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Data Sources and Methods for the Sulphur Dioxide, Nitrogen Dioxide and Volatile Organic Compounds Air Quality Indicators

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Canada

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1 Introduction

The national, regional and local air quality indicators are part of the Canadian Environmental Sustainability Indicators (CESI) (http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=47F48106-1) program, which provides data and information to track Canada's performance on key environmental sustainability issues.

Air quality indicators report on three air pollutants: sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and volatile organic compounds (VOC). These indicators are intended as state/condition indicators to inform policy-makers, decision-makers and the public as to whether progress is being made towards improving ambient air quality.

2 Description and rationale of the sulphur dioxide, nitrogen dioxide and volatile organic compounds air quality indicators

2.1 Description

Air quality indicators track the average of ambient concentrations of sulphur dioxide (SO2), nitrogen dioxide (NO2) and volatile organic compounds (VOC). In addition to causing human health effects, these three air pollutants are precursors to ozone and PM2.5, two main components of smog. More specifically, NO2 and VOC are ozone precursors. In the presence of sunlight and warm stagnant air, these two pollutants react to produce ozone in ambient air. These two pollutants and SO2 are also PM2.5 precursors. SO2 and NO2 also contribute to acid rain. SO2, NO2 and VOC indicators are based on the annual average of the daily 24-hour mean concentrations.

The SO2, NO2 and VOC air quality indicators are calculated on an annual basis (and not for the warm season alone, as is the case for ground-level ozone and fine particulate matter) since they are less influenced by weather and more by local emission sources.

2.2 Changes since last report

This is the first time that these indicators are being reported as part of the Canadian Environmental Sustainability Indicators (CESI).

3 Data

3.1 Data source

Air quality monitoring stations are located across Canada and are managed by the provinces, municipalities, territories and Environment Canada. Almost all stations collecting sulphur dioxide (SO2), nitrogen dioxide (NO2) and volatile organic compounds (VOC) data are operated under the National Air Pollution Surveillance (NAPS) program (http://www.ec.gc.ca/rnspa-naps/default.asp?lang=En&n=5C0D33CF-1).

Established in 1969, NAPS is a cooperative arrangement among the federal government and its provincial, territorial and municipal partners (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 and to store that data in the Canada-wide air quality database.

3.2 Spatial coverage

Air quality monitoring stations are spread across the country, but are more concentrated in urban areas. The monitoring stations used to calculate the air quality indicators are located in areas where most Canadians live, work and play.

The SO_2, NO_2 and VOC air quality indicators are provided by region. The following table provides the regions used by air pollutant. Refer to Appendix A to find the full list of stations used to calculate the national and regional indicators.

Table 2: Regions used for the regional indicators

Region Code	Region
ATL	Atlantic Canada
QUE	Quebec
ONT	Ontario
PRA	Prairies
BCO	British Columbia

3.3 Temporal coverage

The air quality indicators were calculated for the following time series.

Table 1: Time series range for the air quality indicators

Air Pollutants	Time series
SO_2	1996–2010
NO_2	1996–2010
VOC	1996–2010

Although minute-by-minute data are recorded, only hourly average readings are transmitted for SO_2 and NO_2.

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 1996. There are a number of reasons for this, including short-term technical problems, the commissioning or decommissioning of 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 (QA/QC) standards laid out in Table 3. Environment Canada conducts a national audit program to ensure consistency between jurisdictions across Canada.

Table 3: Data quality objectives[1] and specifications

Parameter	SO_2	NO_2	VOC
Accuracy	±15%	±15%	Species-dependent
Precision	< 10%	< 10%	Species-dependent
Completeness	> 75%	> 75%	
Comparability	Traceable to standard reference material	Traceable to standard reference material	Individual lab standard
Averaging period	Hourly	Hourly	*24 hr or 4 hr
Measurement cycle	Year-round	Year-round	*Year-round

* At urban monitoring sites, VOC samples are usually collected over 24-hour periods once every 6 days, and at rural sites these sites samples are collected over 4-hour sampling periods (12:00-16:00) every 3 days.

3.6 Data timeliness

There is a two-year lag from the last day of a year's data collection to the date at which that year's indicator is published. This lag is due to several intertwining factors, including the connection of the air quality (SO_2, NO_2 and VOC) indicators with other environmental sustainability indicators, raw data verification, compilation of data from all partners at the national level, analysis, review and reporting. The data used in this report were subject to quality assurance and quality control procedures to ensure that they adhere to the guidelines followed by Environment Canada and its partners.

4 Methods

Air quality (SO_2, NO_2 and VOC) indicators are calculated on the basis of common definitions used by Environment Canada and other jurisdictions like the United States Environmental Protection Agency (U.S. EPA). These definitions are based on the annual average of daily average concentrations (24-hour).

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 have been validated by the monitoring organization, quality control and assurance procedures outlined by the United States Environmental Protection Agency (U.S. EPA) are also undertaken. The originating agency must confirm data automatically (or manually flag data) before they are stored in the Canada-wide air quality database.

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

Yearly criteria (data completeness)

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

For the sulphur dioxide (SO_2) and the nitrogen dioxide (NO_2) indicators, a station is included only when

- each day has data for at least 18 hours;
- each month has data for at least 50% of valid days;
- each quarter (3 months) has data for at least 2 valid months; and
- each year has 4 valid quarters.

There are fewer data for the monitoring of the volatile organic compounds (VOC) indicator and so data completeness criteria are different. Samples are done once every 6 days in urban monitoring sites and 1 every 3 days in rural areas. A station is included only when

- each day has data for a consecutive 24 hours in an urban site and for a consecutive 4 hours in a rural area;
- each quarter (3 months) has data for at least 5 samples; and
- each year has 3 valid quarters.

In 2010, the number of stations that satisfied the yearly data requirements is as follows.

Table 4: Number of stations that satisfied the yearly completeness criteria

Air Pollutant	SO_2	NO_2	VOC
Number of stations	115	137	46

Monitoring station concentrations calculations

After the yearly criteria have been applied, the SO_2, NO_2 and VOC concentrations can be calculated for the selected stations.

The SO_2, NO_2 and urban VOC use a 24-hour average concentration. For rural VOC monitors, a 4-hour average concentration is used. A daily value for these pollutants refers to the 24-hour average concentration measured from midnight to midnight or the 4-hour average for rural VOC. The yearly average value for SO_2, NO_2 and urban VOC monitors is the average of the 24-hour average daily concentrations during the whole year. The 24-hour values for SO_2 and NO_2 were used to determine data completeness, but annual averages were calculated using all hourly averages for a site.

Each station meeting the yearly criteria for one year is then assessed to see if sufficient data is available for other years.

Time series criteria for SO_2, NO_2 and VOC

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 as follows.

- For the SO_2, NO_2 and VOC time series, each station must have data that satisfied the yearly criteria described above for at least 11 of the 15 years.
- Stations missing more than 2 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 changed location, were decommissioned or commissioned but sometimes are located close to one another. Data from neighbouring stations were used to supplement missing data and produce time series that meet the time series criteria.

Table 5: Stations grouped together for the SO_2 air quality indicator

NAPS ID	Province	City	Years
50203 50204	QUEBEC	GATINEAU	1996 1998–2010
50307 50308	QUEBEC	QUÉBEC	1996–1997 1998–2010
50602 50604	QUEBEC	ROUYN-NORANDA	1996–2002 2001–2010
60403 60430	ONTARIO	TORONTO	1996–2000 2003–2010
60413 60433	ONTARIO	TORONTO	1996–2002 2003–2010
60607 60609	ONTARIO	SUDBURY	1996–2004 2005–2010
60707 60709	ONTARIO	SAULT STE. MARIE	1996–2003 2004–2010
100401 100402	BRITISH COLUMBIA	KAMLOOPS	1996–2006 2007–2010

Table 6: Stations grouped together for the NO_2 air quality indicator

NAPS ID	Province	City	Years
50203 50204	QUEBEC	GATINEAU	1996 1998–2010
50307 50308	QUEBEC	QUÉBEC	1996–1997 1999–2010
60403 60429	ONTARIO	TORONTO	1996–2000 2003–2010
60807 60809	ONTARIO	THUNDER BAY	1996–2003 2007–2010
61602 61603	ONTARIO	OAKVILLE	1996–2002 2004–2010
61701 61702	ONTARIO	OSHAWA	1996–2004 2006–2010
63201 65101	ONTARIO	STOUFFVILLE NEWMARKET	1997–2000 2002–2010

NAPS ID	Province	City	Years
101002 101003	BRITISH COLUMBIA	METRO VAN - ABBOTSFORD	1996–1997 1999–2010

Table 7: Stations grouped together for the VOC air quality indicator

NAPS ID	Province	City	Years
54301 55201	QUEBEC	STE-FRANÇOISE LEMIEUX	1996–1999 2000–2010
60403 60429 60435	ONTARIO	TORONTO	1996–2000 2002–2008 2009
63201 65101	ONTARIO	STOUFFVILLE NEWMARKET	1996–2005 2006–2010

Measurement of SO_2, NO_2 and VOC (technology)

SO_2 measurements are made at sites in the NAPS network using pulse-fluorescence ultraviolet (UV) adsorption instruments. NO_2 measurements are made with analyzers operating on the principle of chemiluminescence involving the gas phase reaction of NO with O_3. Since these analyzers only measure NO directly, NO_2 is measured by reducing it to NO using a catalytic converter.

At urban monitoring sites, VOC samples are usually collected over 24-hour periods once every 6 days and analyzed for C_2 to C_{12} hydrocarbon species. VOC measurements are also made at rural sites and at these sites samples are collected over 4-hour sampling periods (12:00–16:00) every 3 days to capture the well-mixed atmosphere and avoid local site influences during nighttime.

Ambient air samples are collected in 6-L or 3.2-L stainless steel canisters in the field and are shipped back to the laboratory in Ottawa under pressure for subsequent analysis. A combined gas chromatography/flame ionization detector (GC/FID) system is used for quantification of C_2 hydrocarbons, while a combined gas chromatography/mass selective detector (GC/MSD) system operating in selected ion monitoring (SIM) mode is used for quantification of C_3 to C_{12} hydrocarbons.

Approximately 120 compounds (including a number of biogenic species such as isoprene and pinenes) are routinely quantified in the samples. Note that not all species are detected in all samples. The calculation of total VOC in ppbC is carried out by summing the concentration of all detected species.

A listing of target species is contained in Appendix B.

National and regional indicators

In total, 45 sulphur dioxide, 58 nitrogen dioxide, and 29 VOC monitoring stations satisfy the data requirements and were included in the national air quality indicators.

The following table provides the number of monitoring stations that were included for the calculation of the regional indicators.

Table 8: Number of stations selected for the regional air quality indicators

Region	SO_2	NO_2	VOC
Atlantic Canada	3	2	4
Quebec	14	12	8
Ontario	11	15	11
Prairies	7	13	4
British Columbia	10	16	2

Local indicators

Local data for the annual SO_2, NO_2 and VOC concentrations are also presented in the CESI interactive map.(http://maps-cartes.ec.gc.ca/indicators-indicateurs/default.aspx?lang=en) These snapshots are the average annual concentration for 2010 by station obtained from all the monitoring stations across Canada that satisfy the 2010 yearly criteria.

4.2 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 of the annual average pollutant concentrations over time at the 90% confidence level. The *Sen's pairwise slope method* was used to again test the presence of a linear trend at the 90% confidence level and estimate the slope between pollutant concentrations and time. Both the Mann-Kendall and the Sen's methods were applied to the annual average concentrations level for SO_2, NO_2 and VOC (1996–2010). A trend is reported when both the Mann-Kendall and Sen's tests indicate the presence of a trend at the 90% confidence level.

The following tables present the rate of change per year for the national and regional air quality indicators estimated with the Sen's method. The units for SO_2, NO_2 and VOC are expressed in rate of change per year in percent change based on the median of the 1996–2010 time series.

Table 9: Rate of change per year for the national and regional SO_2 air quality indicator, 1996 to 2010

SO_2 indicator	Number of stations	Median rate of change per year	90% lower confidence interval	90% upper confidence interval
	Number	%	%	%
National	45	-4.41	-5.04	-3.50
Atlantic Canada	3	-6.44	-7.67	-4.95
Quebec	14	-4.09	-5.27	-3.27
Ontario	11	-4.67	-5.45	-3.92
Prairies	7	-4.66	-5.81	-3.88
British Columbia	10	-1.64	-3.26	-0.53

Table 10: Rate of change per year for the national and regional NO_2 air quality indicator, 1996 to 2010

NO_2 indicator	Number of stations	Median rate of change per	90% lower confidence interval	90% upper confidence interval

		year		
	Number	%	%	%
National	58	-2.68	-2.92	-2.51
Atlantic Canada	2	-3.34	-6.17	-0.95
Quebec	12	-2.58	-3.19	-1.95
Ontario	15	-3.19	-3.63	-2.64
Prairies	13	-2.56	-3.03	-1.91
British Columbia	16	-2.30	-2.58	-2.02

Table 11: Rate of change per year for the national and regional VOC air quality indicator, 1996 to 2010

VOC indicator	Number of stations	Median rate of change per year	90% lower confidence interval	90% upper confidence interval
	Number	%	%	%
National	29	-4.09	-4.92	-3.16
Atlantic Canada	4	-2.33	-3.54	-1.15
Quebec	8	-4.79	-5.61	-4.08
Ontario	11	-4.95	-6.25	-4.07
Prairies	4	-3.60	-4.33	-2.63
British Columbia	2	-3.51	-4.60	-2.45

Based on a 90% confidence interval, test results for the SO_2, NO_2 and VOC indicators show statistically significant trends at the national level and at the regional levels for all three air pollutants. Results of the tests are available in Appendix C.

5 Caveats and limitations

Measurement error: While instrument measurement error is inevitable, Environment Canada and its provincial partners have deployed quality control and quality assurance procedures for monitoring instruments to ensure that sources of measurement error are controlled and minimized. The error is estimated to be ± 15% for sulphur dioxide, ± 15% for nitrogen dioxide, while for volatile organic compounds the error varies depending on the species sampled. For more information consult the National Air Pollution Surveillance Network Quality Assurance and Quality Control Guidelines (www.etc-cte.ec.gc.ca/publications/naps/NAPSQAQC.pdf) from Environment Canada and the Ambient Air Monitoring Protocol for $PM_{2.5}$ and Ozone (http://www.ccme.ca/assets/pdf/pm_oz_cws_monitoring_protocol_pn1456_e.pdf) from the Canadian Council of Ministers of the Environment (CCME).

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 a number of organizations, including the World Health Organization and the United States Environmental Protection Agency (U.S. EPA), as well as expert opinion. Even with the use of data completeness criteria, some gaps can be found in the air quality data.

Special interpretation cases: Two cases were identified where further explanations are necessary.

The first one is for the region of Quebec for SO_2 concentration, in which a 40% decrease in concentration was observed between 2010 and 2009**.** The reduction in SO_2 observed in 2010 is not only explained by the general reduction of SO_2 emissions but also by the absence of monitoring data in 2010 for three stations located close to industrial complexes (Temiscaming, Sorel and Shawinigan).The decrease is mostly explained by these stations not reporting values in 2010. This is the same reason for 1996, when many stations did not report values. It has to be noted that, even though these stations did not report any values for a year, they still respected the time series criteria.

The second case is in British Columbia for SO_2, in which a 35% increase in concentration was observed in 2010 compared to 2009. The increase is mostly explained by the Trail station, which did not report in 2009 but reported in 2010. This station had high level of SO_2 compared to the other stations because it is close to an industrial plant. In general, most of the other stations had decreasing SO_2 values.

6 References and further reading

Environment Canada (2004) National Air Pollution Surveillance Network Quality Assurance and Quality Control Guidelines. Retrieved in January 2012. Available from: http://www.etc-cte.ec.gc.ca/publications/napsreports_e.html.

Environment Canada (2012) National Air Pollution Surveillance Program (NAPS). Retrieved in January 2012. Available from: http://www.ec.gc.ca/rnspa-naps/Default.asp?lang=En&n=5C0D33CF-1.

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
SO_2	If not empty, the station contributes data to the time series trend analysis for 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 nitrogen dioxide in the national indicator and regional indicator of the identified region.
VOC	If not empty, the station contributes data to the time series trend analysis for volatile organic compounds in the national indicator and regional indicator of the identified region.
ACRONYMS	**DESCRIPTION**
ATL	Atlantic Region CESI regional indicator
QUE	Quebec CESI regional indicator
ONT	Ontario CESI regional indicator
PRA	Prairies CESI regional indicator
BCO	British Columbia CESI regional indicator

Monitoring Stations

NAPS ID	PROV	CITY	ADDRESS	SO_2	NO_2	VOC
10102	NL	ST. JOHN'S	354 WATER STREET	ATL	ATL	
30118	NS	HALIFAX	1657 BARRINGTON STREET			ATL
30501	NS	KEJIMKUJIK	NATIONAL PARK			ATL
40203	NB	SAINT JOHN	MOUNTAIN ROAD	ATL		ATL
40206	NB	SAINT JOHN	189 PRINCE WILLIAM	ATL	ATL	
40501	NB	POINT LEPREAU	RECREATION AREA			ATL
50102	QC	MONTRÉAL	BOUL. ROSEMONT	QUE		
50103	QC	MONTRÉAL	1050 A, BOUL. SAINT-JEAN-BAPTISTE	QUE	QUE	QUE
50104	QC	MONTRÉAL	1125 RUE ONTARIO EST			QUE
50109	QC	MONTRÉAL	2495 DUNCAN / DÉCARIE, MT-ROYAL		QUE	
50110	QC	MONTRÉAL	11280 BOUL. PIE IX, MTL NORD		QUE	
50113	QC	LAVAL	1160 BOUL PIE X		QUE	
50115	QC	MONTRÉAL	1001 BOUL DE MAISONNEUVE OUEST	QUE	QUE	QUE
50116	QC	MONTRÉAL	3161 JOSEPH, VERDUN		QUE	
50119	QC	LONGUEUIL	FACE AU 1819 RUE VICTORIA		QUE	
50121	QC	LONGUEUIL	8361 RUE OCÉANIE - BROSSARD	QUE	QUE	QUE
50128	QC	MONTRÉAL	90-A RUE HERVÉ-SAINT-MARTIN, DORVAL		QUE	

NAPS ID	PROV	CITY	ADDRESS	SO_2	NO_2	VOC
50204*	QC	GATINEAU	255 ST-RÉDEMPTEUR, HULL	QUE	QUE	
50308*	QC	QUÉBEC	600 RUE DES SABLES	QUE	QUE	
52601	QC	VARENNES	4744 MONTÉE BARONIE		QUE	
50604*	QC	ROUYN-NORANDA	1570 RUE PARADIS	QUE		
50801	QC	TROIS-RIVIÈRES	FACE AU 678 RUE HART	QUE		
50902	QC	SAGUENAY	2885 BERTHIER (ARVIDA), JONQUIÈRE	QUE		
51201	QC	SHAWINIGAN	363 RUE FRIGON	QUE		
51801	QC	SAINT-JOSEPH-DE-SOREL	FACE AU 113 LÉON-XIII	QUE		
51802	QC	SOREL-TRACY	80 RUE GEORGE	QUE		
52701	QC	TÉMISCAMING	RUE BOUCHER	QUE		
54102	QC	SUTTON	MONT SUTTON/ROUND TOP RIDGE			QUE
55201*	QC	LEMIEUX	1290 RTE DES ATOCAS			QUE
54401	QC	SAINT-ANICET	1128 DE LA GUERRE			QUE
54501	QC	L'ASSOMPTION	801 ST-ÉTIENNE/ROUTE 344			QUE
54703	QC	BÉCANCOUR	8310 BOUL. BÉCANCOUR	QUE		
60104	ON	OTTAWA	RIDEAU & WURTEMBURG	ONT	ONT	ONT
60204	ON	WINDSOR	467 UNIVERSITY AVE. WEST	ONT	ONT	
60211	ON	WINDSOR	COLLEGE & SOUTH ST.	ONT		ONT
60429*	ON	TORONTO	1 ETONA COURT		ONT	
60435*	ON	TORONTO	461 KIPLING AVE			ONT
60430*	ON	TORONTO	125 RESOURCES ROAD	ONT		
60410	ON	TORONTO	LAWRENCE & KENNEDY		ONT	
60413	ON	TORONTO	ELMCREST ROAD		ONT	ONT
60421	ON	TORONTO	YONGE ST. & FINCH AVE.		ONT	
60433*	ON	TORONTO	BAY & WELLESLEY	ONT		
60512	ON	HAMILTON	ELGIN & KELLY	ONT	ONT	ONT
60513	ON	HAMILTON	VICKERS RD. & EAST 18TH. ST.	ONT		
60609*	ON	SUDBURY	RAMSEY LAKE ROAD	ONT		
60709*	ON	SAULT STE. MARIE	443 NORTHERN AVE., SAULT COLLEGE	ONT		
60809*	ON	THUNDER BAY	421 JAMES STREET SOUTH		ONT	
60903	ON	LONDON	900 HIGHBURY AVENUE	ONT	ONT	
61004	ON	SARNIA	FRONT ST. AT C.N. TRACKS	ONT	ONT	
61104	ON	PETERBOROUGH	10 HOSPITAL DRIVE			ONT
61502	ON	KITCHENER	WEST AVE. & HOMEWOOD		ONT	
61603*	ON	OAKVILLE	8TH LINE/GLENASHTON DR.; HALTON RESERVE		ONT	
61702*	ON	OSHAWA	2200 SIMCOE STREET NORTH		ONT	
62601	ON	SIMCOE	EXPERIMENTAL FARM			ONT
63001	ON	BURLINGTON	HWY 2 & NORTH SHORE BLVD.		ONT	
65101*	ON	NEWMARKET	EAGLE ST. & McCAFFREY RD.		ONT	ONT
63601	ON	LONGWOODS	LONGWOODS CONS. AUTHORITY			ONT
64401	ON	EGBERT	EGBERT			ONT
64601	ON	PT. PETRE	PT. PETRE			ONT
70118	MB	WINNIPEG	299 SCOTIA ST.		PRA	
70119	MB	WINNIPEG	65 ELLEN STREET		PRA	PRA
70203	MB	BRANDON	1430 VICTORIA AVENUE EAST		PRA	
80110	SK	REGINA	2505 11TH. AVENUE	PRA	PRA	

NAPS ID	PROV	CITY	ADDRESS	SO_2	NO_2	VOC
80211	SK	SASKATOON	511 1ST AVENUE NORTH	PRA	PRA	
90121	AB	EDMONTON	17 STREET & 105 AVENUE	PRA	PRA	PRA
90130	AB	EDMONTON	10255 - 104TH STREET		PRA	PRA
90218	AB	CALGARY	49 AVENUE & 15TH STREET S.E.	PRA	PRA	
90222	AB	CALGARY	39 ST. & 29 AVE. N.W.		PRA	
90227	AB	CALGARY	611-4TH STREET S.W.			PRA
90601	AB	FORT SASKATCHEWAN	9209A-96 AVE	PRA	PRA	
90701	AB	FORT MCMURRAY	FRANKLIN AVENUE	PRA	PRA	
90801	AB	FORT MACKAY	MAIN STREET	PRA		
91401	AB	VIOLET GROVE	SE 17 48 08 W5		PRA	
91501	AB	BEAVERLODGE	BEAVERLODGE RESEARCH FARM		PRA	
100110	BC	METRO VAN - BURNABY	6400 E. HASTINGS & KENSINGTON	BCO	BCO	
100111	BC	METRO VAN - PORT MOODY	MOODY & ESPLANADE PORT MOODY	BCO	BCO	BCO
100112	BC	METRO VAN - VANCOUVER	ROBSON/HORNBY	BCO	BCO	
100118	BC	METRO VAN - VANCOUVER	2550 WEST 10TH AVENUE	BCO	BCO	
100119	BC	METRO VAN - BURNABY	5455 RUMBLE STREET		BCO	
100121	BC	METRO VAN - VANCOUVER	75 RIVERSIDE DR. N. VANCOUVER		BCO	
100125	BC	METRO VAN - DELTA	8544 116TH AVE. DELTA		BCO	
100126	BC	METRO VAN - BURNABY	RING ROAD BURNABY		BCO	
100127	BC	METRO VAN - SURREY	19000 & 72ND AVE. SURREY		BCO	
100128	BC	METRO VAN - RICHMOND	WILLIAMS & ARAGON RICHMOND	BCO	BCO	
100132	BC	METRO VAN - VANCOUVER	16TH ST. & JONES AVE NORTH VAN	BCO	BCO	
100133	BC	METRO VAN - BURNABY	7815 SHELLMOUNT			BCO
100136	BC	METRO VAN - BURNABY	GROSVENOR CRESENT - BURNABY	BCO		
100402*	BC	KAMLOOPS	MAYFAIR STREET	BCO		
101003*	BC	METRO VAN - ABBOTSFORD	32995 BEVAN AVE.		BCO	
101101	BC	METRO VAN-CHILLIWACK	46244 AIRPORT ROAD		BCO	
101301	BC	METRO VAN-LANGLEY	23752 52ND AVENUE		BCO	
101401	BC	METRO VAN-HOPE	62715 AIRPORT ROAD		BCO	
101501	BC	METRO VAN - MAPLE RIDGE	23124 118TH AVENUE		BCO	
102201	BC	TRAIL	BUTLER PARK	BCO		
104301	BC	TAYLOR	MCMAHON COMPLEX	BCO		

* These stations were merged with past stations located nearby to respect data completeness criteria. See tables 5 and 6 for details.

Appendix B

Table B1: Volatile organic compounds species

Compounds	CAS	Compounds	CAS
1,2,3-Trimethylbenzene	526-73-8	Butane	106-97-8
1,2,4-Trimethylbenzene	95-63-6	Camphene	79-92-5
1,2-Diethylbenzene	135-01-3	cis-1,2-Dimethylcyclohexane	2207-01-04
1,3,5-Trimethylbenzene	108-67-8	cis-1,3-Dimethylcyclohexane	638-04-0
1,3-Butadiene	106-99-0	cis-2-Butene	590-18-1
1,3-Diethylbenzene	141-93-5	cis-2-Heptene	6443-92-1
1,4-Diethylbenzene	105-05-5	cis-2-Hexene	7688-21-3
1-Butene	115-11-7	cis-2-Octene	7642-04-08
1-Butyne	107-00-6	cis-2-Pentene	627-20-3
1-Decene	872-05-9	cis-3-Heptene	7642-10-06
1-Heptene	592-76-7	cis-3-Methyl-2-pentene	922-61-2
1-Hexene	592-41-6	cis-4-Methyl-2-pentene	4461-48-7
1-Methylcyclohexene	591-49-1	Cyclohexane	110-82-7
1-Methylcyclopentene	693-89-0	Cyclohexene	110-83-8
1-Nonene	124-11-8	Cyclopentane	287-92-3
1-Octene	111-66-0	Cyclopentene	142-29-0
1-Pentene	109-67-1	Decane	124-18-5
1-Propyne	74-99-7	d-Limonene	5989-27-5
1-Undecene	821-95-4	Dodecane	112-40-3
2,2,3-Trimethylbutane	464-06-2	Ethane	74-84-0
2,2,4-Trimethylpentane	540-84-1	Ethylbenzene	100-41-4
2,2,5-Trimethylhexane	3522-94-9	Ethylene	74-85-1
2,2-Dimethylbutane	75-83-2	Heptane	142-82-5
2,2-Dimethylhexane	590-73-8	Hexane	110-54-3
2,2-Dimethylpentane	590-35-2	Hexylbenzene	1077-16-3
2,2-Dimethylpropane	463-82-1	Indane	496-11-7
2,3,4-Trimethylpentane	565-75-3	Isobutane	75-28-5
2,3-Dimethylbutane	79-29-8	iso-Butylbenzene	538-93-2
2,3-Dimethylpentane	565-59-3	Isopentane	78-78-4
2,4-Dimethylhexane	589-43-5	Isoprene	78-79-5
2,4-Dimethylpentane	108-08-7	iso-Propylbenzene	98-82-8
2,5-dimethylheptane	2216-30-0	m and p-Xylene	108-38-3
2,5-Dimethylhexane	592-13-2	Methylcyclohexane	108-87-2
2-Ethyl-1-butene	760-21-4	Methylcyclopentane	96-37-7
2-Ethyltoluene	611-14-3	n-Butylbenzene	104-51-8
2-methyl-1-butene	563-46-2	Nonane	111-84-2
2-Methyl-1-Pentene	763-29-1	n-Propylbenzene	103-65-1
2-Methyl-2-butene	513-35-9	Octane	111-65-9
2-Methyl-2-pentene	625-27-4	o-Xylene	95-47-6
2-Methylheptane	592-27-8	p-Cymene	99-87-6
2-Methylhexane	591-76-4	Pentane	109-66-0
2-Methylpentane	107-83-5	Propane	74-98-6
3,6-Dimethyloctane	15869-94-0	Propylene	115-07-1

Compounds	CAS	Compounds	CAS
3-Ethyltoluene	620-14-4	sec-Butylbenzene	135-98-8
3-Methyl-1-Butene	563-45-1	Styrene	100-42-5
3-Methyl-1-pentene	760-20-3	tert-Butylbenzene	1998-06-06
3-Methylheptane	589-81-1	Toluene	108-88-3
3-Methylhexane	589-34-4	trans-1,2-Dimethylcyclohexane	6876-23-9
3-Methyloctane	2216-33-3	trans-1,4-Dimethylcyclohexane	2207-04-07
3-Methylpentane	96-14-0	trans-2-Butene	624-64-6
4-Ethyltoluene	622-96-8	trans-2-Heptene	14686-13-6
4-Methyl-1-pentene	691-37-2	trans-2-Hexene	4050-45-7
4-Methylheptane	589-53-7	trans-2-Octene	13389-42-9
4-Methyloctane	2216-34-4	trans-2-Pentene	646-04-8
Acetylene	74-86-2	trans-3-Heptene	14686-14-7
a-Pinene	80-56-8	trans-3-Methyl-2-pentene	616-12-6
Benzene	71-43-2	trans-4-Methyl-2-pentene	674-76-0
b-Pinene	127-91-3	Undecane	1120-21-4

Appendix C

Legend for tables C1 and C2

FIELD	DESCRIPTION
Time series	Names of the time series
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
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 4 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-first Data Year)+B for a linear trend
Bmin90	Estimate of the constant Bmin90 in equation f(year)=Qmin99*(year-first Data Year)+Bmin90 for 90% confidence level of linear trend
Bmax90	Estimate of the constant Bmax90 in equation f(year)=Qmax99*(year-

FIELD	DESCRIPTION
	first Data Year)+Bmax90 for 90% confidence level of linear trend

Trend equation

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

Where First Data Year = 1996 for SO_2, NO_2 and VOC

Table C1. Mann-Kendall and Sen's tests results for SO_2

STATISTICS	Sulphur dioxide (SO_2)					
	NATIONAL	ATL	QUE	ONT	PRA	BCO
First Year	1996	1996	1996	1996	1996	1996
Last Year	2010	2010	2010	2010	2010	2010
N	15	15	15	15	15	15
Test Z	-4.35	-4.16	-3.66	-4.16	-4.65	-2.38
Significant	Yes ***	Yes ***	Yes ***	Yes ***	Yes ***	Yes *
Q	-0.24	-0.47	-0.31	-0.30	-0.09	-0.05
Qmin90	-0.28	-0.56	-0.40	-0.34	-0.11	-0.10
Qmax90	-0.19	-0.36	-0.25	-0.25	-0.07	-0.02
B	5.55	7.26	7.60	6.32	1.91	2.98
Bmin90	5.79	7.93	8.44	6.74	2.08	3.29
Bmax90	5.14	6.15	7.11	6.02	1.77	2.78

Table C2. Mann-Kendall and Sen's tests results for NO_2

STATISTICS	Nitrogen dioxide (NO_2)					
	NATIONAL	ATL	QUE	ONT	PRA	BCO
First Year	1996	1996	1996	1996	1996	1996
Last Year	2010	2010	2010	2010	2010	2010
N	15	15	15	15	15	15
Test Z	-4.95	-2.38	-4.16	-4.55	-4.75	-4,75
Significant	Yes ***	Yes *	Yes ***	Yes ***	Yes ***	Yes ***
Q	-0.48	-0.36	-0.47	-0.67	-0.40	-0.41
Qmin90	-0.52	-0.67	-0.58	-0.76	-0.48	-0.46
Qmax90	-0.45	-0.10	-0.34	-0.55	-0.30	-0.36
B	17.96	10.78	18.11	20.92	15.80	17.67
Bmin90	18.28	13.81	19.24	21.74	16.56	18.08
Bmax90	17.67.04	9.01	17.52	20.08	14.90	17.42

Table C3. Mann-Kendall and Sen's tests results for VOC

STATISTICS	Volatile organic compounds (VOC)					
	NATIONAL	ATL	QUE	ONT	PRA	BCO
First Year	1996	1996	1996	1996	1996	1996
Last Year	2010	2010	2010	2010	2010	2010
N	15	15	15	15	15	15
Test Z	-4.75	-2.87	-4.26	-4.95	-4.16	-3.76

STATISTICS	Volatile organic compounds (VOC)					
	NATIONAL	ATL	QUE	ONT	PRA	BCO
Significant	**Yes *****	**Yes ****	**Yes *****	**Yes *****	**Yes *****	**Yes *****
Q	-5.27	-1.64	-5.25	-5.10	-8.63	-7.19
Qmin90	-6.33	-2.49	-6.15	-6.44	-10.38	-9.42
Qmax90	-4.07	-0.81	-4.47	-4.19	-6.30	-5.02
B	128.64	70.30	109.61	103.02	239.78	204.96
Bmin90	137.19	78.74	119.22	111.31	248.60	221.94
Bmax90	114.75	66.43	104.94	93.86	215.67	190.54

www.ec.gc.ca

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