupational Health and Safety, *www.ccohs.ca/oshanswers/chemicals/chem_profiles/toluene/basic_tol.html*.
18. United States Environmental Protection Agency, *National Air Quality and Emission Trends, 1998*.

19. United States Environmental Protection Agency, *National Air Quality and Emission Trends, 1997*.

20. Wolff, G.T., Kelley, N.A. and Ferman, M.A., 1982. *Source Regions of Summertime Ozone and Haze Episodes in the Eastern U.S. Water,* Air and Soil Pollution, 18: pp. 65–81.

21. Written communication with T. Dann, Environmental Protection Service, Environment Canada, Ontario, Canada, 2003.

22. Written communication with G. Engler, Ohio Environmental Protection Agency, Ohio, United States of America, 2003.

23. Written communication with S. Haidinger, Wisconsin Department of Natural Resources, Bureau of Air Management, Wisconsin, United States of America.

24. Written communication with M. Heindorf, Michigan Department of Environmental Quality, Michigan, United States of America, 2003.

25. Written communication with B. Swinford, Illinois Environmental Protection Agency, Illinois, United States of America, 2003.

26. Written communication with R. Twadell, New York State Department of Environmental Conservation, New York, United States of America, 2003.

27. Yap, D., Fraser, D., Kiely, P., Bitzos, M., Dempsey, F., De Brou, G. 2003. *Data Analysis of Real-time $PM_{2.5}$ Measurements in Ontario.* Presented at the 96th Air and Waste Management Association Annual Conference, San Diego, California, June 2003.

28. Yap, D., Fraser, D., Kiely, P. and De Brou, G. 1998. *Preliminary Data Analysis of Real-Time and Daily PM_{10}/$PM_{2.5}$ Monitoring Networks in Ontario.* AWMA paper, 91st Annual Conference, San Diego, June 1998.

29. Yap, D., Fraser , D., Kiely, P., De Brou, G. and Dong, W. 1997. *The Role of Trans-boundary Flow on 1995 Ozone Levels in Ontario.* Presented at the 90th Air and Waste Management Association Annual Conference, Toronto, Ontario, June 1997.

30. Yap, D., Ning, D.T. and Dong, W., 1988. *An Assessment of Source Contribution to the Ozone Concentrations in Southern Ontario.* Atmospheric Environment, Vol. 22, No. 6, pp. 1161–1168.