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Data Sources and Methods for the Air Quality Indicators

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1 Introduction

The Air Quality Indicators (http://ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=7DCC2250-1) are part of the Canadian Environmental Sustainability Indicators (CESI) program (http://ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=47F48106-1), which provides data and information to track Canada's performance on key environmental sustainability issues. These indicators are also used to measure progress towards the goals and targets of the Federal Sustainable Development Strategy (http://www.ec.gc.ca/dd-sd/default.asp?lang=En&n=CD30F295-1).

2 Description and rationale of the Air Quality indicators

2.1 Description

The Air Quality Indicators track the ambient concentrations of fine particulate matter ($PM_{2.5}$), ground-level ozone (O_3), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and volatile organic compounds (VOCs) at the national and regional levels and at the local monitoring-station level.

Table 1: Air Quality Indicators definitions

Pollutant	Indicator	Statistics	Units*
$PM_{2.5}$	Annual average	Annual average of the 24-hour average concentrations	$\mu g/m^3$
$PM_{2.5}$	Peak (98th percentile) 24-hour	Annual 98th percentile of the daily 24-hour average concentrations	$\mu g/m^3$
O_3	Annual average	Annual average of the daily maximum 8-hour average concentrations	ppb
O_3	Peak (4th-highest) 8-hour	Annual 4th-highest daily maximum 8-hour average concentrations	ppb
SO_2	Annual average	Annual average of the 24-hour average concentrations	ppb
NO_2	Annual average	Annual average of the 24-hour average concentrations	ppb
VOCs	Annual average	Annual average of the 24-hour average concentrations	ppbC

Note: * Units: $\mu g/m^3$ = micrograms per cubic metre, ppb = parts per billion, ppbC = parts per billion carbon.

Canadian Ambient Air Quality Standards

In October 2012, federal, provincial and territorial Environment Ministers agreed to take further action to protect the health of Canadians and the environment, with the implementation of the New Air Quality Management System (AQMS) (http://www.ccme.ca/ourwork/air.html?category_id=146). The system was developed in collaboration with federal, provincial and territorial governments, and stakeholders representing industry as well as health and environmental organizations. The AQMS includes the New Canadian Ambient Air Quality Standards (CAAQS) (http://www.ccme.ca/ourwork/air.html?category_id=146#490) for $PM_{2.5}$ and O_3, standards that were established as objectives under the *Canadian Environmental Protection Act, 1999* (CEPA 1999) on May 25, 2013. The CAAQS are health-based numerical values of outdoor air concentrations of pollutants intended to drive air quality improvement across Canada. They are more ambitious and

comprehensive than the previous *Canada-wide Standards for Particulate Matter (PM) and Ozone* (http://www.ccme.ca/ourwork/air.html?category_id=99). The CAAQS provide short-term limits for $PM_{2.5}$ and O_3, and a new limit for long-term exposure (annual) for $PM_{2.5}$. Table 2 provides details of the new standards.

Table 2: Canadian Ambient Air Quality Standards (CAAQS) for fine particulate matter ($PM_{2.5}$) and ozone (O_3)

Pollutant	Averaging time	2015 standard (numerical value)	2020 standard (numerical value)	Metric
$PM_{2.5}$	24-hour (calendar day)	28 µg/m^3	27 µg/m^3	3-year average of the annual 98th percentile of the daily 24-hour average concentrations
$PM_{2.5}$	Annual (calendar year)	10.0 µg/m^3	8.8 µg/m^3	3-year average of the annual average concentrations
O_3	8-hour	63 ppb	62 ppb	3-year average of the annual 4th-highest daily maximum 8-hour average concentrations

Calculations of the Air Quality Indicators follow the same data-handling conventions as those used for calculating CAAQS values. It is important to note that the achievement of the CAAQS for $PM_{2.5}$ and O_3 are calculated using the three-year averages of the measured concentrations at the local level, while the indicator values are calculated at the national and regional levels using a single year only. As such, the comparison of the indicator values to the standards is provided for indicative purposes only.

2.2 Rationale

Canadians are exposed to air pollutants on a daily basis, and this exposure can cause adverse health and environmental effects. Some of the VOCs are defined as toxic under CEPA 1999. Exposure to toxic pollutants can increase the risk, over a lifetime, of developing serious health conditions like cancer (http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/news/news/2013/10/outdoor-air-pollution-a-leading-environmental-cause-of-cancer-deaths). Exposure to toxic pollutants can also increase the risk of serious health conditions as a result of acute (short-term) exposures. Exposure to even low concentrations of pollutants like O_3 and $PM_{2.5}$ has been linked to a number of adverse effects on health (http://ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=CB7B92BA-1).

$PM_{2.5}$ and ground-level O_3 are key components of smog and two of the most widespread air pollutants to which people are exposed. While causing effects of their own, NO_2 and VOCs are the main contributors to ground-level ozone. NO_2, SO_2 and VOCs also lead to the formation of $PM_{2.5}$ in the air, thereby contributing to the $PM_{2.5}$ that is also emitted directly. SO_2 and NO_2 can also lead to the formation of acid deposition that can harm the environment, materials, living organisms and humans.

These indicators are intended as state/condition indicators to inform decision-makers and the public about the state of the environment and the progress toward improved ambient air quality in Canada.

2.3 Recent changes to the indicator

This is the second edition of the air quality indicators aligned with the CAAQS for the $PM_{2.5}$ and O_3 indicators. These indicators are based on data collected throughout the year (rather than only during the warm season) and are not population-weighted.

The stations used to calculate the indicators vary slightly between editions of the indicator. There are more stations used this year than in the previous release for all the pollutants. For more information, consult section 5.

3 Data

3.1 Data source

Air quality monitoring stations are located across Canada and are managed by the provinces, territories, some municipalities and Environment Canada. Data from stations collecting $PM_{2.5}$, ground-level O_3, SO_2, NO_2[1] and VOCs levels were obtained from the National Air Pollution Surveillance (NAPS) program (http://ec.gc.ca/rnspa-NAPS/default.asp?lang=En&n=5C0D33CF-1), a cooperative arrangement between the federal government and its provincial, territorial and regional government partners (http://ec.gc.ca/rnspa-naps/Default.asp?lang=En&n=31258671-1) that has existed since 1969. The goal of the NAPS program is to provide accurate, long-term air quality data of a uniform standard throughout Canada, and to store the data collected in the Canada-wide air quality database (CWAQD) (http://maps-cartes.ec.gc.ca/rnspa-naps/data.aspx?lang=en).[2]

The CWAQD also includes O_3 data collected by the Canadian Air and Precipitation Monitoring Network (CAPMoN) (http://ec.gc.ca/rs-mn/default.asp?lang=En&n=752CE271-1), which is operated by Environment Canada. The CAPMoN stations were established to research and monitor air pollution outside urban areas. The CWAQD also includes data collected by provincial, territorial and municipal monitoring stations that are not part of the NAPS program.

The CAAQS (http://www.ec.gc.ca/default.asp?lang=En&n=56D4043B-1&news=A4B2C28A-2DFB-4BF4-8777-ADF29B4360BD) for $PM_{2.5}$ and O_3 were formally established by federal Environment and Health Ministers on May 25, 2013. These standards are key components of the New AQMS (http://www.ccme.ca/ourwork/air.html?category_id=146), which is being implemented in collaboration with the provinces and territories under the auspices of the Canadian Council of Ministers of the Environment (CCME) (http://www.ccme.ca/about/index.html).

[1] NO_2 is measured indirectly by subtraction following a measurement of the total of nitrogen oxides (NO_X = $NO+NO_2$) and nitric oxide (NO) alone.
[2] Other pollutants measured through NAPS include carbon monoxide (CO), NO, NO_x, particulates with an aerodynamic diameter less than 10 µm (PM_{10}), metals, and a variety of semi-volatile organic compounds (e.g., Polycyclic Aromatic Hydrocarbons (PAHs)).

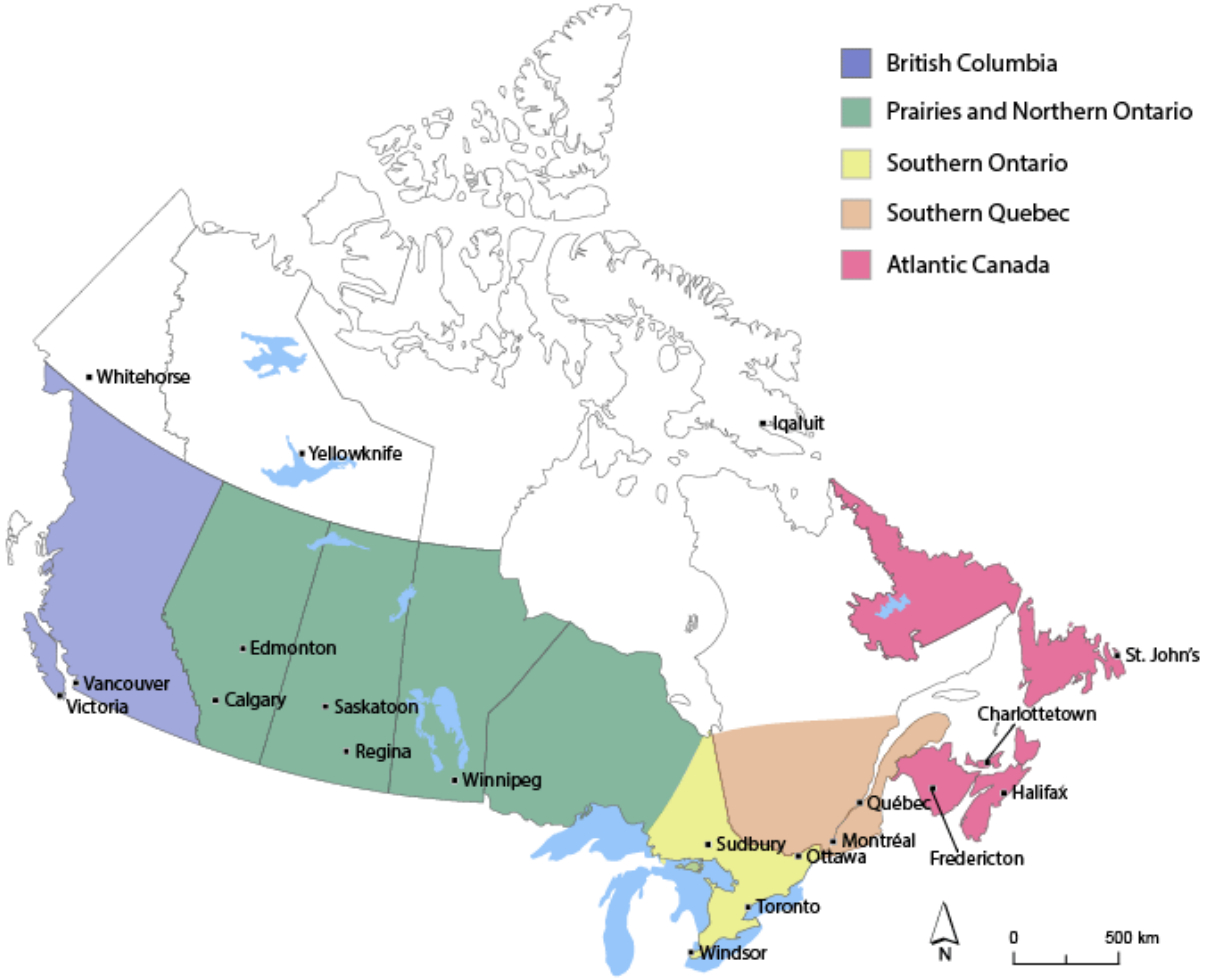
3.2 Spatial coverage

Air quality monitoring stations are spread across the country, but are more concentrated in urban areas.[3] The $PM_{2.5}$, O_3, SO_2, NO_2 and VOCs indicators are provided nationally and by region. Table 3 lists the regions used for these indicators. Refer to Appendix A for the full list of stations used to calculate the national and regional indicators.

Table 3: Regions used for the regional air quality indicators

Region code	Region
ATL	Atlantic Canada
SQC	Southern Quebec
SON	Southern Ontario
PNO	Prairies and northern Ontario
BCO	British Columbia

Figure 1: Regions used for the regional air quality indicators



[3] Area with a population of at least 1000 and no fewer than 400 persons per square kilometre.

The $PM_{2.5}$, O_3, SO_2, NO_2 and VOCs ambient levels by monitoring station are also shown in the CESI interactive map (http://maps-cartes.ec.gc.ca/indicators-indicateurs/default.aspx?lang=en).

3.3 Temporal coverage

The annual Air Quality Indicators for O_3, SO_2, NO_2 and VOCs were calculated for the most recent 15 years with available data (1998 to 2012). For $PM_{2.5}$, the time series spans the years 2000 to 2012 because earlier comparable data were unavailable. Although minute-by-minute data are recorded by monitoring instruments, only hourly average readings are transmitted and stored as the working data in the CWAQD.

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 1998 or 2000 (for $PM_{2.5}$). There are a number of reasons for this, including short-term technical problems, maintenance and routine repairs, calibration and checks, and the commissioning or decommissioning of 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 program perform routine audits, and all strive to adhere to established quality assurance and quality control (QA/QC) standards,[4] which were developed under the auspices of the CCME and are provided in Table 4. Environment Canada conducts a national audit program to ensure consistency among jurisdictions across Canada.

Table 4: Data quality objectives and specifications for $PM_{2.5}$, O_3, SO_2, NO_2 and VOCs

Parameter	$PM_{2.5}$	O_3	SO_2	NO_2	VOCs
Accuracy	± 20%	± 10%	± 15%	± 15%	Species-dependent
Precision	< 10%	< 10%	< 10%	< 10%	Species-dependent
Completeness	> 75%	> 75%	> 75%	> 75%	
Traceability	Reference method	Traceable to primary standard	Traceable to standard reference material	Traceable to standard reference material	Individual lab standard
Averaging period	24 hours	Hourly	Hourly	Hourly	*24 hours or 4 hours
Measurement cycle	Year-round	Year-round	Year-round	Year-round	*Year-round

Note: * At urban monitoring stations, VOCs samples are usually collected over a 24-hour period once every six days, and, at rural stations, samples are collected over a 4-hour sampling period (12:00 to 16:00) once every three days.

[4] Canadian Council of Ministers of the Environment (CCME) 2011 Ambient Air Monitoring Protocol for $PM_{2.5}$ and Ozone. Canada-wide Standards for Particulate Matter and Ozone (PDF; 787 KB). Available at: http://www.ccme.ca/assets/pdf/pm_oz_cws_monitoring_protocol_pn1456_e.pdf

Accuracy is the nearness of a measurement to an accepted value; expressed in terms of error, usually as ± percentage difference from standard value. Precision is the degree of mutual agreement among several values measured by the same systems; often expressed as the deviation from the mean in terms of the relative standard deviation (% RSD). Completeness is the degree to which valid measurements are available for a given period; often described as the percentage of total possible measurements. Traceability is the nearness of two different measurement systems; expressed in terms of difference, usually as ± percentage difference.

3.6 Data timeliness

There is a 15-month lag between the last year of data available for the compilation of the Air Quality Indicators and the publication of the indicators. This lag is due to several factors, including data verification, transmission of the data into the CWAQD, compilation at the national level from all partners, analysis, review and reporting. The validation of approximately 44 000 measurements at a single station measuring all five pollutants is required for each year of data used for the compilation of the indicators.

4 Methods

The Air Quality Indicators are calculated according to the following steps.

4.1 Data collection and quality assurance and quality control

Data obtained from the NAPS program (http://ec.gc.ca/rnspa-NAPS/default.asp?lang=En&n=5C0D33CF-1) monitoring stations are converted to a format compatible for entry into the CWAQD. All data in the CWAQD have a comparable level of quality, because jurisdictions adhere to established QA/QC procedures as outlined in the NAPS QA/QC Guidelines and by deploying instruments approved by the United States Environmental Protection Agency (U.S. EPA) as a federal reference method (FRM) or federal equivalent method (FEM). Some of these procedures include national independent audits of instruments conducted by Environment Canada; independent audits conducted by jurisdictions; routine maintenance and calibration procedures; and computerized and visual data inspection. The government organizations must confirm the data, either automatically or by manually flagging it, before storing the data in the CWAQD.

4.2 Data completeness criteria

The following criteria are used to determine which stations have sufficient hourly and daily measurements in each year to be considered valid for inclusion in the indicators. In general they follow the same criteria that can be found in the CCME's *Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone* (PDF; 264 KB). (http://www.ccme.ca/assets/pdf/pn_1483_gdad_eng.pdf)

Fine particulate matter ($PM_{2.5}$):

- A valid day has data for at least 18 hours (75%);
- A station is included only when

- at least 75% of days in the year are valid; and
- at least 60% of days in each quarter (three months) in a calendar year are valid.

For the peak (98th percentile) 24-hour $PM_{2.5}$ indicator, a station is also included if it exceeds the 24-hour standards of 28 µg/m^3 even if the above data completeness criteria are not satisfied.

Ground-level ozone (O_3):

- A valid 8-hour period has data for at least 6 hours (75%);
- A valid day requires data for at least 18 hours (75%); and
- A station is included only when at least 75% of days in the combined second and third quarters (April 1 to September 30) are valid.

For the peak (4th-highest) 8-hour O_3 indicator, a station is also included if it exceeds the 8-hour standard of 63 ppb even if the above data completeness criteria are not satisfied.

Sulphur dioxide (SO_2) and nitrogen dioxide (NO_2):

- A valid day requires data for at least 18 hours;
- A valid month requires data for at least 50% of valid days;
- A valid quarter (three months) requires data for at least two valid months; and
- A station is included only if the year has four valid quarters.

Volatile organic compounds (VOCs):

There are fewer data for the monitoring of the VOCs, and therefore data completeness criteria are different. Samples are collected once every six days at urban monitoring stations and once every three days in rural areas. Data completeness criteria are as follows:

- A valid day requires data for a consecutive 24 hours in an urban station and for a consecutive 4 hours in a rural area;
- A valid quarter (three months) requires data for at least 5 samples; and
- A station is included only if the year has three valid quarters.

Table 5: Number of stations that satisfied the data completeness criteria for 2012

Air pollutant	Number of stations
Peak (98th percentile) 24-hour $PM_{2.5}$	176
Annual average $PM_{2.5}$	172
Peak (4th-highest) 8-hour O_3	195
Annual average O_3	193
SO_2	116
NO_2	146
VOCs	48

After the data completeness criteria have been applied, the pollutant concentrations are calculated for the selected stations. Specifics on calculation for each pollutant at a station are provided in the following section.

4.3 Pollutant-specific calculations

Fine particulate matter ($PM_{2.5}$): The $PM_{2.5}$ annual average and annual peak (98th percentile) 24-hour indicators are based on the 24-hour daily average concentrations (daily average) for the whole year. The daily average value for $PM_{2.5}$ is measured from midnight to midnight.

For a given station, the annual average indicator is calculated by summing all the valid daily averages and dividing by the number of valid days. The annual peak (98th percentile) 24-hour indicator is obtained by determining the 98th percentile value of all the 24-hour daily values for a given year. The 98th percentile value corresponds to the concentration for which 98% of all the daily 24-hour values are less than, and 2% are greater than or equal to it. For example, the 98th percentile value of 25 µg/m^3 at a given station means that, of all daily 24-hour average concentrations at the station, 98% were less than 25 µg/m^3, and that only 2% were equal to, or greater than, 25 µg/m^3. Table 6 provides the rank of the 98th percentile value depending on the number of available daily measurements.

Table 6: 98th percentile rank based on the number of available measurements[5]

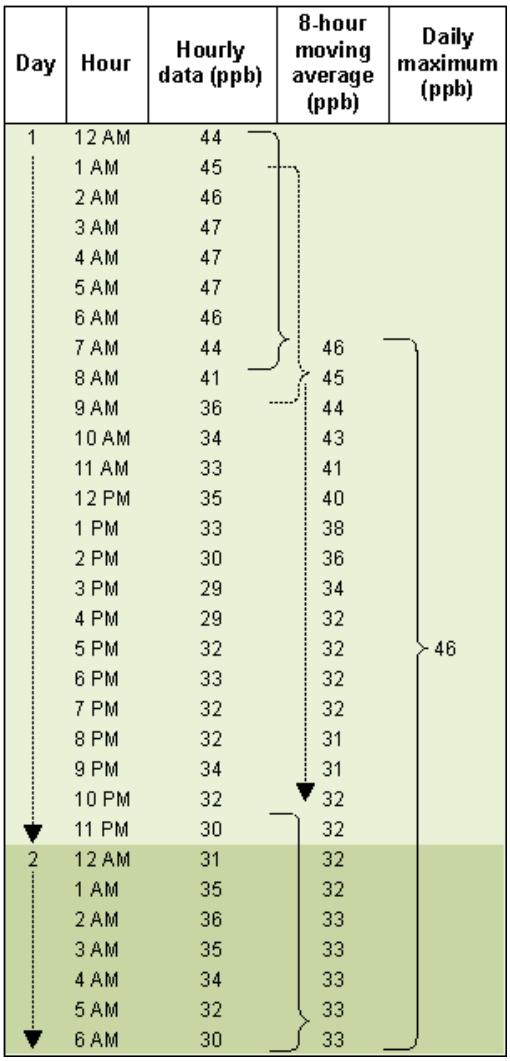
Number of available daily measurements in a year	98th percentile rank
1–50	1st highest
51–100	2nd highest
101–150	3rd highest
151–200	4th highest
201–250	5th highest
251–300	6th highest
301–350	7th highest
351–366	8th highest

[5] To obtain the different 98th percentile values in this table, the same calculation method was used as the one proposed in section 4.1.2 of the CCME report on *Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone* (PDF; 264 KB). Available at: http://www.ccme.ca/assets/pdf/pn_1483_gdad_eng.pdf

The regional and national indicators (annual average and annual peak [98th percentile] 24-hour) for $PM_{2.5}$ are calculated by averaging the station-level annual average and station-level annual peak values, respectively, for selected stations within either the region or throughout Canada.

Ground-level ozone (O_3): For O_3, concentrations are calculated in ppb. There are 24 consecutive 8-hour average concentrations (8-hour rolls) that can be possibly calculated for each day. The highest value of those 24 concentrations is the daily maximum. See Figure 2 for an illustration of the 8-hour averages.

Figure 2: Calculation of the ground-level ozone daily maximum 8-hour average concentration (in parts per billion)



For each station, the annual average O_3 indicator is calculated by taking the average of the daily maximums from January 1 to December 31. The regional and national annual averages for O_3 are obtained by averaging the station-level annual averages for selected stations within either the region or throughout Canada, respectively.

For each station, the annual peak (4th-highest) 8-hour O_3 indicator is based on the 4th-highest of the daily maximum 8-hour average concentrations measured over a given year. All of the daily maximum 8-hour average concentrations are ordered in an array from highest to lowest, with equal values repeated as often as they occur. Each value is assigned a rank. For that year, the 4th-highest ranking value in the array is identified as annual peak (4th-highest) 8-hour O_3 concentration for that station. The regional and national annual peak O_3 indicators are obtained by averaging all the 4th-highest values from selected stations within either the region or throughout Canada, respectively.

Sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and volatile organic compounds (VOCs): The SO_2, NO_2 and urban station VOCs indicators are calculated from daily average concentrations (24-hour average concentrations) and rural VOCs stations are calculated from daily 4-hour average. The daily 24-hour average concentrations are based on measurements taken from midnight to midnight. For a station, the annual average indicator is calculated by taking the average of the daily concentrations throughout a given year.

The regional and national annual average indicators for SO_2, NO_2 and VOCs are obtained by averaging the station-level annual averages from selected stations within either the region or throughout Canada, respectively.

Note that because of data availability issues, the regional southern Ontario VOCs annual average was not estimated for 2011.

4.4 Station selection criteria, for inclusion in national and regional indicators (time-series)

Station-level indicators were calculated for the years 1998 to 2012 for all air pollutants except for $PM_{2.5}$, where indicators were calculated for the years 2000 to 2012. Each station was then assessed for its suitability (sufficient data, no large gaps at the beginning or end) for inclusion in the national and regional time series. The specific criteria are as follows:

- For the O_3, SO_2, NO_2 and VOCs national and regional time series for the years 1998 to 2012, a station is included if it satisfies the data completeness criteria described above for at least 11 of the 15 years. Stations are excluded if data are missing for more than two consecutive years at the beginning or end of the time series. This measure avoids use of data from stations that were commissioned or decommissioned at the beginning or end of the time series.
- For the $PM_{2.5}$ national and regional time series for the years 2000 to 2012, a station is included if it satisfies the data completeness criteria described above for at least 10 of the 13 years. Stations missing more than two years at the beginning or end of the time series are excluded. This measure avoids use of data from stations that were commissioned or decommissioned at the beginning or end of the time series.

4.5. Imputation

Stations that do not have enough measurements to meet the time series criteria for every year are excluded from the national and regional indicators. However, in some cases, monitoring stations

are located close enough to others to allow data from neighbouring stations to be used to supplement missing data. Stations that were moved but remain relatively close to their previous location were also imputed. The following tables outline when imputations were done using neighbouring stations.

Table 7: Imputations done using neighbouring stations for the $PM_{2.5}$ national and regional annual average indicators

NAPS ID	Province	City	Years
60415	Ontario	Mississauga	2000-2003
60432	Ontario	Mississauga	2005-2007
60434	Ontario	Mississauga	2008-2012
60424	Ontario	Toronto	2001
60433	Ontario	Toronto	2003-2012
60708	Ontario	Sault Ste. Marie	2000
60709	Ontario	Sault Ste. Marie	2004-2012
61701	Ontario	Oshawa	2000-2004
61702	Ontario	Oshawa	2006-2012
90227	Alberta	Calgary	2000-2007
90228	Alberta	Calgary	2010-2011
100401	British Columbia	Kamloops	2011-2012
100402	British Columbia	Kamloops	2000-2009

Table 8: Imputations done using neighbouring stations for the $PM_{2.5}$ national and regional annual peak (98th percentile) 24-hour indicators

NAPS ID	Province	City	Years
60403	Ontario	Toronto	2000
60429	Ontario	Toronto	2001, 2003-2008, 2010-2011
60435	Ontario	Mississauga	2012
60415	Ontario	Mississauga	2000-2003
60432	Ontario	Mississauga	2004-2007
60434	Ontario	Mississauga	2008-2012
60424	Ontario	Toronto	2001-2002
60433	Ontario	Toronto	2003-2012
60708	Ontario	Sault Ste. Marie	2000-2001
60709	Ontario	Sault Ste. Marie	2004-2012
61701	Ontario	Oshawa	2000-2004
61702	Ontario	Oshawa	2005-2012
90227	Alberta	Calgary	2000-2007
90228	Alberta	Calgary	2008, 2010-2011
100401	British Columbia	Kamloops	2010-2012

NAPS ID	Province	City	Years
100402	British Columbia	Kamloops	2000–2009

Table 9: Imputations done using neighbouring stations for the O_3 national and regional annual average indicators

NAPS ID	Province	City	Years
50104	Quebec	Montreal	1999–2007
50134	Quebec	Montreal	2009–2012
60302	Ontario	Kingston	1998–2005
60303	Ontario	Kingston	2007–2012
60403	Ontario	Toronto	1998, 2000
60429	Ontario	Toronto	2002–2008, 2010–2011
60435	Ontario	Mississauga	2012
60415	Ontario	Mississauga	1998–2003
60432	Ontario	Mississauga	2005–2007
60434	Ontario	Mississauga	2008–2012
60424	Ontario	Toronto	1998–2002
60433	Ontario	Toronto	2003–2012
60607	Ontario	Sudbury	1999–2003
60609	Ontario	Sudbury	2005–2012
60707	Ontario	Sault Ste. Marie	1998–2001
60709	Ontario	Sault Ste. Marie	2004–2012
60807	Ontario	Thunder Bay	1998–2001, 2003
60809	Ontario	Thunder Bay	2004–2012
61602	Ontario	Oakville	1998, 2000–2001
61603	Ontario	Oakville	2004–2012
61701	Ontario	Oshawa	1998–2004
61702	Ontario	Oshawa	2006–2012
62701	Ontario	Long Point	1998–2001
65301	Ontario	Port Stanley	2003–2012
63201	Ontario	Stouffville	1998–2003, 2005
65101	Ontario	Newmarket	2006–2012
90227	Alberta	Calgary	1998–2007
90228	Alberta	Calgary	2009–2012

Table 10: Imputations done using neighbouring stations for the O_3 national and regional annual peak (4th-highest) 8-hour indicators

NAPS ID	Province	City	Years
50104	Quebec	Montreal	1998–2008
50134	Quebec	Montreal	2009–2012
60302	Ontario	Kingston	1998–2005
60303	Ontario	Kingston	2007--2012
60403	Ontario	Toronto	1998–2000
60429	Ontario	Toronto	2001–2011
60435	Ontario	Mississauga	2012
60415	Ontario	Mississauga	1998–2003
60432	Ontario	Mississauga	2004–2007
60434	Ontario	Mississauga	2008–2012
60424	Ontario	Toronto	1998–2002
60433	Ontario	Toronto	2003–2012
60607	Ontario	Sudbury	1998–2004
60609	Ontario	Sudbury	2005–2012
60707	Ontario	Sault Ste. Marie	1998–2003
60709	Ontario	Sault Ste. Marie	2004–2012
60807	Ontario	Thunder Bay	1998–2003
60809	Ontario	Thunder Bay	2004–2012
61602	Ontario	Oakville	1998–2002
61603	Ontario	Oakville	2003–2012
61701	Ontario	Oshawa	1998–2004, 2008
61702	Ontario	Oshawa	2005–2007, 2009–2012
62701	Ontario	Long Point	1998–2001
65301	Ontario	Port Stanley	2002–2012
63201	Ontario	Stouffville	1998–2003, 2005
65101	Ontario	Newmarket	2006–2012
90227	Alberta	Calgary	1998–2007
90228	Alberta	Calgary	2008–2012

Table 11: Imputations done using neighbouring stations for the SO_2 national and regional annual average indicators

NAPS ID	Province	City	Years
30118	Nova Scotia	Halifax	1998, 2000-2006, 2011-2012
30120	Nova Scotia	Dartmouth	2007, 2009
50602	Quebec	Rouyn-Noranda	1998-2002
50604	Quebec	Rouyn-Noranda	2003-2012
60403	Ontario	Toronto	1998, 2000
60430	Ontario	Toronto	2003-2012
60413	Ontario	Toronto	1998, 2000-2002
60433	Ontario	Toronto	2003-2010
60415	Ontario	Mississauga	1998-2001, 2003
60432	Ontario	Mississauga	2005
60434	Ontario	Mississauga	2008-2012
60607	Ontario	Sudbury	1998-2004
60609	Ontario	Sudbury	2005-2012
60707	Ontario	Sault Ste. Marie	1998-2003
60709	Ontario	Sault Ste. Marie	2004-2012
100401	British Columbia	Kamloops	1998-2000, 2002-2006, 2011-2012
100402	British Columbia	Kamloops	2007-2008
129002	Northwest Territories	Yellowknife	1998-2001
129003	Northwest Territories	Yellowknife	2003-2011

Table 12: Imputations done using neighbouring stations for the NO_2 national and regional annual average indicators

NAPS ID	Province	City	Years
60403	Ontario	Toronto	1998, 2000
60429	Ontario	Toronto	2003-2008, 2010-2011
60435	Ontario	Mississauga	2012
60424	Ontario	Toronto	1998-2002
60433	Ontario	Toronto	2003-2012
60707	Ontario	Sault Ste. Marie	1998, 2000-2001, 2003
60709	Ontario	Sault Ste. Marie	2006-2012
60807	Ontario	Thunder bay	1998, 2000-2003
60809	Ontario	Thunder bay	2007-2012
61602	Ontario	Oakville	1998, 2000-2002
61603	Ontario	Oakville	2004-2012
61701	Ontario	Oshawa	1998-2004

61702	Ontario	Oshawa	2006-2012
63201	Ontario	Stouffville	1998-2000
65101	Ontario	Newmarket	2002-2012
90227	Alberta	Calgary	1998-2007
90228	Alberta	Calgary	2009-2012

Table 13: Imputations done using neighbouring stations for the VOCs national and regional annual average indicators

NAPS ID	Province	City	Years
50104	Quebec	Montreal	1998-2008
50134	Quebec	Montreal	2009-2012
54301	Quebec	Ste-Françoise	1998-1999
55201	Quebec	Lemieux	2000-2012
60403	Ontario	Toronto	1998-2000
60429	Ontario	Toronto	2002-2008
60435	Ontario	Mississauga	2009-2010, 2012
63201	Ontario	Stouffville	1998-2005
65101	Ontario	Newmarket	2006-2010, 2012
90227	Alberta	Calgary	1998-2007
90228	Alberta	Calgary	2008-2012

4.6 Number of stations selected

The following tables indicate the number of monitoring stations that satisfied the selection criteria (data completeness and time series), and that were thus included in the national and regional Air Quality Indicators for the time series.

Table 14: Number of stations selected for the national Air Quality Indicators

Air pollutant	Canada
Peak (98th percentile) 24-hour $PM_{2.5}$	75
Average $PM_{2.5}$	64
Peak (4th-highest) 8-hour O_3	137
Average O_3	129
SO_2	50
NO_2	77
VOCs	31

Table 15: Number of stations eligible for the regional Air Quality Indicators

Air pollutant	Atlantic Canada	Southern Quebec	Southern Ontario	Prairies and northern Ontario	British Columbia
Peak (98th percentile) 24-hour $PM_{2.5}$	5	13	30	13	14
Average $PM_{2.5}$	5	9	24	12	14
Peak (4th-highest) 8-hour O_3	17	36	34	24	26
Average O_3	13	35	31	24	26
SO_2	4	10	12	6	17
NO_2	2*	15	17	20	22
VOCs	4	8	13	4	2*

Note: The sum of the regional stations for SO_2 does not match the national SO_2 station number because one station from the Northwest Territories was added to the national total.
* Three or more stations are required to estimate the regional indicators. Regions with two or fewer eligible stations were not included in the regional indicators.

Local (station-level) indicators for O_3, $PM_{2.5}$, SO_2, NO_2 and VOCs are also presented in the CESI interactive map (http://maps-cartes.ec.gc.ca/indicators-indicateurs/default.aspx?lang=en). The stations displayed on the map satisfy the data completeness criteria.

4.7 Monitoring equipment

$PM_{2.5}$ monitoring equipment: Four types of monitoring equipment are used to monitor ambient $PM_{2.5}$ concentrations:

- Older technology: Tapered element oscillating microbalance (TEOM)
- New technology: TEOM 1400a with the Series 8500C Filter Dynamics Measurement System (FDMS)
- New technology: Met-One 1020 Beta Attenuation Mass (BAM)
- New technology: Thermo Sharp 5030 or 5030i (Sharp)

The new technologies have been approved by the U.S. EPA as Class III federal equivalent methods (FEMs) and are being deployed across the NAPS network to replace older TEOM instruments that have been found to exclude a portion of the $PM_{2.5}$ mass from being measured.

The following table lists the stations used for the national and regional indicators that are operating with new technologies, along with the type of equipment and year of installation.

Table 16: Stations included in the national and regional indicators that use new monitoring technologies for $PM_{2.5}$

NAPS ID	Province	City	New equipment, first year provided
10102	Newfoundland and Labrador	St. John's	BAM, 2010
40103	New Brunswick	Fredericton	BAM, 2007
40203	New Brunswick	Saint John	BAM, 2007
40302	New Brunswick	Moncton	BAM, 2008
40901	New Brunswick	St. Andrews	BAM, 2008
50105	Quebec	Montreal	FDMS, 2008
50109	Quebec	Montreal	FDMS, 2008
50110	Quebec	Montreal	FDMS, 2008
50126	Quebec	Montreal	FDMS, 2008
50128	Quebec	Montreal	FDMS, 2008
50129	Quebec	Montreal	FDMS, 2008
50308	Quebec	Quebec City	BAM, 2010
50504	Quebec	Saguenay	BAM, 2010
50801	Quebec	Trois-Rivières	BAM, 2009
54401	Quebec	Saint-Anicet	BAM, 2007
54501	Quebec	L'Assomption	BAM, 2008
54703	Quebec	Bécancour	BAM, 2009
55301	Quebec	Saint-Jean-sur-Richelieu	BAM, 2005
70118	Manitoba	Winnipeg	SHARP, 2011
70119	Manitoba	Winnipeg	SHARP, 2012
70203	Manitoba	Brandon	SHARP, 2012
90121	Alberta	Edmonton	FDMS, 2010
90130	Alberta	Edmonton	FDMS, 2010
90228	Alberta	Calgary	FDMS, 2010
90302	Alberta	Red Deer	FDMS, 2010
90701	Alberta	Fort McMurray	FDMS, 2011
90801	Alberta	Fort Mackay	FDMS, 2011
100304	British Columbia	Victoria	BAM, 2010
100401	British Columbia	Kamloops	BAM, 2010

The next table provides the number of stations for Canada and by region that uses data from new $PM_{2.5}$ monitoring equipment.

Table 17: Number of stations included in the national and regional indicators that use new monitoring technologies for $PM_{2.5}$

$PM_{2.5}$	National	Atlantic Canada	Southern Quebec	Southern Ontario	Prairies and northern Ontario	British Columbia
Peak (98th percentile) 24-hour	27	5	13	0	7	2
Average	25	5	9	0	9	2

SO_2, NO_2 and VOCs monitoring equipment: SO_2 measurements are made using pulse-fluorescence ultraviolet (UV) adsorption instruments. NO_2 is measured by subtraction following measurement of the total of NO + NO_2 and NO alone with analyzers that reduce NO_x to NO with a catalytic converter, and then use chemiluminescence to measure the gas phase reaction of NO with O_3. For VOCs: at urban monitoring stations, ambient samples are usually collected over a 24-hour period once every six days. Air samples are collected at rural stations over 4-hour sampling periods (12:00 to 16:00) every three days. The air samples are collected in 6 litre or 3.2 litre stainless steel canisters and shipped to the Environment Canada analysis laboratory in Ottawa. A combined gas chromatography / flame ionization detector (GC/FID) system is used for quantification of VOCs containing two carbons, while a combined gas chromatography / mass selective detector (GC/MSD) system operating in selected ion monitoring (SIM) mode is used for quantification of VOCs containing three to twelve carbons. Approximately 120 VOCs (including a number of biogenic species such as isoprene and pinenes) are targeted for quantification in the samples, but not all VOCs are detectable in each sample. The total concentration of VOCs in parts per billion carbon (ppbC) is calculated from the total mass of all species detected in the sample. A list of target VOCs is provided in Appendix B.

4.8 Statistical analysis

Non-parametric statistical tests were carried out on temporal concentration data to detect the presence of a linear trend and, if present, to determine the orientation (positive or negative) and magnitude of the rate of change (slope). The standard Mann-Kendall trend test was used to detect trend presence and orientation, while the Sen's pairwise slope method was also used to detect the trend and to estimate the slope. Results of the tests are available in Appendix C. Both tests were applied to the regional and national levels for data on O_3 (1998–2012), $PM_{2.5}$ (2000–2012), SO_2 (1998–2012), NO_2 (1998–2012) and VOCs (1998–2012). A trend was reported when both the Mann-Kendall and Sen's tests indicated the presence of a trend at the 95% confidence level.

Table 18 presents the rate of change per year (slopes expressed in median annual percentage change, relative to the value in the first year of each time series) for the national and regional Air Quality Indicators. The values apply to 2000–2012 for $PM_{2.5}$ and to 1998–2012 for O_3, SO_2, NO_2 and VOCs.

Table 18: Rate of change per year for the national and regional Air Quality Indicators

Area	$PM_{2.5}$ annual average (median annual % change)	$PM_{2.5}$ peak (98th percentile) 24-hour (median annual % change)	O_3 annual average (median annual % change)	O_3 peak (4th-highest) 8-hour (median annual % change)	SO_2 annual average (median annual % change)	NO_2 annual average (median annual % change)	VOCs annual average (median annual % change)
National	*	*	*	-1.06%	-4.79%	-2.93%	-3.85%
Atlantic Canada	*	*	*	-1.21%	-7.13%	**	-2.23%
Southern Quebec	3.30%	*	*	-1.52%	-4.70%	-2.91%	-4.62%
Southern Ontario	-3.02%	-3.83%	*	-1.21%	-5.03%	-3.74%	-4.66%
Prairies and northern Ontario	*	*	0.41%	*	-4.84%	-2.40%	-3.66%
British Columbia	-1.37%	*	0.77%	*	-1.91%	-2.51%	**

Note: *Indicates that the Mann-Kendall or Sen's method failed to reject the null hypothesis at the 95% confidence level, meaning a trend was not detected.
** No trend analysis was conducted for this region, because an insufficient number of monitoring stations met the selection criteria.

5 Caveats and limitations

Accuracy: Environment Canada and its provincial partners use QA/QC procedures to minimize measurement error. The data accuracy objectives are ± 10% for O_3, ± 15% for SO_2 and NO_2, and ± 20% for $PM_{2.5}$, while for VOCs the accuracy objective varies depending on the species sampled. For more information, consult Environment Canada's National Air Pollution Surveillance Network Quality Assurance and Quality Control Guidelines and the CCME's *Ambient Air Monitoring Protocol for $PM_{2.5}$ and Ozone. Canada-wide Standards for Particulate Matter and Ozone* (PDF; 787 KB). (http://www.ccme.ca/assets/pdf/pm_oz_cws_monitoring_protocol_pn1456_e.pdf)

Data completeness: Some data collected at stations cannot be used in calculation of the indicators because the data do not meet data completeness criteria. Those criteria are based on standard practices that are followed by a number of organizations such as the World Health Organization, the CCME and the U.S. EPA, and that are supported by expert opinion. The criteria do allow for some data gaps.

Number of stations selected: Monitoring stations are selected with the help of time series criteria (see section 4.4) for the calculation of the air quality indicators. Because of these criteria, the number of stations selected may vary from one release to the other and may change the historical trends. Caution is advised when comparing different releases of the air quality indicators.

Table 19: number of stations removed and number of new stations

Air pollutant	Number of stations removed*	Number of new stations
Peak (98th percentile) 24-hour $PM_{2.5}$	3	15
Average $PM_{2.5}$	3	11
Peak (4th-highest) 8-hour O_3	4	9
Average O_3	6	8
SO_2	4	6
NO_2	1	10
VOCs	0	1

Note: * These stations do not respect the time series criteria anymore and were removed from the calculation of the national and regional indicators for the whole time series.

Effect on trend of new $PM_{2.5}$ measurement technologies:

Since 2005, the TEOM monitors in the NAPS program have gradually been replaced by newer monitoring technologies (Federal Equivalency Method [FEM]-approved instruments). Many studies conducted in Canada, the United States and other countries have found that the TEOM monitors under-report concentrations compared with the newer monitors, especially when the air contains a large proportion of semi-volatile particulate matter, which may be the case during cooler seasons when the air contains a greater proportion of ammonium nitrate and semi-volatile organic compounds.

Because of the deployment of these newer monitors across the NAPS program, part of any year-to-year variations in the $PM_{2.5}$ air quality indicator may be due to the introduction of the newer monitoring technologies rather than changes in actual ambient concentrations only. As such, any trend in $PM_{2.5}$ concentrations may have been masked because of the replacement of TEOM monitors. To better understand the comparison between monitoring instruments, data from a number of collocated TEOM and newer technology monitors deployed at monitoring stations in Canada and the United States were analyzed. Data were collected between 2008 and 2012, involving 39 stations in Canada and 69 stations in the United States close to Canada. These stations contained two or more collocated monitors consisting of the continuous TEOM monitors operated at 30 to 50°C, the filter-based reference methods (U.S. Federal Reference Method [FRM] and NAPS FRM), and the continuous SHARP FEM monitors.

Based on the data from studies,[6] seasonal linear regression equations were developed; the results are presented in Table 20. In this table, slopes higher than 1 indicate under-reporting of the monitor, while slopes lower than 1 indicate over-reporting. As can be seen from the table, the widely used TEOM monitor under-reported $PM_{2.5}$ concentrations compared to the FRM and SHARP in the cold season, and over-reported in the warm season. The seasonal regression equations developed for the TEOM were then applied to the $PM_{2.5}$ data measured from the TEOM in order to obtain "adjusted TEOM $PM_{2.5}$ concentrations."

Two national annual averages were then computed: one based on the adjusted $PM_{2.5}$ concentrations and the other based on the as-measured concentrations from the existing mix of older and newer monitors. The results are displayed in the chart below. The adjusted concentrations provide a qualitative indication of what the national annual average $PM_{2.5}$ concentrations could have been if $PM_{2.5}$ monitoring technologies would have been similar to the newer monitors throughout the period

[6] Dann T (2013) Comparison of CESI $PM_{2.5}$ Air Indicators with Transformed Data (FEM Basis); Dann T (2012) CESI $PM_{2.5}$ Air Indicator Using Transformed Data.

from 2000 to 2012. As such, the convergence of the adjusted $PM_{2.5}$ concentrations and the as-measured concentrations after 2005 is consistent with the increasing deployment of the newer monitors after 2005.

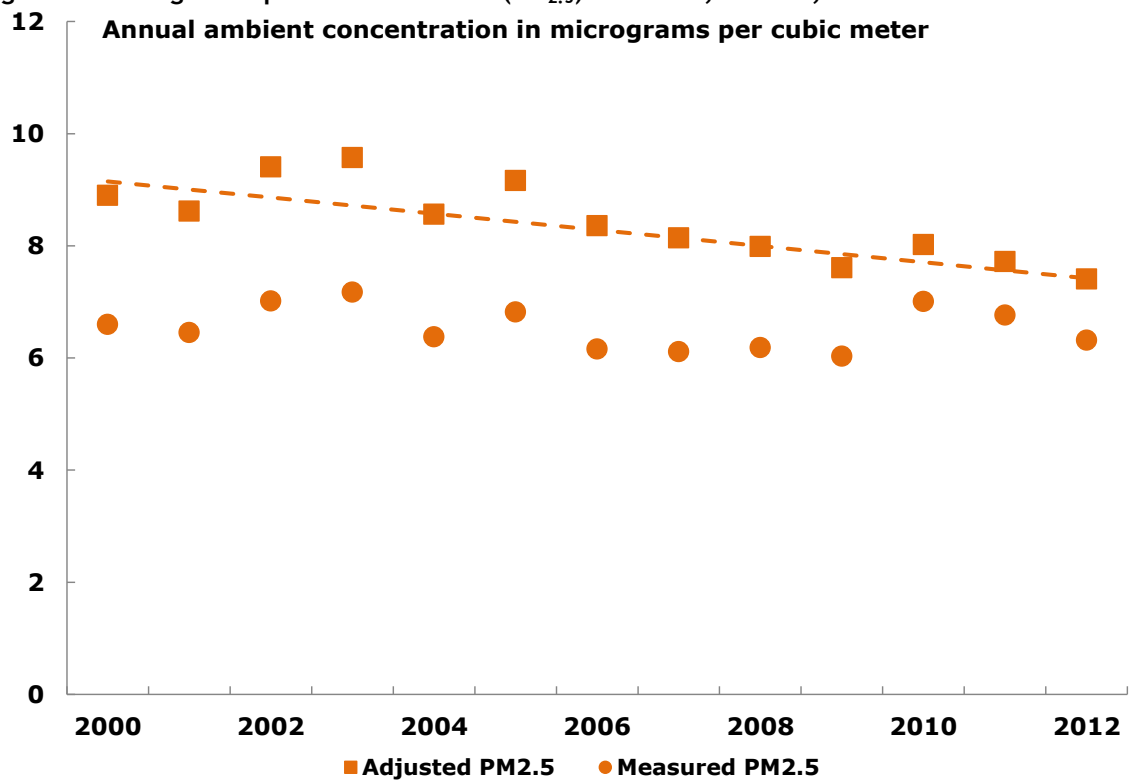
This table conveys two important observations: first, the adjusted concentrations were higher than the as-measured concentrations; and second, and more importantly, while there was no trend in the as-measured concentrations, there was a decreasing trend in the adjusted concentrations, with a 19% reduction (or a 1.6% annual decrease) between 2000 and 2012. This latter information indicates that, had the monitoring technology been similar to the newer monitors throughout the 2000 to 2012 period, the national annual average $PM_{2.5}$ concentration would have undergone a decreasing trend. This suggests that the deployment of the newer monitors since 2005 may have contributed to producing a lack of trend in the national annual average concentrations.

Table 20: Regression coefficients by technology type, region and season

Technology comparison (old to new)	Data origin	Season	Slope	Intercept
FRM to FEM	United States	Cold	1.02	0.81
FRM to FEM	United States	Warm	1.04	0.47
FRM to SHARP	Canada (2013)	Cold	1.05	0.35
FRM to SHARP	Canada (2013)	Warm	0.99	0.22
TEOM to SHARP	Canada (2013)	Cold	1.49	1.35
TEOM to SHARP	Canada (2013)	Warm	0.92	1.47
TEOM30 to FRM	Canada (2012)	Cold	1.44	0.47
TEOM30 to FRM	Canada (2012)	Warm	0.98	1.24
TEOM40 to FRM	Canada (2012)	Cold	1.3	0.94
TEOM40 to FRM	Canada (2012)	Warm	0.94	1.72

Note: The adjustment factors were calculated as follows:
$Mass_{Filter\text{-}based\ sampler}$ = Intercept + Slope * $Mass_{Continuous\ sampler}$
FRM = NAPS Federal Reference Method.
FEM = Class III Federal Equivalency Method.
SHARP = Thermo Sharp 5030 monitor.
TEOM = tapered element oscillating microbalance monitor.
TEOM30 = TEOM with sample equilibration system operating at 30°C.
TEOM40 = TEOM operating at 40°C.
Source: Dann T (2013) Comparison of CESI $PM_{2.5}$ Air Indicators with Transformed Data (FEM Basis); Dann T (2012) CESI $PM_{2.5}$ Air Indicator Using Transformed Data.

Figure 3: Average fine particulate matter ($PM_{2.5}$) indicator, Canada, 2000 to 2012



Note: The national annual average $PM_{2.5}$ indicator is based on the annual average concentrations recorded at 64 monitoring stations across Canada. A trend line (dotted line) is reported only when a statistical trend is detected at the 95% confidence level.
Source: Dann T (2013) Comparison of CESI $PM_{2.5}$ Air Indicators with Transformed Data (FEM Basis). Prepared for Environment Canada.

6 References and further reading

6.1 References

Canadian Council of Ministers of the Environment (2000) Canada-wide Standards for Particulate Matter and Ozone. (PDF; 38 KB) (http://www.ccme.ca/assets/pdf/pmozone_standard_e.pdf) Retrieved on 26 February, 2014.

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Environment Canada (2004) National Air Pollution Surveillance Network Quality Assurance and Quality Control Guidelines. Retrieved on 26 February, 2014.

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6 Appendix A

Air quality monitoring stations reported in the Canadian Environmental Sustainability Indicators (CESI) for the national and regional indicators.

Table A1: Legend for Table A3

Column	Description
NAPS ID	Monitoring station NAPS identifier
Province and City	Location of monitoring station
Average $PM_{2.5}$	If not empty, the station contributes data to the time series trend analysis for the annual average fine particulate matter in the national indicator and regional indicator of the identified region.
Peak $PM_{2.5}$	If not empty, the station contributes data to the time series trend analysis for the annual peak (98th percentile) 24-hour fine particulate matter in the national indicator and regional indicator of the identified region.
Average O_3	If not empty, the station contributes data to the time series trend analysis for the annual average ozone in the national indicator and regional indicator of the identified region.
Peak O_3	If not empty, the station contributes data to the time series trend analysis for the annual peak (4th-highest) 8-hour ozone in the national indicator and regional indicator of the identified region.
SO_2	If not empty, the station contributes data to the time series trend analysis for the annual average sulphur dioxide in the national indicator and regional indicator of the identified region.
NO_2	If not empty, the station contributes data to the time series trend analysis for the annual average nitrogen dioxide in the national indicator and regional indicator of the identified region.
VOCs	If not empty, the station contributes data to the time series trend analysis for the annual average volatile organic compounds in the national indicator and regional indicator of the identified region.

Table A2: Acronyms for Table A3

Acronym	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
BCO	British Columbia CESI regional indicator
NAT	Stations only used in calculation of the CESI national indicator

Table A3: Air quality monitoring stations used in calculation of national and regional indicators

NAPS ID	Province	City	Peak $PM_{2.5}$	Average $PM_{2.5}$	Peak O_3	Average O_3	SO_2	NO_2	VOCs
10102	NL	St. John's	ATL	ATL	ATL	ATL	ATL	ATL	
30118	NS	Halifax			ATL	ATL	ATL*		ATL
30120	NS	Dartmouth					ATL*		
30501	NS	Kejimkujik			ATL	ATL			ATL
30701	NS	Aylesford			ATL				
30801	NS	Yarmouth			ATL				
40103	NB	Fredericton	ATL	ATL	ATL	ATL		ATL	
40203	NB	Saint John	ATL	ATL	ATL	ATL	ATL		ATL
40206	NB	Saint John			ATL	ATL	ATL	ATL	
40207	NB	Saint John			ATL	ATL			
40302	NB	Moncton	ATL	ATL	ATL	ATL			
40401	NB	Fundy Nat. Park			ATL				
40501	NB	Point Lepreau			ATL	ATL			ATL
40601	NB	Central Blissville			ATL	ATL			
40701	NB	Norton			ATL	ATL			
40801	NB	Dow Settlement			ATL	ATL			
40901	NB	St. Andrews	ATL	ATL	ATL	ATL			
41101	NB	St. Leonard			ATL				
50103	QC	Montreal			SQC	SQC	SQC	SQC	SQC
50104	QC	Montreal			SQC*	SQC*			SQC*
50105	QC	Montreal	SQC	SQC					
50134	QC	Montreal			SQC*	SQC*			SQC*
50109	QC	Montreal	SQC		SQC	SQC		SQC	
50110	QC	Montreal	SQC		SQC	SQC		SQC	
50113	QC	Laval			SQC	SQC		SQC	
50115	QC	Montreal			SQC	SQC	SQC	SQC	SQC
50116	QC	Montreal			SQC	SQC		SQC	
50119	QC	Longueuil			SQC	SQC		SQC	
50121	QC	Longueuil			SQC	SQC	SQC	SQC	SQC
50126	QC	Montreal	SQC	SQC	SQC	SQC		SQC	
50128	QC	Montreal	SQC	SQC	SQC	SQC		SQC	
50129	QC	Montreal	SQC	SQC	SQC	SQC			
50204	QC	Gatineau			SQC	SQC	SQC	SQC	
50308	QC	Quebec	SQC	SQC	SQC	SQC	SQC	SQC	
50504	QC	Saguenay	SQC						
50602	QC	Rouyn-Noranda					SQC*		
50604	QC	Rouyn-Noranda					SQC*		
50801	QC	Trois-Rivières	SQC	SQC	SQC	SQC	SQC		
50902	QC	Saguenay					SQC		
51501	QC	St. Zéphirin-			SQC	SQC			

NAPS ID	Province	City	Peak $PM_{2.5}$	Average $PM_{2.5}$	Peak O_3	Average O_3	SO_2	NO_2	VOCs
		De-Courval							
51802	QC	Sorel-Tracy					SQC		
52001	QC	Charette			SQC	SQC			
52201	QC	Saint-Simon			SQC	SQC			
52301	QC	Saint-Faustin-Lac-Carré			SQC	SQC			
52401	QC	La Pêche			SQC	SQC			
52601	QC	Varennes			SQC	SQC		SQC	
53201	QC	La Doré			SQC	SQC			
53301	QC	Deschambault			SQC	SQC			
53401	QC	Ste-Catherine-de-la-Jacques-Cartier			SQC	SQC			
53501	QC	Saint-François			SQC	SQC			
53601	QC	Notre-Dame-Du-Rosaire			SQC	SQC			
53701	QC	St-Hilaire-De-Dorset			SQC	SQC			
53801	QC	Tingwick			SQC	SQC			
53901	QC	Lac-Édouard			SQC	SQC			
54102	QC	Sutton							SQC
54301	QC	Ste-Françoise							SQC*
54401	QC	Saint-Anicet	SQC	SQC	SQC	SQC			SQC
54501	QC	L'Assomption	SQC	SQC	SQC	SQC			SQC
54703	QC	Bécancour	SQC				SQC	SQC	
54801	QC	Stukely-Sud			SQC	SQC			
54901	QC	La Patrie			SQC	SQC			
55001	QC	Ferme Neuve			SQC	SQC			
55201	QC	Lemieux			SQC				SQC*
55301	QC	Saint-Jean-Sur-Richelieu	SQC	SQC	SQC	SQC		SQC	
60104	ON	Ottawa	SON	SON	SON	SON	SON	SON	SON
60204	ON	Windsor	SON	SON	SON	SON	SON	SON	
60211	ON	Windsor	SON		SON	SON	SON		SON
60302	ON	Kingston			SON*	SON			
60303	ON	Kingston			SON*	SON*			
60403	ON	Toronto	SON*		SON*	SON*	SON*	SON*	SON*
60429	ON	Toronto	SON*		SON*	SON*		SON*	SON*
60435	ON	Mississauga	SON*		SON*	SON*		SON*	SON*
60410	ON	Toronto	SON	SON	SON	SON		SON	
60413	ON	Toronto	SON		SON		SON*		SON
60415	ON	Mississauga	SON*	SON*	SON*	SON*	SON*		
60432	ON	Mississauga	SON*	SON*	SON*	SON*	SON*		
60434	ON	Mississauga	SON*	SON*	SON*	SON*	SON*		
60421	ON	Toronto	SON	SON	SON	SON		SON	
60424	ON	Toronto	SON*	SON*	SON	SON*		SON*	

NAPS ID	Province	City	Peak $PM_{2.5}$	Average $PM_{2.5}$	Peak O_3	Average O_3	SO_2	NO_2	VOCs
60433	ON	Toronto	SON*	SON*	SON	SON*	SON*	SON*	
60428	ON	Brampton	SON	SON	SON				
60430	ON	Toronto	SON	SON			SON*		
60512	ON	Hamilton	SON	SON	SON	SON	SON	SON	SON
60513	ON	Hamilton	SON	SON	SON	SON	SON		
60607	ON	Sudbury			SON*	SON*	SON*		
60609	ON	Sudbury			SON*	SON*	SON*		
60707	ON	Sault Ste. Marie			SON*	SON*	SON*	SON*	
60708	ON	Sault Ste. Marie	SON*	SON*					
60709	ON	Sault Ste. Marie	SON*	SON*	SON*	SON*	SON*	SON*	
60807	ON	Thunder Bay			PNO*	PNO*		PNO*	
60809	ON	Thunder Bay			PNO*	PNO*		PNO*	
60903	ON	London	SON	SON	SON	SON	SON	SON	SON
61004	ON	Sarnia	SON		SON	SON	SON	SON	SON
61104	ON	Peterborough	SON	SON	SON	SON		SON	
61201	ON	Cornwall			SON	SON			
61302	ON	St. Catharines	SON	SON	SON	SON			
61502	ON	Kitchener	SON	SON	SON	SON		SON	SON
61602	ON	Oakville			SON*	SON*		SON*	
61603	ON	Oakville			SON*	SON*		SON*	
61701	ON	Oshawa	SON*	SON*	SON*	SON*		SON*	
61702	ON	Oshawa	SON*	SON*	SON*	SON*		SON*	
61802	ON	Guelph	SON	SON	SON				
62001	ON	North Bay	SON	SON	SON	SON			
62501	ON	Tiverton	SON	SON	SON	SON			
62601	ON	Simcoe	SON	SON	SON	SON			SON
62701	ON	Long Point			SON*	SON*			
65301	ON	Port Stanley	SON		SON*	SON*			
63001	ON	Burlington	SON	SON	SON	SON		SON	
63201	ON	Stouffville			SON*	SON*		SON*	SON*
65101	ON	Newmarket			SON*	SON*		SON*	SON*
63301	ON	Dorset	SON	SON	SON	SON			
63601	ON	Longwoods							SON
63701	ON	Grand Bend			SON	SON			
64001	ON	Exp. Lakes Area			PNO	PNO			
64101	ON	Algoma			SON	SON			
64401	ON	Egbert			SON	SON			SON
64601	ON	Pt. Petre							SON
65001	ON	Barrie	SON	SON					
65101	ON	Newmarket	SON	SON					
65401	ON	Belleville	SON						
70118	MB	Winnipeg	PNO	PNO	PNO	PNO		PNO	

NAPS ID	Province	City	Peak $PM_{2.5}$	Average $PM_{2.5}$	Peak O_3	Average O_3	SO_2	NO_2	VOCs
70119	MB	Winnipeg	PNO	PNO	PNO	PNO		PNO	PNO
70203	MB	Brandon	PNO	PNO	PNO	PNO		PNO	
80110	SK	Regina			PNO	PNO	PNO	PNO	
80211	SK	Saskatoon			PNO	PNO	PNO	PNO	
80901	SK	Bratt's Lake			PNO	PNO			
90121	AB	Edmonton	PNO	PNO	PNO	PNO	PNO	PNO	PNO
90130	AB	Edmonton	PNO	PNO	PNO	PNO		PNO	PNO
90218	AB	Calgary			PNO	PNO	PNO	PNO	
90222	AB	Calgary			PNO	PNO		PNO	
90227	AB	Calgary	PNO*	PNO*	PNO*	PNO*		PNO*	PNO*
90228	AB	Calgary	PNO*	PNO*	PNO*	PNO*		PNO*	PNO*
90302	AB	Red Deer	PNO	PNO	PNO	PNO		PNO	
90601	AB	Fort Saskatchewan	PNO		PNO	PNO	PNO	PNO	
90701	AB	Fort Mcmurray	PNO	PNO	PNO	PNO	PNO	PNO	
90702	AB	Fort Mcmurray	PNO	PNO	PNO	PNO		PNO	
90801	AB	Fort Mackay	PNO	PNO	PNO	PNO		PNO	
91001	AB	Esther			PNO	PNO			
91301	AB	Tomahawk	PNO	PNO	PNO	PNO		PNO	
91401	AB	Violet Grove			PNO	PNO		PNO	
91501	AB	Beaverlodge			PNO	PNO		PNO	
91601	AB	Carrot Creek			PNO	PNO		PNO	
91801	AB	Fort Chipewyan	PNO	PNO	PNO	PNO		PNO	
100110	BC	Metro Van - Burnaby			BCO	BCO	BCO	BCO	
100111	BC	Metro Van - Port Moody			BCO	BCO	BCO	BCO	BCO
100112	BC	Metro Van - Vancouver			BCO	BCO	BCO	BCO	
100118	BC	Metro Van - Vancouver			BCO	BCO	BCO	BCO	
100119	BC	Metro Van - Burnaby			BCO	BCO	BCO	BCO	
100121	BC	Metro Van - Vancouver			BCO	BCO	BCO	BCO	
100125	BC	Metro Van - Delta			BCO	BCO		BCO	
100126	BC	Metro Van - Burnaby			BCO	BCO		BCO	
100127	BC	Metro Van - Surrey			BCO	BCO		BCO	
100128	BC	Metro Van - Richmond			BCO	BCO	BCO	BCO	
100132	BC	Metro Van - Vancouver			BCO	BCO	BCO	BCO	

NAPS ID	Province	City	Peak $PM_{2.5}$	Average $PM_{2.5}$	Peak O_3	Average O_3	SO_2	NO_2	VOCs
100133	BC	Metro Van - Burnaby							BCO
100134	BC	Metro Van - Richmond	BCO	BCO	BCO	BCO		BCO	
100136	BC	Metro Van - Burnaby					BCO		
100137	BC	Metro Van - Burnaby					BCO		
100202	BC	Prince George	BCO	BCO	BCO	BCO		BCO	
100304	BC	Victoria	BCO	BCO	BCO	BCO	BCO		
100401	BC	Kamloops	BCO*	BCO*			BCO*		
100402	BC	Kamloops	BCO*	BCO*			BCO*		
100701	BC	Kelowna	BCO	BCO	BCO	BCO		BCO	
101003	BC	Metro Van - Abbotsford			BCO	BCO	BCO	BCO	
101101	BC	Metro Van- Chilliwack	BCO	BCO	BCO	BCO		BCO	
101202	BC	Metro Van- Pitt Meadows	BCO	BCO	BCO	BCO	BCO	BCO	
101301	BC	Metro Van- Langley	BCO	BCO	BCO	BCO		BCO	
101401	BC	Metro Van- Hope			BCO	BCO		BCO	
101501	BC	Metro Van - Maple Ridge			BCO	BCO		BCO	
101601	BC	Squamish			BCO	BCO	BCO		
101701	BC	Quesnel	BCO	BCO					
101702	BC	Quesnel	BCO	BCO					
101704	BC	Quesnel	BCO	BCO					
102001	BC	Saturna			BCO	BCO			
102102	BC	Nanaimo	BCO	BCO	BCO	BCO			
102201	BC	Trail					BCO		
102301	BC	Powell River						BCO	
102401	BC	Smithers			BCO	BCO		BCO	
102701	BC	Williams Lake	BCO	BCO	BCO	BCO			
104301	BC	Taylor					BCO		
105101	BC	Houston	BCO	BCO					
129002	NT	Yellowknife					NAT*		
129003	NT	Yellowknife					NAT*		

* These stations were merged with stations located nearby, to satisfy data completeness criteria. See tables 7 to 13 for details.

6 Appendix B

Table B1: Volatile organics compounds (VOC) targeted for quantification

Compound	CAS registry number
1,2,3-Trimethylbenzene	526-73-8
1,2,4-Trimethylbenzene	95-63-6
1,2-Diethylbenzene	135-01-3
1,3,5-Trimethylbenzene	108-67-8
1,3-Butadiene	106-99-0
1,3-Diethylbenzene	141-93-5
1,4-Diethylbenzene	105-05-5
1-Butene	115-11-7
1-Butyne	107-00-6
1-Decene	872-05-9
1-Heptene	592-76-7
1-Hexene	592-41-6
1-Methylcyclohexene	591-49-1
1-Methylcyclopentene	693-89-0
1-Nonene	124-11-8
1-Octene	111-66-0
1-Pentene	109-67-1
1-Propyne	74-99-7
1-Undecene	821-95-4
2,2,3-Trimethylbutane	464-06-2
2,2,4-Trimethylpentane	540-84-1
2,2,5-Trimethylhexane	3522-94-9
2,2-Dimethylbutane	75-83-2
2,2-Dimethylhexane	590-73-8
2,2-Dimethylpentane	590-35-2
2,2-Dimethylpropane	463-82-1
2,3,4-Trimethylpentane	565-75-3
2,3-Dimethylbutane	79-29-8
2,3-Dimethylpentane	565-59-3
2,4-Dimethylhexane	589-43-5
2,4-Dimethylpentane	108-08-7
2,5-dimethylheptane	2216-30-0
2,5-Dimethylhexane	592-13-2
2-Ethyl-1-butene	760-21-4
2-Ethyltoluene	611-14-3
2-methyl-1-butene	563-46-2
2-Methyl-1-Pentene	763-29-1
2-Methyl-2-butene	513-35-9
2-Methyl-2-pentene	625-27-4
2-Methylheptane	592-27-8

Compound	CAS registry number
2-Methylhexane	591-76-4
2-Methylpentane	107-83-5
3,6-Dimethyloctane	15869-94-0
3-Ethyltoluene	620-14-4
3-Methyl-1-Butene	563-45-1
3-Methyl-1-pentene	760-20-3
3-Methylheptane	589-81-1
3-Methylhexane	589-34-4
3-Methyloctane	2216-33-3
3-Methylpentane	96-14-0
4-Ethyltoluene	622-96-8
4-Methyl-1-pentene	691-37-2
4-Methylheptane	589-53-7
4-Methyloctane	2216-34-4
Acetylene	74-86-2
a-Pinene	80-56-8
Benzene	71-43-2
b-Pinene	127-91-3
Butane	106-97-8
Camphene	79-92-5
cis-1,2-Dimethylcyclohexane	2207-01-04
cis-1,3-Dimethylcyclohexane	638-04-0
cis-2-Butene	590-18-1
cis-2-Heptene	6443-92-1
cis-2-Hexene	7688-21-3
cis-2-Octene	7642-04-08
cis-2-Pentene	627-20-3
cis-3-Heptene	7642-10-06
cis-3-Methyl-2-pentene	922-61-2
cis-4-Methyl-2-pentene	4461-48-7
Cyclohexane	110-82-7
Cyclohexene	110-83-8
Cyclopentane	287-92-3
Cyclopentene	142-29-0
Decane	124-18-5
d-Limonene	5989-27-5
Dodecane	112-40-3
Ethane	74-84-0
Ethylbenzene	100-41-4
Ethylene	74-85-1
Heptane	142-82-5
Hexane	110-54-3
Hexylbenzene	1077-16-3

Compound	CAS registry number
Indane	496-11-7
Isobutane	75-28-5
iso-Butylbenzene	538-93-2
Isopentane	78-78-4
Isoprene	78-79-5
iso-Propylbenzene	98-82-8
m and p-Xylene	108-38-3
Methylcyclohexane	108-87-2
Methylcyclopentane	96-37-7
n-Butylbenzene	104-51-8
Nonane	111-84-2
n-Propylbenzene	103-65-1
Octane	111-65-9
o-Xylene	95-47-6
p-Cymene	99-87-6
Pentane	109-66-0
Propane	74-98-6
Propylene	115-07-1
sec-Butylbenzene	135-98-8
Styrene	100-42-5
tert-Butylbenzene	1998-06-06
Toluene	108-88-3
trans-1,2-Dimethylcyclohexane	6876-23-9
trans-1,4-Dimethylcyclohexane	2207-04-07
trans-2-Butene	624-64-6
trans-2-Heptene	14686-13-6
trans-2-Hexene	4050-45-7
trans-2-Octene	13389-42-9
trans-2-Pentene	646-04-8
trans-3-Heptene	14686-14-7
trans-3-Methyl-2-pentene	616-12-6
trans-4-Methyl-2-pentene	674-76-0
Undecane	1120-21-4

6 Appendix C

Mann-Kendall and Sen's pairwise statistical parameters used for the analysis of trends.

Table C1. Legend for tables in Appendix C

Field	Description
First year	Starting year of each time series
Last year	Ending year of each time series
N	Number of annual values in the calculation, excluding missing values
Z-Test	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 at the selected level α of significance. A positive (negative) value 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; if n is at least 10, the test is based on the Z statistic (normal approximation). For the four tested significance levels, the following symbols are used: *** 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)
Qmin95	The lower limit of the 95% confidence interval of Q (α = 0.05)
Qmax95	The upper limit of the 95% confidence interval of Q (α = 0.05)
B	Estimate of the constant B in equation f(year) = Q*(year-first Data Year) + B for a linear trend
Bmin95	Estimate of the constant Bmin95 in equation f(year) = Qmin95*(year-first Data Year) + Bmin90 for 95% confidence level of linear trend
Bmax95	Estimate of the constant Bmax95 in equation f(year) = Qmax95*(year-first Data Year) + Bmax90 for 95% confidence level of linear trend

The trend equation is:

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

where "First Data Year" = 1998 for O_3, SO_2, NO_2 and VOCs or 2000 for $PM_{2.5}$.

Table C2. Mann-Kendall and Sen's tests results for the national and regional annual average $PM_{2.5}$ indicators

Statistics	NAT	ATL	SQC	SON	PNO	BCO
First year	2000	2000	2000	2000	2000	2000
Last Year	2012	2012	2012	2012	2012	2012
N	13	13	13	13	13	13
Z-Test	-1.16	1.16	2.5	-3.11	1.04	-2.26
Significant	NO	NO	YES*	YES**	NO	YES*
Q	-0.04	0.06	0.24	-0.26	0.09	-0.09
Qmin95	-0.09	-0.05	0.06	-0.35	-0.08	-0.2
Qmax95	0.04	0.21	0.37	-0.18	0.42	0
B	6.6	4.6	7.22	8.63	4.4	6.31
Bmin95	6.89	5.05	8.25	9.21	5.39	6.96
Bmax95	6.32	3.33	6.6	8.16	3.03	5.81

Table C3. Mann-Kendall and Sen's tests results for the national and regional annual peak (98th percentile) 24-hour $PM_{2.5}$ indicators

Statistics	NAT	ATL	SQC	SON	PNO	BCO
First year	2000	2000	2000	2000	2000	2000
Last Year	2012	2012	2012	2012	2012	2012
N	13	13	13	13	13	13
Z-Test	-1.28	-0.06	0	-2.75	1.16	-0.79
Significant	NO	NO	NO	YES**	NO	NO
Q	-0.35	-0.03	0	-1.22	0.37	-0.13
Qmin95	-0.95	-0.54	-0.76	-2.01	-0.34	-0.58
Qmax95	0.17	0.49	0.7	-0.49	1.88	0.34
B	24.53	16.12	26.68	31.86	15.25	18.77
Bmin95	28.48	20.49	33.33	37.56	18.09	21.25
Bmax95	20.91	12.52	22.65	26.72	9.14	15.91

Table C4. Mann-Kendall and Sen's tests results for the national and regional annual average O_3 indicators

Statistics	NAT	ATL	SQC	SON	PNO	BCO
First year	1998	1998	1998	1998	1998	1998
Last Year	2012	2012	2012	2012	2012	2012
N	15	15	15	15	15	15
Z-Test	1.39	0.1	-1.29	1.19	1.98	2.38
Significant	NO	NO	NO	NO	YES*	YES*
Q	0.07	0.01	-0.11	0.08	0.13	0.19
Qmin95	-0.04	-0.14	-0.28	-0.06	0	0.04
Qmax95	0.18	0.23	0.1	0.3	0.27	0.34
B	31.98	32.27	33.75	36.8	31.21	24.99

Statistics	NAT	ATL	SQC	SON	PNO	BCO
Bmin95	32.71	33.37	34.7	37.5	32.29	26.15
Bmax95	31.07	30.69	31.74	34.52	30.55	23.73

Table C5. Mann-Kendall and Sen's tests results for the national and regional annual peak (4th-highest) 8-hour O_3 indicators

Statistics	NAT	ATL	SQC	SON	PNO	BCO
First year	1998	1998	1998	1998	1998	1998
Last Year	2012	2012	2012	2012	2012	2012
N	15	15	15	15	15	15
Z-Test	-2.08	-3.37	-2.47	-2.38	0	0
Significant	YES*	YES***	YES*	YES*	NO	NO
Q	-0.72	-0.77	-1.12	-1.01	-0.01	0.01
Qmin95	-1.1	-1.34	-1.8	-1.93	-0.28	-0.47
Qmax95	-0.05	-0.4	-0.28	-0.3	0.3	0.19
B	68.48	63.19	73.89	83.33	56.7	49.37
Bmin95	71.14	68.37	79.34	91.14	58.9	53.44
Bmax95	62.11	59.28	65.27	80.44	54.23	48.54

Table C6. Mann-Kendall and Sen's tests results for the national and regional annual average SO_2 indicators

Statistics	NAT	ATL	SQC	SON	PNO	BCO
First year	1998	1998	1998	1998	1998	1998
Last Year	2012	2012	2012	2012	2012	2012
N	15	14	15	15	15	15
Z-Test	-4.85	-4.27	-4.45	-4.26	-4.35	-2.67
Significant	YES***	YES***	YES***	YES***	YES***	YES**
Q	-0.2	-0.54	-0.23	-0.3	-0.08	-0.04
Qmin95	-0.22	-0.68	-0.28	-0.36	-0.09	-0.09
Qmax95	-0.17	-0.43	-0.19	-0.22	-0.06	-0.03
B	4.11	7.59	4.92	5.89	1.63	2.35
Bmin95	4.35	8.51	5.28	6.27	1.7	2.81
Bmax95	3.96	6.94	4.68	5.25	1.52	2.22

Table C7. Mann-Kendall and Sen's tests results for the national and regional annual average NO_2 indicators

Statistics	NAT	ATL	SQC	SON	PNO	BCO
First year	1998		1998	1998	1998	1998
Last Year	2012		2012	2012	2012	2012
N	15		15	15	15	15
Z-Test	-5.05		-4.45	-4.65	-4.55	-4.35
Significant	YES***		YES***	YES***	YES***	YES***

Q	-0.46		-0.47	-0.74	-0.31	-0.4
Qmin95	-0.51		-0.58	-0.8	-0.41	-0.48
Qmax95	-0.43		-0.39	-0.65	-0.24	-0.31
B	15.67		16.12	19.66	12.94	15.79
Bmin95	16.06		16.84	20.1	13.87	16.33
Bmax95	15.35		15.43	19.06	12.44	15.27

Table C8. Mann-Kendall and Sen's tests results for the national and regional annual average VOCs indicators

Statistics	NAT	ATL	SQC	SON	PNO	BCO
First year	1998	1998	1998	1998	1998	
Last Year	2012	2012	2012	2012	2012	
N	15	15	15	15	15	
Z-Test	-4.65	-2.74	-4.35	-4.38	-4.26	
Significant	YES***	YES**	YES***	YES***	YES***	
Q	-4.05	-1.45	-4.45	-3.86	-7.75	
Qmin95	-5.11	-2.67	-5.26	-5.04	-10.04	
Qmax95	-2.94	-0.55	-3.72	-2.47	-5.72	
B	105.13	65.21	96.22	82.79	212.04	
Bmin95	115.5	75.67	102.74	91.77	235.41	
Bmax95	96.03	59.09	87.99	71.52	194.53	

www.ec.gc.ca

Additional information can be obtained at:
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