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Data Sources and Methods for the Air Quality (O3 and PM2.5) Indicators.

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Canada

1 Introduction

The national, regional and local air quality indicators are part of the Canadian Environmental Sustainability Indicators (CESI) program which provides data and information to track Canada's performance on key environmental sustainability issues.

Air quality indicators report on two air pollutants: ground-level ozone (O_3) and fine particulate matter ($PM_{2.5}$). These indicators are intended as state/condition indicators to inform policy, decision makers and the public as to whether progress is being made towards improving ambient air quality.

2 Description and rationale of the air quality indicators

2.1 Description

Air quality indicators track the average of ambient concentrations of ground-level ozone (O_3) and particulate matter ($PM_{2.5}$) during the warm season (April 1 to September 30). The air quality indicators are population-weighted, i.e. ambient concentration measurements are weighted by the population attributed to a monitoring station when compiling the national and regional averages.

O_3 and $PM_{2.5}$ pollutants are key components of smog and two of the most widespread air pollutants to which people are exposed. The O_3 indicator is based on the highest 8-hour daily average concentration in parts per billion (ppb), while the $PM_{2.5}$ indicator is based on the 24-hour average daily concentration in micrograms per cubic meter (ug/m^3).

Since adverse health effects of air pollution (e.g., cardiovascular and respiratory effects) can be observed even at low levels of exposure, especially for ground-level ozone and $PM_{2.5}$, the calculation of air indicators are based on daily average concentrations rather than on daily peak concentrations. During the warm season, events of peak pollutant concentrations are rather sporadic and the daily average concentration provides a better measure of exposure.

The air quality indicators consider O_3 and $PM_{2.5}$ concentrations during the warm season (April 1-September 30), which is the period when Canadians are most active outdoors (Leech et al. 2002). Meteorological conditions during these months tend to favor the formation of ground-level O_3. While fine particulate matter is usually a concern during winter, challenges with instrument variability in cold weather are preventing effective all-year measurements of $PM_{2.5}$ for the purpose of these indicators.

2.2 Rationale

Other methods exist to report on O_3 and $PM_{2.5}$ concentrations, usually with different purposes in mind and often providing different results. For example, the Canada-wide Standard (CWS) for ozone, based on the three-year average of the annual fourth highest daily maximum eight-hour concentration, reflects the effects of acute (short-term) exposure to peak air pollution rather then trying to approximate human exposure to O_3 and $PM_{2.5}$ over time like the CESI air quality indicators do.

2.3 Changes since last report

The most important change since the last report of air quality indicators occurred for the $PM_{2.5}$ indicators. Two monitoring stations (Station ID 50105 and 50129, both located in Montreal) were added as they now meet time series data completeness criteria, and one station was removed (Station ID 102301 - located in the Lower Fraser Valley) due to no longer meeting time series data completeness criteria.

New population statistics were used to do the population weighting for the stations included in the calculation of the national and regional air quality indicators. These statistics are updates from Statistics Canada Census of Population, available from: http://www40.statcan.gc.ca/l01/ind01/l3_3867-eng.htm?hili_none.

The 2000-2008 indicator values in this report reflect those changes so that values are comparable with 2009 measurements.

3 Data

3.1 Data source

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 (O_3) and fine particulate matter ($PM_{2.5}$) data are under the National Air Pollution Surveillance (NAPS) program available from: available from: http://www.ec.gc.ca/rnspa-naps/default.asp?lang=En&n=5C0D33CF-1, a cooperative arrangement among the federal government, and provincial, territorial and municipal partners that has existed since 1969 available from: http://www.ec.gc.ca/rnspa-naps/Default.asp?lang=En&n=31258671-1.The goal of the NAPS program is to provide accurate and long-term air quality data of a uniform standard throughout Canada that are stored in the Canada-wide air quality database[1].

The Canada-wide air quality database also includes ground-level ozone data information from the Canadian Air and Precipitation Monitoring Network (CAPMoN) available from: http://www.ec.gc.ca/rs-mn/default.asp?lang=En&n=752CE271-1, operated by Environment Canada. The CAPMoN stations were established for research purposes and to monitor air pollution outside of urban areas.

Population data used for the population weighted calculation were taken from the Census of Population and the annual population updates compiled by Statistics Canada available from: http://www40.statcan.gc.ca/l01/ind01/l3_3867-eng.htm?hili_none.

3.2 Spatial coverage

Air quality monitoring stations are spread across the country, but are more concentrated in urban areas. Monitoring stations used to calculate the air quality indicators are located in areas where most Canadians live, work and play. Refer to appendix A to find the full list of stations used to calculate the national and regional indicators.

3.3 Temporal coverage

O_3 data were provided for the years 1990 to 2009 and $PM_{2.5}$ data for the years 2000 to 2009. Although minute-by-minute data are recorded, only hourly average readings are transmitted.

3.4 Data completeness

The monitoring stations do not all have the same time series of data available, nor have they all been operating continuously since 1990 or 2000 for $PM_{2.5}$. There are a number of reasons for this, including short-term technical problems, the commissioning or decommissioning of

[1] Other parameters measured through NAPS include sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), nitric oxide (NO), nitrogen oxides (NO_X), coarse particulates (PM_{10}), volatile organic compounds (VOC), heavy metals, toxics and a variety of semi-volatile organic compounds.

stations, and incomplete records from some stations. However these short data gaps have little effect on long-term averages at individual stations.

3.5 Data Quality

Agencies contributing to the NAPS network perform routine audits, and all strive to adhere to established quality assurance and quality control standards laid out in table 1. 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% (Halman, pers. comm.[2]). The error for $PM_{2.5}$ is conservatively estimated at ± 20% (Dann, pers. comm.[3]).

Table 1: Data quality objectives and specifications for O_3 and $PM_{2.5}$

Parameter	O_3	$PM_{2.5}$
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

3.6 Data timeliness

There is a lag of two years from the last day of a year's data collection to when that year's indicator being published. This 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 was subject to quality assurance and quality control procedures to ensure that they adhere to Environment Canada's and partners' guidelines.

4 Methods

Air quality indicators are calculated based on definitions established by the National Round Table of Economy and Environment (NRTEE 2003). The section below details the step-by-step methodology.

4.1 Calculation of air quality concentrations

Data Collection and QA/QC

The data are taken from the Canada-wide air quality database. The data are validated using automated and manual procedures. Data from monitoring network organizations are converted to a compatible format and then entered in the Canada-wide air quality database. Although the data has been validated by the monitoring organization, quality control and assurance procedures outlined by the U.S. Environmental Protection Agency (US EPA) are also

[2] Halman, R. 2007. Personal communication (Environmental Science and Technology Centre, Environment Canada).

[3] Dann, T. 2007. Personal communication (Environmental Science and Technology Centre, Environment Canada).

undertaken. The originating agency must confirm automatically or manually flagged data before they are stored in the Canada-wide air quality database.

Yearly Criteria

Yearly criteria are used to select stations that have enough hourly and daily measures to be included in the air quality indicators.

For the ground-level ozone (O_3) indicator, a station is included when:

- 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% of the days (i.e., minimum of 138 days of data).

For the fine particulate matter ($PM_{2.5}$) indicator, a station is included when:

- 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 (i.e., minimum of 69 days of data per quarter).

In 2009, 188 ground-level ozone and 156 $PM_{2.5}$ monitoring stations satisfied the yearly data requirements and were used to calculate the annual air quality indicators

Monitoring station's concentrations calculations

After having applied the yearly criteria, the O_3 and $PM_{2.5}$ concentrations can be calculated for the selected stations.

For O_3, the daily maximum 8-hour average concentration is calculated in parts per billion (ppb). There are 24 consecutive 8-hour averages (8-hour rolls) that can be possibly 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 Figure 1 for an illustration of the 8-hour averages.

Figure 1: Calculation of the ground-level ozone daily maximum 8-hour average concentration (in 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	

The warm-season average of ground-level concentrations is the average of the highest daily maximum 8-hour average concentrations during the period from April 1 to September 30.

The $PM_{2.5}$ indicator uses a single roll, or 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. 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.

Each station answering the yearly criteria obtained O_3 and/or $PM_{2.5}$ values as calculated in the manner described above. Calculations are done from 1990 to 2009 for O_3 and from 2000 to 2009 for $PM_{2.5}$. Each station is then assessed to see if sufficient yearly data is available.

Time series criteria for O3 and $PM_{2.5}$

To be included in the national and regional indicators, stations should have enough years of data available and no data gap should exist at the beginning or end of the time series. The criteria for the time series are:

- For the 1990–2009 O_3 time series, each station must have data that satisfied the yearly criteria described above for at least 15 of the 20 years. For the 2000–2009 $PM_{2.5}$ time series, each station should have data that satisfied the yearly criteria described above for at least 7 of the 10 years.
- 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.

Imputation

Certain stations do not always have measurements for all the years. Hence, if they do not meet the time series criteria, they are excluded from the national and regional indicators. However certain monitoring stations are located close to each other. Data from neighbouring stations were used to supplement missing data and produce time series that meets the time series criteria. Table 2 lists stations grouped together to obtain complete time series.

Table 2: Stations grouped together in the O_3 air quality indicator

STATION ID	PROVINCE	CITY	YEARS OF DATA MERGED
60302 60303	ONTARIO	KINGSTON	1990, 1991, 1993-2005 2007-2009
60403 60429	ONTARIO	TORONTO	1990-2000 2001-2009
60415 60432 60434	ONTARIO	MISSISSAUGUA	1990-2003 2005-2007 2008-2009
60424 60433	ONTARIO	TORONTO	1991-1995, 1998-2002 2003-2009
61602 61603	ONTARIO	OAKVILLE	1990-2002 2004-2009
60607 60609	ONTARIO	SUDBURY	1990-2003 2005-2009
60707 60709	ONTARIO	SAULT STE. MARIE	1990-2003 2005-2009
60807 60809	ONTARIO	THUNDER BAY	1990-2003 2004-2009
60901 60903	ONTARIO	LONDON	1990-1994 1996-2009
61701 61702	ONTARIO	OSHAWA	1990, 1992-2004 2006-2009
62701 65301	ONTARIO	PORT STANLEY / LONG POINT	1990-2001 2003-2009
63201 65101	ONTARIO	NEWMARKET /STOUFVILLE	1990-1995, 1997-2001 2002-2009
80209 80211	SASKATCHEWAN	SASKATOON	1991-1992 1993-1999, 2001-2009
90227 90228	ALBERTA	CALGARY	1990-2007 2008-2009
101001 101002 101003	BRITISH COLUMBIA	METRO VAN - ABBOTSFORD	1990-1991 1992-1998 1999-2009
101201 101202	BRITISH COLUMBIA	METRO VAN-PITT MEADOWS	1990-1995 1998-2004, 2006-2009

Table 3: Stations grouped together in the $PM_{2.5}$ air quality indicator

STATION ID	PROVINCE	CITY	YEARS OF DATA MERGED
60403 60429	ONTARIO	TORONTO	2000 2001, 2003-2009
60415 60432 60434	ONTARIO	MISSISSAUGUA	2000-2003 2004-2007 2008-2009
60424 60433	ONTARIO	TORONTO	2000-2002 2003-2009
61701 61702	ONTARIO	OSHAWA	2000-2004 2005-2009
90218 90227	ALBERTA	CALGARY	2008 2000-2007
100307 100316	BRITISH COLUMBIA	VICTORIA	2001-2008 2009

Exclusion criteria

The locations of certain stations in the NAPS network are not always ideal for O_3 and/or $PM_{2.5}$ monitoring purposes. For instance, certain stations have been 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 community-wide air pollutant levels and therefore, data from these stations have not been included in the O_3 and $PM_{2.5}$ air quality indicators. Certain monitoring stations have been excluded, even though they met the time series and yearly criteria, because of additional factors such as; high NOx scavenging[4] and station at high elevation.

Table 4: Monitoring stations from the NAPS network excluded from the national and regional indicators

STATION ID	PROVINCE	CITY	ADDRESS
O_3 (NO_X Scavenging)			
50109	QUÉBEC	MONTRÉAL	2495 DUNCAN / DÉCARIE, MT-ROYAL
50115	QUÉBEC	MONTRÉAL	1001 BOUL DE MAISONNEUVE OUEST
100112	BRITISH COLUMBIA	METRO VAN - VANCOUVER	ROBSON/HORNBY
100121	BRITISH COLUMBIA	METRO VAN - VANCOUVER	75 RIVERSIDE DR. N. VANCOUVER
$PM_{2.5}$ (High Elevation station)			
91201	ALBERTA	HIGHTOWER RIDGE	SE 11 54 2 W6

Selection of $PM_{2.5}$ data for multiple technology records

Different sampling methods are used in the NAPS network to measure ambient $PM_{2.5}$ concentrations:

- Tapered Element Oscillating Microbalance (TEOM)
- TEOM with a Filter Dynamics Measurement System (FDMS)
- Beta Attenuation Mass (BAM)

[4] 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 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 NOx scavenging.

New sampling instruments that are approved as U.S. EPA Class III Federal Equivalent Methods (FEMs) such as TEOM-FDMS and BAM are being deployed across the NAPS network to replace older instruments which have been found to lose a portion of the $PM_{2.5}$ mass. Duplication of measurements exists for certain station as the new technology is being deployed. Therefore, more than 2 records can be found for a given station in a given year but using different sampling methods.

For the national and regional air quality indicators, the measurements using the TEOM method are preferred over measurements using BAM or FDMS methods to ensure consistency and comparability given that the TEOM has been the most widely used continuous sampling method in the NAPS network. Table 5 lists stations with duplicate measurements. The NEW TECH column identifies the year that the new technology was implemented. As a rule the TEOM measurements were used when more than one technology were available in a given year.

Table 5: Stations with new sampling technologies in the $PM_{2.5}$ air quality indicator

NAPS ID	PROVINCE	CITY	ADDRESS	TYPE	NEW TECH
40103	NB	FREDERICTON	437 ABERDEEN STREET	TEOM	BAM 2008
40203	NB	SAINT JOHN	MOUNTAIN ROAD	TEOM	BAM 2007+
40302	NB	MONCTON	5 THANET STREET	TEOM	BAM 2008+
40901	NB	ST. ANDREWS	BRANDY COVE ROAD	TEOM	BAM 2008+
50105	QC	MONTRÉAL	1212 RUE DRUMMOND	TEOM	BAM 2008+
50110	QC	MONTRÉAL	11280 BOUL. PIE IX, MTL NORD	TEOM	BAM 2008+
50126	QC	MONTRÉAL	20965 CH. SAINTE-MARIE, STE-ANNE dB	TEOM	FDMS 2009
50128	QC	MONTRÉAL	90-A RUE HERVÉ-SAINT-MARTIN, DORVAL	TEOM	FDMS 2008+
50129	QC	MONTRÉAL	12400 WILFRID-OUELLETTE	TEOM	FDMS 2008+
50131	QC	MONTRÉAL	3250 STE-CATHERINE EST	TEOM	FDMS 2008
50801	QC	TROIS-RIVIÈRES	FACE AU 678 RUE HART	TEOM	BAM 2009
54401	QC	SAINT-ANICET	1128 DE LA GUERRE	TEOM	BAM 2008+
54501	QC	L'ASSOMPTION	801 ST-ÉTIENNE/ROUTE 344	TEOM	BAM 2008+
55301	QC	SAINT-JEAN-SUR-RICHELIEU	FERME EXP., 1134 ROUTE 219	TEOM	BAM 2008+

4.2 Population Weighting

The air quality indicators are calculated using a population-weighted approach, weighting the annual warm-season average values of monitoring stations across Canada. Monitoring stations are scattered from coast to coast, in different areas with different populations. Therefore, proportionally adjusting air pollution levels measured at a monitoring station based on the size of the population residing near the station provides a surrogate estimate of exposure to ground-level ozone (O_3) and fine particulate matter ($PM_{2.5}$).[5]

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-weighted concentration level for each year (E_{year}) is calculated by multiplying the population (P) of a monitoring station by the average warm-season ambient level (C) of O_3 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

[5] 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.

together and collectively divided by the sum of the total population, which is the sum of population counts of all the monitoring stations.

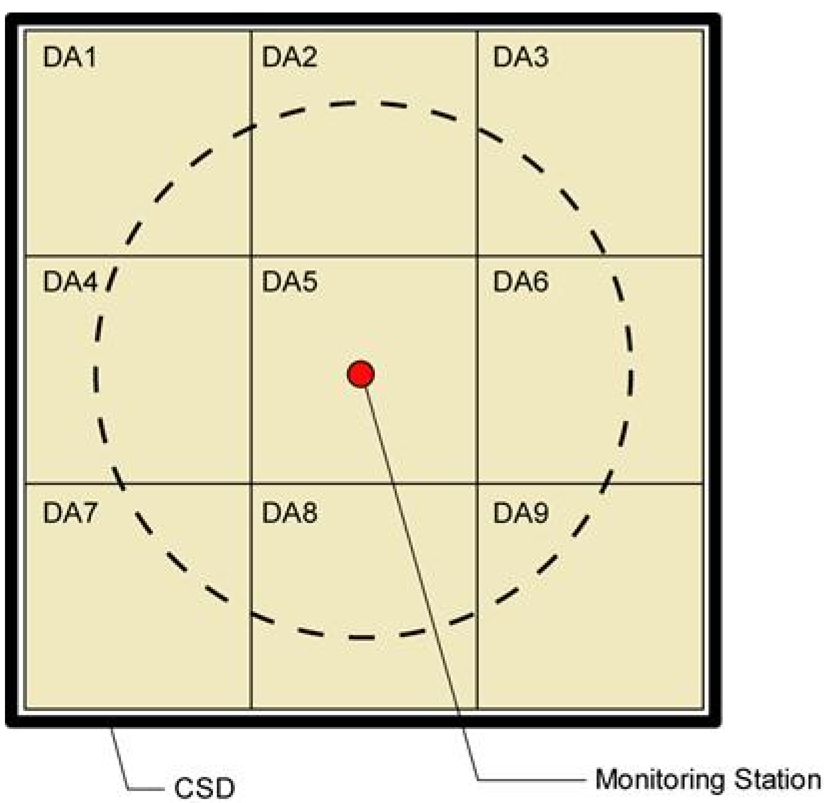
$$E_{year} = \frac{\Sigma (P_n \, x \, C_n)}{\Sigma \, P_n}$$

Estimating population weights

The estimation of population weights for each monitoring station relies on data from the latest Census of Population down to the dissemination area (DA) level and, for non-census years, the yearly population estimates for each census subdivision (CSD) provided by Statistics Canada. Each CSD is made up of several DAs and, in non-census years, the population of each DA is estimated using the annual population estimates 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 2 presents a conceptual framework for estimating the population in a circular area around a monitoring station.

Figure 2: Conceptual diagram, estimating the population around a monitoring station



Note: 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 (40-km radius) 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 time frame 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, on a five-year cycle, when new census data then become available. In non-census years, the latest census data are used as the basis for deriving the degree to which each DA contributes to the population of a CSD (as a percentage), using Statistics Canada's yearly population estimates for each CSD.

National and Regional Indicators

In total, 83 ground-level ozone and 64 $PM_{2.5}$ monitoring stations satisfied the data requirements and were included in the national air quality indicators.

The regional indicators for O_3 were based on 6 stations in Atlantic Canada, 21 stations in southern Quebec, 31 stations in southern Ontario, 13 stations in the Prairies and 12 stations in the lower Fraser Valley in British Columbia.

The regional indicators for $PM_{2.5}$ were based on 5 stations in Atlantic Canada, 12 stations in southern Quebec, 22 stations in southern Ontario, 12 stations in the Prairies and northern Ontario and 13 stations in the lower Fraser Valley in British Columbia.

Local data of the 2009 warm-season O_3 and $PM_{2.5}$ concentrations are also presented in the CESI mapping application available from: http://maps-cartes.ec.gc.ca/indicators-indicateurs/default.aspx?lang=en. These snapshots are average concentration obtained from 188 ground-level ozone and 156 $PM_{2.5}$ monitoring stations across Canada. Those stations have only satisfied the 2009 yearly criteria.

4.3 Statistical Analysis

Non-parametric statistics tests were conducted to detect the presence of a linear trend and determine its magnitude. The standard Mann-Kendall trend test was used to detect the presence and direction (positive or negative) of a linear trend between the annual average pollutant concentrations (O_3 and $PM_{2.5}$) and time at the 90% confidence level. Sen's pairwise slope method was used to test the presence of a linear trend at the 90% confidence level and also to estimate the slope between pollutant concentrations and time. The Mann-Kendall and the Sen Methods were applied to the annual average warm-season population-weighted concentration levels for O_3 (1990–2009) and $PM_{2.5}$ (2000–2009) data. A trend is reported when both the Mann-Kendall and Sen's tests indicate the presence of a trend at the 90% confidence level.

Tables 6 and 7 present the rate of change per year for the national and regional O_3 and $PM_{2.5}$ indicators, estimated with the Sen's method. The units for O_3 are in parts per billion (ppb) by volume concentration (i.e., one part of ground-level ozone per billion parts of air) and are also expressed in percent change based on the median of the 1990-2009 time series. The units for $PM_{2.5}$ are in micrograms $PM_{2.5}$ per one cubic meter of air and also expressed as a percent change based on the median of the 2000-2009 time series.

Table 6: Rate of change per year for the national and regional O_3 air quality indicators, 1990 to 2009

Ground-level ozone indicator	Number of stations	Median rate of change per year		90% Lower confidence interval	90% Upper confidence interval
	Number	ppb	%	%	%
National	83	0.19	0.50	0.09	0.89
Atlantic Canada	6	**	**	-	-
Southern Quebec	21	**	**	-	-
Southern Ontario	31	0.26	0.63	0.09	1.20
Prairies and Northern Ontario	13	**	**	-	-
Lower Fraser Valley	12	**	**	-	-

** indicates that Mann-Kendall or the Sen's method failed to reject the no-trend hypothesis at the 90% confidence level.

Table 7: Rate of change per year for the national and regional $PM_{2.5}$ air quality indicators, 2000 to 2009

$PM_{2.5}$ indicator	Number of stations	Median rate of change per year		90% Lower confidence interval	90% Upper confidence interval
	Number	ug/m3	%	%	%
National	64	**	**	-	-
Atlantic Canada	5	**	**	-	-
Southern Quebec	12	**	**	-	-
Southern Ontario	22	-0.37	-3.68	-6.70	-1.54
Prairies and Northern Ontario	12	**	**	-	-
Lower Fraser Valley	13	**	**	-	-

** indicates that Mann-Kendall or the Sen's method failed to reject the no-trend hypothesis at the 90% confidence level.

Based on a 90% confidence interval, test results for the O_3 indicator at the national level and in southern Ontario and for $PM_{2.5}$ in southern Ontario presented a statistically significant trend. The no-trend hypothesis could be not be rejected for all other national and regional time series. Results of the tests are available in appendix B.

5 Caveats and limitations

Measurement error: Environment Canada and provincial partners have deployed quality control and quality assurance procedures for monitoring instruments to ensure that sources of measurement error are controlled and minimized.

Data completeness: An important amount of measurement data is not used due to data completeness criteria. 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.

$PM_{2.5}$ sampling equipments: Different sampling methods for measuring $PM_{2.5}$ are used in the NAPS network so caution needs to be used when comparing results among stations and cities. $PM_{2.5}$ monitors based on newer technologies are being deployed across the NAPS network to replace older instruments which have been found to lose a portion of the $PM_{2.5}$ mass. So far, 14 of the 64 monitoring stations used in the calculation of this indicator were upgraded: 1 in 2007, 11 in 2008 and 2 in 2009. Caution should be used when interpreting PM2.5 levels and trends, as measurements from these newer methods may not be directly comparable with data from the older instruments.

Regional groupings: The definitions of the regions used for reporting are not the same as those used in the 2006 and earlier releases of CESI. Accordingly, the "Quebec and eastern Ontario" region as presented in the earlier reports has been changed to include stations that are only in southern Quebec.

Population weighting: The population weighting method used in CESI assumes uniform concentrations of ground-level ozone and $PM_{2.5}$ within relatively arbitrary zones. These uniform concentrations therefore do not factor prevailing winds and the location of major emissions sources.

6 References and further reading

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Appendix A

Table A: Air Quality Monitoring Stations Reported in CESI for the National and Regional Indicators

Legend and Acronyms

COLUMN	DESCRIPTION
NAPS ID	Monitoring station NAPS Identifier
PROV, CITY and ADDRESS	Location of monitoring station
O_3	The asterisk (*) indicates a station that met the yearly criteria in 2009 for ground-level ozone.
$PM_{2.5}$	The asterisk (*) indicates a station that met the yearly criteria in 2009 for fine particulate matter.
IO_3:	If not empty, station contributes data to the time series trend analysis for ground level ozone in the national indicator and regional indicator of the identified region.
$IPM_{2.5}$	If not empty, station contributes data to the time series trend analysis for fine particulate matter in the national indicator and regional indicator of the identified region.
ACRONYMS	**DESCRIPTION**
ATL	Atlantic Region CESI Regional Indicator
SQC	Southern Quebec CESI Regional Indicator
SON	Southern Ontario CESI Regional Indicator
PNO	Prairies and Northern Ontario CESI Regional Indicator
LFV	Lower Fraser Valley CESI Regional Indicator

Monitoring Stations

NAPS ID	PROV	CITY	ADDRESS	O3	PM2.5	IO3	IPM2.5
10102	NL	ST. JOHN'S	354 WATER STREET	*	*	ATL	ATL
30501	NS	KEJIMKUJIK	NATIONAL PARK	*		ATL	
40103	NB	FREDERICTON	437 ABERDEEN STREET		*		ATL
40203	NB	SAINT JOHN	MOUNTAIN ROAD	*	*	ATL	ATL
40302	NB	MONCTON	5 THANET STREET		*		ATL
40401	NB	FUNDY NAT. PARK	HASTINGS TOWER	*		ATL	
40601	NB	CENTRAL BLISSVILLE	AIRPNORT ROAD	*		ATL	
40701	NB	NORTON	308 HWY 124	*		ATL	
40901	NB	ST. ANDREWS	BRANDY COVE ROAD		*		ATL
50102	QC	MONTRÉAL	BOUL. ROSEMONT	*		SQC	
50103	QC	MONTRÉAL	1050 A, BOUL. SAINT-JEAN-BAPTISTE	*		SQC	
50104	QC	MONTRÉAL	1125 RUE ONTARIO EST	*		SQC	
50105	QC	MONTRÉAL	1212 RUE DRUMMOND		*		SQC
50110	QC	MONTRÉAL	11280 BOUL. PIE IX, MTL NORD	*	*	SQC	SQC
50113	QC	LAVAL	1160 BOUL PIE X	*		SQC	
50116	QC	MONTRÉAL	3161 JOSEPH, VERDUN	*		SQC	
50119	QC	LONGUEUIL	FACE AU 1819 RUE VICTORIA	*		SQC	
50126	QC	MONTRÉAL	20965 CH. SAINTE-MARIE, STE-ANNE		*		SQC
50128	QC	MONTRÉAL	90-A RUE HERVÉ-SAINT-MARTIN, DORVAL		*		SQC
50129	QC	MONTRÉAL	12400 WILFRID-OUELLETTE		*		SQC
50131	QC	MONTRÉAL	3250 STE-CATHERINE EST		*		SQC
50308	QC	QUÉBEC	600 RUE DES SABLES		*		SQC
50801	QC	TROIS-RIVIÈRES	FACE AU 678 RUE HART		*		SQC
51201	QC	SHAWINIGAN	363 RUE FRIGON		*		SQC
51501	QC	ST. ZÉPHIRIN-DE-COURVAL	701 RANG SAINT-MICHEL	*		SQC	

52001	QC	CHARETTE	AU NORD DU 170 2E RANG	*		SQC	
52201	QC	SAINT-SIMON	DERRIÈRE LE 83, 4E RANG EST	*		SQC	
52301	QC	SAINT-FAUSTIN-LAC-CARRÉ	CHEMIN DU LAC (CARIBOU)	*		SQC	
52401	QC	LA PÊCHE	LAC PHILIPPE - MASHAM	*		SQC	
53201	QC	LA DORÉ	ROUTE 167- LA DORÉ	*		SQC	
53501	QC	SAINT-FRANÇOIS	FACE AU 198, ROYALE ÎLE D'ORLÉANS	*		SQC	
53601	QC	NOTRE-DAME-DU-ROSAIRE	RANG ST-LOUIS	*		SQC	
53701	QC	ST-HILAIRE-DE-DORSET	RANG DORSET	*		SQC	
53801	QC	TINGWICK	CHEMIN RADAR ET WARWICK	*		SQC	
53901	QC	LAC-ÉDOUARD	DERRIÈRE L'HÔPITAL VILLAGE	*		SQC	
54401	QC	SAINT-ANICET	1128 DE LA GUERRE		*		SQC
54501	QC	L'ASSOMPTION	801 ST-ÉTIENNE/ROUTE 344		*		SQC
54801	QC	STUKELY-SUD	CHEMIN MONTBEL	*		SQC	
54901	QC	LA PATRIE	RANG PETIT CANADA OUEST	*		SQC	
55001	QC	FERME NEUVE	215 4 IÈME RANG GRAVEL	*		SQC	
55301	QC	SAINT-JEAN-SUR-RICHELIEU	FERME EXP., 1134 ROUTE 219		*		SQC
60104	ON	OTTAWA	RIDEAU & WURTEMBURG	*	*	SON	SON
60204	ON	WINDSOR	467 UNIVERSITY AVE. WEST	*	*	SON	SON
60303/60302	ON	KINGSTON	752 KING ST. WEST	*		SON	
60429/60403	ON	TORONTO	1 ETONA COURT	*	*	SON	SON
60410	ON	TORONTO	LAWRENCE & KENNEDY	*		SON	
60413	ON	TORONTO	ELMCREST ROAD	*		SON	
60434/60415	ON	MISSISSAUGUA	3359 MISSISSAUGA ROAD NORTH	*	*	SON	SON
60421	ON	TORONTO	YONGE ST. & FINCH AVE.	*	*	SON	SON
60433/60424	ON	TORONTO	900 BAY STREET	*	*	SON	SON
60428	ON	BRAMPTON	525 MAIN ST. N. BRAMPTON		*		SON
60430/60413	ON	TORONTO	125 RESOURCES ROAD		*		SON
60512	ON	HAMILTON	ELGIN & KELLY	*	*	SON	SON
60513	ON	HAMILTON	VICKERS RD. & EAST 18TH. ST.	*	*	SON	SON
60609/60607	ON	SUDBURY	RAMSEY LAKE ROAD	*		SON	
60609/60707	ON	SAULT STE. MARIE	443 NORTHERN AVE., SAULT COLLEGE	*		SON	
60809/60807	ON	THUNDER BAY	421 JAMES STREET SOUTH	*		SON	
60903/60901	ON	LONDON	900 HIGHBURY AVENUE	*		SON	
60903	ON	LONDON	900 HIGHBURY AVENUE		*		SON
61004	ON	SARNIA	FRONT ST. AT C.N. TRACKS	*	*	SON	SON
61104	ON	PETERBOROUGH	10 HOSPITAL DRIVE		*		SON
61201	ON	CORNWALL	BEDFORD & THIRD ST.	*		SON	
61302	ON	ST. CATHARINES	ARGYLE CRESCENT	*	*	SON	SON
61502	ON	KITCHENER	WEST AVE. & HOMEWOOD	*	*	SON	SON
61603/61602	ON	OAKVILLE	8TH LINE/GLENASHTON DR.; HALTON RESERVE.	*		SON	
61702/61701	ON	OSHAWA	2200 SIMCOE STREET NORTH	*	*	SON	SON
61802	ON	GUELPH	70 DIVISION STREET; EXHIBITION PARK	*	*	SON	SON

62001	ON	NORTH BAY	CHIPPEWA ST.	*	*	SON	SON
62501	ON	TIVERTON	BRUCE NUCLEAR VISITOR CTR	*	*	SON	SON
62601	ON	SIMCOE	EXPERIMENTAL FARM	*	*	SON	SON
63001	ON	BURLINGTON	HWY 2 & NORTH SHORE BLVD.	*	*	SON	SON
65101/63 201	ON	NEWMARKET-STOUFFVILLE	EAGLE ST. & McCAFFREY RD	*		SON	
63301	ON	DORSET	HWY 117 & PAINT LAKE ROAD	*	*	SON	SON
64101	ON	ALGOMA	ALGOMA	*		SON	
64401	ON	EGBERT	EGBERT	*		SON	
65301	ON	PNORT STANLEY	43665 DEXTER LINE	*		SON	
64001	ON	EXP. LAKES AREA	EXP. LAKES AREA	*		PNO	
70118	MB	WINNIPEG	299 SCOTIA ST.	*	*	PNO	PNO
70119	MB	WINNIPEG	65 ELLEN STREET	*	*	PNO	PNO
70203	MB	BRANDON	1430 VICTORIA AVENUE EAST	*		PNO	
80110	SK	REGINA	2505 11TH. AVENUE	*	*	PNO	PNO
80211/80 209	SK	SASKATOON	511 1ST AVENUE NORTH	*		PNO	
90121	AB	EDMONTON	17 STREET & 105 AVENUE	*	*	PNO	PNO
90130	AB	EDMONTON	10255 - 104TH STREET	*	*	PNO	PNO
90218	AB	CALGARY	49 AVENUE & 15TH STREET S.E.	*		PNO	
90222	AB	CALGARY	39 ST. & 29 AVE. N.W.	*		PNO	
90228/90 227	AB	CALGARY	620 7TH AVE SW	*	*	PNO	PNO
90302	AB	RED DEER	73 STREET & RIVERSIDE DRIVE		*		PNO
90601	AB	FORT SASKATCHEWAN	9209A-96 Ave	*		PNO	
90701	AB	FORT MCMURRAY	FRANKLIN AVENUE	*	*	PNO	PNO
90702	AB	FORT MCMURRAY	TIMBERLEA SUBDIVISION		*		PNO
90801	AB	FORT MACKAY	MAIN STREET		*		PNO
91301	AB	TOMAHAWK	SE 2 51 6 W5		*		PNO
91801	AB	FORT CHIPEWYAN	FORT CHIPEWYAN		*		PNO
100110	BC	METRO VAN - BURNABY	6400 E. HASTINGS & KENSINGTON	*		LFV	
100111	BC	METRO VAN - PNORT MOODY	MOODY & ESPLANADE PNORT MOODY	*		LFV	
100118	BC	METRO VAN - VANCOUVER	2550 WEST 10TH AVENUE	*		LFV	
100125	BC	METRO VAN - DELTA	8544 116TH AVE. DELTA	*		LFV	
100126	BC	METRO VAN - BURNABY	RING ROAD BURNABY	*		LFV	
100127	BC	METRO VAN - SURREY	19000 & 72ND AVE. SURREY	*		LFV	
100128	BC	METRO VAN - RICHMOND	WILLIAMS & ARAGON RICHMOND	*		LFV	
100132	BC	METRO VAN - VANCOUVER	16TH ST. & JONES AVE NORTH VAN	*		LFV	
100134	BC	METRO VAN - RICHMOND	3153 TEMPLETON STREET		*		LFV
100202	BC	PRINCE GEORGE	1011 4TH AVENUE		*		LFV
100304	BC	VICTORIA	923 TOPAZ		*		LFV
100307	BC	VICTORIA	2005 SOOKE ROAD		*		LFV
100402	BC	KAMLOOPS	MAYFAIR STREET		*		LFV
100701	BC	KELOWNA	3333 COLLEGE WAY	*	*	LFV	LFV
101004/1 01001	BC	ABBOTSFORD	31790 WALMSLEY AVENUE	*		LFV	
101101	BC	METRO VAN-CHILLIWACK	46244 AIRPNORT ROAD	*	*	LFV	LFV
101101/1 01202	BC	METRO VAN-PITT MEADOWS	18477 DEWDNY TRUNK	*	*		LFV
101701	BC	QUESNEL	585 CALLANAN STREET		*		LFV
101702	BC	QUESNEL	950 MOUNTAIN ASH ROAD		*		LFV

101704	**BC**	**QUESNEL**	**CORRELIEU SCHOOL**		*****		**LFV**
102102	**BC**	**NANAIMO**	**280 LABIEUX ROAD**		*****		**LFV**
102706/102701	**BC**	**WILLIAMS LAKE**	**180 NORTH 3RD AVE**		*****		**LFV**

Appendix B

Legend for tables B1 and B2

FIELD	DESCRIPTION
Time series	The names of the time series
First year	Starting year of each time series
Last year	Ending year of each time series
N	The number of annual values in the calculation excluding missing values
Test Z	If n is at least 10, the test statistic Z is displayed. The absolute value of Z is compared to the standard normal cumulative distribution to define if there is a trend or not at the selected level α of significance. A positive (negative) value of indicates an upward (downward) trend. If n is 9 or less, this cell is empty.
Significant	The smallest significance level α at which the test shows that the null hypothesis of no trend can be rejected. If n is 9 or less, the test is based on the S statistic and if n is at least 10, the test is based to the Z statistic (normal approximation). For the four tested significance levels the following symbols are used in the template: *** if trend at α = 0.001 level of significance ** if trend at α = 0.01 level of significance * if trend at α = 0.05 level of significance + if trend at α = 0.1 level of significance If the cell is blank, the significance level is greater than 0.1.
Q	The Sen's estimator for the true slope of linear trend i.e. change per unit time period (in this case a year)
Qmin90	The lower limit of the 90 % confidence interval of Q (α= 0.1)
Qmax90	The upper limit of the 90 % confidence interval of Q (α= 0.1)
B	Estimate of the constant B in equation f(year)=Q*(year-firstYear)+B for a linear trend
Bmin90	Estimate of the constant Bmin90 in equation f(year)=Qmin99*(year-firstYear)+Bmin90 for 90% confidence level of linear trend.
Bmax90	Estimate of the constant Bmax90 in equation f(year)=Qmax99*(year-firstYear)+Bmax90 for 90% confidence level of linear trend.

Trend Equation

f(year) = Q*(year-First Data Year) + B

Where First Data Year = 1990 for O_3 and 2000 for $PM_{2.5}$

Table B1. Mann-Kendall and SEN Tests results for O_3

STATISTICS	Ground -level Ozone (O_3)					
	NATIONAL	ATL	SQC	SON	PNO	LFV
First Year	1990	1990	1990	1990	1990	1990
Last Year	2009	2009	2009	2009	2009	2009
N	20	20	20	20	20	20
Test Z	1.91	0.62	1.33	2.11	1.40	1.59
Significant	Yes +			Yes *		
Q	0.18			0.26		
Qmin90	0.03			0.04		
Qmax90	0.33			0.50		
B	35.38			39.28		
Bmin90	36.63			41.20		
Bmax90	34.14			37.84		

Table B2. Mann-Kendall and SEN Tests results for $PM_{2.5}$

STATISTICS	Fine particulate matter ($PM_{2.5}$)					
	NATIONAL	ATL	SQC	SON	PNO	LFV
First Year	2000	2000	2000	2000	2000	2000
Last Year	2009	2009	2009	2009	2009	2009
N	10	10	10	10	10	10
Test Z	-1.61	0.36	0.72	-2.15	0.00	-0.54
Significant				Yes *		
Q				-0.37		
Qmin90				-0.68		
Qmax90				-0.16		
B				11.39		
Bmin90				13.06		
Bmax90				10.65		