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Canadian Environmental Sustainability Indicators: Air Quality Indicators: Data Sources and Methods

2007

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Canadian Environmental Sustainability Indicators: Air Quality Indicators: Data Sources and Methods

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.. not available for a specific reference period
... not applicable
0 true zero or a value rounded to zero
0s value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
p preliminary
r revised
x suppressed to meet the confidentiality requirements of the *Statistics Act*
E use with caution
F too unreliable to be published

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1 Introduction

Canadians' health and their social and economic well-being are highly dependent on 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 2007 CESI report.

2 Description of the indicators

Poor air quality has significant negative effects on the natural environment, human health, and economic and biological productivity. The 2007 CESI air quality indicators track measures of long term exposure of Canadians to ground-level ozone and fine particulate matter ($PM_{2.5}$). These pollutants are key components of smog and are two of the most pervasive and widely spread air pollutants to which people are exposed. Studies indicate that adverse health effects can occur even with low concentrations of these pollutants in the air.

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

The air quality 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 air quality 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 air quality indicators track measures of long-term exposure of Canadians to ground-level ozone and $PM_{2.5}$. They are intended as state/condition indicators to inform policy analysts, decision makers and the public as to whether progress is being made towards improved air quality, in terms of reduced burden of population exposure to ground-level ozone and $PM_{2.5}$ over the longer term.

1. www.environmentandresources.gc.ca and www.statcan.ca.

4 How the indicators are calculated

4.1.1 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 4.1 for an illustration of the 8-hour averages.

4.1.2 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.

4.1.3 Calculating the 24-hour average concentration for $PM_{2.5}$

The $PM_{2.5}$ exposure indicator is calculated in exactly the same way as the ground-level ozone exposure 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.

4.1.4 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 4.1
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	

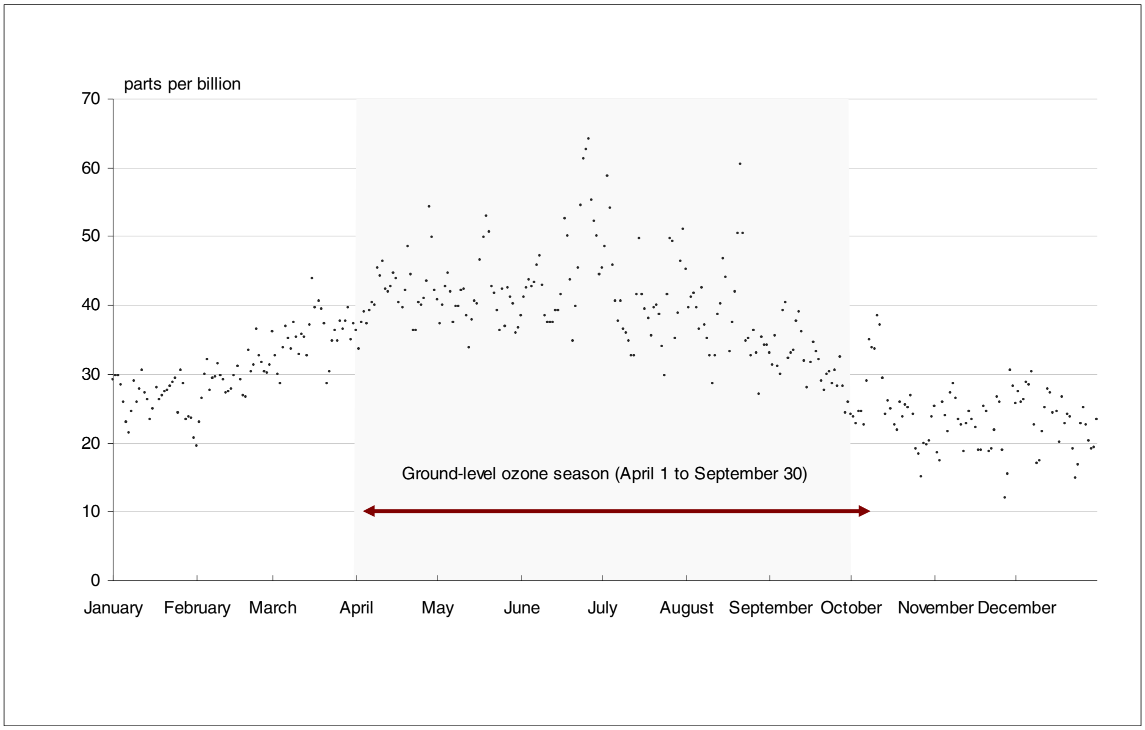
4.1 Daily averages

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 to 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 4.1 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 2007 CESI report.

Figure 4.1
Daily maximum eight-hour average ground-level ozone values, mean of 79 monitoring stations across Canada



Note(s): The daily values are not population-weighted.
Source(s): Environment Canada, National Air Pollution Surveillance Network Database.

4.3 Population weighting

In the 2005, 2006 and 2007 CESI reports the air quality indicators were calculated using a population-weighted approach, weighting annual warm-season average values of monitoring stations across Canada. Since monitoring stations are scattered coast to coast, in different areas with different populations, proportionally adjusting air pollution levels measured at a monitoring site based on the size of the population residing near the station provides a more relevant estimate of exposure to ground-level ozone and $PM_{2.5}$[3].

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.
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.

An annual population-weighted concentration level was calculated for each year 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. The population weighting concentration level for each year (E_{year}), is calculated by multiplying the population (P) of a monitoring station with respective average warm season ambient level (C) of ozone or $PM_{2.5}$ measured at that station. For example, P_n in the equation below represents the population within a 40-km radius of station (n) for a specific year and C_n is the average warm-season concentration level at station (n) during the same year. The products for each monitoring station were then added together and collectively divided by the sum of the total population, which is the sum of population counts of all the monitoring stations.

$$E_{year} = \frac{\sum (P_n \times C_n)}{\sum P_n}$$

For ground-level ozone, the considered ambient level (C) is the warm season average of all daily maximum 8-hour average ozone levels, and for $PM_{2.5}$ the considered ambient level (C) is the warm season average of all daily 24-hour average (midnight to midnight) levels.

This population weighting method assigns more weight to ozone and $PM_{2.5}$ concentrations to those stations located in more populated areas. Applying different population estimates (P_n) by consecutively halving the radius from 40 km to 20 km to 10 km and to 5 km did not impact the results of the indicators, including the fifteen year trend for ozone or the five year trend for $PM_{2.5}$ at a statistically significant level.

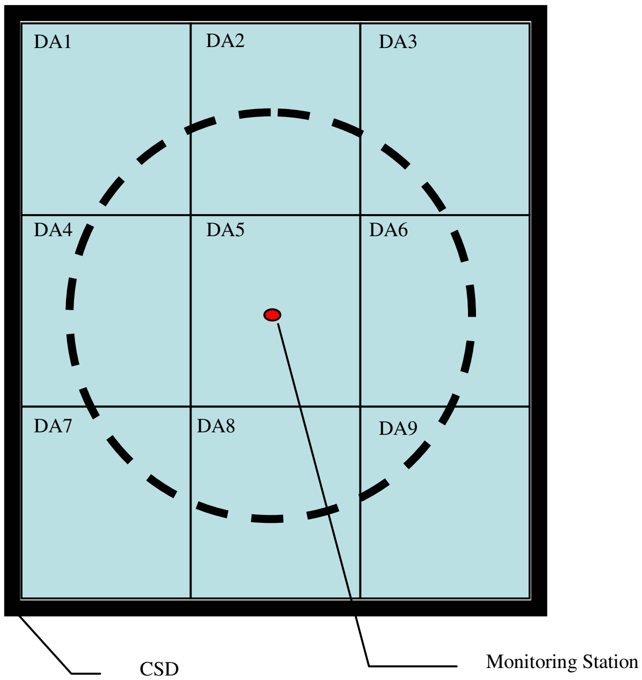
The population-weighted method used for the indicators are closely aligned with the recommendation from the National Round Table on the Environment and the Economy (NRTEE) that the air quality indicators include a population dimension to the ambient air quality data available.

4.3.1 Estimating population weights

The estimation of population weights for each monitoring station relies on data from the Census of Population (Statistics Canada 2002). Census data are only collected once every five years, known as census years. In non-census years, Statistics Canada generates yearly population estimates for 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 neighboring blocks with a population of 400 to 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 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 air quality indicators, the population in each circle is estimated based on the proportion of the area of DAs. Figure 4.2 presents a conceptual framework for estimating the population in a circle around a monitoring station.

Figure 4.2
Conceptual diagram, estimating the population around a monitoring station



Note(s): The large square with a dark boundary line in Figure 2 represents a census subdivision (CSD) containing nine dissemination areas (DA1 to DA9) presented as small squares. The dashed circle represents a conceptual circular area around a monitoring station. The contribution of each DA to the population in the circle is based on area-proportion, that is to say, 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. The percentage of the area of each DA in relation to the circle is constant throughout the entire timeframe used in the calculation of the indicators. The percentage of the population of each DA to the overall population of its CSD is, however, updated once every census year, a five-year cycle, since new census data then become available. In non-census years, the latest census data are used as the basis to derive the percentages in population contribution among the DAs of a CSD using Statistics Canada's yearly population estimates for each CSD.

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 Monitoring networks

In 2005, the NAPS and CAPMoN together consisted of 308 monitoring stations in 198 communities across Canada. In total, the stations were equipped with 805 continuous monitors measuring ground-level ozone, particulate matter, sulphur dioxide, carbon monoxide, and nitrogen dioxide and 165 air samplers measuring components of particulate matter, various volatile organic compounds, and other toxic substances (Figure 5.1).

Figure 5.1
Air quality monitoring station

4. Environment Canada, National Air Pollution Surveillance Network reports, Ottawa (http://www.etc-cte.ec.gc.ca/publications/napsreports_e.html).

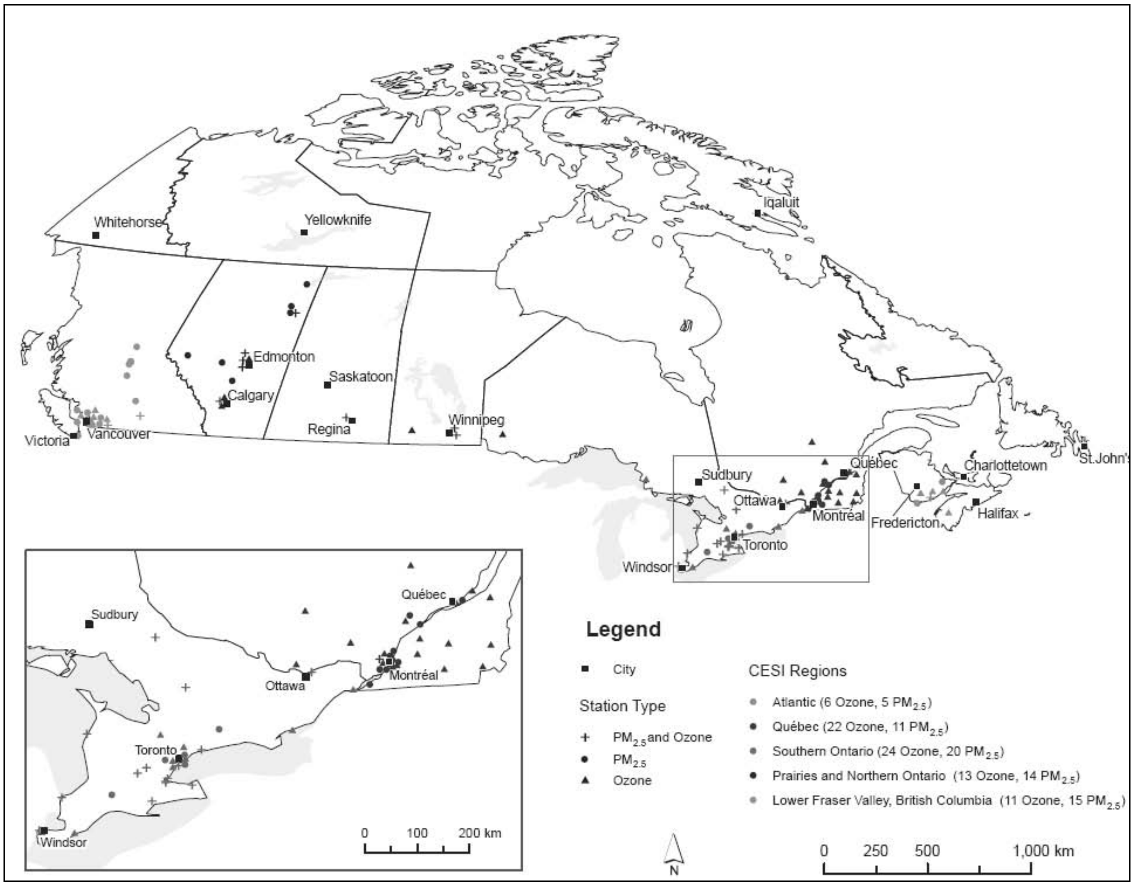
There are standards and procedures for the selection and positioning of stations and their sampling equipment. Probes for ground-level ozone and other pollutants, for example, are sited using a set of criteria for probe height, probe distance from roadways and stationary air emission sources, probe distance 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.

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 air quality indicators represent the areas where most Canadians live, work and play. Monitoring networks have been installed to track regional and provincial air quality conditions for urban and non-urban sites. Despite some differences in regional priorities in terms of spatial coverage, the current available monitoring networks offer a representative national and regional coverage for ground-level ozone and $PM_{2.5}$ monitoring.

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. National Air Pollution Surveillance Network: Quality Assurance and Quality Control Guidelines Accessed April 2, 2006 (PDF Format, 1.5MB).

Figure 5.2
Locations of monitoring stations contributing to the air quality indicators – national and regional

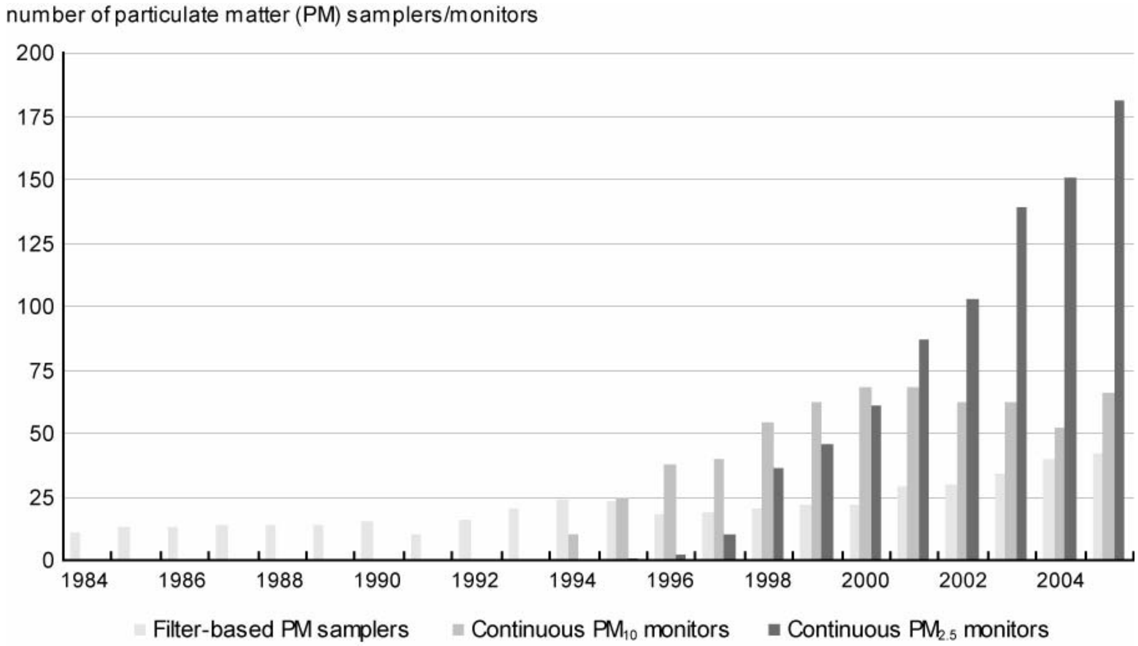


Note(s): Total number of monitoring stations: 76 for ozone and 65 for $PM_{2.5}$. Regional groupings have changed from previous reports.

Source(s): The stations are part of the National Air Pollution Surveillance (NAPS) Network and the Canadian Air and Precipitation Monitoring Network (CAPMoN).

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 2007 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. Figure 5.3 presents the growth in the number of particulate matter monitors across Canada.

Figure 5.3
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 such 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 5.1). Additional stations could have been excluded for similar reasons, but these did not meet the inclusion criteria for data completeness.

Text table 5.1
Four monitoring stations that met all the inclusion criteria but were not representative of the general air quality at their respective sites

Monitoring Station (identification code and location)	Reason for exclusion
50109, Montreal, Quebec	NO_x scavenging
50115, Montreal, Quebec	NO_x scavenging
60101, Ottawa, Ontario	NO_x scavenging
100112, Greater Vancouver Regional District, British Columbia	NO_x scavenging

Note(s): NO_x 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 NO_x, with NO_2 computed as a difference. At the low concentrations typical of rural areas, NO_x makes a net positive contribution to photochemical ozone formation, but at the higher concentrations typical to urban centres the balance is shifted to ozone consumption, so that higher transportation emissions can decrease ozone locally. This phenomenon is referred to as NO_x scavenging.

5.3 Data quality and completeness

Each of the organizations participating in the monitoring program, NAPS and CAPMoN, forwards data to the Environmental Technology Centre at Environment Canada. Although minute by minute data are recorded only hourly average readings are 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%[9]. The error for $PM_{2.5}$ is conservatively estimated at ±20%[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 5.2 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 5.2
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.

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.

- Each warm-season period (April 1 to September 30 = 183 days) must have data for at least 75% of the days (that is, minimum of 138 days of data).

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% of the days (that is, minimum of 69 days of data per quarter).

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

- For the 1990 to 2005 ground level ozone time series, and for each station, at least 12 of the 16 years must have data that have satisfied the yearly criteria mentioned above. For the 2000 to 2005 $PM_{2.5}$ time series, this means that 4 of the 6 years of data are required per station.
- 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 260 ground-level ozone and 162 $PM_{2.5}$ monitoring stations, only 175 ground-level ozone and 144 $PM_{2.5}$ monitoring stations satisfied the 2005 yearly data requirements, while 76 ground-level ozone and 65 $PM_{2.5}$ stations have satisfied the requirements of the time-series criteria and contributed data to the time-series trend analysis. In one case, data from two neighboring stations within Mississauga, Ontario, were used to supplement each other, estimating a 2005 data point and imputing a 2004 data point. This type of statistical imputation technique is used for the first time in the CESI 2007 report. Mississauga, Ontario was selected for data imputation because of its relatively large population and hence its weight on the indicator. This example also contributed to test the potential application of standard data imputation techniques for use in upcoming CESI reports.

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 quality 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. These national trends were based on the 76 ground-level ozone and 65 $PM_{2.5}$ monitoring stations across Canada that satisfied the requirements for yearly and time-series inclusion criteria.

The regional trends for ground-level ozone were based on 6 stations in Atlantic Canada, 22 stations in southern Quebec, 24 stations in southern Ontario, 13 stations in the Prairies and 11 stations in the lower Fraser Valley, British Columbia. These stations, a total of 76, have all satisfied the requirements for the yearly and the time-series inclusion criteria. The regional trends for $PM_{2.5}$ were based on 5 stations in Atlantic Canada, 11 stations in southern Quebec, 20 stations in southern Ontario, 14 stations in the Prairies and northern Ontario and 15 stations in the lower Fraser Valley, British Columbia. These stations, a total of 65, have all satisfied the requirements for the yearly and the time-series inclusion criteria.

In addition to the ozone and $PM_{2.5}$ exposure indicators, the 2005 warm-season ground-level ozone and $PM_{2.5}$ concentrations were also presented in the 2007 report. These snapshots are average concentration values obtained from 175 ground-level ozone and 144 $PM_{2.5}$ monitoring stations across Canada. Those stations have only satisfied the requirements for the 2005 yearly inclusion criteria.

Appropriate non-parametric statistical tests were conducted to examine the direction and the magnitude of the annual rate of change from 1990 to 2005 for ground-level ozone and $PM_{2.5}$. The standard Mann-Kendall trend test was used to determine the average direction of yearly changes and Sen's non-parametric pair-wise slope estimator was applied to determine the magnitude of the trend in terms of unit change per year, expressed as a percentage change per year with 90% confidence limits. The Mann-Kendall and the Sen methods were applied to the annual average warm-season population-weighted concentration levels for 1990 to 2005 and 2000 to 2005, for ground-level ozone and $PM_{2.5}$ data respectively.

The application of both the Mann-Kendall 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 Mann-Kendall test is suitable for cases where the trend is monotonic. To this end, and only if a significant trend is detected, the Median test is applied to determine if annual data reveal a decreasing or increasing monotonic trend along the period of the time series in question.

Significant trends were only detected on ground-level ozone data at the national level and in the southern Quebec and southern Ontario regions. The annual warm season population-weighted ground-level ozone levels of these three areas were grouped into two distinct and equally spaced time periods: from 1990 to 1997 and from 1998 to 2005. The Median test examines whether the two distinct time periods are statistically similar, testing the null hypothesis that the median values of the two periods are equal. For those data showing significant trends and based on the results of the Median test, the average warm-season population-weighted annual ground-level ozone levels in both the national and southern Quebec did satisfy the monotonic assumption at $p<0.14$. In southern Ontario, however, the average warm season population-weighted annual ground-level ozone levels only partly satisfied the monotonic assumption at $p<0.32$.

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 annual data means that the yearly values may depend on the previous years' values. In other words, last year's ground-level ozone value could predict this year's value, and so forth. A standard autocorrelation test was performed to determine the degree of dependency in residuals between the calculated versus the predicted annual warm season population-weighted ground- level ozone levels. Based on the results of the Durbin-Watson autocorrelation test, no evidence against independence was detected at the 0.05 significance level.

The results of these statistical methods need to be placed in perspective and interpreted with prudence. The Sen method predicts the trend, which is expressed as the median slope with associated confidence intervals. Conservatively, it serves as an approximation to temporal variation in the annual values. To this end, the emphasis on interpretation should be more on the confidence interval rather than on the median rate/slope. Thus, for each significant trend, rate or slope, an accompanying confidence interval (CI) at 90% level was also reported. A confidence interval sheds a better light on the concept of the indicator. In other words, since the real rate of change, which is used to represent the indicator value, is not known and practically can not be obtained or estimated with a 100% confidence, the 90% confidence interval reveals that 18 times out of 20 the reported interval may contain the actual value of the indicator. It then follows that two times out of 20, the reported interval may not contain the actual value of the indicator. The next section presents the results of the CESI 2007 air quality indicators with associated confidence intervals.

6.1 Summary of results

Text tables 6.1 and 6.2 present the estimated rate of change per year for the national and regional ground-level ozone and $PM_{2.5}$ exposure indicators. The units for ground-level ozone are in ppb by volume concentration (that is, one part of ground-level ozone per billion parts of air) and also in percentage change based on the median of the 16 annual levels. The units for $PM_{2.5}$ are in micrograms $PM_{2.5}$ per one cubic metre of air and also in percentage change based on the median of the 5 annual levels.

Text table 6.1
Rate of change per year of the ground-level ozone exposure indicator, 1990 to 2005

Ground-level ozone exposure indicator	Stations	Median rate of change per year	Median rate of change per year	90% confidence interval
	number	parts per billion (ppb)	percent	percent
National	76	0.3	0.8	+0.1 to +1.4
Atlantic Canada	6	n.s.s[1]	n.s.s[1]	-1.1 to +1.3
Southern Quebec	22	0.3	1.0	+0.2 to +1.7
Southern Ontario	24	0.5	1.1	+0.3 to +1.9
Prairies and northern Ontario	13	n.s.s[1]	n.s.s[1]	-0.3 to +0.9
Lower Fraser Valley, British Columbia	11	n.s.s[1]	n.s.s[1]	-0.1 to +0.7

1. Indicates that the rate of change is statistically not significant at the 90% confidence level.

Text table 6.2
Rate of change per year of the $PM_{2.5}$ exposure indicator, 1990 to 2005

$PM_{2.5}$ exposure indicator	Stations	Median rate of change per year	Median rate of change per year	90% confidence interval
	number	micrograms per cubic metre ($\mu g/m^3$)	percent	percent
National	65	n.s.s[1]	n.s.s[1]	-4.5 to +7.8
Atlantic Canada	5	n.s.s[1]	n.s.s[1]	-12.5 to +1.9
Southern Quebec	11	n.s.s[1]	n.s.s[1]	-5.8 to +6.9
Southern Ontario	20	n.s.s[1]	n.s.s[1]	-3.3 to +6.5
Prairies and Northern Ontario	14	n.s.s[1]	n.s.s[1]	-14.1 to +4.7
Lower Fraser Valley, British Columbia	15	n.s.s[1]	n.s.s[1]	-7.5 to +3.1

1. Indicates that the rate of change is statistically not significant at the 90% confidence level.

Based on the 90% confidence intervals, results for the ground-level ozone exposure indicator at the national level, and in southern Quebec and southern Ontario regions exhibited a statistically significant increasing trend. The confidence intervals of the rates of change in ground-level ozone in the other regions and for the $PM_{2.5}$ at the national and all regional levels showed no evidence against the null trend hypothesis.

7 Caveats and limitations of the indicators 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. A broader trend analysis is 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. In this report, and based on the promising results of evaluations so far conducted, data from two neighbouring stations within Mississauga, Ontario, were used to supplement each other, estimating a 2005 data and imputing a 2004 data. This type of statistical imputation technique is used for the first time in the CESI 2007 report. Mississauga, Ontario was selected for data imputation because of its relatively large population and hence its weight on the indicator and also for testing the potential application of imputation techniques for use in future reports.

Regional groupings: The definitions of the regions used for reporting in 2007 were based on general regional patterns and the expert judgment of the scientists involved. Regional groupings have slightly changed from the previous reports for a better geographical representation. For example, stations in eastern Ontario are now included with the stations in southern Ontario, rather than with those in Quebec. Thus, these two regions in the 2007 CESI reports are not the same as those used in previous reports. Accordingly, last year's Quebec and eastern Ontario region has been changed to include stations that are only in Southern Quebec. Although indicator levels (that is, yearly values) for all regions in this report should not be compared with those in previous reports, the exposure indicators (that is, national and regional trends) are generally comparable regardless of minor adjustments in regional boundaries. Different regional boundaries, however, could be established in the future based on more detailed analysis of regional air pollutants and precursors concentrations, demography, topology, and weather patterns. The latter is a major undertaking that requires fundamental research and development.

Population weighting: The population weighting method used in the CESI reports is one approach among others to population weighting. Some approaches accommodate the uneven distribution of monitoring stations across the country in relation to population density. The methodology used in this report could benefit from better estimations of ground-level ozone and $PM_{2.5}$ concentrations between nearby stations and in particular those with overlapping 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 year-to-year comparison. 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 indicators respond to temporal and meteorological factors (for example, day of the week, temperature) compared with changes in sources of pollutants and related precursors. The latter is a major undertaking that requires further research and development.

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 a preliminary step. 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 (for example, health, age). Determining an individual's exposure to these pollutants requires consideration of factors such as the amount of time the individual spends doing outdoor activities, particularly during the warm season. The use of Statistics Canada's General Social Survey and its time budget and human activity pattern would enhance the spatial and temporal dimensions of the air quality indicators. Improvements have been made from last year, with the addition of regional $PM_{2.5}$ air quality indicators, as well as some additional and relevant interpretations of the results and associated factors. 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 indicators:

Indicators: 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 and $PM_{2.5}$. 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 indicators; nevertheless, they will help to monitor background levels and improve understanding of the complete data set. For the purposes of the air quality indicators, the monitoring networks should ideally provide a balanced coverage of the Canadian population to best represent Canadians' exposure to air pollutants.

Analysis: Currently, calculations of the air quality indicators do not make full use of the existing National Air Pollution Surveillance (NAPS) network and available population data due to the stringent inclusion criteria used in NAPS annual reported data. Various trend analyses, modeling, and imputation methods are being investigated to exploit a larger set of NAPS' data and to provide more robust estimates of national and regional trends in the exposure of Canadians to the air they breathe. Another important area of research is determining the relative importance of

12. Burnett, R.T., S. Bartlett, B. Jessiman, P. Blagden, P.R. Samson, S. Cakmak, D. Stieb, M. Raizenne, J.R. Brook, and T. Dann. 2005. "Measuring progress in the management of ambient air quality: the case for population health." *J. Toxicol. Environ. Health* A, 68 (13–14): 1289–1300.

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.

Surveys: The 2007 **Households and the Environment Survey** will include more detailed questions about home heating and air conditioning, the use of gasoline-powered recreational and small household engines, as well as more information on the types of motor vehicles owned by Canadians. As in 2006, respondents will be asked whether they are aware of air quality advisories and whether they have changed their normal behaviours in light of this awareness; this year, however, the survey will expand the question to ask which specific behaviours were changed.

References

Statistics Canada. 2002. *A National Overview — Population and Dwelling Counts, 2001 Census*. Ottawa (Statistics Canada Catalogue No. 93-360-XPB).