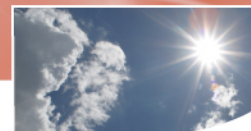




Environment
Canada

Environnement
Canada

www.ec.gc.ca



Air Quality and Air Pollutant Emissions Indicators

Data Sources and Methods

December 2010

Catalogue #: En4-141/2010E-PDF
ISBN: 978-1-100-17540-9

Canada

Table of contents

1. Introduction	3
2. Air Quality Indicators	4
2.1 Description of the air quality indicators.....	4
2.2 How the air quality indicators are used	5
2.3 How the air quality indicators are calculated	6
2.3.1 Daily averages.....	7
2.3.2 Time period	8
2.3.3 Population weighting	8
2.4 Data sources	10
2.4.1 Monitoring networks	10
2.4.2 Spatial coverage of data	11
2.4.3 Data quality and completeness.....	11
2.4.4 Timeliness	12
2.5 Statistical analysis	13
2.5.1 Summary of results.....	13
2.6 International comparison	15
2.7 Caveats and limitations	18
3.0 Air emissions indicators.....	20
3.1 Description of the air emissions indicators.....	20
3.2 How the air emissions indicators are compiled.....	21
3.3 Data sources	22
3.4 International comparison	23
3.5 Caveats and limitations	25
3.6 Charts Data.....	27
4.0 References.....	29
APPENDIX	30
A. Air Quality Monitoring Stations Reported in CESI.....	30
B. Mann-Kendall and SEN Tests results	37
C. Data sources for international air quality comparison	38

1. Introduction

This report is released under the Canadian Environmental Sustainability Indicators (CESI) initiative. Each indicator reported under CESI has an associated “data sources and methods” report to provide technical details and other background that will facilitate interpretation and allow others to conduct further analysis using the CESI data and methods as a starting point.

This report deals with the underlying methods and data for the air quality and emissions indicators published in December 2010 on the CESI website.

2. Air Quality Indicators

2.1 Description of the air quality indicators

Poor air quality has significant negative effects on the natural environment, human health, and economic and biological productivity. The CESI air quality indicators track ground-level ozone and fine particulate matter ($PM_{2.5}$) concentrations. These pollutants are key components of smog and are two of the most widespread air pollutants to which people are exposed.

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

The CESI air quality indicators have been designed to approximate human population exposure to ground-level ozone and $PM_{2.5}$ over time. They are intended as a general indicator to alert policy analysts and decision-makers as to whether progress towards improved air quality is being made or if problems persist.

Other methods exist to measure ground-level ozone and $PM_{2.5}$ concentrations, often with different purposes in mind and often providing different results. For example, the Canada-wide Standard (CWS) for ozone, based on the three-year average of the annual fourth highest daily maximum eight-hour concentration, is focused on reflecting the effects of acute (short-term) exposure to peak air pollution.

2.2 How the air quality indicators are used

The CESI initiative aims to provide Canadians with regular and reliable information on the state of Canada's environment and the related impact of human activities.

The CESI air quality indicators, ground-level ozone and $PM_{2.5}$, are intended as state/condition indicators to inform policy analysts, decision makers and the public as to whether progress is being made towards improved air quality.

2.3 How the air quality indicators are calculated

Ground-level ozone

Calculating the daily maximum 8-hour average concentration

There are 24 consecutive 8-hour averages (8-hour rolls) that can be possibly calculated for each day. The daily maximum 8-hour average concentration for a given day is the highest of the 24 possible 8-hour averages computed for that day. See Table 1 for an illustration of the 8-hour averages.

Calculating the warm-season average value

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

Fine particulate matter (PM_{2.5})

Calculating the 24-hour average concentration

The PM_{2.5} indicator is calculated the same way as the ground-level ozone exposure indicator, but uses a single roll, or 24-hour average concentration. A daily value for PM_{2.5} refers to the 24-hour average concentration of PM_{2.5} measured from midnight to midnight.

Calculating the warm-season average value

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

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

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

2.3.1 Daily averages

Since some adverse health effects of air pollution (e.g., cardiovascular and respiratory effects) are observed even at low levels of exposure, especially for ground-level ozone and $PM_{2.5}$, the calculation of each respective air indicator is based on daily relative average concentrations rather than on daily peak concentrations. Over the course of the warm season, peak concentrations are rather sporadic, while daily average concentrations are relatively more common and hence a better measure of exposure.

2.3.2 Time period

The air quality indicators consider daily ground-level ozone and PM_{2.5} concentrations during the warm season (April 1-September 30), which is also the period when Canadians are most active outdoors (Leech et al. 2002). These months tend to have meteorological conditions that favour the formation of ground-level ozone. While fine particulate matter is a concern in winter, current monitoring methods present challenges with instrument variability in cold weather. Omitting this portion of the data also allows for better comparability with the ground-level ozone data. Warm-season PM_{2.5} data are, therefore, used in this release of CESI Air Quality and Emissions Indicators.

2.3.3 Population weighting

In this release of CESI, the air quality indicators were calculated using a population-weighted approach, weighting annual warm-season average values of monitoring stations across Canada. Monitoring stations are scattered from coast to coast, in different areas with different populations. Therefore, proportionally adjusting air pollution levels measured at a monitoring site based on the size of the population residing near the station provides a surrogate estimate of exposure to ground-level ozone and PM_{2.5}.¹

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

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

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

This population-weighted method assigns more weight to ozone and PM_{2.5} concentrations reported at those stations located in more populated areas. Applying different population estimates (P_n) by consecutively halving the radius from 40 km to 20 km to 10 km and to 5 km did not impact the trend for ozone or the trend for PM_{2.5} at a statistically significant level.

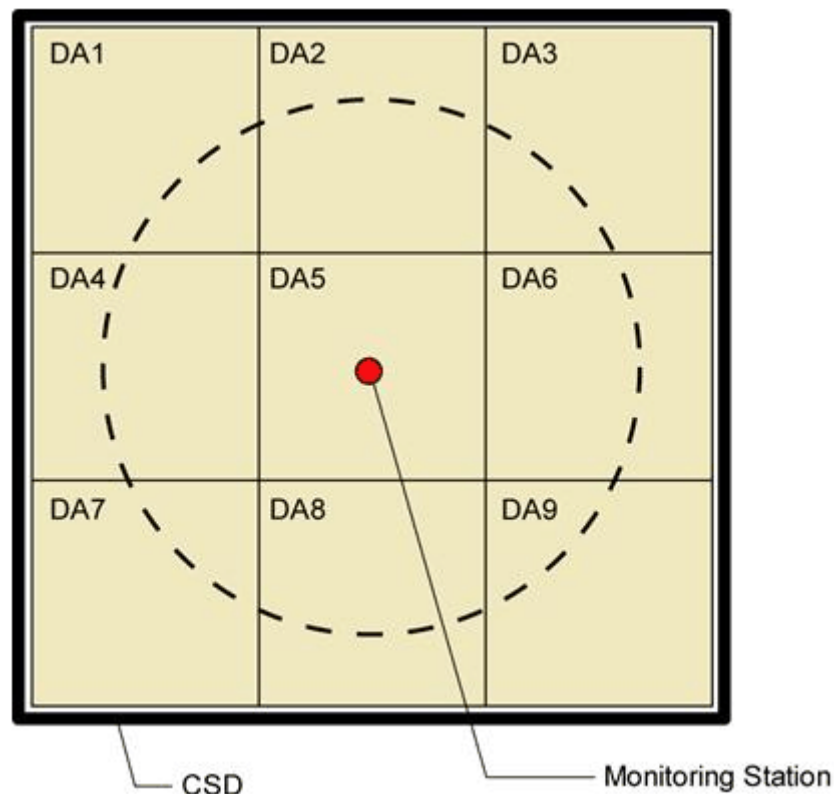
¹ This approach is similar to and more general than the pilot method used for the National Round Table on the Environment and the Economy (2003) discussion paper on the Environment and Sustainable Development Indicators.

Estimating population weights

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

Since the boundaries of DAs do not always fit precisely with the boundaries of the 40-km radius circles around the monitoring stations used for the air quality indicators, the population in each circle is estimated based on the proportion of the area of DAs. Figure 2 presents a conceptual framework for estimating the population in a circle around a monitoring station.

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



Note: The large square with a dark boundary line in Figure 2 represents a census subdivision (CSD) containing nine dissemination areas (DA1 to DA9) presented as small squares. The dashed circle represents a conceptual circular area (40-km radius) around a monitoring station. The contribution of each DA to the population in the circle is based on area-proportion, that is to say, the percentage of the area of each DA that falls in the circle. For example, DA5 contributes all its population, while DA2 contributes approximately half of its population to the population of the circle. The percentage of the area of each DA in relation to the circle is constant throughout the entire time frame used in the calculation of the indicators. The percentage of the population of each DA to the overall population of its CSD is, however, updated once every census year, on a five-year cycle, since new census data then become available. In non-census years, the latest census data are used as the basis for deriving the degree to which each DA contributes to the population of a CSD (as a percentage), using Statistics Canada's yearly population estimates for each CSD.

2.4 Data sources

Air quality monitoring stations are located across Canada and are managed by provinces, municipalities, territories and Environment Canada. Almost all stations collecting ground-level ozone and PM_{2.5} data are organized under the National Air Pollution Surveillance (NAPS) program, a cooperative arrangement among the federal government, provinces and territories that has existed since 1970. In appendix A, you will find the list of all the monitoring stations used by CESI and its interactive map, including stations used for computing time-series and trends at the national and regional levels.

The goal of the NAPS program is to provide accurate and long-term air quality data of a uniform standard throughout Canada. Data from the NAPS network are stored in the Canada-wide Air Quality Database and are published in annual or semi-annual air quality data summary reports.² The database also includes ground-level ozone data information from the Canadian Air and Precipitation Monitoring Network (CAPMoN), run by Environment Canada. The CAPMoN stations were established for research purposes and for monitoring air pollution outside of urban areas.

2.4.1 Monitoring networks

In 2008, NAPS and CAPMoN operated a total of 289 monitoring stations in 200 communities across Canada reported to the NAPS Canada-wide database. In NAPS only, there were 205 ozone monitors and 210 continuous PM_{2.5} instruments reporting to the database. There were an additional 36 filter-based PM_{2.5} instruments in operation. Other parameters measured through NAPS include sulphur dioxide (SO₂), carbon monoxide (CO), nitrogen dioxide (NO₂), nitric oxide (NO), nitrogen oxides (NO_x), coarse particulates (PM₁₀), volatile organic compounds (VOC), heavy metals, toxics and a variety of semi-volatile organic compounds.

There are standards and procedures for the selection and positioning of stations and their sampling equipment. Probes for ground-level ozone and other pollutants, for example, are sited using a set of criteria for probe height, probe distance from roadways and stationary air emission sources, probe distance from airflow restrictions, and probe distance from trees (Environment Canada 2004).

Sampling methods are governed by standard operating practices and related quality assurance procedures. The calibration standards used to calibrate ground-level ozone monitors are traceable to the United States National Institute of Standards and Technology's primary ozone reference standard. The air analyzers that are used to sample ground-level ozone all satisfy the requirements of the U.S. Environmental Protection Agency. Environment Canada has documented the processes for collecting and handling the data through the NAPS program. Fine particulate matter is measured using tapered element oscillating micro-balance (TEOM) continuous monitors.

² Available from: <http://www.ec.gc.ca/rnsps-naps/default.asp?lang=En&n=77FECF05-1#reports>

2.4.2 Spatial coverage of data

Air quality monitoring stations are spread across the country, but are concentrated more heavily in urban areas. The monitoring stations used in calculating the air quality indicators correspond to the areas where most Canadians live, work and play. Monitoring networks have been installed to track regional and provincial air quality conditions for urban and non-urban sites.

Since monitoring stations are used to track multiple pollutants, their locations are not always ideal for ground-level ozone and/or $PM_{2.5}$ monitoring purposes. Some stations were placed in areas to measure the effects of stationary and/or mobile sources, including emissions from industrial plants and vehicular traffic. These stations do not represent the normal air quality for the general area. Such monitoring stations were not considered representative of the general air quality, and the readings from those stations were excluded from the calculations and are not considered by CESI.

2.4.3 Data quality and completeness

Each of the organizations participating in the monitoring program, NAPS and CAPMoN, forwards data to the Analysis and Air Quality Section at Environment Canada. Although minute-by-minute data are recorded, only hourly average readings are transmitted.

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

The possible measurement error for ground-level ozone concentrations at individual stations is conservatively estimated at $\pm 10\%$ (Halman, pers. comm.³). The error for $PM_{2.5}$ is conservatively estimated at $\pm 20\%$ (Dann, pers. comm.⁴). The stations do not all have the same time series of data available, nor have they all been operating continuously since 1990. There are a number of reasons for this, including short-term technical problems, the commissioning or decommissioning of stations, and incomplete records from some stations. Short data gaps will have little effect on computed long-period averages or trends of concentrations at individual stations.

Table 3 presents some of the general sets of specifications related to ground-level ozone and $PM_{2.5}$. More detail on $PM_{2.5}$ and ozone monitoring methods can be found in the Canada-wide standard monitoring protocol report (CCME, undated).

³ Halman, R. 2007. Personal communication (Environmental Science and Technology Centre, Environment Canada).

⁴ Dann, T. 2007. Personal communication (Environmental Science and Technology Centre, Environment Canada).

Table 3: Data quality objectives for ground-level ozone and PM_{2.5}

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

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

Yearly criteria for ground-level ozone

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

Yearly criteria for PM_{2.5}

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

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

- For the 1990-2008 ground-level ozone time series, and for each station, at least 15 of the 19 years must have data that have satisfied the yearly criteria mentioned above. For the 2000-2008 PM_{2.5} time series, this means that at least 6 of the 9 years of data are required per station.
- Stations missing more than two consecutive years at the start or end of the time series are excluded to avoid using data from stations commissioned or decommissioned during the beginning or end of the period.

As a result of applying these sets of data completeness and inclusion criteria, 209 ground-level ozone and 167 PM_{2.5} monitoring stations satisfied the 2008 yearly data requirements. For the time-series criteria, 83 ground-level ozone and 63 PM_{2.5} stations satisfied the requirements and contributed data to the time-series trend analysis.

2.4.4 Timeliness

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

2.5 Statistical analysis

Different sets of information were extracted from data provided by the monitoring stations. National trends on population-weighted warm-season average values for ground-level ozone and $PM_{2.5}$ were calculated. These national trends were based on the 83 ground-level ozone and 63 $PM_{2.5}$ monitoring stations across Canada that satisfied the requirements for time-series inclusion criteria.

The regional trends for ground-level ozone were based on 6 stations in Atlantic Canada, 21 stations in southern Quebec, 31 stations in southern Ontario, 13 stations in the Prairies and 12 stations in the lower Fraser Valley, British Columbia. These 83 stations have all satisfied the requirements for the time-series inclusion criteria. The regional trends for $PM_{2.5}$ were based on 5 stations in Atlantic Canada, 10 stations in southern Quebec, 22 stations in southern Ontario, 12 stations in the Prairies and northern Ontario and 14 stations in the lower Fraser Valley, British Columbia. These 63 stations have all satisfied the requirements for time-series inclusion criteria.

In addition to the ozone and $PM_{2.5}$ exposure indicators, the 2008 warm-season ground-level ozone and $PM_{2.5}$ concentrations were also presented on a map in CESI. These snapshots are average concentration values obtained from 209 ground-level ozone and 167 $PM_{2.5}$ monitoring stations across Canada. Those stations have satisfied only the requirements for the 2008 yearly inclusion criteria.

Appropriate non-parametric statistical tests were conducted to examine the direction and the magnitude of the annual rate of change from 1990 to 2008 for ground-level ozone and from 2000 to 2008 for $PM_{2.5}$. The standard Mann-Kendall trend test was used to determine the average direction of yearly changes, and Sen's non-parametric pair-wise slope estimator was applied to determine the magnitude of the trend in terms of unit change per year, expressed as a percentage change per year with 90% confidence limits. The Mann-Kendall and the Sen Methods were applied to the annual average warm-season population-weighted concentration levels for ground-level ozone (1990-2008) and $PM_{2.5}$ (2000-2008) data.

The indicator is considered and reported as statistically significant only when both tests indicate statistically significant upward or downward trends in both the direction (Mann-Kendall) and the magnitude (Sen) of the rates of change at the 90% significance level. If only one of the above tests failed to reject the no-trend hypothesis, then the indicator is not reported as statistically significant.

The results of these statistical methods demonstrate how the indicator data need to be placed in perspective and interpreted with caution. The indicator should be viewed as an approximation of the real world, or a "probability" measurement. The Sen Method predicts the trend, which is expressed as the median slope with associated confidence intervals. The real rate of change is not known and can not feasibly be obtained or estimated with 100% confidence. The 90% confidence interval means that the reported interval should contain the actual value of the indicator 18 times out of 20.

2.5.1 Summary of results

Tables 4 and 5 present the estimated rate of change per year for the national and regional ground-level ozone and $PM_{2.5}$ exposure indicators. The units for ground-level ozone are in parts per billion (ppb) by volume concentration (i.e., one part of ground-level ozone per billion parts

of air) and also in percentage change based on the median of the 19 annual levels. The units for PM_{2.5} are in micrograms PM_{2.5} per one cubic metre of air and also in percentage change based on the median of the 9 annual levels.

Table 4: Rate of change per year of the ground-level ozone exposure indicator, 1990 to 2008

Ground-level ozone indicator	Number of stations	Median rate of change per year	Median rate of change per year	90% confidence interval
	Number	ppb	%	%
National	83	0.2	0.6	+0.1 to +1.0
Atlantic Canada	6	**	**	
Southern Quebec	21	0.2	0.6	>0 to +1.1
Southern Ontario	31	0.4	0.9	+0.3 to +1.4
Prairies and Northern Ontario	13	**	**	
Lower Fraser Valley, British Columbia	12	**	**	

*** indicates that both the Mann-Kendall and the Sen Tests failed to reject the no-trend hypothesis and hence the rate of change is statistically not significant at the 90% confidence level.*

Table 5: Rate of change per year of the PM_{2.5} exposure indicator, 2000 to 2008

PM _{2.5} exposure indicator	Number of stations	Median rate of change per year	Median rate of change per year	90% confidence interval
	Number	µg/m ³	%	%
National	63	**	**	
Atlantic Canada	5	**	**	
Southern Quebec	10	**	**	
Southern Ontario	22	*	*	
Prairies and Northern Ontario	12	**	**	
Lower Fraser Valley, British Columbia	14	**	**	

*** indicates that both the Mann-Kendall and the Sen Tests failed to reject the no-trend hypothesis and hence the rate of change is statistically not significant at the 90% confidence level.*

** indicates that at least one of the tests, the Mann-Kendall or the Sen, failed to reject the no-trend hypothesis and hence the rate of change is statistically not significant at the 90% confidence level.*

Based on the 90% confidence intervals, test results for the ground-level ozone exposure indicator at the national level and in southern Quebec and southern Ontario exhibited a statistically significant increasing trend. Otherwise, statistical tests using the confidence intervals of the rates of change in ground-level ozone and for the PM_{2.5} indicator showed no evidence against the no-trend hypothesis. Results of the tests are available in appendix B.

2.6 International comparison

The mean annual concentrations of ground-level ozone and fine particulate matter ($PM_{2.5}$) from four Canadian cities are presented in CESI and are compared with the values of many international cities. International cities were selected from a selection of OECD countries.

How the measure was calculated

Unlike CESI's air quality comparison for Canada, ozone and $PM_{2.5}$ indicators used in the international comparison were based on an annual average rather than warm season average (April 1st to September 30th).

Ozone was calculated by using the daily maximum 8-hour average (ppb). The data was not population weighted. Some international cities (many within the United States) provided annual data which was already in this format. Other international cities - mainly cities in European countries - were calculated by using raw data which was provided through the EU AirBase database or country specific databases. Internationally, ozone levels are reported in several units (i.e. ppb, ppm and $\mu g/m^3$). In order to provide readers with a more clear and compatible comparison, all international units were converted to ppb. CESI calculated ozone levels for 19 international cities.

$PM_{2.5}$ was calculated using the annual 24-hour mean based on continuous and non-continuous measurements. Internationally, $PM_{2.5}$ is measured in $\mu g/m^3$, therefore no conversions were necessary. CESI calculated $PM_{2.5}$ levels for 20 international cities. It must be noted that differences in measurement methods among countries, and even (in 2008) between different Canadian cities, can distort comparisons of $PM_{2.5}$ levels. The calculated air quality indicators were obtained by taking the arithmetic average of all the yearly values from the monitoring stations encountered in the city boundary, or a 40km radius when the city boundaries were not well enough defined..

The cities displayed in the International Comparison were chosen based on two selection criteria: population (urban areas) and data availability. Table 6a gives the ozone and $PM_{2.5}$ values used in CESI website charts and Table 6b gives the city and urban area populations.

Table 6a: Ozone annual daily maximum 8-hour mean concentrations and PM_{2.5} annual mean concentrations for selected international cities for 2008

City	Country	Ozone Annual Daily Maximum 8-hour Average (ppb)	PM _{2.5} Annual Average (µg/m ³)
Amsterdam	Netherlands	24.82	N/A
Athens	Greece	39.53	24.27
Barcelona	Spain	30.69	21.00
Berlin	Germany	32.88	17.21
Boston	United States	37.14	10.77
Calgary	Canada	32.55	5.65
Chicago	United States	36.86	12.17
Cleveland	United States	44.86	13.17
Houston	United States	36.82	12.19
London	United Kingdom	25.17	14.96
Milwaukee	United States	39.55	13.03
Montreal	Canada	30.01	12.12
Paris	France	29.53	18.33
Perth	Australia	N/A	7.43
Phoenix	United States	47.02	9.95
Pittsburgh	United States	41.40	14.12
Prague	Czech Republic	30.83	16.07
Rome	Italy	33.19	19.07
Rotterdam	Netherlands	25.93	17.62
Seattle	United States	31.15	8.43
Stockholm	Sweden	32.21	10.28
Sydney	Australia	N/A	9.10
Toronto	Canada	33.44	7.07
Vancouver	Canada	24.52	4.56
Zürich	Switzerland	32.14	10.80

Table 6b: Population for selected international urban areas

City	Urban Area
London	12,400,000
Paris	10,400,000
Chicago	9,850,000
Houston	5,900,000
Boston	5,750,000
Toronto	5,509,874
Sydney	4,475,000
Phoenix	4,400,000
Berlin	4,325,000
Barcelona	4,300,000
Seattle	4,025,000
Athens	3,775,000
Montreal	3,695,790
Rome	3,550,000
Cleveland	2,775,000
Pittsburgh	2,350,000
Vancouver	2,285,893
Stockholm	2,000,000
Milwaukee	1,760,000
Perth	1,610,000
Prague	1,370,000
Calgary	1,139,726
Zurich	1,106,451
Amsterdam	1,022,487
Rotterdam	985,950

Note: Urban area populations are for the years 2007 or 2010 depending on source data

Sources: U.N. population estimates (2007)

<http://unstats.un.org/unsd/demographic/products/dyb/dyb2007/Table08.pdf>, Thomas Brinkhoff: City Population (2010), <http://www.citypopulation.de>

Data source(s)

The data used for the international comparison were gathered from a variety of metadata databases, including: AirBase Viewer Database (EU) and Air Quality System (U.S. EPA). Annual ozone and PM_{2.5} data are available in individual country's annual air quality reports.

For more information

Information on international cities' data and air quality reports used in the international comparison are available online and can be accessed from the government websites listed in appendix C.

2.7 Caveats and limitations

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

Data completeness: A significant amount of measurement data is not used due to data completeness criteria. The criteria for determining whether stations have sufficiently complete data for inclusion in indicator analysis are based on standard practices followed by organizations including the World Health Organization and the U.S. Environmental Protection Agency, as well as expert opinion.

PM_{2.5} monitoring stations equipments: Different monitoring methods for measuring PM_{2.5} are used in Canada (NAPS) so caution needs to be used when comparing results among stations and cities.

PM_{2.5} monitors based on newer technologies are being deployed across the NAPS network to replace older instruments which have been found to lose a portion of the PM_{2.5} mass. This transition is under way and is expected to take 1 to 2 years to complete. In the meantime, caution should be used when interpreting PM_{2.5} levels and trends, as measurements from these newer methods may not be directly comparable with data from the older instruments.

Regional groupings: The definitions of the regions used for reporting are not the same as those used in the 2006 and earlier releases of CESI. Accordingly, the “Quebec and eastern Ontario” region as presented in the earlier reports has been changed to include stations that are only in southern Quebec. Consequently, the “snapshot” indicator levels (i.e., yearly values) for all regions can only be compared to the last two previous releases of CESI’s air quality indicators to do analysis that incorporates trends and spatial patterns. However, the trend indicators themselves (i.e., national and regional trends) are generally comparable regardless of minor adjustments in regional boundaries.

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

International comparison: Although efforts were made to limit the amount of data inconsistencies between international cities, caveats and limitations can still be found in each country’s monitoring methods, instrument operations and station siting procedures; therefore, comparisons among international cities should not be viewed as a definitive ranking. Rather, they should be viewed as an approximation.

A valid annual mean required at least 6570 hourly readings. In addition, the second and third quarters of the year should have 75% valid data for ozone, whereas for PM_{2.5}, each quarter of the year should have 75% valid data.

To “For the international cities comparison, population city size and the availability of data were city selection criteria. Also, because an annual air quality definition was used, it may be that the impact of weather is more important than if a three years average, like the Canada Wide Standard (CWS) definition, were used. No other selection criteria were used for this comparison.

Caution needs to be exercised when comparing Canadian cities. As an example, a comparison of $PM_{2.5}$ concentrations for Montreal and Toronto using data from our reference samplers reveals that levels are almost identical. However, because different monitoring methods were used for measuring $PM_{2.5}$ in 2008 for the two cities, it appears that Montreal has a much higher annual concentration, which may not actually be the case.

3.0 Air Emissions Indicators

3.1 Description of the Air Emissions Indicators

The Air Emissions Indicators in CESI use data from Canada's National Air Pollutant Emissions Inventory to identify the Canadian sources of air pollution that influence the ambient levels of ground-level ozone and $PM_{2.5}$. The pollutants of concern are $PM_{2.5}$, sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOC) and ammonia (NH_3). These emissions are found in the 2008 National Air Pollutant Emissions Inventory.

Air pollutant (AP) emission summaries and trends are compiled annually by Environment Canada to inform Canadians about pollutants that affect their health and the environment; identify priorities for action; allow tracking of progress in pollution prevention; support the development of regulations and air quality modeling; and meet domestic and international reporting requirements such as Canada-Wide Standards (CWS), the Canada U.S.-Air Quality Agreement, and the United Nations Economic Commission for Europe Convention on Long-range Transboundary Air Pollution (UNECE LRTAP).

3.2 How the Air Emissions Indicators are compiled

The air pollutant emission summaries and trends are compiled by Environment Canada Pollution Data Branch in collaboration with provincial, territorial and regional environmental agencies. The Air Emissions Indicators are extracted from the emissions summaries published on the Environment Canada National Pollutant Release Inventory (NPRI) website.

The summaries include emissions reported by facilities to the NPRI, as well as emissions estimated by Environment Canada using the latest published statistics or other sources of information such as surveys and reports, providing a comprehensive emissions inventory of all the possible air pollution sources for Canada.

The emissions summaries provide data at the national and provincial and territorial level for 2008 and national data for the years 1985 to 2007. The emissions are sorted into categories and sectors. Sub-sectors are also provided for certain sectors.

The methodologies used to estimate emissions are reviewed, updated and improved on a periodic basis. Collaborative work with sector experts from within or outside Environment Canada is undertaken to incorporate available expertise and the latest advancements in scientific knowledge. Emissions estimates reported by the facilities in NPRI are based on one of the following methods:

- Continuous Emission Monitoring Systems (CEMS)
- Predictive Emission Monitoring (PEM)
- Source testing
- Mass balance
- Site-specific emission factor
- Published emission factor
- Engineering estimates

The emissions data coming from the provincial emissions inventories are also derived from similar methods to calculate emissions.

3.3 Data sources

The source of the emissions data used to produce the national, regional charts and the contribution charts is the 2008 Air Pollutant Emissions Summaries and Trends, from the National Pollutant Release Inventory developed by the Pollution Data Division of Environment Canada.

The Air Pollutant Emissions Inventory (AP) website provides the emissions inventory, the trends and the forecast for AP emissions. It also provides more information about the methods used in the AP Inventory for estimating the emissions and compiling the data, as well as information on the geographical distribution of AP emissions.

Website: <http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=4EA89B8B-1>

3.4 International comparison

This section looks at the comparison of the 1998 and 2008 emissions of air pollutants (VOC, NO_x, SO_x and NH₃) that contribute to smog for G8 Countries.

How the measure was calculated

Emissions from 8 countries were used to make the comparisons. These countries are; the United States, Canada, the United Kingdom, France, Italy, Germany, Russia and Japan. The comparison was done on the total air pollutant emissions each country submitted to the United Nations in the context of the Framework Convention on Climate Change (UNFCCC) and the Convention on Long-Range Transboundary Air Pollution (CLRTAP).

Emissions are reported in two different ways; National emissions and emissions per Gross Domestic Product (GDP). National emissions for 1998 and 2008 for all G8 countries except Japan were retrieved from the CLRTAP Inventory Submissions 2010 from the Centre on Emission Inventories and Projections (CEIP) website. Japan's emissions were retrieved from the National GHG Submission to the UNFCCC.

For Gross Domestic Products Data, we used the GDP in current US\$ and constant purchasing power parity. GDP is expressed in millions of US dollars. The GDP and the National emissions are used to get the emissions per GDP for each country. The GDP were obtained for the years 1998 and 2008 from the OECD Statistical Library.

Table 7: Air pollutant emissions from the G8 countries in 1998 and 2008 (kilotonnes)

Country	SO _x 1998	SO _x 2008	NO _x 1998	NO _x 2008	VOC 1998	VOC 2008	NH ₃ 1998	NH ₃ 2008
United States	17,186	10,400	22,152	14,693	17,039	14,410	4,481	3,663
Canada	2,318	1,730	2,436	2,076	2,551	2,106	469	474
United Kingdom	1,622	512	2,007	1,403	1,791	942	340	282
France	826	358	1,731	1,272	2,048	1,086	787	754
Italia	994	293	1,645	1,061	1,865	1,126	447	403
Germany	964	498	1,943	1,393	1,902	1,267	594	587
Russia	2,275	1,436	2,488	3,492	2,376	2,323	675	548
Japan*	906	783	2,053	1,874	1,746	1,571		

* Japan data are coming from the UNFCCC GHG national submission (summary 1.B)

* Natural and Open sources are excluded in this table. Ammonia emissions from Agriculture activities are included.

Table 8: GDP (in million of current US dollars, constant purchasing power parity, for the G8 Countries in 1998 and 2008

GDP (million \$US)	1998	2008
United States	9,060,996	11,742,288
Canada	787,075	1,049,488
United Kingdom	1,427,980	1,842,289
France	1,429,899	1,751,035
Italy	1,385,375	1,556,578
Germany	2,025,887	2,351,804
Russian Federation	853,034	1,651,173
Japan	3,164,366	3,579,616

Table 9: Air Pollutant Emissions per GDP for the G8 Countries in 1998 and 2008 (tonnes/millions \$US GDP)

Country / Emissions	SO _x 1998	SO _x 2008	NO _x 1998	NO _x 2008	VOC 1998	VOC 2008	NH ₃ 1998	NH ₃ 2008
United States	1.9	0.9	2.4	1.3	1.9	1.2	0.5	0.3
Canada	2.9	1.6	3.1	2.0	3.2	2.0	0.6	0.5
United Kingdom	1.1	0.3	1.4	0.8	1.3	0.5	0.2	0.2
France	0.6	0.2	1.2	0.7	1.4	0.6	0.6	0.4
Italia	0.7	0.2	1.2	0.7	1.3	0.7	0.3	0.3
Germany	0.5	0.2	1.0	0.6	0.9	0.5	0.3	0.2
Russia	2.7	0.9	2.9	2.1	2.8	1.4	0.8	0.3
Japan	0.3	0.2	0.6	0.5	0.6	0.4		

Data sources for international data.

National Emissions Data are coming from the Centre on Emission Inventories and Projections (CEIP) website for all countries except Japan. Data from Japan were obtained through the National GHG Submission to the UNFCCC. GDP data were extracted from the OCDE Statistical Library under the national accounts section.

3.5 Caveats and limitations

National and Regional Charts

The emissions used to produce the national and regional charts in CESI used the total emissions without the open and natural sources except for ammonia where agricultural emissions, the highest source for ammonia emissions, were kept.

Emission Sources

A slightly different classification is used in CESI than the one used in the Environment Canada AP Inventory tables. Categories were sometimes grouped, while at other times they were split in order to have only one sector or specific sectors together. The CESI emissions contribution comparisons do not include AP emissions from open and natural sources except for NH₃ (ammonia from agriculture).

Table 10: Reconciliation of sectors and categories used in CESI and NPRI

CESI Sector/Category	NPRI air pollutant Emissions Sources Category/Sectors
PAINTS AND SOLVENTS	General Solvent Use
	Surface Coatings
INCINERATION AND MISCELLANEOUS	Incineration Sources
	Miscellaneous sources less the sectors General Solvent Use and Surface Coatings
HOME FIREWOOD BURNING	Residential Fuel Wood Combustion
FUEL FOR ELECTRICITY AND HEATING	Electric Power Generation (utilities)
	Commercial Fuel Combustion
	Residential Fuel Combustion
OFF ROAD VEHICLES	Off Road use of Diesel
	Off Road use of Gasoline/LPG/CNG
TRANSPORTATION (ROAD, RAIL, AIR, MARINE)	Air Transportation
	Heavy-duty diesel vehicles
	Heavy-duty gasoline trucks
	Light-duty diesel trucks
	Light-duty diesel vehicles
	Light-duty gasoline trucks
	Light-duty gasoline vehicles
	Marine Transportation
	Motorcycles
	Rail Transportation
	Tire Wear and Brake Linings
OIL AND GAS INDUSTRY	Upstream Petroleum Industry
	Downstream Petroleum Industry
OTHER INDUSTRIES	All Industrial Sources less the sectors Upstream Petroleum Industry and Downstream Petroleum Industry
AGRICULTURE (LIVESTOCK AND FERTILIZER)	Agriculture

International Comparison

Air Pollutant Emissions Inventories from different countries are being estimated with the best data, measurements and methodologies available. Even though the national emissions inventory used for these comparisons follow the same CLRTAP structure, the user needs to be cautious when comparing the data. When comparing emissions between countries, it should be noted that emissions estimation methodologies among countries may differ and reduce the validity of such comparison.

3.6 Charts Data

National Air Emissions

Table 11: Main air pollutants emissions trends for Canada, 1985 to 2008, Mt

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
SO _x	3.7	3.3	3.6	3.7	3.4	3.2	3.3	3.1	2.4	2.4
NO _x	2.5	2.5	2.6	2.6	2.6	2.5	2.4	2.4	2.4	2.5
VOC	2.4	2.4	2.4	2.5	2.5	2.5	2.4	2.4	2.4	2.4
PM _{2.5}	0.7	0.6	0.7	0.7	0.4	0.4	0.4	0.4	0.4	0.4
NH ₃	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
SO _x	2.5	2.4	2.4	2.3	2.3	2.3	2.4	2.3	2.3	2.2
NO _x	2.5	2.4	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4
VOC	2.4	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.1	2.1
PM _{2.5}	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3
NH ₃	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Year	2005	2006	2007	2008						
SO _x	2.1	2.0	1.9	1.7						
NO _x	2.4	2.3	2.3	2.1						
VOC	1.9	1.9	2.0	1.8						
PM _{2.5}	0.3	0.3	0.3	0.3						
NH ₃	0.6	0.5	0.5	0.5						

Regional Air Emissions

Table 12: Provincial and Territorial Air Pollutant Emissions for 2008, kilotonnes

Prov-Terr	SO _x	NO _x	VOC	PM _{2.5}	NH ₃
NL	43.0	54.4	82.6	10.1	1.1
PE	1.7	5.8	6.1	1.2	2.8
NS	136.8	71.7	42.1	12.2	4.5
NB	49.0	52.7	42.7	8.9	4.2
QC	170.7	258.6	322.6	76.4	74.7
ON	381.6	434.9	430.5	68.0	101.9
MB	349.6	66.4	72.4	9.6	52.6
SK	123.4	164.8	175.7	13.9	85.3
AB	377.3	754.9	389.8	31.2	120.4
BC	98.6	255.0	209.5	35.0	20.9
YU	0.6	1.3	1.9	0.2	0.0
NU	0.1	4.5	1.4	0.3	0.0
NT	0.5	9.7	3.0	0.6	0.0
CANADA	1,732.8	2,134.7	1,780.5	267.7	468.5

Air Pollutant Emissions Sources

Table 13: Air pollutant emission sources that generate ground-level ozone and fine particulate matter, 2008 (% of emissions total)

SECTORS	SO _x	NO _x	VOC	PM _{2.5}	NH ₃
PAINTS AND SOLVENTS	0.0%	0.0%	18.6%	0.0%	0.0%
INCINERATION AND MISCELLANEOUS	0.1%	0.1%	6.6%	3.7%	0.4%
HOME FIREWOOD BURNING	0.1%	0.5%	8.6%	39.8%	0.2%
FUEL FOR ELECTRICITY AND HEATING	27.4%	13.7%	0.3%	4.5%	0.2%
OFF ROAD VEHICLES	0.2%	20.1%	15.6%	14.8%	0.1%
TRANSPORTATION (ROAD, RAIL, AIR, MARINE)	5.2%	34.5%	14.2%	8.5%	4.6%
OIL AND GAS INDUSTRY	21.5%	22.1%	27.2%	4.3%	0.8%
OTHER INDUSTRIES	45.5%	9.0%	9.0%	24.5%	3.4%
AGRICULTURE (LIVESTOCK AND FERTILIZER)	-	-	-	-	90.3%

4.0 References

Canadian Council of Ministers of the Environment, “Ambient Air Monitoring Protocol for PM_{2.5} and Ozone. Canada-wide Standards for Particulate Matter and Ozone”.

Environment Canada. 2008. National Air Pollution Surveillance (NAPS) Network Annual Data Summary for 2005-2006. Ottawa (Report EPS 7/AP/39).

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

National Round Table on the Environment and the Economy, 2003. Environment and Sustainable Development Indicators for Canada. Ottawa.

APPENDIX

A. Air Quality Monitoring Stations Reported in CESI

LEGEND

NAPS ID: Monitoring station NAPS Identifier

PROV, CITY and ADDRESS: Location of monitoring station

O₃: Has a "*" if station data met yearly criteria in 2008 for ground ozone level and represented in CESI interactive map

PM₂₅: Has a "*" if station data met yearly criteria in 2008 for fine particulate matter and presented in CESI interactive map

PM₂₅E: Type of equipment used for monitoring fine particulate matter

I_O₃: If not empty, station contributes data to the time-series trend analysis for ground level ozone in national indicator and regional indicator of region identified.

I_PM: If not empty, station contributes data to the time-series trend analysis for fine particulate matter in national indicator and regional indicator of region identified

ACRONYMS

TEOM: Tapered Element Oscillating Microbalance

TEOM-FDMS: Tapered Element Oscillating Microbalance - Filter Dynamics Measurement System

BAM: Beta Attenuation Monitoring

ATL: Atlantic Region CESI Regional Indicator

SQC: Southern Quebec CESI Regional Indicator

SON: Southern Ontario CESI Regional Indicator

PNO: Prairies and Northern Ontario CESI Regional Indicator

LFV: Lower Fraser Valley CESI Regional Indicator

NAPS ID	PROV	CITY	ADDRESS	O ₃	PM ₂₅	PM ₂₅ E	I_O ₃	I_PM
10102	NL	ST. JOHN'S	354 WATER STREET	*		TEOM	ATL	ATL
10301	NL	CORNER BROOK	BROOK STREET	*	*	TEOM		
10401	NL	MOUNT PEARL	OLD PLACENTIA ROAD	*	*	TEOM		
10501	NL	GRAND FALLS - WINDSOR	SCOTT AVENUE	*				
10601	NL	HAPPY VALLEY - GOOSE BAY	ABBOT STREET	*				
30113	NS	HALIFAX	1672 GRANVILLE STREET		*	BAM		
30120	NS	DARTMOUTH	CHERRYBROOK ROAD	*	*	TEOM		
30310	NS	SYDNEY	71 WELTON STREET	*				
30501	NS	KEJIMKUJIK	NATIONAL PARK	*			ATL	
30801	NS	YARMOUTH	YARMOUTH WEATHER OFFICE, DAYTON	*				
30901	NS	PICTOU	91 BEACHES ROAD		*	BAM		
31101	NS	KENTVILLE	32 MAIN STREET	*				
40103	NB	FREDERICTON	437 ABERDEEN STREET	*	*	BAM		ATL
40203	NB	SAINT JOHN	MOUNTAIN ROAD	*	*	BAM	ATL	ATL
40206	NB	SAINT JOHN	189 PRINCE WILLIAM	*				
40207	NB	SAINT JOHN	476 LANCASTER AVENUE W.	*	*	BAM		
40302	NB	MONCTON	5 THANET STREET	*	*	BAM		ATL
40401	NB	FUNDY NAT. PARK	HASTINGS TOWER	*			ATL	
40501	NB	POINT LEPREAU	RECREATION AREA	*				
40601	NB	CENTRAL BLISSVILLE	AIRPORT ROAD	*			ATL	
40701	NB	NORTON	308 HWY 124	*			ATL	
40801	NB	DOW SETTLEMENT	487 ROUTE 122	*				
40901	NB	ST. ANDREWS	BRANDY COVE ROAD	*	*	BAM		ATL
41101	NB	ST. LEONARD	312 CH L'AEROPORT	*				
41201	NB	LOWER NEWCASTLE	55 ROUTE 11 HWY	*				

NAPS ID	PROV	CITY	ADDRESS	O ₃	PM ₂₅	PM ₂₅ E	I_O ₃	I_PM
41302	NB	BATHURST	1255 ROUGH WATERS DRIVE	*	*	BAM		
50102	QC	MONTRÉAL	BOUL. ROSEMONT	*			SQC	
50103	QC	MONTRÉAL	1050 A, BOUL. SAINT-JEAN-BAPTISTE	*			SQC	
50104	QC	MONTRÉAL	1125 RUE ONTARIO EST	*			SQC	
50105	QC	MONTRÉAL	1212 RUE DRUMMOND		*	TEOM-FDMS		
50109	QC	MONTRÉAL	2495 DUNCAN / DÉCARIE, MT-ROYAL	*	*	TEOM-FDMS		
50110	QC	MONTRÉAL	11280 BOUL. PIE IX, MTL NORD	*	*	TEOM-FDMS	SQC	SQC
50113	QC	LAVAL	1160 BOUL PIE X	*			SQC	
50115	QC	MONTRÉAL	1001 BOUL DE MAISONNEUVE OUEST	*				
50116	QC	MONTRÉAL	3161 JOSEPH, VERDUN	*			SQC	
50119	QC	LONGUEUIL	FACE AU 1819 RUE VICTORIA	*			SQC	
50121	QC	LONGUEUIL	8361 RUE OCÉANIE - BROSSARD	*				
50126	QC	MONTRÉAL	20965 CH. SAINTE-MARIE, STE-ANNEdB	*		TEOM		SQC
50128	QC	MONTRÉAL	90-A RUE HERVÉ-SAINT-MARTIN, DORVAL	*	*	TEOM-FDMS		SQC
50129	QC	MONTRÉAL	12400 WILFRID-OUELLETTE	*	*	TEOM-FDMS		
50131	QC	MONTRÉAL	3250 STE-CATHERINE EST		*	TEOM-FDMS		SQC
50133	QC	MONTRÉAL	8200A RUE CHENIER, ANJOU		*	TEOM-FDMS		
50204	QC	GATINEAU	255 ST-RÉDEMPTEUR, HULL	*				
50308	QC	QUÉBEC	600 RUE DES SABLES	*	*	TEOM		SQC
50310	QC	QUÉBEC	1150 BOUL. RENÉ-LÉVESQUE O.	*	*	TEOM		
50311	QC	QUÉBEC	1465, RUE FÉLIX-ANTOINE-SAVARD	*	*	BAM		
50404	QC	SHERBROOKE	655, RUE PAPINEAU	*				
50504	QC	SAGUENAY	789 BOUL DES ÉTUDIANTS, CHICOUTIMI	*	*	TEOM		
50604	QC	ROUYN-NORANDA	1570 RUE PARADIS	*	*	BAM		
50801	QC	TROIS-RIVIÈRES	FACE AU 678 RUE HART	*		TEOM		SQC
51201	QC	SHAWINIGAN	363 RUE FRIGON		*	TEOM		SQC
51501	QC	ST. ZÉPHIRIN-DE-COURVAL	701 RANG SAINT-MICHEL	*	*	BAM	SQC	
52001	QC	CHARENTE	AU NORD DU 170 2E RANG	*	*	BAM	SQC	
52201	QC	SAINT-SIMON	DERRIÈRE LE 83, 4E RANG EST	*	*	BAM	SQC	
52301	QC	SAINT-FAUSTIN-LAC-CARRÉ	CHEMIN DU LAC (CARIBOU)	*	*	BAM	SQC	
52401	QC	LA PÊCHE	LAC PHILIPPE - MASHAM	*	*	BAM	SQC	
52601	QC	VARENNES	4744 MONTÉE BARONIE	*				
52701	QC	TÉMISCAMING	RUE BOUCHER	*				
52801	QC	AUCLAIR	66 RANG ST-GRÉGOIRE NORD	*	*	BAM		
53201	QC	LA DORÉ	ROUTE 167- LA DORÉ	*	*	BAM	SQC	

NAPS ID	PROV	CITY	ADDRESS	O ₃	PM ₂₅	PM ₂₅ E	I_O ₃	I_PM
53301	QC	DESCHAMBAULT	334, 3 E RANG - DESHAMBAULT	*	*	BAM		
53401	QC	STE-CATH.-DE-J-CARTIER	FACE AU 56 LAURIER	*				
53501	QC	SAINT-FRANÇOIS	FACE AU 198, ROYALE ÎLE D'ORLÉANS	*			SQC	
53601	QC	NOTRE-DAME-DU-ROSAIRE	RANG ST-LOUIS	*	*	BAM	SQC	
53701	QC	ST-HILAIRE-DE-DORSET	RANG DORSET	*	*	BAM	SQC	
53801	QC	TINGWICK	CHEMIN RADAR ET WARWICK	*	*	BAM	SQC	
53901	QC	LAC-ÉDOUARD	DERRIÈRE L'HÔPITAL VILLAGE	*	*	BAM	SQC	
54201	QC	CHAPAIS	CHAPAIS	*				
54401	QC	SAINT-ANICET	1128 DE LA GUERRE	*	*	BAM		SQC
54501	QC	L'ASSOMPTION	801 ST-ÉTIENNE/ROUTE 344	*	*	BAM		SQC
54703	QC	BÉCANOUR	8310 BOUL. BÉCANOUR		*	TEOM		
54801	QC	STUKELY-SUD	CHEMIN MONTBEL	*	*	BAM	SQC	
54901	QC	LA PATRIE	RANG PETIT CANADA OUEST	*	*	BAM	SQC	
55001	QC	FERME NEUVE	215 4 IÈME RANG GRAVEL	*	*	BAM	SQC	
55101	QC	SENNETERRE	CHEMIN RIVIÈRE BELL	*	*	BAM		
55201	QC	LEMIEUX	1290 RTE DES ATOCAS	*	*	BAM		
55301	QC	SAINT-JEAN-SUR-RICHELIEU	FERME EXP., 1134 ROUTE 219	*	*	BAM		SQC
55501	QC	FRELIGHSBURG	FRELIGHSBURG	*				
55601	QC	MINGAN	MINGAN	*				
55701	QC	LÉVIS	2254, ROTONDE, CHARNY	*				
60104	ON	OTTAWA	RIDEAU & WURTEMBURG	*	*	TEOM	SON	SON
60106	ON	OTTAWA	960 CARLING AVE	*	*	TEOM		
60204	ON	WINDSOR	467 UNIVERSITY AVE. WEST	*	*	TEOM	SON	SON
60211	ON	WINDSOR	COLLEGE & SOUTH ST.	*	*	TEOM		
60302	ON	KINGSTON	133 DALTON AVENUE	*			SON	
60303	ON	KINGSTON	752 KING ST. WEST	*	*	TEOM		
60403	ON	TORONTO	EVANS & ARNOLD AVE.	*	*		SON	SON
60410	ON	TORONTO	LAWRENCE & KENNEDY	*	*	TEOM	SON	
60413	ON	TORONTO	ELMCREST ROAD	*	*	TEOM	SON	
60415	ON	MISSISSAUGA	QUEENSWAY W & HURONTARIO	*	*		SON	SON
60421	ON	TORONTO	YONGE ST. & FINCH AVE.	*	*	TEOM	SON	SON
60424	ON	TORONTO	BAY & WELLESLEY	*	*		SON	SON
60428	ON	BRAMPTON	525 MAIN ST. N. BRAMPTON	*	*	TEOM		SON
60429	ON	TORONTO	1 ETONA COURT	*	*	TEOM		
60430	ON	TORONTO	125 RESOURCES ROAD	*	*	TEOM		SON
60433	ON	TORONTO	BAY & WELLESLEY	*	*	TEOM		
60434	ON	MISSISSAUGUA	3359 MISSISSAUGUA ROAD NORTH	*	*	TEOM		
60512	ON	HAMILTON	ELGIN & KELLY	*	*	TEOM	SON	SON
60513	ON	HAMILTON	VICKERS RD. & EAST 18TH. ST.	*	*	TEOM	SON	SON
60607	ON	SUDBURY	100 RAMSEY LAKE RD.	*			SON	
60609	ON	SUDBURY	RAMSEY LAKE ROAD	*	*	TEOM		
60707	ON	SAULT STE. MARIE	331 PATRICK ST.	*			SON	

NAPS ID	PROV	CITY	ADDRESS	O ₃	PM ₂₅	PM ₂₅ E	I_O ₃	I_PM
60807	ON	THUNDER BAY	615 JAMES STREET SOUTH	*			SON	
60809	ON	THUNDER BAY	421 JAMES STREET SOUTH	*	*	TEOM		
60901	ON	LONDON	KING & RECTORY	*			SON	
60903	ON	LONDON	900 Highbury Avenue	*	*	TEOM		SON
61004	ON	SARNIA	FRONT ST. AT C.N. TRACKS	*	*	TEOM	SON	SON
61104	ON	PETERBOROUGH	10 HOSPITAL DRIVE	*	*	TEOM		SON
61201	ON	CORNWALL	BEDFORD & THIRD ST.	*	*	TEOM	SON	
61302	ON	ST. CATHARINES	ARGYLE CRESCENT	*	*	TEOM	SON	SON
61402	ON	BRANTFORD	324 GRAND RIVER AVE.	*	*	TEOM		
61502	ON	KITCHENER	WEST AVE. & HOMEWOOD	*	*	TEOM	SON	SON
61602	ON	OAKVILLE	BRONTE RD. & WOBURN CRES.	*			SON	
61603	ON	OAKVILLE	8TH LINE/GLENASHTON DR.;HALTON RESERVE	*	*	TEOM		
61701	ON	OSHAWA	RITSON RD. & OLIVE AVE.	*	*		SON	SON
61702	ON	OSHAWA	2200 SIMCOE STREET NORTH	*	*	TEOM		
61802	ON	GUELPH	70 DIVISION STREET; EXHIBITION PARK	*	*	TEOM	SON	SON
62001	ON	NORTH BAY	CHIPPEWA ST.	*	*	TEOM	SON	SON
62501	ON	TIVERTON	BRUCE NUCLEAR VISITOR CTR	*	*	TEOM	SON	SON
62601	ON	SIMCOE	EXPERIMENTAL FARM	*	*	TEOM	SON	SON
63001	ON	BURLINGTON	HWY 2 & NORTH SHORE BLVD.	*	*	TEOM	SON	SON
63201	ON	STOUFFVILLE	HWY 47 & HWY 48	*			SON	
63301	ON	DORSET	HWY 117 & PAINT LAKE ROAD	*	*	TEOM	SON	SON
63701	ON	GRAND BEND	HWY 21 & COUNTY RD 83	*	*	TEOM		
64001	ON	EXP. LAKES AREA	EXP. LAKES AREA	*			PNO	
64101	ON	ALGOMA	ALGOMA	*			SON	
64401	ON	EGBERT	EGBERT	*			SON	
65001	ON	BARRIE	85 PERRY STREET	*	*	TEOM		
65101	ON	NEWMARKET	EAGLE ST. & McCaffrey Rd.	*	*	TEOM		
65201	ON	PARRY SOUND	7 BAY STREET	*	*	TEOM		
65301	ON	PORT STANLEY	43665 DEXTER LINE	*	*	TEOM	SON	
65401	ON	BELLEVILLE	2 SIDNEY STREET	*	*	TEOM		
65601	ON	ESSEX	360 FAIRVIEW AVE. W.	*	*	TEOM		
65701	ON	MORRISBURG	COUNTY RD.2 / MORRISGURG WATER TOWER	*	*	TEOM		
65801	ON	CHATHAM	435 GRAND AVENUE W.	*	*	TEOM		
65901	ON	PICKLE LAKE	PICKLE LAKE	*				
66101	ON	MOONBEAM	BONNER LAKE	*				
66201	ON	CHALK RIVER	CLOUTHIER ROAD	*	*	TEOM		
70118	MB	WINNIPEG	JEFFERSON & SCOTIA	*	*	TEOM	PNO	PNO
70119	MB	WINNIPEG	65 ELLEN STREET	*	*	TEOM	PNO	PNO
70203	MB	BRANDON	1430 VICTORIA AVENUE EAST	*	*	TEOM	PNO	
70301	MB	FLIN FLON	143 MAIN STREET		*	TEOM		
80110	SK	REGINA	2505 11TH. AVENUE	*	*	TEOM	PNO	PNO
80209	SK	SASKATOON	IDYLWYLD DR. & 33RD ST.	*			PNO	
80211	SK	SASKATOON	511 1ST AVENUE NORTH	*	*	TEOM		
80402	SK	PRINCE ALBERT	63 - 12th STREET EAST	*	*	TEOM		

NAPS ID	PROV	CITY	ADDRESS	O ₃	PM ₂₅	PM ₂₅ E	I_O ₃	I_PM
80901	SK	BRATT'S LAKE	RADIATION OBSERVATORY	*				
90120	AB	EDMONTON	6240 113 STREET	*	*	TEOM		
90121	AB	EDMONTON	17 STREET & 105 AVENUE	*	*	TEOM	PNO	PNO
90130	AB	EDMONTON	10255 - 104TH STREET	*	*	TEOM	PNO	PNO
90132	AB	EDMONTON	4946-89 STREET		*	TEOM-FDMS		
90218	AB	CALGARY	49 AVENUE & 15TH STREET S.E.	*	*	TEOM	PNO	
90222	AB	CALGARY	39 ST. & 29 AVE. N.W.	*	*	TEOM	PNO	
90227	AB	CALGARY	611-4TH STREET S.W.	*	*		PNO	PNO
90302	AB	RED DEER	73 STREET & RIVERSIDE DRIVE	*	*	TEOM		PNO
90402	AB	MEDICINE HAT	12 ST NW & DIVISION AVE.	*	*	TEOM		
90502	AB	LETHBRIDGE		*	*	TEOM		
90601	AB	FORT SASKATCHEWAN	9209A-96 AVE.	*	*	TEOM	PNO	
90701	AB	FORT MCMURRAY	FRANKLIN AVENUE	*	*	TEOM	PNO	PNO
90702	AB	FORT MCMURRAY	TIMBERLEA SUBDIVISION	*	*	TEOM		PNO
90703	AB	FORT MCMURRAY			*	TEOM		
90801	AB	FORT MACKAY	MAIN STREET	*	*	TEOM		PNO
90806	AB	FORT MACKAY	SYNCRUDE UE1	*	*	TEOM		
91001	AB	ESTHER	ESTHER	*				
91101	AB	ELK ISLAND	NATIONAL PARK	*	*	TEOM		
91301	AB	TOMAHAWK	SE 2 51 6 W5	*	*	TEOM		PNO
91401	AB	VIOLET GROVE	SE 17 48 08 W5	*				
91501	AB	BEAVERLODGE	BEAVERLODGE RESEARCH FARM	*	*	TEOM		
91601	AB	CARROT CREEK	SE 31 53 13 W5	*				
91801	AB	FORT CHIPEWYAN	FORT CHIPEWYAN	*	*	TEOM		PNO
91901	AB	CAROLINE	16-30-034-5 W5	*	*	TEOM		
92001	AB	GRANDE PRAIRIE	10327 - 107 AVENUE	*	*	TEOM		
92201	AB	LAMONT	RGE RD 203 & TWP RD 550	*	*	BAM		
92601	AB	BRETON	HWY 20	*				
92801	AB	DRAYTON VALLEY	48 AVE.		*	TEOM		
92901	AB	EDSON	7 AVE.		*	TEOM		
93001	AB	GRANDE PRAIRIE	EVERGREEN PARK		*	TEOM		
93101	AB	THORSBY	RANGE ROAD 15	*	*	TEOM		
93901	AB	THORSBY	RANGE ROAD 11		*	TEOM		
94001	AB	DEBOLT	GOODWIN ROAD		*	TEOM		
94301	AB	COLD LAKE	15 AVE.	*				
100110	BC	METRO VAN - BURNABY	6400 E. HASTINGS & KENSINGTON	*	*	TEOM	LFV	
100111	BC	METRO VAN - PORT MOODY	MOODY & ESPLANADE PORT MOODY	*	*	TEOM	LFV	
100112	BC	METRO VAN - VANCOUVER	ROBSON/HORNBY	*				
100118	BC	METRO VAN - VANCOUVER	2550 WEST 10TH AVENUE	*	*	TEOM	LFV	
100119	BC	METRO VAN - BURNABY	5455 RUMBLE STREET	*	*	TEOM		

NAPS ID	PROV	CITY	ADDRESS	O ₃	PM ₂₅	PM ₂₅ E	I_O ₃	I_PM
100121	BC	METRO VAN - VANCOUVER	75 RIVERSIDE DR. N. VANCOUVER	*				
100125	BC	METRO VAN - DELTA	8544 116TH AVE. DELTA	*			LFV	
100126	BC	METRO VAN - BURNABY	RING ROAD BURNABY	*			LFV	
100127	BC	METRO VAN - SURREY	19000 & 72ND AVE. SURREY	*			LFV	
100128	BC	METRO VAN - RICHMOND	WILLIAMS & ARAGON RICHMOND	*			LFV	
100132	BC	METRO VAN - VANCOUVER	16TH ST. & JONES AVE NORTH VAN	*			LFV	
100134	BC	METRO VAN - RICHMOND	3153 TEMPLETON STREET	*	*	TEOM		LFV
100135	BC	METRO VAN - COQUITLAM	1250 PINETREE WAY	*				
100138	BC	METRO VAN - VANCOUVER WEST	6350 MARINE DRIVE		*	TEOM		
100202	BC	PRINCE GEORGE	1011 4TH AVENUE	*	*	TEOM		LFV
100205	BC	PRINCE GEORGE	GLADSTONE SCHOOL		*	TEOM		
100304	BC	VICTORIA	923 TOPAZ	*	*	TEOM		LFV
100307	BC	VICTORIA	2005 SOOKE ROAD	*	*	TEOM		LFV
100314	BC	VICTORIA	TSARTLIP BAND PROPERTY	*	*	TEOM		
100315	BC	VICTORIA	DND PROPERTY AT ROCKY POINT	*	*	TEOM		
100402	BC	KAMLOOPS	MAYFAIR STREET	*	*	TEOM		LFV
100701	BC	KELOWNA	3333 COLLEGE WAY	*	*	TEOM	LFV	LFV
101001	BC	ABBOTSFORD	AIRPORT	*			LFV	
101003	BC	METRO VAN - ABBOTSFORD	32995 BEVAN AVE.	*				
101004	BC	METRO VAN - ABBOTSFORD	31790 WALMSLEY AVENUE		*	TEOM		
101101	BC	CHILLIWACK	46244 AIRPORT ROAD	*	*	TEOM	LFV	LFV
101201	BC	METRO VAN-PITT MEADOWS	AIRPORT	*			LFV	
101202	BC	METRO VAN-PITT MEADOWS	18477 DEWDNY TRUNK	*	*	TEOM		LFV
101301	BC	METRO VAN-LANGLEY	23752 52ND AVENUE	*	*	TEOM		
101401	BC	HOPE	62715 AIRPORT ROAD	*	*	TEOM		
101501	BC	MAPLE RIDGE	23124 118TH AVENUE	*				
101701	BC	QUESNEL	585 CALLANAN STREET	*	*	TEOM		LFV
101702	BC	QUESNEL	950 MOUNTAIN ASH ROAD		*	TEOM		LFV
101704	BC	QUESNEL	CORRELIEU SCHOOL		*	TEOM		LFV
102102	BC	NANAIMO	280 LABIEUX ROAD	*	*	TEOM		LFV
102301	BC	POWELL RIVER	WILDLIFE SANCTUARY					LFV
102401	BC	SMITHERS	4020 BROADWAY AVENUE	*	*	TEOM		
102501	BC	TERRACE	104 - 3220 EBY STREET		*	TEOM		
102701	BC	WILLIAMS LAKE	1045 WESTERN AVENUE	*	*	TEOM		LFV
102706	BC	WILLIAMS LAKE	180 NORTH 3RD AVE		*	TEOM		
102801	BC	CAMPBELL RIVER	ADJACENT TO 660 WESTMERE	*	*	TEOM		
102802	BC	CAMPBELL RIVER	2662 TYEE SPIT ROAD		*	TEOM		
103302	BC	NELSON	333 VICTORIA STREET	*	*	TEOM		

NAPS ID	PROV	CITY	ADDRESS	O ₃	PM ₂₅	PM ₂₅ E	I_O ₃	I_PM
103402	BC	REVELSTOKE	402 DOWNIE STREET		*	TEOM		
103901	BC	KITIMAT	653 COLUMBIA STREET		*	TEOM		
104003	BC	VERNON	2704 HIGHWAY 6	*	*	TEOM		
104101	BC	GRAND FORKS	CITY HALL		*	TEOM		
104601	BC	TELKWA	1304 BIRCH STREET		*	TEOM		
105001	BC	WHISTLER	MEADOW PARK	*	*	TEOM		
105101	BC	HOUSTON	FIREHALL		*	TEOM		
105201	BC	BURNS LAKE	FIRE CENTRE		*	TEOM		
105604	BC	OSOYOOS	202 HWY 97 SOUTH	*	*	TEOM		
119003	YU	WHITEHORSE	1091 - 1ST AVENUE	*	*	TEOM		
129003	NT	YELLOWKNIFE	52ND AVE & 49T STREET	*				
129102	NT	NORMAN WELLS	#7 FORESTRY ROAD N. WELLS	*				
129103	NT	FORT LAIRD	AIRPORT ROAD	*				
129202	NT	INUVIK	KINGMINGYA RD / BLOCK 17	*				
129401	NU	ALERT	ALERT	*				

B. Mann-Kendall and SEN Tests results

Ground-level Ozone

Kendall trend

Time series	First year	Last Year	N	Test S	Test Z	Significant
<i>National</i>	1990	2008	19		2.24	*
<i>Atlantic</i>	1990	2008	19		0.70	
<i>Quebec</i>	1990	2008	19		1.75	+
<i>Ontario</i>	1990	2008	19		2.45	*
<i>Prairies</i>	1990	2008	19		1.05	
<i>BC</i>	1990	2008	19		1.19	

* Significant at the 95% CI.

+ Significant at the 90% CI.

Sen slope estimate

Time series	Q	Qmin90	Qmax90	B	Bmin90	Bmax90
<i>National</i>	0.2306	0.0416	0.3844	34.8785	36.7485	34.1096
<i>Atlantic</i>						
<i>Quebec</i>	0.2122	0.0061	0.4022	33.5498	35.4034	32.8505
<i>Ontario</i>	0.3763	0.1186	0.6002	38.5525	40.1216	36.7733
<i>Prairies</i>						
<i>BC</i>						

Trend Equation

$$f(\text{year}) = Q * (\text{year} - \text{First Data Year}) + B$$

where First Data Year = 1990

Fine particulate matter (PM_{2.5})

Kendall trend

Time series	First year	Last Year	N	Test S	Test Z	Significant
<i>National</i>	2000	2008	9	-12		
<i>Atlantic</i>	2000	2008	9	-12		
<i>Quebec</i>	2000	2008	9	6		
<i>Ontario</i>	2000	2008	9	-16		
<i>Prairies</i>	2000	2008	9	-8		
<i>BC</i>	2000	2008	9	-12		

No trend detected for PM_{2.5}

C. Data sources for international air quality comparison

Air Quality Data

[ADEQ] Arizona Department of Environmental Quality. 2009. 2009 Air Quality Annual Report. Available from:
http://www.azdeq.gov/function/forms/download/2009_Annual_Report-AQD.pdf

Air Quality Expert Group. 2009. Ozone in the United Kingdom. Department for the Environment, Food and Rural Affairs. Available from:
<http://www.defra.gov.uk/environment/quality/air/airquality/publications/ozone/documents/aqeg-ozone-report.pdf>

AIRPARIF. 2008. Surveillance de la Qualite de l'air en Ile-de France: Rapport d'activite (Monitoring Air Quality in the Ile-de France: Activity Report Summary). Available from: <http://www.airparif.asso.fr/airparif/pdf/2008.pdf>

Auckland Regional Council. 2010. Air Quality: Publications and Documents. Available from: <http://www.arc.govt.nz/environment/air-quality/aucklands-air-quality/publications-and-documents.cfm#aucklandsAirPollution>

Australian State of the Environment Commission. 2006. "Australia State of the Environment 2006". Available from:
<http://www.environment.gov.au/soe/2006/publications/report/pubs/soe-2006-report.pdf>

Department of Environment and Conservation. 2009. 2008 Western Australia Air Monitoring Report. Available from:
http://www.ephc.gov.au/sites/default/files/AAQ_MntRpt__2008_WA_Report_Final.pdf

Department of Environment, Climate Change and Water NSW. 2009. New South Wales Annual Compliance Report 2008. Available from:
http://www.ephc.gov.au/sites/default/files/AAQ_MntRpt__2008_NSW_Report_Final_0.pdf

[DEP] Pennsylvania Department of Environmental Protection. 2010. Bureau of Air Quality. Available from:
<http://www.dep.state.pa.us/dep/deputate/airwaste/aq/default.htm>

[EEA] European Environment Agency. 2010. Air Quality Data: AirBase. Available from:
<http://www.eea.europa.eu/themes/air/airbase/map-statistics>

[EPA] United States Environmental Protection Agency. 2008. Air Quality System (AQS) Web Application. Available from: <http://www.epa.gov/ttn/airs/airsaqs/aqsweb/>

- [EPA] United States Environmental Protection Agency. 2010. AirData: Access to Air Pollution Data. Available from: <http://www.epa.gov/air/data/index.html>
- [EPHC] Environment Protection and Heritage Council. 2010. Monitoring Reports. Available from: <http://www.ephc.gov.au/taxonomy/term/34>
- [GENCAT] Generalitat de Catalunya. Web del Departament de Medi Ambient i Habitatge. 2008. Contaminant: O₃. Accessed from : http://www.mediambient.gencat.cat/cat/el_medi/atmosfera/immissions/balansos/2008/ozo.pdf
- [GENCAT] Generalitat de Catalunya. Web del Departament de Medi Ambient i Habitatge. 2008. Contaminant: Suspended Particles (PM_{2.5}). Accessed from: http://www.mediambient.gencat.cat/cat/el_medi/atmosfera/immissions/balansos/2008/pm25.pdf
- [IVL] Swedish Environmental Research Institute. 2010. Krondroppsnätet (Net throughfall). Available from: <http://www.krondroppsnatet.ivl.se/>
- [LAQN] The London Air Quality Network. 2006. Homepage. Available from: http://www.londonair.org.uk/london/asp/default.asp?la_id=&showbulletins=&width=1440
- [RIVM] National Institute for Health and Environment. Undated. Validated Data Accessed February 3, 2010. Available from: [RIVM] National Institute for Health and Environment. Undated. Validated Data Accessed February 3, 2010. Available from: http://www.lml.rivm.nl/data_val/index.html

Urban Area Population Data

- City Population. 2010. Agglomerations. Available from: <http://www.citypopulation.de/world/Agglomerations.html>
- United Nations. 2007. Demographic Yearbook Table 8: Population of capital cities and cities of 100 000 or more inhabitants: latest available year, 1988 - 2007 Available from: <http://unstats.un.org/unsd/demographic/products/dyb/dyb2007/Table08.pdf>