# Canadian Environmental Sustainability Indicators 2006

## Air Quality Indicators

### Data Sources and Methods

July, 2007

Environment Canada
Statistics Canada
Health Canada

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# 1. Introduction

Canadians' health and their social and economic well-being are fundamentally linked to the quality of their environment. Recognizing this, in 2004, the Government of Canada committed to establishing national indicators of air quality, greenhouse gas emissions, and freshwater quality. The goal of these indicators is to provide Canadians with more regular and reliable information on the state of their environment and how it is linked with human activities. Environment Canada, Statistics Canada, and Health Canada are working together to further develop and communicate these indicators. Reflecting the joint responsibility for environmental management in Canada, this effort has benefited from the cooperation and input of the provinces and territories.

This report is part of a suite of documents released under the Canadian Environmental Sustainability Indicators (CESI) initiative.[1] Each indicator reported in a given year under CESI has an associated "data sources and methods" report to provide technical detail and other background that will facilitate interpretation of each indicator or allow others to conduct further analysis using the CESI data and methods as a starting point.

This report deals with the underlying methods and data for the air quality indicators, as published in the 2006 CESI report.

# 2. Description of the indicators

Poor air quality has significant negative effects on the natural environment, human health, and productivity. Human exposure to ground-level ozone and fine particulate matter ($PM_{2.5}$) is of particular concern because there are no established threshold concentrations below which these pollutants are safe and do not pose a risk to human health. The 2006 CESI air quality indicators estimate the potential burden on Canadians of exposure to ground-level ozone and $PM_{2.5}$. These pollutants are key components of smog and are among the most common and harmful outdoor air pollutants.

The air quality indicators are population-weighted estimates based on warm-season (April 1–September 30) average concentrations of ground-level ozone and $PM_{2.5.}$ The ground-level ozone indicator is based on the highest 8-hour daily average concentrations, while the $PM_{2.5}$ indicator is based on the 24-hour average daily concentration.

The indicators are not driven solely by maximum or peak observations. They are designed to reflect longer term potential health impacts attributed to ground-level ozone and $PM_{2.5}$ concentrations. The indicators are population-weighted and reported with the assumption that ground-level ozone and $PM_{2.5}$ concentrations are homogeneous within a radius of 40 km of each monitoring station.

# 3. How the indicators are used

The CESI initiative aims to provide Canadians with more regular and reliable information on the state of Canada's environment and related impacts of human activities. The CESI air quality indicators are developed and designed to estimate the average burden on Canadians of exposure to ground-level ozone and $PM_{2.5}$ over time. They are intended as state/condition indicators to inform policy analysts and decision makers as to whether progress is being made towards

1. http://www.environmentandresources.gc.ca/indicators and www.statcan.ca

improved air quality, in terms of reduced burden of population exposure to ground-level ozone and $PM_{2.5}$ over the longer term.

# 4. How the indicators are calculated

**Calculating the daily maximum 8-hour average concentration for ground-level ozone**
There are 24 possible 8-hour averages (8-hour rolls) that can be calculated for each day. The daily maximum 8-hour average concentration for a given day is the highest of the 24 possible 8-hour averages computed for that day. See Text table 1 for an illustration of the 8-hour averages.

**Calculating the warm-season average value for ground-level ozone**
The warm-season average value for a given ground-level ozone monitor is the average of the highest daily maximum 8-hour average concentrations during the period from April 1 to September 30. It is during these six months of the year that ground-level ozone levels are typically higher.

**Calculating the 24-hour average concentration for $PM_{2.5}$**
The air quality indicator for $PM_{2.5}$ is calculated in exactly the same way as the ground-level ozone indicator, but uses a single roll—a 24-hour average concentration. A daily value for $PM_{2.5}$ refers to the 24-hour average concentration of $PM_{2.5}$ measured from midnight to midnight.

**Calculating the warm-season average value for $PM_{2.5}$**
The warm-season average value for a given $PM_{2.5}$ monitor is the average of the 24-hour average daily concentrations during the period from April 1 to September 30.

**Text table 1 Graphic description of calculation of ground-level ozone maximum eight-hour average for each day (parts per billion)**

| Day | Hour | Hourly data (ppb) | 8-hour moving average (ppb) | Daily maximum (ppb) |
|---|---|---|---|---|
| 1 | 12 AM | 44 | | |
| | 1 AM | 45 | | |
| | 2 AM | 46 | | |
| | 3 AM | 47 | | |
| | 4 AM | 47 | | |
| | 5 AM | 47 | | |
| | 6 AM | 46 | | |
| | 7 AM | 44 | 46 | |
| | 8 AM | 41 | 45 | |
| | 9 AM | 36 | 44 | |
| | 10 AM | 34 | 43 | |
| | 11 AM | 33 | 41 | |
| | 12 PM | 35 | 40 | |
| | 1 PM | 33 | 38 | |
| | 2 PM | 30 | 36 | |
| | 3 PM | 29 | 34 | |
| | 4 PM | 29 | 32 | |
| | 5 PM | 32 | 32 | 46 |
| | 6 PM | 33 | 32 | |
| | 7 PM | 32 | 32 | |
| | 8 PM | 32 | 31 | |
| | 9 PM | 34 | 31 | |
| | 10 PM | 32 | 32 | |
| | 11 PM | 30 | 32 | |
| 2 | 12 AM | 31 | 32 | |
| | 1 AM | 35 | 32 | |
| | 2 AM | 36 | 33 | |
| | 3 AM | 35 | 33 | |
| | 4 AM | 34 | 33 | |
| | 5 AM | 32 | 33 | |
| | 6 AM | 30 | 33 | |

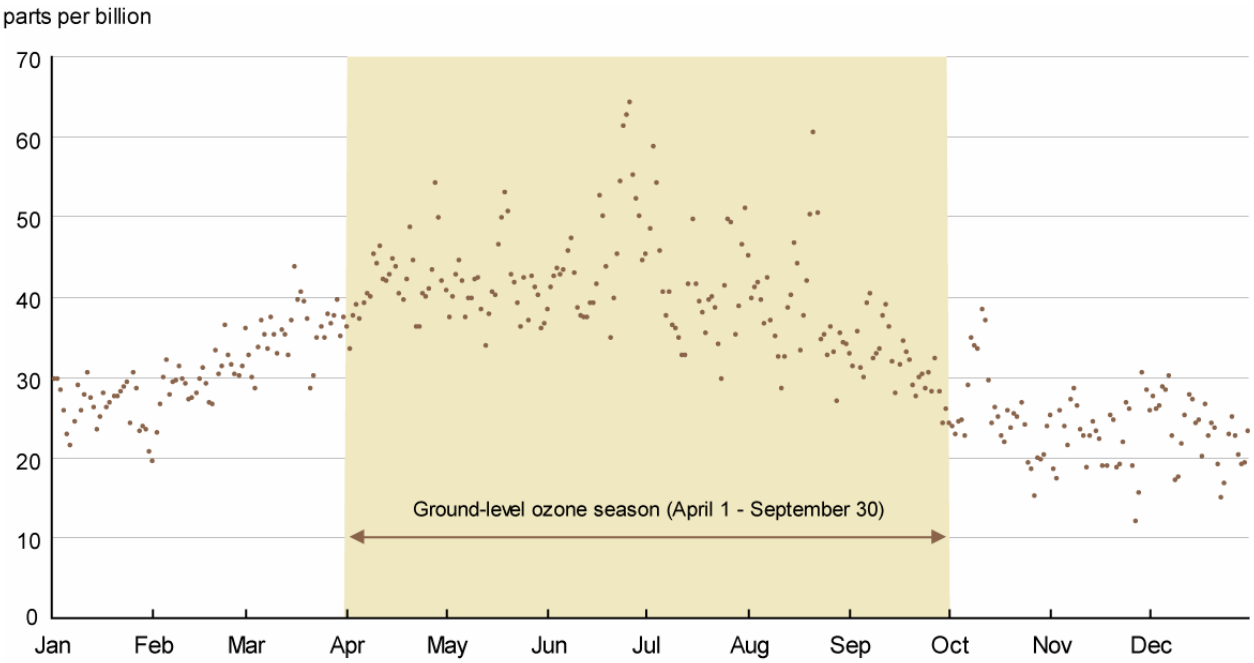
## *4.1 Daily averages*

Since the adverse health effects of air pollution can occur even at low levels of exposure, especially for ground-level ozone and $PM_{2.5}$, the air quality indicators are based on daily average concentrations rather than on the daily highest or peak concentrations. Over the course of a year, peak concentrations constitute a small minority of occurrences, while average values more comprehensively reflect Canadians' day-to-day exposure to air pollutants.

## 4.2 Time period

The air quality indicators consider daily ground-level ozone and $PM_{2.5}$ concentrations during the warm season (April 1–September 30), which is also the same time as Canadians are most active outdoors.[2] These months tend to have meteorological conditions that favour the formation of ground-level ozone. Figure 1 shows an example of a seasonal pattern for ground-level ozone concentrations in a typical year. While winter PM is a concern, current monitoring methods present challenges with instrument variability in cold weather; warm-season $PM_{2.5}$ data are, therefore, used in the 2006 CESI report.

**Figure 1 Daily maximum 8-hour average ground-level ozone levels, mean of 79 monitoring stations across Canada**




Note: This is not population-weighted.
Source: Environment Canada, National Air Pollution Surveillance Network Database

2. Leech, J.A., W.C. Nelson, R.T. Burnett, S. Aaron, and M. Raizenne. 2002. "It's about time: a comparison of Canadian and American time-activity patterns." *Journal of Exposure Analysis and Environmental Epidemiology*, 12: 427–432.

## 4.3 Population weighting

In the 2005 and 2006 CESI reports the air quality indicators were calculated using population-weighted monitoring station data. Population weighting is necessary because National Air Pollution Surveillance (NAPS) network monitoring stations tend to be located in more populated (urban) areas, but the stations are not located in direct proportion to the total population in each area. Hence proportionally adjusting for population exposure through population weighting provides a more relevant estimate of the potential human exposure to ground-level ozone and $PM_{2.5}$.[3]

The population-weighted concentration was calculated by estimating the number of people living within a 40-km radius of each monitoring station, hence assigning each monitoring station a weight relative to its population (P). The population weighting concentration (P) was multiplied by the ambient levels (C) of ozone or $PM_{2.5}$ measured at that station (e.g., P*C). The products for each monitoring station were then added together and divided by the sum of the total population in all the circles (the sum of population counts of all the monitoring stations).

$$\text{Exposure indicator} = \frac{P_1{*}C_1 + P_2{*}C_2 + P_3{*}C_3 + \cdots P_n{*}C_n}{P_1 + P_2 + P_3 + \cdots P_n}$$

$P_n$ is the population within a 40-km radius of the monitoring station and $C_n$ is the ambient level of either ozone (for the *ozone indicator*) or $PM_{2.5}$ (for the *$PM_{2.5}$ indicator*) measured at monitoring station n. For ozone, the considered ambient level (C) is the daily maximum of all 8-hour average ozone levels in the day, and for $PM_{2.5}$ the considered ambient level is the daily 24-hour average (midnight to midnight) level.

Using this method results in more weight being assigned to ozone and $PM_{2.5}$ concentrations in more populated urban areas. Reducing the radius from 40 km to 20 km did not influence the relative weights and hence, the magnitude of the air quality indicators.

The population-weighted mean methodology of the CESI indicator closely aligns with the recommendation from the National Round Table on the Environment and the Economy (NRTEE) that the air quality indicator include a population dimension to the raw ambient air quality data available via the NAPS network.

**Estimating population weights**

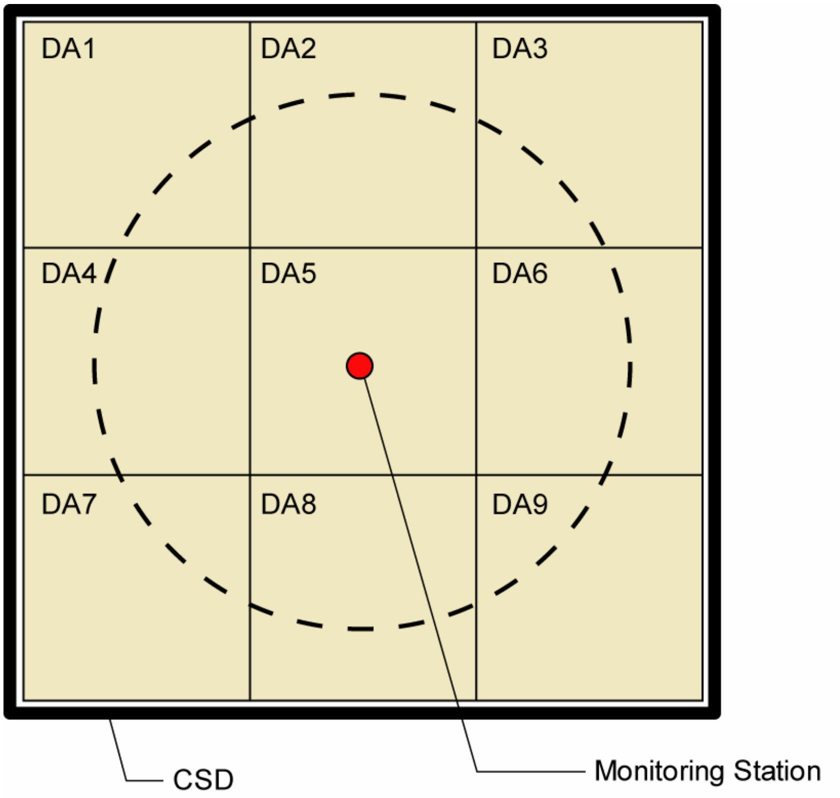
The estimation of population weights for each monitoring station relies on data from the Census of Population. Census data are only collected once every five years, known as census years. In non-census years, Statistics Canada generates estimates of yearly population in each census subdivision (CSD). There are some 5 600 CSDs that together cover the area of Canada. Each CSD is made up of several dissemination areas (DAs), the geographic areas consisting of neighbouring blocks with a population of 400–700 persons. In census years, the population of each DA is readily available in the Census of Population data. In non-census years the population of each DA is calculated by using the aforementioned estimated population of each corresponding CSD.

Since the boundaries of DAs do not always fit precisely with the boundaries of the 40-km radius circles around the monitoring stations used for the indicators, the population in each circle is

3. This approach is similar to and more general than the pilot method used for the National Round Table on the Environment and the Economy (2003) discussion paper on the Environment and Sustainable Development Indicators, prepared at Statistics Canada.

calculated based on the proportion of the area of DAs. Figure 2 presents a conceptual framework for estimating the population in a circle around a monitoring station.

**Figure 2  Conceptual diagram, estimating population weights for a monitoring station**




Note: The large square with a dark boundary line represents a census subdivision (CSD) containing nine dissemination areas (DA1 to DA9) presented as small squares. The dashed circle represents a circular area around a monitoring station. The contribution of each DA to the population in the “circle” is based on area-proportion, the percentage of the area of each DA that falls in the circle. For example, DA5 contributes all its population, while DA2 contributes approximately half of its population to the population of the circle. These DAs and their area-based percentages are constant throughout the entire timeframe used in the calculation of the population-weighted air quality indicators. However, the percentage contribution of each daughter DA to the population of its mother CSD changes once every census year, a five-year cycle. The proportion of population among the DAs of a CSD in a given census year was used to derive the population of the DAs in the following non-census years.

# 5. Data sources

Air quality monitoring stations are located across Canada and are managed by provinces, municipalities, territories and Environment Canada. Almost all stations collecting ground-level ozone and $PM_{2.5}$ data are organized under the National Air Pollution Surveillance (NAPS) program, a cooperative arrangement among the federal government, provinces and territories that has existed since 1970. The goal of the NAPS program is to provide accurate and long-term air quality data of a uniform standard throughout Canada. Data from the NAPS network are stored in the Canada-wide Air Quality Database and are published in annual air quality data summary reports.[4] The database also includes ground-level ozone data information from the Canadian Air and Precipitation Monitoring Network (CAPMoN), run by Environment Canada. The CAPMoN stations have been established for research purposes and to monitor air pollution outside of urban areas.

## *5.1 Physical monitoring techniques*

**Figure 3    An air quality monitoring station**

In 2004, the NAPS network consisted of 259 monitoring stations in communities across Canada. In total, the stations were equipped with 664 continuous monitors measuring ground-level ozone, particulate matter, sulphur dioxide, carbon monoxide, and nitrogen dioxide and 106 air samplers measuring components of particulate matter, various volatile organic compounds, and other toxic substances (Figure 3).

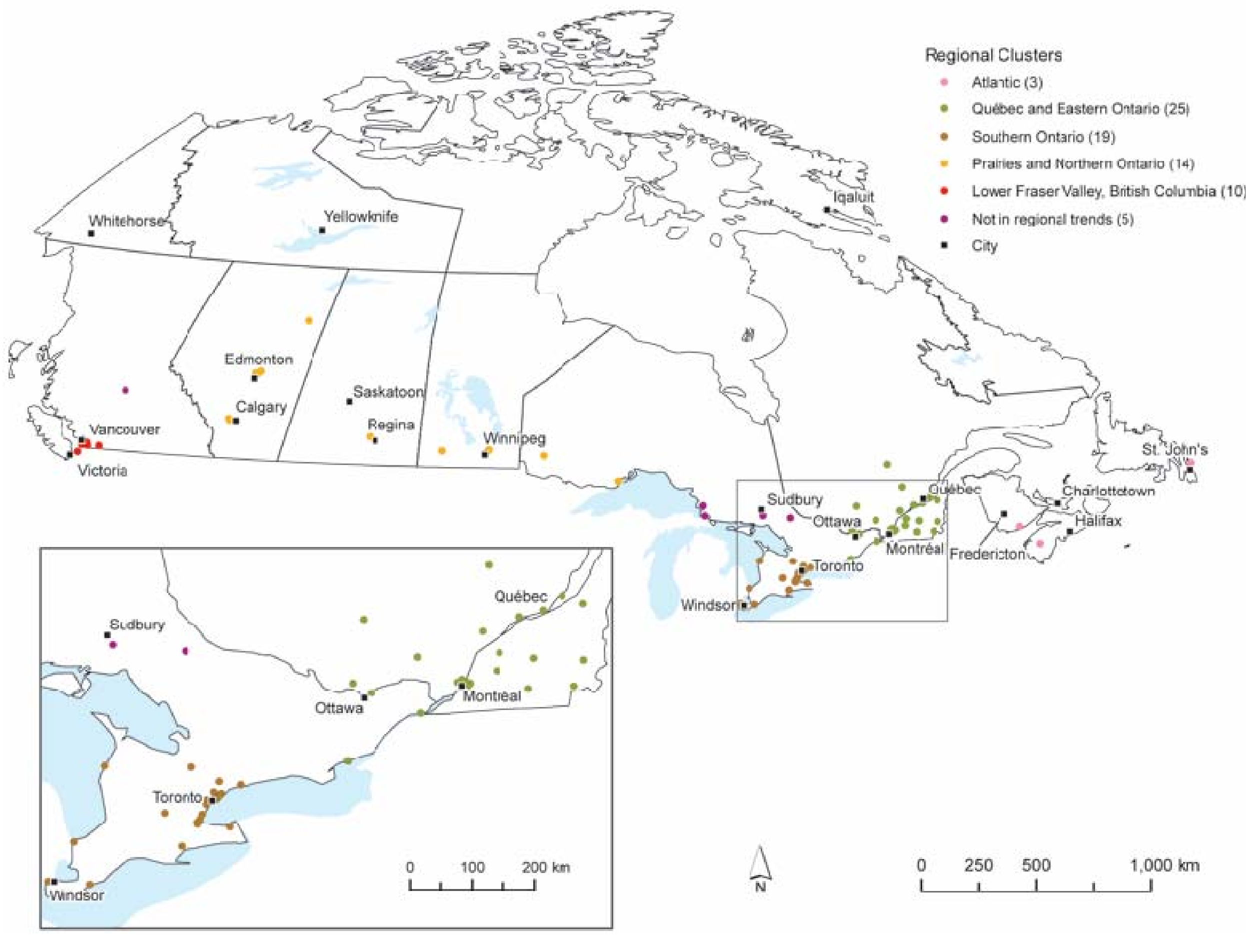
There are standards and procedures for the selection and positioning of stations and their sampling equipment. Probes for ground-level ozone and other pollutants, for example, are sited using a set of criteria for probe height, probe distance from roadways and stationary air emission sources, probe distance from airflow restrictions, and probe distance from trees.[5] Sampling methods are governed by standard operating practices and related quality assurance procedures. Ground-level ozone calibration standards used are certified by the United States National Institute of Standards and Technology.[6] The air analyzers that are used to sample ground-level ozone all satisfy the requirements of the U.S. Environmental Protection Agency.[7] Environment Canada has documented the processes for collecting and handling the data through the NAPS program.[8] Fine particulate matter is measured using Tapered Element Oscillating Micro-Balance (TEOM) continuous monitors.

4. www.etc-cte.ec.gc.ca/publications/napsreports_e.html
5. Environment Canada. 2004. *National Air Pollution Surveillance Network Quality Assurance and Quality Control Guidelines*. Analysis and Air Quality Division, Environmental Technology Centre, Environment Canada, Ottawa.
6. National Institute of Standards and Technology, USA; see Environment Canada. 2005. *National Air Pollution Surveillance (NAPS) Network—Annual Data Summary for 2003*. Ottawa (Report EPS 7/AP/37)
7. U.S. Environmental Protection Agency
8. www.etc-cte.ec.gc.ca/publications/naps/NAPSQAQC.pdf  Accessed April 2, 2006

## *5.2 Spatial coverage of data*

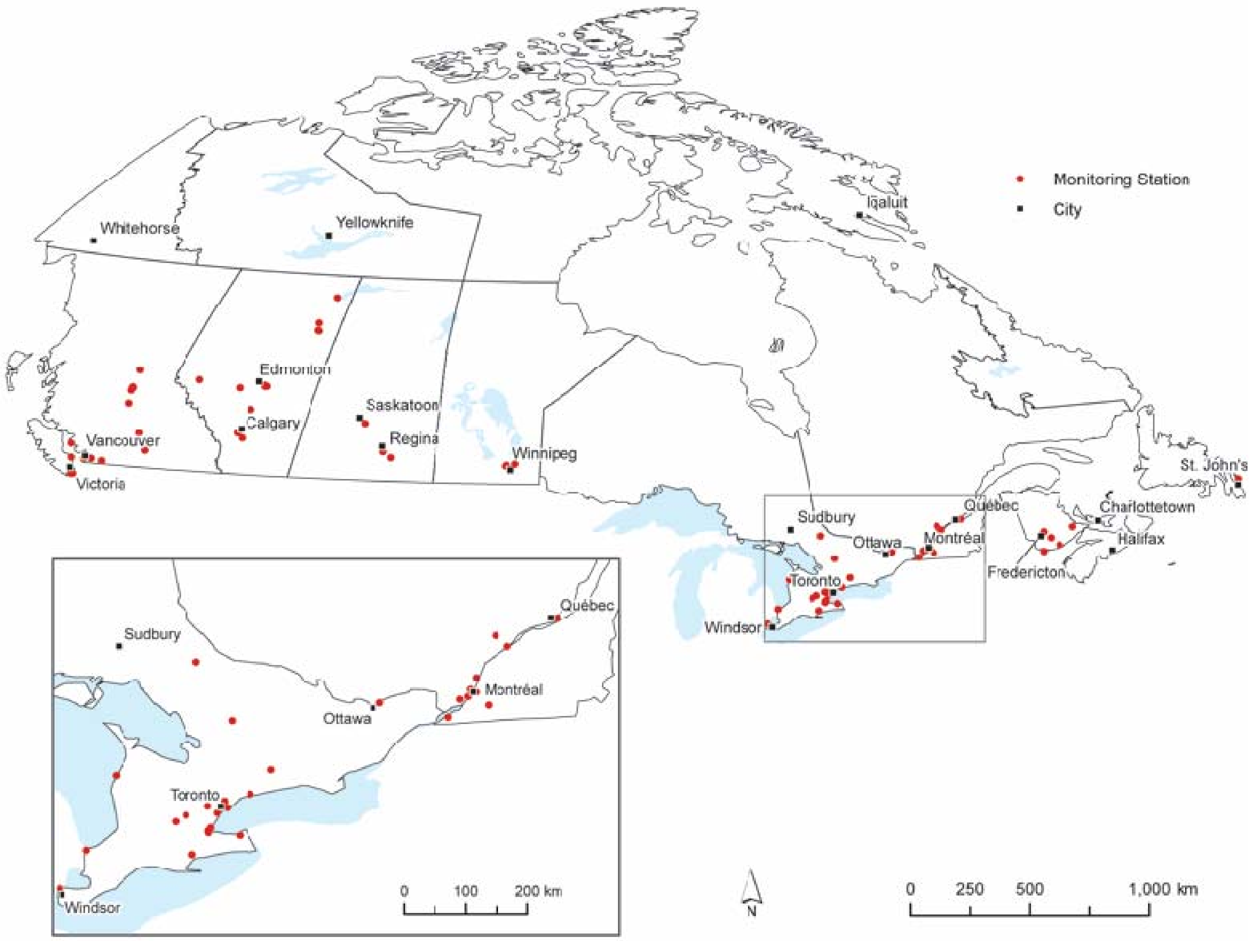
Air quality monitoring stations are spread across the country, but are concentrated more heavily in urban areas. The monitoring stations used in calculating the 2006 CESI air quality indicators cover almost 65 percent of Canada's population. As the NAPS network includes stations that have been established for differing needs, the spatial distribution of the network is not systematic. Each participating NAPS partner has prioritized and established its spatial coverage, networks and groupings of monitoring stations to track its own regional air quality conditions for urban and non-urban sites. Despite some differences in regional priorities in terms of spatial coverage, the NAPS network offers a representative national and regional coverage for ground-level ozone monitoring.

**Figure 4 Locations of monitoring stations used for ground-level ozone indicator trends**




Note: Number of monitoring stations is 76. Regional clusters were defined by Environment Canada.
Source: Environment Canada, National Air Pollution Surveillance Network Database, Statistics Canada, Environment Accounts and Statistics Division

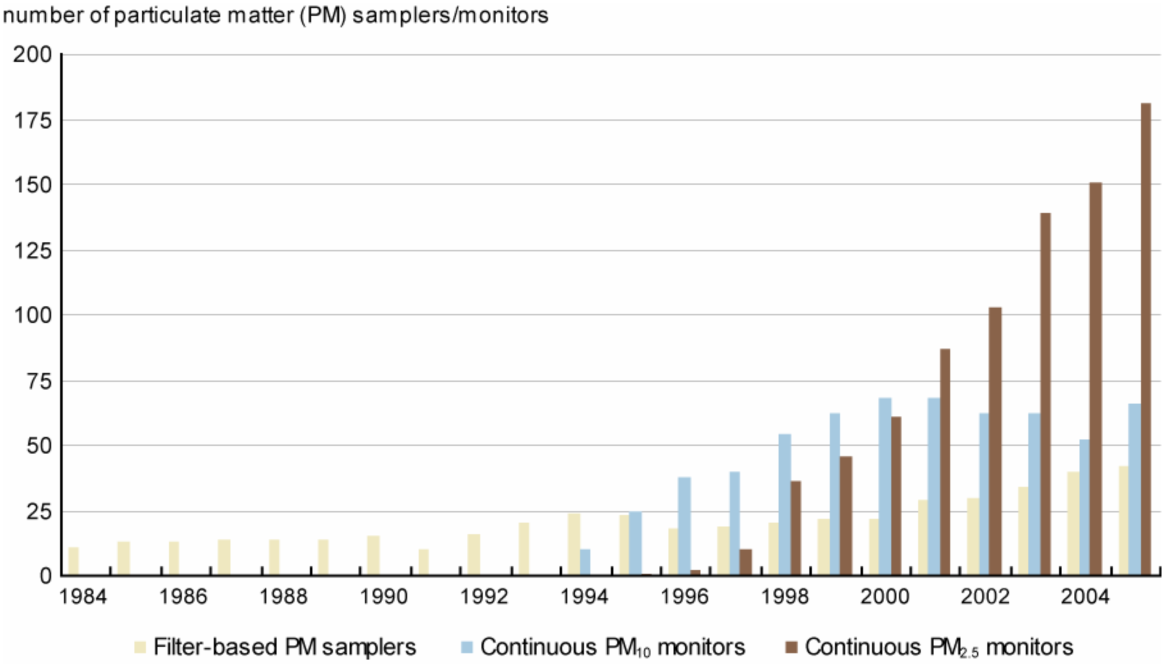
**Figure 5 Locations of monitoring stations used for $PM_{2.5}$ indicator trends**




Note: Number of monitoring stations is 63. Regional clusters were defined by Environment Canada.
Source: Environment Canada, National Air Pollution Surveillance Network Database, Statistics Canada, Environment Accounts and Statistics Division

With respect to $PM_{2.5}$, the number of monitoring sites with continuous monitors has been increasing since the year 2000, and data from these stations are used in the 2006 CESI report. The original manual filter-weighing sampling network that began in 1984 is kept in operation at over 40 sites across Canada for validation purposes, with no data provided to the 2006 CESI report. Figure 6 presents the growth in the number of particulate matter monitors across Canada.

**Figure 6  Growth in the number of particulate matter monitors, Canada**




Since monitoring stations are used to track multiple pollutants, their locations are not always ideal for ground-level ozone and/or $PM_{2.5}$ monitoring purposes. Some stations were placed in areas to measure the effects of stationary and/or mobile sources, including emissions from industrial plants and vehicular traffic. These stations do not represent the normal air quality for the general area. Four NAPS monitoring stations were not considered representative of the general air quality and the readings from those stations were excluded from the indicator calculations (Text table 2). Additional stations could have been excluded for similar reasons, but these did not meet the inclusion criteria for data completeness.

**Text table 2  The four monitoring stations that met the inclusion criteria but were not representative of the general air quality at their respective sites**

| Station (NAPS identification code and location) | Reason for exclusion |
|---|---|
| 50115, Montréal, Quebec | High levels of NOx scavenging |
| 60101, Ottawa, Ontario | High levels of NOx scavenging |
| 100112, Greater Vancouver Regional District, British Columbia | High levels of NOx scavenging |
| 91201, Hightower Ridge, Alberta | High elevation of the station |

Note: NOx is a term applied to the sum of nitric oxide and nitrogen dioxide (NO plus $NO_2$) as a chemical family. Reversible conversion of one of these oxides of nitrogen to the other is common in the atmosphere, in a reaction usually involving ground-level ozone. Operational networks actually measure NO and NOx, with $NO_2$ computed as a difference. At the low concentrations typical of rural areas, NOx makes a net positive contribution to photochemical ground-level ozone formation, but at the higher concentrations typical to urban centres the balance is shifted to ground-level ozone consumption, so that higher transportation emissions can decrease ground-level ozone locally. This phenomenon is referred to as NOx scavenging.

## 5.3 Data quality and completeness

Each of the organizations participating in the NAPS program forwards data to the Environmental Technology Centre at Environment Canada. Since the volume of data resulting from continuous measurements would be difficult to store and manage, only hourly average readings are recorded and transmitted.

Agencies contributing to the Canada-wide Air Quality Database perform routine audits, and all strive to adhere to established quality assurance and quality control standards. Environment Canada conducts a national audit program to ensure consistency between jurisdictions across Canada.

The possible measurement error for ground-level ozone concentrations at individual stations is conservatively estimated at ±10 percent.[9] The error for $PM_{2.5}$ is estimated at ±20 percent.[10] The stations do not all have the same time series of data available, nor have they all been operating continuously since 1990. There are a wide variety of reasons for this, including short-term technical problems, the commissioning or decommissioning of stations, and incomplete records from some stations. Short data gaps will have little effect on computed long-period averages or trends of concentrations at individual stations.

Text table 3 presents some of the general sets of specifications related to ground-level ozone and $PM_{2.5}$. More detail on $PM_{2.5}$ and ozone monitoring methods can be found in the Canada-wide standard monitoring protocol report.[11]

**Text table 3 Data quality objectives for ground-level ozone and $PM_{2.5}$**

| Parameter | Ozone | $PM_{2.5}$ |
|---|---|---|
| Accuracy | ±10% | ±20% |
| Precision | <10% | <10% |
| Completeness | >75% | >75% |
| Comparability | Traceable to primary standard | Reference method |
| Averaging period | Hourly | 24 hours |
| Measurement cycle | Year-round | Year-round |

The following criteria are used to determine the observations and the stations for inclusion in the air quality indicators calculation. They were divided into two sets: yearly criteria and time-series criteria. The latter include the criteria of the former.

Yearly criteria for ground-level ozone:

- Each eight-hour period must have data for at least six hours.
- Each day must have data for at least 18 hours.
- Each warm-season period (April 1 to September 30 = 183 days) must have data for at least 75 percent of the days (i.e., minimum of 138 days of data).

9. Halman, R. 2007 Personal communication from R. Halman (Environmental Science and Technology Centre, Environment Canada).
10. Dann, T. 2007 Personal communication from T. Dann (Environmental Science and Technology Centre, Environment Canada).
11. Canadian Council of Ministers of the Environment, “Ambient Air Monitoring Protocol for $PM_{2.5}$ and Ozone. Canada-wide Standards for Particulate Matter and Ozone”. Unpublished, accessed April 5, 2006.

Yearly criteria for $PM_{2.5}$

- Each day must have data for at least 18 hours.
- Each of the two quarters (April to June and July to September) must have data for at least 75 percent of the days (i.e., minimum of 69 days of data per quarter).

Time-series criteria for ground-level ozone and $PM_{2.5}$

- Stations must have yearly warm-season values for 75 percent or more of the years. For the 1990–2004 ozone time series, this means that at least 12 of the 15 years must have data that have satisfied the yearly criteria mentioned above. For the 2000–2004 $PM_{2.5}$ time series, this means that 4 of the 5 years of data are required.
- Stations missing more than two consecutive years at the start or end of the time series are excluded to avoid using data from stations commissioned or decommissioned during the beginning or end of the period.

As a result of applying these sets of data completeness and inclusion criteria on 255 ground-level ozone and 136 $PM_{2.5}$ monitoring stations, only 159 ground-level ozone and 117 $PM_{2.5}$ monitoring stations satisfied the 2004 yearly data requirements. Seventy-six (76) ground-level ozone and 63 $PM_{2.5}$ stations have satisfied the requirements of the time-series criteria and contributed data to the time-series trend analysis.

## *5.4 Timeliness*

There is a time lag of two years from the last day of a year's data collection (September 30) to when that year's indicator is published. This time lag is due to several intertwining factors including the link of the air indicators with other environmental sustainability indicators, raw data verification, compilation at the national level from all partners, analysis, review, and reporting. The data used in this report were subject to quality assurance and quality control procedures to ensure that they adhere to Environment Canada's and partners' guidelines. Improvements are planned to reduce this time lag for future reports.

# 6. Statistical analysis

Different sets of information were extracted from data provided by the monitoring stations. National trends on population-weighted warm-season average values for ground-level ozone and $PM_{2.5}$ were calculated. The national trends were based on the 76 ground-level ozone and 63 $PM_{2.5}$ monitoring stations across Canada that satisfied the requirements for yearly and time-series inclusion criteria. Regional trends were calculated for ground-level ozone only. The regional trends for ground-level ozone were based on 3 stations in Atlantic Canada, 25 stations in Quebec/eastern Ontario, 19 stations in southern Ontario, 14 stations in the Prairies and 10 stations in the lower Fraser Valley of British Columbia. These stations, a total of 71, plus five stations that did not fit into any one of the previously mentioned five regional clusters, have all satisfied the requirements for the yearly and the time-series inclusion criteria. There were insufficient time-series data to calculate regional trends for $PM_{2.5}$.

In addition to the ozone and $PM_{2.5}$ air quality indicators, snapshots of the 2004 warm-season ground-level ozone and $PM_{2.5}$ concentrations were also presented in the 2006 report. These snapshots are average concentration values obtained from 159 ground-level ozone and 117 $PM_{2.5}$ monitoring stations across Canada. Those stations have satisfied the requirements for the 2004 yearly inclusion criteria.

Appropriate non-parametric statistical tests were conducted to examine the direction and the magnitude of the annual rate of change between 1990 and 2004 for the ground-level ozone indicator only. The standard Mann-Kendall (MK) trend test was used to determine the direction of yearly changes and the Sen slope estimator was conducted to determine the magnitude of the trend (change per year).

The MK and the Sen methods were only applied to the ground-level ozone indicator, which had 15 years of data. The limited period in the $PM_{2.5}$ indicator, which only included five years of annual data, was not considered sufficient for the application of the aforementioned methods.

The application of both the MK and Sen methods is appropriate for the detection of potential trends in air quality data provided that the underlining assumptions of the tests are satisfied. For example, the MK test is suitable for cases where the trend is monotonic. To this end, the median test was used to determine if ground-level ozone data revealed a decreasing or increasing trend. The indicator data were thus grouped into two time periods: before 1997 (the year falling in the middle of the ozone indicator's 1990–2004 reference period) and after 1997, one above the median of all respective estimates and one below the median of all respective estimates. The two groups were then tested to determine if there is a statistically significant difference between them at the 80 percent probability. The national data and all regional data except for the Atlantic have satisfied the monotonic assumption ($p<0.13$).

Another underlying assumption for these methods is that there should be no seasonality and no autocorrelation in the data. The ground-level ozone data represent concentrations obtained only from warm-season periods, thus the non-seasonality assumption is partly satisfied. Autocorrelation in the CESI ozone indicator data means that the yearly values may depend on the previous years' data. In other words, last year's data could predict this year's data. A standard autocorrelation test was performed to determine the degree of dependency between the values of the time series consisting of the CESI annual data points. Based on the results of the autocorrelation test, no dependencies were observed.

The results of these statistical methods need to be placed in perspective and interpreted with prudence. The Sen method predicts the trend (the slope of the line), based on a median rate (a unit change per year). It serves as an approximation to temporal variation in the predicted values.

## *6.1 Summary of results*

Text table 4 presents the estimated rate of change per year for the national and regional ground-level ozone indicator in ppb (one part of ground-level ozone per billion parts of air) units and in percentage of the median value of the entire period (15 years).

**Text table 4 Rate of change per year of the ground-level ozone indicator between 1990 and 2004, based on the Sen method**

| Ground-level ozone indicator | Number of stations | Rate of change per year | Rate of change per year | 90% confidence interval |
|---|---|---|---|---|
| | Number | ppb | % | % |
| National | 71 | 0.3 | 0.9 | +0.1 to +1.6 |
| Atlantic Canada | 3 | 0.1 | 0.3 | -1.3 to +2.1 |
| Quebec and Eastern Ontario | 25 | 0.4 | 1.2 | 0.0 to +1.9 |
| Southern Ontario | 19 | 0.5 | 1.3 | +0.1 to +2.6 |
| Prairies and Northern Ontario | 14 | 0.2 | 0.4 | -0.1 to +1.3 |
| Lower Fraser Valley, British Columbia | 10 | 0.1 | 0.3 | -0.2 to +0.8 |

Based on the 90 percent confidence intervals, the national and southern Ontario region ground-level ozone indicators exhibited an increasing trend. The confidence intervals of the rates of change in the other regions did not support the hypothesis of an increasing trend.

# 7. Caveats and limitations of the indicator and data

**Measurement error:** With respect to the monitoring instruments, quality control and quality assurance procedures have been deployed by Environment Canada and provincial partners to ensure that sources of measurement error are controlled and minimized.

**Data completeness:** The criteria for determining whether stations have sufficiently complete data for inclusion in indicator analysis are based on standard practices followed by organizations including the World Health Organization and the U.S. Environmental Protection Agency, as well as expert opinion. However, a broader trend analysis is currently being evaluated for inclusion in future reports. This broader approach could relax some of the data completeness criteria and rely on appropriate statistical and analytical tools to compensate for missing values.

**Regional divisions**: The definitions of the regions used for reporting in 2006 were based on general regional patterns and the expert judgment of the scientists involved. Different regional boundaries could be established based on a more detailed analysis of regional ground-level ozone and precursors concentrations, demography, topology, and weather patterns.

**Population weighting:** The method used for the 2006 report is one approach to population weighting. Other approaches could accommodate the uneven distribution of monitoring stations across the country in relation to population density. The methodology could also benefit from better estimations of ground-level ozone and $PM_{2.5}$ concentrations between nearby stations, and in particular those with overlapping population area boundaries.

**Trend analysis:** Despite the statistical significance of some of the trends reported in the population-weighted ground-level ozone levels, the current method used for trend analysis is conservative in terms of its ability to shed light on consecutive year-to-year trends. A synthesis of the daily, weekly, monthly, and seasonal cycles in pollution levels would enhance the breadth of the analysis. This would be useful for understanding how the indicator responds to temporal and meteorological factors (e.g., day of the week, temperature) compared with changes in sources of pollutants and related precursors.

# 8. Future improvements

The air quality indicators build on the base of an established national monitoring network. However, ground-level ozone and $PM_{2.5}$ levels are influenced by complex factors, including weather and transboundary flows of pollutants. The approach taken in this report—analyzing the observed concentration in relation to where people live—is just a start. The risk to an individual's health from air pollution is a complex function of a number of factors, including the quality of the air (level of pollutant), their level of exposure, and their particular situation (e.g., health, age). Determining an individual's exposure to these pollutants requires consideration of factors such as the amount of time the individual spends doing outside activities, particularly during the warm season. The approach will benefit from refinements in future reports. Improvements have been made from last year, with the addition of a $PM_{2.5}$ air quality indicator, and a more refined statistical methodology. However, ground-level ozone and $PM_{2.5}$ are only two components of air pollution. Systematic measurements of other pollutants will need to be analyzed. The intention is to explore this cumulative effect and integrate associated risk factors into a comprehensive air quality and health indicator.

The following improvements are planned for the air quality indicator:

**Indicator:** Health Canada scientists are examining the feasibility of a broader indicator (Air Health Indicator) based on the health risk caused by exposure to a combination of several air pollutants. This should provide a more comprehensive picture than examining pollutants individually.[12] This indicator would be based on linking deaths and hospitalizations due to heart and lung problems with air pollutants present at particular locations and times. The indicator would incorporate ground-level ozone, $PM_{2.5}$, nitrogen dioxide and sulphur dioxide. By focusing on the association between exposure and consequences—deaths or hospitalizations—the new indicator would reflect changes over time both in exposure and health risks, the latter potentially attributable to changes in population susceptibility (e.g., due to aging) or the nature of the air pollution mix.

**Monitoring:** Environment Canada will continue to invest in new instruments to fill gaps in pollutant coverage at existing monitoring facilities. A priority will be placed on upgrading existing continuous $PM_{2.5}$ instruments and improving the $PM_{2.5}$ monitoring sampling and consistency during the cold season, from October 1 to March 31. These improvements may allow cold-season reporting, thereby better representing the regional climatic differences and variations across Canada.

Investment will also be made to establish new stations in more remote locations. These stations will not strongly influence the population-weighted indicator; nevertheless, they will help to monitor background levels and improve understanding of the complete data set. For the purposes of this indicator, the monitoring networks should ideally provide a balanced coverage of the Canadian population to best represent Canadians' exposure to air pollutants.

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**Analysis**: Currently, calculation of the indicators does not make full use of the existing National Air Pollution Surveillance (NAPS) network and population data due to the stringent inclusion criteria used in NAPS reported data. Various trend analyses, modelling, and imputation methods are being investigated to exploit the full set of NAPS' data and to provide more robust estimates of national and regional trends in air quality.

Another important area of research is determining the relative importance of the various factors that affect observed levels of air pollution. For instance, long-range transport of pollutants, sunlight exposure, ambient temperature, and pollutant emissions all influence the observed levels of ground-level ozone and $PM_{2.5}$, but the extent and magnitude of their contributions has not yet been fully investigated. Future work will examine ways to measure the relative contributions of these factors on ambient ground-level ozone and $PM_{2.5}$ levels at both the national and regional levels.

# 9. References


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