Respirable Particulate and Ground-Level Ozone Sampling Study in the City of Greater Sudbury - Summer of 2010

Study Undertaken for the
Environmental Commissioner of Ontario
and Clean Air Sudbury

By

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1.0 INTRODUCTION

There is increasing interest in knowing how current regional air quality forecasting and monitoring programs adequately represent the true air pollution exposure of urban populations. The majority of air quality monitoring stations in Ontario and Canada are in urban and rural locations removed from sources of air pollution such as major traffic corridors and significant point sources. Many of these are best described as urban background stations.

In order to gain a better understanding of these programs, in 2007 the Environmental Commissioner of Ontario (ECO) commissioned a review of current practices in Ontario and in the rest of Canada[1].

The review included a summary of initiatives used in other national and international jurisdictions, current state-of-the-science for systems designed to predict air quality at street level, and where the science is headed. The review indicated that the Ontario Ministry of the Environment (MOE) current air quality forecasting and monitoring system, which is similar to the systems used by Environment Canada, the USEPA and many North American cities, provides general information to the public on regional air quality. However this approach does not provide data needed to assess air quality at street level in the urban environment.

The review revealed that some advanced European systems provide near real-time air quality information on both urban background and roadside pollutant levels using data from comprehensive and state-of-the-science ambient air monitoring networks. For example, in some European cities real-time analyzers are positioned at key traffic intersections and have the ability to control traffic lights based on measured pollutant levels. These advanced systems more reliably approximate potential human exposures in urban settings.

The August 2009 Air and Waste Management Association publication, *EM- The Magazine for Environmental Managers*[2], featured research articles on near-roadway health effects from air pollution and possible ways to mitigate air quality impacts from roadways. It was indicated that recent studies have confirmed the risk to human health for populations spending significant amounts of time near large roadways. Research studies also show elevated air pollutant concentrations of gaseous and particulate compounds near roads.

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[1] Predicting Air Quality at Street Level - A State-of-Science Review, Project Number: #W08-5129A, 25 March 2008

[2] EM – The Magazine for Environmental Managers, Air and Waste Management Association, August 2009

In order to obtain a better understanding of particulate concentrations near street level locations and in other locations not routinely monitored by agencies in North America, the ECO commissioned summer sampling programs in a number of communities and urban centres in the Province.

2.0 SAMPLING PROGRAM

2.1 Sampling Campaigns (2007 and 2008)

The initial study took place in 2007. It was aimed at estimating the concentrations of the very coarse (Total Suspended Particulate – TSP) and fine (respirable particulate matter as $PM_{2.5}$) that Ontario residents can be exposed to during short time periods in locations not monitored by the Provincial Air Quality Monitoring Network operated by the MOE. These locations included rural background, small/large urban areas, busily travelled downtown locations and public areas. High-volume (hi-vol) samplers, placed in the open cargo area of a half-ton pick-up truck and powered by a gasoline generator, were used to measure the TSP and $PM_{2.5}$ particle size fractions collected on quartz filters.

The study was repeated in the summer of 2008 and comprised simultaneous measurements of ground-level ozone (O_3) and $PM_{2.5}$, again using the hi-vol method.

$PM_{2.5}$ and ground-level ozone are both implicated in several current air quality issues in Ontario: they are the main constituents of smog and are linked to climate change and acid deposition[3]. $PM_{2.5}$ is also responsible for reduced visibility and regional haze. Both pollutants are the focus of air quality management programs both in Canada and in the U. S.

The results of the 2007 and 2008 sampling programs revealed that the hi-vol method does not appear to be a reliable method for measuring $PM_{2.5}$ concentrations since it tends to frequently overestimate expected and true ambient values by significant amounts. It is suspected that the hi-vol sampler at times collects particulate matter greater in size than 2.5 microns. The study also revealed that for short time periods, the levels of TSP can be quite elevated due to emissions from natural and anthropogenic sources in a variety of urban and rural environments.

The 2008 study showed that the ozone concentrations obtained with a portable ozone analyzer were in the range measured at the closest MOE Air Quality Index (AQI) stations for the same time periods.

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[3] Air Quality in Ontario, 2007 Report, Ontario Ministry of the Environment, Publication PIBS 6930e © Queen's Printer of Ontario, 2008

2.2 Sampling Campaign (2009) – City of Greater Sudbury

In the summer of 2009, the provincial study was undertaken in the same communities sampled in 2008. The City of Greater Sudbury had not been included in the earlier studies. Ground-level ozone concentrations were again measured with a portable analyzer. $PM_{2.5}$ measurements were taken with a portable GRIMM model 107 particulate analyzer. Both sampling methods and the instruments used to measure wind, barometric pressure and relative humidity are described below.

Clean Air Sudbury (CAS), a non-profit community group focused on air quality issues in Greater Sudbury, expressed an interest in this study and approached the ECO to include the City of Greater Sudbury in the 2009 sampling campaign. This in part stems from concerns by the CAS committee that exposure of the population to street level air pollution may not be adequately monitored by the MOE AQI station located on the southern shore of Ramsey Lake near Laurentian University. This station is considered to represent urban background air quality.

The results of the 2009 sampling program, undertaken at five locations in August in the City of Greater Sudbury were reported earlier.[4] The air quality sampling results for the other communities in Ontario were presented in a separate report.[5]

The results of the 2009 sampling campaign were as follows:

- The air quality was determined to be very good to good, based on ground-level ozone and $PM_{2.5}$ measurements. In the majority of cases, the ground-level ozone sub-index was highest and determined the overall air quality in accordance with the reporting system used by the MOE.
- The maximum hourly ground-level ozone concentration was 42 ppb, considerably less than the MOE criterion of 80 ppb.
- The maximum $PM_{2.5}$ concentration measured over a 3-hour period was 15.0 $\mu g/m^3$, which is considerably lower than the reference level of 45 $\mu g/m^3$ used by the MOE.
- The $PM_{2.5}$ concentrations measured at the study sites with a GRIMM model 107 analyzer were generally higher than those measured at the MOE AQI site, in several instances by as much as a factor of two.
- There was good agreement in the ground-level ozone measurements taken at the study sites with measurements at the MOE AQI site. For the three (3) hour sampling periods, the differential was less than 5 ppb. Overall, the average

[4] Respirable Particulate and Ground-level Ozone Sampling Study in the City of Greater Sudbury – Summer 2009, Report Prepared for the Environmental Commissioner of Ontario and Clean Air Sudbury, December 2009.

[5] Respirable Particulate and Ground-level Ozone Sampling Study in Ontario Communities – Summer 2009, Report Prepared for the Environmental Commissioner of Ontario, January 2011.

concentrations were slightly lower at the study sites presumably due to the scavenging of ozone by oxides of nitrogen from traffic-related emissions.

- The results suggested that the concentrations of $PM_{2.5}$ at street-level near busy intersections in the City of Greater Sudbury, at times can be substantially higher than measured at the air quality monitoring station located near Ramsey Lake.

2.2.1 Particulate Analyzer

A portable battery-operated particulate analyzer (model 107), manufactured by GRIMM was used to simultaneously measure concentrations of TSP, PM10 and PM2.5 in units of µg/m3 for particles ranging in size from 0.25 to 34 microns (µm). The mass concentration range is 0.1 to 1500 µg/m3. The measuring principle is laser light scattering at 90°. The unit's spectrometer is single particle detection and counting system. It is thus designed to measure every single particle and classify it by size. It continuously measures the particle concentration and the complete counts by size range are shown within 6 seconds. The data are reported in 1 minute intervals and stored on a removable data logger card. The analyzer is factory calibrated by the manufacturer. The calibration cannot be adjusted in the field but is required to be checked every 18 to 24 months by the manufacturer or an authorized firm capable of providing this service.

The model 107 is listed as an acceptable dust monitor by the MOE[6]. It does not have USEPA or European approval. However it should be noted that the GRIMM model 180, which is the rack-mounted version and uses the same laser spectrometer system, has European approval for $PM_{2.5}$. This model has been submitted to the USEPA for approval which is expected in the spring of 2010 for $PM_{2.5}$. Preliminary EPA test results show very good comparison with a Federal Reference Method (FRM) sampler for $PM_{2.5}$.[7]

Brief inter-comparisons of $PM_{2.5}$ data collected with the portable Grimm analyzer near the MOE North Bay and Toronto Downtown (Bay Street and Wellesley Avenue) AQI stations during the study period revealed that, on an hourly basis, the concentrations obtained from the GRIMM analyzer were within about 1 to 1.5 µg/m^3 of the values reported by the TEOM analyzer at the AQI stations.

Using the 107 dust spectrometer as a handheld instrument outdoors without an automatic correction system for high Relative Humidity (RH) values (≥70% RH) can give results higher than expected since the high humidity may produce super-saturation and

[6] Operations Manual for Air Quality Monitoring in Ontario, Ontario Ministry of the Environment, Operations Division, Technical Support Section, March 2008

[7] Personal communication with Gil Cossette, Representative of GRIMM Aerosol Canada Inc.

an artificial particle growth of the aerosols. At a high level of humidity (≥ 90% RH), some condensation will occur in the optics which will increase the instrument readings. Other than water vapor at RH >70%, no other compounds will affect the readings.[8]

2.2.2 Ground-Level Ozone Analyzer

Ground-level O_3 measurements were simultaneously taken with a portable monitor (Model 202) supplied by 2B Technologies Inc. in Boulder Colorado. The monitor measures atmospheric O_3 in the concentration range 1.5 to 100 part per million of air by volume (ppmv) using the well-established technique of ultraviolet (UV) absorption at 254 nanometers (nm). This instrument features high precision, small size and weight (2.1 kg) and low power consumption (4.0 watts at 12 V DC). It can operate from an external battery or AC adapter. It is well-suited for remote and urban network applications.

The calibration of the monitor was independently audited by Rotek Inc. located in Hamilton, an environmental firm specializing in air quality monitoring instrumentation and monitoring programs. The audit report shows that the calibration of the Model 202 monitor was within 4% of the test gas value using an Environics Model 6103 ozone calibrator. This deviation is well within the ± 10% data acceptability criterion used by the MOE. The analyzer response to the audit test gas was linear. A copy of the audit report is provided in Appendix A. During the study, ambient O_3 concentrations were measured as 5 minute averages while the GRIMM analyzer was in operation. The 5 minute averages were then used to calculate 1 hour averages to compare against the Ontario Ministry of the Environment (MOE) Ambient Air Quality Criterion (AAQC) for 1 hour.

Most of the time, the analyzers were powered with an inverter. The GRIMM analyzer usually ran on its internal battery which was re-charged as required. A gasoline powered Honda generator was available as back-up in case of failure of the inverter. Figure B-1 in Appendix B is a photo of the analyzers used in this study.

2.2.3 Temperature, Relative Humidity and Barometric Pressure Sensors

Ambient temperature (°F), relative humidity (%) and barometric pressure (inches of mercury) readings were obtained every hour with a portable weather station (model TWS Weather Station) made by Oneworld GMS from San Francisco, CA. The temperature and barometric pressure readings were converted to SI units (°C and kilopascals - kPa).

[8] Personal communication with Gil Cossette, Representative of GRIMM Aerosol Canada Inc

2.2.4 Wind Speed Sensor

Wind speed readings (in knots) were taken every hour with a portable sensor (Dwyer model A376 wind meter) made by Dwyer Instruments Inc. located in Michigan City, Indiana. The wind speed values were converted to kilometres per hour (km/h).

2.3 Sampling Campaign (2010) – City of Greater Sudbury

In the summer of 2010, the study was undertaken at three (3) locations proposed by Clean Air Sudbury, compared to five (5) locations in 2009. These locations were part of the 2009 are as follows:

- Intersection of Lasalle Blvd and Notre Dame Ave
- Intersection of Paris Ave and Elm Street
- Intersection of Paris Ave and Regent Street

These street intersections have some of the highest traffic volumes in the city. They also provide a cross-section or mix of vehicular traffic (light duty gasoline vehicles, light and heavy duty diesel vehicles). Lasalle Blvd is the major east/west artery travelled by heavy duty diesel trucks hauling ore and slurry concentrate for the mining sector. Sampling was postponed to late summer (September 13) in an attempt to avoid possible unrepresentative air emissions during the road construction period.

The concentrations of ground-level ozone and $PM_{2.5}$ were measured at these locations and for the sampling periods shown in Table 1. In the summer of 2009, sampling was undertaken once at each site over three (3) hour time intervals. For the 2010 study, measurements were taken twice over three (3) consecutive hours, during the periods 06:00 to 12:00 noon and 13:00 to 18:00. The intent was to collect, as much as possible, air samples closer to peak traffic times than during previous sampling campaigns.

Table 1: Sampling Locations and Periods

Date (2010)	Location	Sampling Period (EST)
August 4	Sudbury (Lasalle and Notre Dame)	14:00 to 17:00
August 9	Sudbury (Paris and Regent)	07:00 to 10:00
August 9	Sudbury (Paris and Regent)	14:00 to 17:00
August 10	Sudbury (Lasalle and Notre Dame)	06:00 to 09:00
September 13	Sudbury (Paris and Elm)	06;00 to 09:00
September 13	Sudbury (Paris and Elm)	14:00 to 17:00

These are very brief time periods and may not be representative of longer term averages over a range of meteorological conditions. Additional sampling over much longer time intervals would be required to obtain a better representation of air quality levels, especially at peak traffic times. However the results are deemed to provide an indication of the air quality at street level under the conditions when the sampling was conducted.

As in 2009, the study results were compared with hourly measurements and Air Quality Index (AQI) values from the MOE AQI stations in these communities which continuously measures ground-level ozone and $PM_{2.5}$ concentrations. Ozone concentrations at these stations are measured with a conventional analyzer using the ultraviolet (UV) absorption method, whereas $PM_{2.5}$ concentrations are measured with a Tapered Oscillating Microbalance (TEOM) analyzer operated at 30℃ and with a Sample Equilibration System (SES). It is important to note that the data from the AQI stations was preliminary from automatically polled data and is subject to change upon final verification by the MOE before it is published.

For this comparison, the MOE data from its public website was used. On its public website, the MOE defines an hourly average as the hour ending, such that the average for the hour 08:00 is for data collected between 07:00 and 08:00. The hourly averages from the study results and the MOE data base were all expressed in Eastern Standard Time (EST). Photos of the sites where sampling was conducted are shown in Appendix C.

3.0 REFERENCE LEVELS AND AQI DETERMINATIONS

3.1 Respirable Particulate

The Canada Wide Standard (CWS) reference level for respirable particulate matter (30 $\mu g/m^3$) is set on the basis of a 24-hour average. For practical reasons, the samples collected in this study were over a 3-hour interval. For such short-term exposures to respirable particulate, Ontario uses a value of 45 micrograms per cubic metre of air ($\mu g/m^3$) which is considered equivalent to the 24-hour CWS reference level of 30 $\mu g/m^3$. In other words, the CWS reference level would likely have been exceeded based on a 3-hour sample result of 45 $\mu g/m^3$. For this study, the equations used in Ontario to calculate the Air Quality Sub-index for $PM_{2.5}$ to categorize the air quality, as ranging from very good to very poor, were used to describe the air quality when and where sampling occurred. The equations used to calculate the sub-index for $PM_{2.5}$ in Ontario are shown in the following table:

Table 2: AQI Equations for $PM_{2.5}$ Sub-Index

Fine Particulate Matter ($PM_{2.5}$)		
AQI Category	**[$PM_{2.5}$] 3-hour average ($\mu g/m^3$)**	**AQI Equation**
Very Good	<12	$1.364 \times [PM_{2.5}] + 0$
Good	12 to 22	$1.500 \times [PM_{2.5}] - 2.000$
Moderate	23 to 45	$0.7727 \times [PM_{2.5}] + 14.228$
Poor	46 to 90	$1.113 \times [PM_{2.5}] - 1.298$
Very Poor	>90	$1.100 \times [PM_{2.5}] + 0$

It is important to note that compliance with the CWS for $PM_{2.5}$ is based on the 98th percentile of the annual daily average, averaged over three consecutive years. Compliance for designated cities (with population over 100,000) is set for 2010. Hence it was not possible or the intent in this study to assess compliance with the CWS.

3.2 Ground-Level Ozone

Ontario has an AAQC of 80 ppb for a 1 hour average. The Canada Wide Standard for O_3 is 65 ppb. It is based on an 8 hour running average and the 4th highest annual average value is averaged over three consecutive years. Again, designated cities meeting the population threshold of 100,000 are to comply with this standard by 2010. Ontario does not have a three hour O_3 average reference level equivalent to the CWS 8 hour running average. Hence the results of this study are compared with the Ontario AAQC of 80 ppb for a 1 hour average. In addition, the equations used in Ontario to calculate the Air Quality Sub-index for O_3 to categorize the air quality, as ranging from very good to very poor, were used to describe the air quality when and where sampling occurred. For this study, the maximum 1 hour average O_3 concentration measured during the 3 hour sampling period for $PM_{2.5}$ was used to calculate the O_3 Sub-index. The equations used to calculate the AQI sub-index for O_3 in Ontario are shown in Table 3.

Table 3: AQI Equations for O_3 Sub-Index

Ozone (O_3)		
AQI Category	**$[O_3]$ (ppb)**	**AQI Equation**
Very Good	0 to 23	$0.6520 \times [O_3] + 0$
Good	24 to 50	$0.5800 \times [O_3] + 2.154$
Moderate	51 to 80	$0.5900 \times [O_3] + 2.1$
Poor	81 to 149	$0.7200 \times [O_3] - 8.37$
Very Poor	>149	$0.7200 \times [O_3] - 8.37$

4.0 STUDY RESULTS

The sampling results are summarized in Table D-1 of Appendix D, and are discussed below for each location. Although simultaneous results of TSP and PM_{10} are available, only the $PM_{2.5}$ results are presented in this report. The traffic volume data was provided by Roads and Transportation, Infrastructure Services, City of Greater Sudbury and is the most recently available.

4.1 Results by Location

Lasalle Blvd and Notre Dame Ave –August 4, pm:

This is a busy intersection with Average Annual Daily Traffic Volumes (AADTV) of over 50,000. It is located at the west end of Lasalle Blvd and consequently has a lot of the east-west traffic travelling on Lasalle Blvd. It is a major north-south artery for traffic from the “Valley” to the city downtown core. It also has a heavy traffic volume of heavy and light duty diesel vehicles. It is bounded to the northeast by a funeral home, to the southeast by the Revenue Canada Taxation Centre and to the northwest by a gasoline dispensing station and a Tim Horton’s outlet**.**

During the sampling period (14:00 to 17:00), the temperature varied from 28°C to 32°C under a mix of overcast skies and sunny skies with cloudy periods. The relative humidity levels varied from 20% to 59%. The barometric pressure was steady at 96.9 kPa. The winds were from the west at 4 to 7 km/h and at times gusting from about 11 to 13 km/h. The mobile sampling unit was located on the northwest corner of the intersection, a bit downwind of traffic from the west of the intersection (see photo, Figure C-1 in Appendix C).

The average $PM_{2.5}$ concentration for the sampling period was 9.8 $\mu g/m^3$, double the average of 4.7 $\mu g/m^3$ for measurements taken at the AQI station over the same time period. The average ground-level ozone concentration at the study site was about 41 parts per billion (ppb) which is slightly higher than the average of 38 ppb obtained for the data at the AQI site.

Based on the $PM_{2.5}$ measurements, the air quality was very good at the study site and at the AQI station with AQI sub-index values of 13 and 6 respectively. The air quality was determined to be good at both locations based on the ozone measurements.

Regent St and Paris St – August 9, am:

This intersection is located in the south end of the city and commonly known as the 'four corners'. It is an area with a significant number of commercial and shopping establishments (shopping mall, strip mall, offices, bank, restaurants, and gasoline refueling station). Although there is some heavy duty truck traffic, a significant portion of the traffic is from light duty vehicles due to the nature of the businesses in the area. The AADTV from a 2006 survey is in the order of 62,000 which qualifies it as the busiest intersection sampled in this study.

During the sampling period (07:00 to 10:00), the temperature varied from 18°C to 23°C. For about half the sampling period, a thick fog blanketed the area. The relative humidity was initially 74% and gradually decreased to 20% as the fog lifted. The conditions were quite stagnant with virtually no measurable wind. When the fog lifted, the wind was from the south southwest at less than 4 km/h. The barometric pressure remained at 97.3 kPa. The mobile sampling unit was located on the northeast corner of the intersection (see photo, Figure C-2 in Appendix C), and consequently downwind of the intersection with the light south southwest wind.

At relative humidity conditions above 70%, the GRIMM analyzer is likely overestimating the particulate concentrations. In fact, the $PM_{2.5}$ measurements were much higher than normal at the beginning of the sampling period, and also much higher than the measurements from the AQI station. As the fog lifted and the relative humidity decreased, the $PM_{2.5}$ concentrations dropped to more normal values. The last two hours of the sampling period, 08:00 to 10:00, probably had reliable hourly average values (20.2 and 15.6 $\mu g/m^3$). For the same hours, the AQI station reported concentrations of 7 and 8 $\mu g/m^3$. The hourly average ground-level ozone concentration at the site varied from 11 to 17 ppb, whereas they were surprisingly very low (2 to 5 ppb) at the AQI station. The fog and accompanying high humidity may have affected the ozone concentrations at the AQI station.

On the assumption that the data at both locations is valid, the air quality was good at the study site and very good at the AQI station based on the $PM_{2.5}$ results. The air quality was very good at both locations on the basis of the low ozone concentrations.

Regent St and Paris St – August 9, pm:

Sampling was also undertaken at that location in the afternoon, from 14:00 to 17:00. By that time, the skies were sunny, the relative humidity was steady at 20% and the temperature ranged from 29℃ to 32℃. The wind was more established from the south southwest but still light from 4 to 7 km/h.

The average $PM_{2.5}$ concentrations at the study location was 13.7 μg/m^3 compared to 7.7 μg/m^3 as measured at the AQI station. Hence the concentrations were lower than in the morning at the study site but essentially unchanged at the AQI station. The ozone concentrations were now essentially the same at both locations with 3-hour averages of 35 and 32 ppb. Hence the air quality was good at both locations based on the ozone results and good to very good due to the $PM_{2.5}$ values at the study site and the AQI station respectively.

Lasalle Blvd and Notre Dame Ave –August 10, am:

The following morning, air sampling was performed at the Lasalle Blvd and Notre Dame Ave from 06:00 to 09:00. The skies were clear, with no wind and with air temperatures from 18°C to 27°C. The relative humidity varied from 40% to 70%.

The $PM_{2.5}$ concentrations at the study decreased from 20.0 to 12.8 μg/m^3 as the sampling period progressed, resulting in a 3-hour average of 15.9 μg/m^3. Over the same period, the AQI station measured an average of 8.7 μg/m^3, almost half as much. The average ozone concentration was 20 ppb at the intersection compared to 6 ppb at the AQI station. Such a large differential is unusual and cannot be explained at this time. The ozone concentrations at the study site are what you would expect, while those at the AQI station are quite low. Overall, the air quality during that time was good to very good.

Paris St and Elm St – September 13, am:

This intersection has lighter traffic volumes with 2008 AADTV in the order of 45,000. It is the 'cross-roads' of the downtown city core. It has a larger fraction of light duty gasoline powered vehicles than on the Lasalle Blvd corridor due to commuters that work downtown and in the south end of the city where the hospitals and Laurentian University are located. Also, the Sudbury transit bus terminal is located on the southwest corner of the intersection and the downtown shopping mall is across the street on the northwest corner. A church occupies the northeast corner.

Sampling at that location was postponed to the end of the summer study period in an attempt to avoid the road construction project at the intersection which lasted all summer. The bulk of the construction activities had been completed by the time sampling was undertaken. The air sampling vehicle was parked on the southwest corner of the intersection. A photo of the sampling location is shown in Figure C-3, Appendix C.

The morning sampling period lasted from 06:00 to 09:00. The skies were mostly overcast with some clearing from time to time. The relative humidity varied from 39% to 57% and the air temperature from 12°C to 21°C.

At the study location, the average $PM_{2.5}$ concentration for the sampling period was 14.0 $\mu g/m^3$. The higher concentration (20.0 $\mu g/m^3$) from 06:00 to 07:00 was likely due to traffic emissions. The hourly average concentration decreased to 9.1 $\mu g/m^3$ between 08:00 to 09:00 possibly due to lower traffic emissions. The 3- hour average $PM_{2.5}$ concentration at the AQI station was much lower at 3 $\mu g/m^3$.

The average ground-level ozone concentration near the intersection was 15 ppb compared to 23 ppb at the AQI site. The lower concentrations at the study site can be explained by the scavenging of ozone by oxides of nitrogen from either the traffic emissions or emissions from the road construction equipment. This phenomenon was likely not present at the AQI site since it is removed from the impact of traffic emissions.

Paris St and Elm St – September 13, pm:

The afternoon sampling session lasted from 14:00 to 17:00. There was a mix of sun and cloud throughout the sampling period. The wind was persistently from the southwest at 6 to 13 km/h. The barometric pressure was steady at 96.7 kPa and the relative humidity was low at 20% to 30%.

The ozone concentrations near the intersection averaged about 20 ppb, while the concentrations reported from the AQI station were higher at 27 ppb. Again traffic emissions could be responsible for the lower ozone values at the study site.

The $PM_{2.5}$ levels near the intersection were considerably lower in the afternoon with a 3-hour average of 5.1 $\mu g/m^3$ compared to 14.0 $\mu g/m^3$ in the morning. The stronger winds during the afternoon could explain the increased dispersion of fine particulates. The $PM_{2.5}$ values at the AQI site were lower still in the afternoon with an average of 1.7 $\mu g/m^3$ compared to an average of 3.0 $\mu g/m^3$ in the morning. Hence in both the morning and afternoon, the $PM_{2.5}$ concentrations near the intersection were considerably higher than at the AQI station.

Nevertheless, the air quality was in the very good category at both locations based on $PM_{2.5}$ measurements, while it was very good at the study site and good at the AQI station based on the ozone data.

5.0 OBSERVATIONS

- During the brief monitoring periods of this study, the air quality was determined to be very good to good, based on ground-level ozone and $PM_{2.5}$ measurements. In the majority of cases, the ground-level ozone sub-index was highest and determined the overall air quality in accordance with the reporting system used by the MOE. On a province-wide basis, the frequency of smog alerts and episodes was much lower than normal in the summer of 2010.
- The maximum hourly ground-level ozone concentration measured in this study was 42 ppb, considerably less than the MOE criterion of 80 ppb.

- The maximum $PM_{2.5}$ concentration measured over a 3-hour period was 20.0 $\mu g/m^3$, which is considerably lower than the reference level of 45 $\mu g/m^3$ used by the MOE.
- The $PM_{2.5}$ concentrations measured at the study sites with a GRIMM model 107 analyzer were generally higher than those measured at the MOE AQI site, in several instances by more than a factor of two. The largest 3-hour average differential, 16 $\mu g/m^3$, was obtained at the Paris St and Regent St intersection in the morning of August 9th. However some of the data collected with the GRIMM analyzer during the first hours of sampling are suspect due to the presence of fog and high relative humidity. The next largest 3-hour differential was 11 $\mu g/m^3$ obtained in the morning of September 13th at the Paris St and Elm St intersection.
- There was more variability in the ground-level ozone measurements taken at the study sites compared with measurements at the MOE AQI site than in 2009. Three of the sampling periods had ozone concentrations higher at the study sites, while three sampling periods had higher concentrations at the AQI station. For the 3- hour sampling periods of this study, the largest differential was 14 ppb, considerably more than the maximum differential of 5 ppb in 2009.
- During at least one sampling period, the expected impact on $PM_{2.5}$ and ground level ozone concentrations from traffic emissions were noted.
- The results of this brief study suggest that the concentrations of $PM_{2.5}$ at street-level near busy intersections, at times can be substantially higher than measured at regional air quality monitoring stations. This is in agreement with the 2009 study findings.

The MOE records for the provincial air quality monitoring network indicate that in 2010 only three smog advisories covering 12 days were issued in Ontario. One of these advisories (May 31st to June 1st) was associated with forest fire impacts in eastern Ontario. Overall, this is among the lowest number of smog advisories issued by MOE over the past decade. The other two advisories were issued for the period July 3rd to July 8th and for the period August 29th to September 1st. During the air quality study reported here, there were no smog advisories issued for the City of Greater Sudbury and vicinity.

The MOE air quality expert[9] believes that there are several reasons for the cleaner air in Ontario in 2010:

- There have been significant emission reductions in both Canada and the U.S. (transportation sources, power plants, and large industries).
- Although there were hot temperatures in the summer, weather conditions favoured less smog formation in the U.S. and over Ontario.

[9] Personal communication with Dr. David Yap, Senior Scientific Advisor, Air Quality and Transboundary Science, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment

- June and July recorded above normal precipitation, and winds in general allowed for more dispersion.
- Transboundary flow of pollutants from the U.S. into Ontario was reduced, and in part reflected economic slowdown impacts.

6.0 RECOMMENDATIONS

- The results of this study are considered ‘snapshots in time’. It is recommended that additional sampling should be done, preferably under a broader range of meteorological conditions, especially those conducive to air quality in the moderate to poor range, for a better understanding of the concentrations of $PM_{2.5}$ and ground-level ozone measured at street-level compared to those from urban background AQI monitoring stations.
- Since the findings are very similar to those obtained in 2009, additional sampling using the same protocols is not recommended at this time.
- This type of study should be undertaken in two to three years from now to determine changes in local air quality. This should be done especially in areas where considerable differences in $PM_{2.5}$ concentrations were noted from measurements taken by the GRIMM analyzer and those reported from TEOM analyzers at the MOE AQI stations, and/or in areas of high pedestrian traffic where air quality is of concern. Such a study should include real-time measurements of carbon monoxide (CO) and oxides of nitrogen (NO_x) to better assess the impact of traffic emissions on air quality at street level locations.
- It is also recommended that, as much as possible, measurements of $PM_{2.5}$ and ozone be taken during some of the peak traffic times.

APPENDIX A

Ozone Analyzer Calibration Audit Report

Pollutant Calibration / Audit Sheet

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Station No.	Station Location	Audit Date
Rotek	SHOP	July 13, 2010

Instrument Make / Model	Instrument Serial Number	Instrument Range
2B Technologies OZONE Model 202	s/n 287	0 - 500 ppb

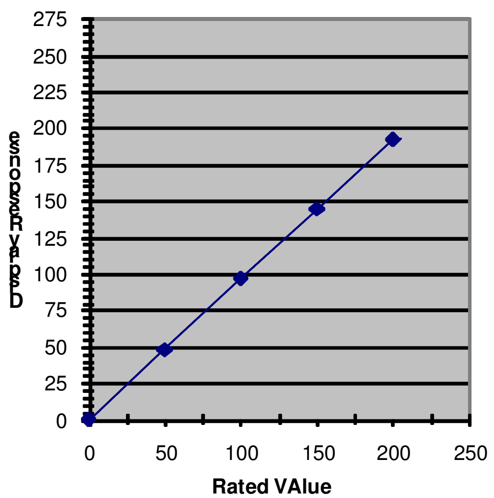
Calibrator Make / Model	Calibrator Serial Number
Environics 6103	3754

Client Company Name	Client Contact Name	Contact Number
Farrow Associates	Wayne Marshall	705 499 1418

Auditor Name	Auditor Contact Number	Auditor Signature
Ralph Frisina	905 573 9533	

Instrument Diagnostics and Response to Test Gases

Calibration Curve



Response to Audit / Calibration Gases. Values in PPB

Test Gas	Rated value	Display Response	% difference	Output Voltage	Instrument Reset
TG1	0.0	0.6	na	-----	no
TG2	50.0	48.6	-2.8	-----	no
TG3	100.0	96.6	-3.4	-----	no
TG4	150.0	144.3	-3.8	-----	no
TG5	200.0	192.0	-4.0	-----	no

stem Audit Results

Did data at the receiving terminal duplicate instrument displayed data?

n/a

Did data averages at receiving terminal duplicate generated averages?

Did not conduct data averaging test.

Audit Comments

Instrument required a zero adjustment from a setting of 2 - 7. RF

Instrument reproduces test gas values w ith a 3.4% - 4% deviation. RF

APPENDIX B

Photo of Ozone and $PM_{2.5}$ Analyzers

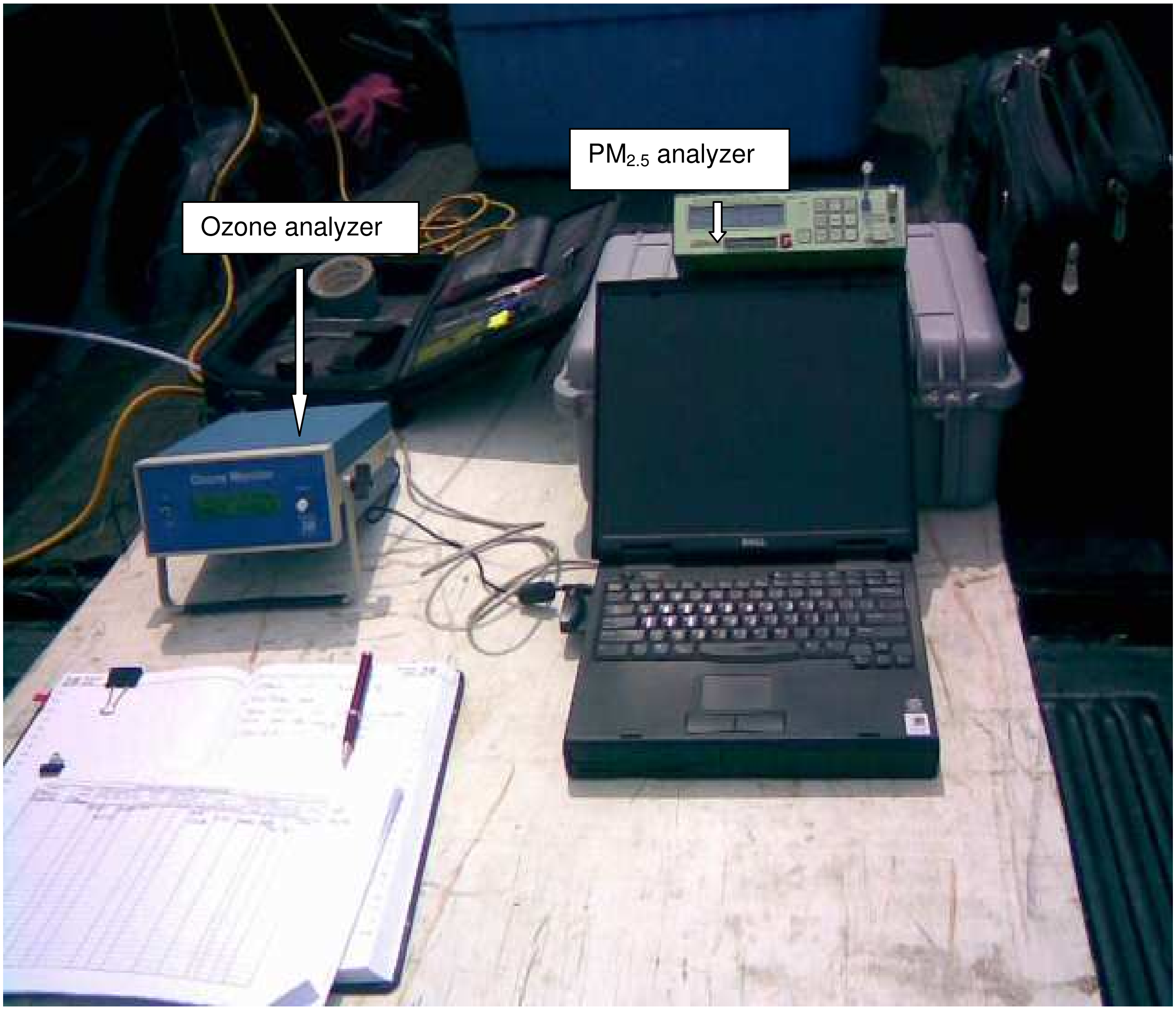


Figure B-1: Ozone and $PM_{2.5}$ Analyzers

APPENDIX C

Photos of Sampling Locations

Figure C-1: Lasalle Blvd and Notre Dame Ave – August 4, 2010 (N 46° 31’ 20”, W 80° 59’ 01”). Looking to the southeast

Figure C-2: Paris St and Regent St – August 9, 2010
(N 46° 27’ 07.4”, W 81° 00’ 12.5”). Looking to the southwest

Figure C-3: Paris St and Elm St – September 13, 2010 (N 46° 29’ 34.5”, W 80° 59’ 27.5”). Looking to the northeast

APPENDIX D

$PM_{2.5}$ and Ozone Study Results

Table D-1: $PM_{2.5}$ and Ground-Level Ozone Measurements in Greater Sudbury

Date (2010)	Location	Hour (EST)	$PM_{2.5}$ (µg/m^3)		Ozone (ppb)	
			ECO	MOE	ECO	MOE
August 4	Lasalle Blvd and Notre Dame Ave	14:00 to 15:00	9.9	6	40.9	35
		15:00 to 16:00	9.5	3	42.2	38
		16:00 to 17:00	9.9	5	41.1	40
		Average	9.8	4.7	41.4	37.7
August 9	Paris St and Regent St	07:00 to 08:00	32.9	6	11.9	2
		08:00 to 09:00	20.2	7	10.8	3
		09:00 to 10:00	15.6	8	16.9	5
		Average	22.9	7.0	13.2	3.3
August 9	Paris St and Regent St	14:00 to 15:00	13.9	8	31.7	30
		15:00 to 16:00	13.6	6	34.9	33
		16:00 to 17:00	13.7	9	37.0	33
		Average	13.7	7.7	34.5	32.0
August 10	Lasalle Blvd and Notre Dame Ave	06:00 to 07:00	20.0	7	6.6	6
		07:00 to 08:00	15.0	8	20.6	7
		08:00 to 09:00	12.8	11	30.3	6
		Average	15.9	8.7	20.2	6.3
September 13	Paris St and Elm St	06:00 to 07:00	20.0	3	11.1	25
		07:00 to 08:00	13.0	3	15.2	23
		08:00 to 09:00	9.1	3	19.9	21
		Average	14.0	3.0	15.4	23.0
September 13	Paris St and Elm St	14:00 to 15:00	7.6	2	18.9	29
		15:00 to 16:00	4.3	1	18.3	27
		16:00 to 17:00	3.3	2	21.4	25
		Average	5.1	1.7	19.5	27.0

Notes:
ECO: Data collected for the Environmental Commissioner's Office by Farrow Associates
MOE: Sampling hour defined as the hour ending

Smog advisories issued for Ontario by the ministry since 1995		
Year	Number of Advisories	Total Number of Days
1995	6	14
1996	3	5
1997	3	6
1998	3	8
1999	5	9
2000	3	4
2001	7	23
2002	10	27
2003	7	19
2004	8	20
2005	15	53
2006	6	17
2007	13	39
2008	8	17
2009	3	5
2010*	3	12

Table D-2

Table D-3: Smog Advisories Issued by the MOE in 2010

Air Quality Forecast Region	No. of advisories issued to 20-Dec	No. of advisory days to 20-Dec	Advisory #1		Advisory #2						Advisory #3			
			May 31	Jun 1	Jul 3	Jul 4	Jul 5	Jul 6	Jul 7	Jul 8	Aug 29	Aug 30	Aug 31	Sep 1
Algonquin	0	0												
Bancroft-Bon Echo	1	5				x	x	x	x	x				
Barrie-Orillia-Midland	1	4				x	x	x	x					
Belleville-Quinte-Northumberland	2	8				x	x	x	x	x		x	x	x
Brockville-Leeds and Grenville	1	2	x	x										
Burk's Falls Bayfield Inlet	0	0												
City of Hamilton	2	8				x	x	x	x	x		x	x	x
City of Ottawa	1	2	x	x										
City of Toronto	2	8				x	x	x	x	x		x	x	x
Cornwall-Morrisburg	1	2	x	x										
Dufferin-Innisfil	1	5				x	x	x	x	x				
Dunnville-Caledonia-Haldimand	2	8				x	x	x	x	x		x	x	x
Elgin	2	10			x	x	x	x	x	x	x	x	x	x
Elliot Lake-Ranger Lake	0	0												
Greater Sudbury and Vicinity	0	0												
Grey-Bruce	2	8				x	x	x	x		x	x	x	x
Haliburton	1	4				x	x	x	x					
Halton-Peel	2	8				x	x	x	x	x		x	x	x
Huron-Perth	2	10			x	x	x	x	x	x	x	x	x	x
Kingston-Prince Edward	2	8				x	x	x	x	x		x	x	x

Air Quality Forecast Region	**No. of advisories issued to 20-Dec**	**No. of advisory days to 20-Dec**	**Advisory #1**		**Advisory #2**						**Advisory #3**			
			May 31	**Jun 1**	**Jul 3**	**Jul 4**	**Jul 5**	**Jul 6**	**Jul 7**	**Jul 8**	**Aug 29**	**Aug 30**	**Aug 31**	**Sep 1**
London-Middlesex	2	9			x	x	x	x	x	x		x	x	x
Manitoulin-Northshore-Killarney	0	0												
Niagara	2	8				x	x	x	x	x		x	x	x
North Bay-West Nipissing	0	0												
Oxford-Brant	2	8				x	x	x	x	x		x	x	x
Parry Sound-Muskoka-Huntsville	1	4				x	x	x	x					
Peterborough-Kawartha Lakes	2	8				x	x	x	x	x		x	x	x
Prescott and Russell	1	2	x	x										
Renfrew-Pembroke-Barry's Bay	1	2	x	x										
Sarnia-Lambton	2	10			x	x	x	x	x	x	x	x	x	x
Sault Ste. Marie-Superior East	0	0												
Simcoe-Delhi-Norfolk	2	10			x	x	x	x	x	x	x	x	x	x
Smiths Falls-Lanark-Sharbot Lake	1	2	x	x										
Stirling-Tweed-South Frontenac	2	8				x	x	x	x	x		x	x	x
Waterloo-Wellington	2	8				x	x	x	x	x		x	x	x
Windsor-Essex-Chatham-Kent	2	10			x	x	x	x	x	x	x	x	x	x
York-Durham	2	8				x	x	x	x	x		x	x	x
ONTARIO	**3**	**12**	x	x	x	x	x	x	x	x	x	x	x	x