2001 National Summary

of Ambient PM$_{2.5}$ and Ozone

Report prepared for the Joint Action Implementation Co-ordinating Committee

by

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1. INTRODUCTION

Environment Canada, at the request of the Joint Action Implementation Co-ordinating Committee (JAICC), prepared this report. The main objective of the report is to provide an overview of the ambient fine particulate (PM$_{2.5}$) and ground-level ozone ("ozone") concentrations observed across Canada in 2001, the most recent year with available data. As such, the report is not intended to provide any detailed assessment of the origin of the observed concentrations. It should also be noted that since the prevailing meteorology influences the formation, dispersion and transport of pollutants, the PM$_{2.5}$ and ozone concentrations observed in 2001 cannot be assumed as being reflective of the levels in past or future years because of the year-to-year variability in meteorology.

1.1 The Canada-wide Standards Numerics and Targets

Using the PM$_{2.5}$ and ozone Guidance Document on Achievement Determination (GDAD), jurisdictions are currently in the process of designating their Canada-wide Standards (CWS) reporting areas and CWS monitoring stations. All information presented in this report that may relate to the CWS is, therefore, strictly preliminary and is not to be construed as being indicative of the achievement status of the Standards. The CWS achievement is due by 2010. The first comprehensive progress reports on all provisions of the CWS, including assessment of ambient levels and trends, and identification of communities where ambient levels are exceeding or approaching the Standards, will be completed in 2006 for the year 2005.

Canada-wide Standards provisions include a 24-hour average Standard for PM$_{2.5}$ set at 30 µg/m$^3$, and an 8-hour average Standard for ozone set at 65 ppb. The achievement of these Standards, due in 2010, is assessed based on the value of a specific statistic, or metric, the value of which depends on the measured ambient concentrations of PM$_{2.5}$ and ozone. Under the CWS, the metrics to use to assess achievement of the Standards are:

- $PM_{2.5}$ CWS metric = the 3-year average of the annual 98th percentile of the 24-hour average (midnight to midnight) PM$_{2.5}$ concentrations.

- Ozone CWS metric = the 3-year average of the annual 4th highest of the daily maximum 8-hour average ozone concentrations.
2. MONITORING NETWORKS

This report presents continuous PM$_{2.5}$ (TEOM©) and ozone concentrations measured at monitoring sites participating in the National Air Pollution Surveillance (NAPS) program, and at monitoring sites of the Canadian Air and Precipitation Monitoring Network (CAPMoN). NAPS is a monitoring program delivered cooperatively by the federal, provincial, territorial and municipal governments. The data provided to NAPS includes stations operated under NAPS and stations that are exclusively operated and maintained by the provinces and some municipalities. CAPMoN is operated by Environment Canada. The NAPS and CAPMoN networks serve different purposes, with NAPS sites being primarily in urban areas while CAPMoN sites are exclusively in rural areas.

In 2001, continuous PM$_{2.5}$ monitoring was conducted at 87 NAPS participating sites (Figure 1) and ozone monitoring at 166 NAPS participating sites (Figure 2). Of the 87 PM$_{2.5}$ sites, 77 are classified as urban sites, based on land use classification from site documentation, and 10 as rural sites. Of the 166 ozone sites, 117 are classified as urban sites and 49 as rural sites. Ozone monitoring under CAPMoN was conducted at seven sites (Figure 3), while continuous PM$_{2.5}$ monitoring was conducted at one of these seven sites.

Figure 1: The 2001 continuous (TEOM) PM$_{2.5}$ monitoring network.
Figure 2: The 2001 ozone monitoring network.

Figure 3: The 2001 CAPMoN ozone monitoring network.
2.1 The TEOM Monitoring Method

The Tapered Element Oscillating Microbalance method (TEOM©) is the most widely used instrument in Canada to continuously monitor particulate matter (PM) concentrations in real-time. Some jurisdictions are currently deploying or are considering for deployment other continuous monitoring methods such as the Beta-Attenuation Module (BAM).

As of January 1, 2002 some of the operation parameters of TEOM units measuring PM$_{2.5}$ have been revised, and existing concentrations measured before this date have been revised downward in all jurisdictions, except Alberta. Since all PM$_{2.5}$ concentrations presented in this report have been measured by the TEOM, this Section provides a background on the TEOM and the implemented revisions.

The TEOM Monitor

The TEOM can measure either PM$_{10}$ or PM$_{2.5}$ mass concentrations depending on the sampling inlet used. In the United States (US), the TEOM is designated as a Federal Equivalent Method (FEM) for PM$_{10}$ by the US Environmental Protection Agency (EPA). For the US, this means that the TEOM can legally be used to assess compliance with the US National Ambient Air Quality Standards (NAAQS) for PM$_{10}$. Because of the FEM designation, all TEOM units are built and sent to customers with default operation parameters related to the designation requirements. These include heating the sampled air at a constant temperature of 50°C and an upward adjustment of the internally-calculated concentration (Ci).

There are specific reasons for the TEOM default operation parameters. Particulate matter (PM) is a complex mixture of substances each having different chemical and physical properties. Because of this complex nature, all PM mass measurement methods are confronted with a number of challenges. The method must be able to maximise the removal of unwanted bounded and unbounded particle-water (water is not, by definition, considered as particulate material), while concurrently maximising the retention of the sampled semi-volatile particulate material (SVPM). SVPM are particulate-phase substances that can change phase and become gaseous substances depending on the atmospheric conditions. SVPM include nitrate and semi-volatile organic compounds (SVOC). Nitrate may be more prevalent in the colder months, while SVOC may be present in varying proportions throughout the year.
In the TEOM, the removal of unwanted particle-water is accomplished by heating the sampled air to 50°C, which causes the volatilisation (changing into the gas phase) of particle-water. Regarding the upward adjustment of the internally-calculated concentrations (Ci), it is believed that the adjusted PM$_{10}$ concentrations would better compare with those that would be obtained with the filter-based Federal Reference Method (FRM) of the EPA. The upward adjustment of Ci was prompted by the results of field studies which found that PM$_{10}$ concentrations obtained with the TEOM were lower, on average, than those obtained with filter-based samplers. The concentration differences between the two methods is believed to be associated with the increased heating of the sampled air to 50°C in the TEOM, which in addition to removing particle-water may also remove (through volatilisation) a greater mass of the sampled SVPM than filter-based samplers.

The TEOM internally-calculated concentration (Ci) is adjusted upward according to the following regression which was developed based on data from a limited number of field studies of collocated TEOM PM$_{10}$ and filter-based samplers:

$$\text{Upward Adjusted Concentration (Ca)} = 3.0 + 1.03\times\text{Ci} \text{ in } \mu g/m^3$$

For most 24-hour average PM$_{2.5}$ concentrations measured across Canada, Ca is 3 to 5 $\mu g/m^3$ higher than Ci.

It should be noted that the volatilisation of SVPM may be prevalent when the PM mixture contains a relatively large proportion of SVPM. When the SVPM proportion is small, the TEOM concentrations are similar to those obtained with filter-based samplers. There are also indications that when the PM mixture consists mostly of non-volatile material, Ca may be higher than the concentrations obtained with filter-based samplers because of the upward adjustment. It should also be noted that filter-based samplers are themselves associated with a number of issues, some of which are less tractable than the volatilisation issue of the TEOM.
Adjustment Factors and PM$_{2.5}$ – Implemented Measures

As of January 1, 2002 the internally-calculated mass concentration is no longer adjusted upwards for TEOM measuring PM$_{2.5}$. This was decided by NAPS managers in the Fall of 2001 and was prompted by uncertainties related to any adjustment of the internally-calculated PM$_{2.5}$ concentration based on a regression developed exclusively from PM$_{10}$ data. To maintain consistency with this approach, the NAPS managers also agreed, with the exception of Alberta, to remove the adjustment effect in all TEOM PM$_{2.5}$ concentrations measured before January 1, 2002.

Volatilisation Issue – Implemented Measures

A number of measures have been implemented in Canada since 1998 to attempt to address the increased volatilisation of SVPM which is believed to be associated with the TEOM. One of these is the lowering of the heating temperature to 40°C. This was prompted by a number of studies in the US and Canada that indicated better comparison between the PM concentrations from TEOM units operated at a lower heating temperature and filter-based samplers. All TEOM units (for both PM$_{10}$ and PM$_{2.5}$) in Canada are operated at a heating temperature of 40°C, and this became effective January 1, 1998.

Another measure is the addition to existing TEOM units of a new Sample Equilibration System (SES). In TEOM units, the removal of particle water is accomplished exclusively through heating of the sampled air. With the addition of the SES, removal of particle-water is also accomplished through the use of a Nafion© dryer. Because the SES removes particle-water, it enables the heating temperature of the sampled air to be lowered to as low as 30°C. This lower heating temperature is closer to the heating temperature associated with filter-based samplers, and it should also contribute to greater retention of the sampled SVPM.

Environment Canada has purchased 45 SES units. These SES units will be installed on existing TEOM units located in airsheds where it is known or suspected that the PM$_{2.5}$ mixture contains a large proportion of SVPM.
3. **PM$_{2.5}$ AIR QUALITY OVERVIEW**

This Section presents an overview of the PM$_{2.5}$ concentrations in 2001 as measured by the TEOM. The presented information include the 98th percentiles of the 24-hour average PM$_{2.5}$ concentrations and the number of days with 24-hour PM$_{2.5}$ above 30 µg/m$^3$. Comparison of the 2001 data with longer-term data is not possible at this time because of the lack of historical TEOM data. All PM$_{2.5}$ concentrations presented in this report, except those from Alberta, are those that have been revised based on the removal of the effect of the upward adjustment factors as discussed in Section 2.1.

3.1 **98th Percentiles in 2001**

Figure 4 presents the 98th percentile of the 24-hour average PM$_{2.5}$ concentrations in 2001 at sites that satisfied the 75% data completeness criterion or that recorded a 98th percentile that was greater than 30 µg/m$^3$. In 2001, the 98th percentile was above 30 µg/m$^3$ at twelve sites. Most of these sites were located in Ontario, few were in Quebec and one in British Columbia (BC). All but one of these latter Ontario sites are urban.

**Figure 4:** The 98th percentiles of the 24-hour PM$_{2.5}$ concentrations in 2001.
3.2 Days with PM$_{2.5}$ Above 30 µg/m$^3$

The number of days with 24-hour PM$_{2.5}$ concentrations above 30 µg/m$^3$ at selected sites in 2001 are indicated in Figure 5. This Figure includes sites that satisfied the data completeness criterion of 75% (most sites), as well as sites that did not satisfy this criterion but who recorded days with PM$_{2.5}$ above 30 µg/m$^3$. In general, most sites in Eastern Canada (Ontario, Québec and the Atlantic Provinces) recorded two to ten days with PM$_{2.5}$ above 30 µg/m$^3$, including sites in Toronto and Montreal. In Western Canada (the Prairie Provinces and BC), only a few sites recorded days with PM$_{2.5}$ above 30 µg/m$^3$, and Edmonton was the only major urban centre with few such days.

**Figure 5:** Number of days with 24 hour PM$_{2.5}$ above 30 µg/m$^3$ in 2001.

Empty squares means no days above 30 µg/m$^3$. 
Figure 6 presents the monthly distribution of the average number of days per site with 24-hour PM$_{2.5}$ concentrations above 30 µg/m$^3$ in 2001 as averaged over the sites within the indicated groups. This number is obtained by summing the number of days above 30 µg/m$^3$ over all sites within a group, and then dividing this sum by the number of sites in the group.

Figure 6 indicates that for both rural and urban sites in Eastern Canada, a higher number of days with PM$_{2.5}$ above 30 µg/m$^3$ occurred in the warmer months (May to September), with much less such days in Fall and Winter. Of interest also is that in Eastern Canada, the considered urban sites recorded more days than the considered rural sites in every month. In Western Canada, only urban sites recorded days with PM$_{2.5}$ above 30 µg/m$^3$, and they were considerably less than at sites in Eastern Canada.

**Figure 6**: Average number of days with 24-hour PM$_{2.5}$ above 30 µg/m$^3$ in 2001.
4. OZONE AIR QUALITY OVERVIEW

This Section presents an overview of the ozone air quality in 2001 as represented by the daily maximum 8-hour average concentration (O$_3$-Dmax-8h). The presented information includes the 4th highest O$_3$-Dmax-8h and the number of days with O$_3$-Dmax-8h above 65 ppb. Where data exists, the 2001 levels are compared with long-term averages, and qualitative trends in levels are presented.

4.1 Fourth Highest Concentrations in 2001

Figure 7 presents the 4th highest O$_3$-Dmax-8h in 2001 at monitoring sites that satisfied the 75% data completeness criterion or that recorded a 4th highest value greater than 65 ppb. In Western Canada, only rural sites recorded 4th highest O$_3$-Dmax-8h values above 65 ppb. In Ontario and Quebec, 4th highest values above 65 ppb were recorded at almost all urban and rural sites, and in Atlantic Canada 4th highest values above 65 ppb occurred mostly at rural sites.

**Figure 7:** The fourth highest, daily maximum 8-hour average ozone concentrations in 2001.
4.2 Days with O$_3$-Dmax-8h Above 65 ppb

Figure 8 presents the number of days with O$_3$-Dmax-8h above 65 ppb at selected sites in 2001. This Figure includes sites that satisfied the data completeness criterion of 75% (most sites), as well as sites that did not satisfy this criterion but who recorded days with O$_3$-Dmax-8h above 65 ppb.

In Eastern Canada, almost all sites recorded one or more days with O$_3$-Dmax-8h above 65 ppb. A higher number of days were recorded at sites in southern Ontario, southern Quebec and south-western Nova Scotia. Long Point, a rural site on the shores of Lake Erie, recorded the highest number of days (55). In Western Canada, sites with two or more days with O$_3$-Dmax-8h above 65 ppb were mostly limited to rural sites in Alberta. Few other sites in BC and Edmonton recorded one to two days with values above 65 ppb. The rural Hightower Ridge site located in Alberta at some 1700 m above sea level recorded the highest number of days (27) with values above 65 ppb.

**Figure 8:** Number of days with daily maximum 8-hour average ozone concentrations above 65 ppb in 2001.

Empty squares means no days above 65 ppb.

**Number of Days with Daily 8 Hour Max Ozone > 65 ppb 2001**
Figure 9 presents the monthly distribution of the average number of days per site with O$_3$-Dmax-8h above 65 ppb in 2001 (see Section 3.2 for an outline of the procedure). In Eastern Canada, days with values above 65 ppb were higher in the warmer months (May to September). Western Canada recorded considerably less number of days with values above 65 ppb, with the highest number of days occurring at rural sites in May.

**Figure 9:** Monthly distribution of the average number of days with daily maximum 8-hour average ozone concentration above 65 ppb in 2001.

To obtain an indication of how O$_3$-Dmax-8h in 2001 compared to other years, the number of days with O$_3$-Dmax-8h above 65 ppb in 2001 was compared to the corresponding six-year average for the period 1995 to 2000 (Figure 10). A six year average was selected as a compromise between length of record and number of sites with available ozone data. In Figure 10, the number of days with values above 65 ppb for the two periods overlay each other and the applicable number for the overlaying period is given by the length of the entire bar consisting of both colour segments. For example, if a green bar segment (2001) overlays the corresponding pink bar segment (6-year average), the number of days in 2001 is represented by the length of the entire bar consisting of both the green and pink segments.
Figure 10 indicates that in 2001 most sites in Eastern Canada recorded a higher number of days with O₃-Dmax-8h above 65 ppb than the six year average. In the southern-most part of southwestern Ontario, the number of days in 2001 was approximately the same as the 6-year averages. In Western Canada, in 2001 all sites recorded less number of days with values above 65 ppb than the six year average. Figure 10 also indicates that for the considered six year period, sites in Western Canada recorded much fewer days with O₃-Dmax-8h above 65 ppb than sites in Eastern Canada. It should be noted that some of the rural sites in Alberta that were considered in Figure 8 (including the High Tower Ridge site), are not included in Figure 10 because they were not operating during the entire 6-year period.

Figure 10: Number of days with daily maximum 8-hour average ozone concentration above 65 ppb in 2001 and for the period 1995 to 2000.

Bars are additive.
It is well documented that high air temperatures (and their commonly associated meteorological conditions) favour the occurrence of elevated ozone concentrations. In Figure 11, the number of days with maximum temperatures above 30°C in 2001 are compared with the average for the six year period from 1995 to 2000. The data for this Figure was collected at weather stations operated by the Meteorological Service of Canada. As in Figure 10, the bar segments are additive.

Figure 11 indicates that at most sites across Canada (except for the Lower Fraser Valley), the number of days with temperatures above 30°C in 2001 was greater than the six-year average. Comparing Figures 11 and 10, it can be seen that sites in Eastern Canada at which the number of days with temperatures above 30°C in 2001 was greater than the 6-year average also recorded more days with O₃-Dmax-8h above 65 ppb in 2001 than the 6-year average. This is consistent with the above noted statement.

**Figure 11:** Number of days with daily maximum air temperature above 30°C in 2001 and for the period 1995 to 2000.

Bars are additive.
4.3 Long Term Trend Indicators

To assess qualitative changes in ozone concentrations, two indicators are used. The first indicator is the 5-year moving average of the composite 20th and 80th percentiles of O$_3$-Dmax-8h. The second indicator is the annual average number of days per site with O$_3$-Dmax-8h above 65 ppb. The composite 20th percentile of a given group of sites is the average of the 20th percentile from each site within the group; similarly for the composite 80th percentile. The average number of days per site with O$_3$-Dmax-8h above 65 ppb is based on the same procedure as outlined in Section 3.2.

The 20th and 80th percentiles can be considered as providing a broad indication of the lower and upper levels, respectively, of the O$_3$-Dmax-8h distribution. A five year moving average of these percentiles was applied to moderate, or "smoothen", the variability in O$_3$-Dmax-8h that may be caused by the annual variability in meteorological conditions and pollutants (precursors) emissions. The annual average number of days per site with O$_3$-Dmax-8h above 65 ppb can be considered as providing an alternate measure of the occurrence of the higher levels of O$_3$-Dmax-8h.

Figure 12 presents the 5-year moving averages of the composite 20th and 80th percentiles of O$_3$-Dmax-8h over the seventeen-year period from 1985 to 2001. Only sites with at least 13 years of data were selected for this analysis. Rural sites in Western Canada are not considered since none of them satisfied this criterion.

Figure 12 indicates that for the considered rural sites in Eastern Canada, the 20th and 80th percentiles of O$_3$-Dmax-8h both changed little over the entire seventeen year period. For urban sites in Eastern Canada, the 20th percentile experienced a gradual increase throughout the period, while the 80th percentile changed little between 1989 and 1996, and then began to increase gradually. These distributions suggest that both the lower and upper levels of O$_3$-Dmax-8h may have remained relatively stable at the rural sites, while they may have both increased at the urban sites especially during the last five years. Of interest is that the 20th and 80th percentiles at the considered rural sites in Eastern Canada have been consistently higher than the corresponding urban sites. For the urban sites in Western Canada, the 20th and 80th percentiles remained more or less stable throughout the period.
**Figure 12:** Five-year moving average of the composite 20th and 80th percentiles of the daily maximum 8-hour average ozone concentrations.
Figure 13 presents the annual average of the number of days per site with O$_3$-Dmax-8h above 65 ppb for the fifteen year period from 1987 to 2001. Only sites with at least 12 years of data were used in the analysis. For rural sites in Western Canada, only the five year period from 1997 to 2001 is considered since the data completeness criterion was not satisfied for longer periods.

For Eastern Canada, Figure 13 indicates yearly fluctuations in the number of days with O$_3$-Dmax-8h above 65 ppb, with 2001 being fairly typical of a year with a high number of days at both the urban and rural sites. Compared to other years with a high number of days with values above 65 ppb, however, fewer days were recorded in 2001. Following a decrease between 1987 and 1992, the number of days remained more or less stable between 1992 and 1997, and then increased again, on average, between 1997 and 2001. For urban sites, this latter increase is consistent with the increase observed in the 5-year moving average of the 80th percentile in Figure 12.

For Western Canada, urban sites recorded very few days with O$_3$-Dmax-8h above 65 ppb, with the number of days between 1991 and 2001 being less than those between 1987 and 1991. At the considered rural sites, the number of days with O$_3$-Dmax-8h above 65 ppb mostly increased between 1997 to 2001. Compared to Eastern Canada, Western Canada recorded significantly less days with O$_3$-Dmax-8h above 65 ppb. Of interest is that the considered rural sites in both Eastern and Western Canada recorded a greater number of days than the considered urban sites.
**Figure 13:** Annual average number of days with daily maximum 8-hour average ozone concentrations above 65 ppb.

The significance of the above changes in the 5-year moving averages of the 20th and 80th percentiles of $O_3$-Dmax-8h is beyond the scope of this report. Since ozone levels depend, among other factors, on ambient levels of ozone precursors, the composite warm season average of nitric oxide (NO), nitrogen dioxide ($NO_2$), and mass-basis total volatile organic compounds (VOC) concentrations at urban sites are presented (Figure 14 and 15) for qualitative purposes only. These Figures indicate that the ambient levels of the ozone precursors have mostly decreased at the considered urban sites, with the $NO_x$ (NO and $NO_2$) decrease being more pronounced at the Urban West sites.
Figure 14: Annual and 5-year moving averages of the composite warm season (April – September) average NO and NO$_2$ concentrations at urban sites.
Figure 15: Annual and 5-year moving averages of the composite warm season (April – September) average total VOC mass-basis concentration at urban sites.
(thirteen Urban East Sites, five Urban West sites)