VOLATILE ORGANIC COMPOUNDS FROM AUTOMOTIVE MANUFACTURING

VOLATILE ORGANIC COMPOUNDS FROM AUTOMOBILE AND LIGHT DUTY TRUCK MANUFACTURING: A REVIEW OF BEST PRACTICES TO MEET REGULATORY REQUIREMENTS

By

DOUGLAS M. YATES, B.A.Sc, M.A.Sc, P.Eng.

A Project
Submitted to the School of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree
Master of Engineering

McMaster University

MASTER OF ENGINEERING (2005) McMaster University
(Civil Engineering) Hamilton, Ontario

TITLE: VOLATILE ORGANIC COMPOUNDS FROM AUTOMOBILE AND LIGHT DUTY TRUCK MANUFACTURING: A REVIEW OF BEST PRACTICES TO MEET REGULATORY REQUIREMENTS

AUTHOR: Douglas M. Yates, B.A.Sc, M.A.Sc, P.Eng. (McMaster University)

SUPERVISOR: Professor Brian Baetz, P.Eng.

NUMBER OF PAGES: xi, 80

ABSTRACT

Smog events continue to occur in Southern Ontario and maximum ground level ozone concentrations exceed the Canada Wide Standard (CWS). Ontario's automotive manufacturing sector, while perceived as a significant contributor to volatile organic compounds (VOC) emissions (an ozone precursor) at 10 kt per year, contributes only 1.5% of Ontario's 649 kt annual emissions.

Canada's current VOC guideline for automotive surface coating for new facilities at 55 g/m^2 is higher than Europe's new standard at 45 g/m^2 or Germany's at 35 g/m^2. However, Canada's VOC guideline for automotive surface coating for existing facilities at 55 g/m^2 is lower than Europe's standard at 60 g/m^2. Canadian auto manufacturers have made significant reductions since the early 1990's and are now achieving VOC emissions on average of approximately 36 g/m^2. General Motors (GM) new paint shop for its Oshawa Car Plant is expected to achieve VOC emissions of approximately 15 g/m^2 in 2006. Therefore, it can be concluded that through a combination of voluntary (Ontario's Anti Smog Action Plan – ASAP), regulatory (air permitting) and corporate initiatives (emission reduction objectives and common paint shop designs), Ontario's automotive manufacturers are achieving VOC emission performance found in the most stringent European jurisdiction (Germany), and with new installations (i.e. GM Oshawa Car) will approach the performance of US Environmental Protection Agency (EPA) Best Available Control Technology (BACT) standards.

Considering the above, it is recommended that the Ontario Ministry of the Environment should continue with its current approach of using the ASAP program and air permitting to control VOC emissions from Ontario's automotive manufacturers.

It is also recommended that the Ministry of the Environment consider, in consultation and cooperation with the Canadian Council of Ministers of the Environment (CCME) and the automotive manufacturing sector in Ontario, updating the New Source Performance Standards and Guidelines for the Reduction of VOC Emissions from Canadian Automotive Original Equipment Manufacturers (OEM) Coating Facilities to reflect the current performance of the Ontario automotive manufacturing sector.

ACKNOWLEDGEMENTS

I wish to acknowledge the tremendous support of Dr. Brian W. Baetz, Ph.D., P.Eng., Professor of Civil Engineering at McMaster University.

I also wish to acknowledge the support of Dr. R. M. Korol, Ph.D., P.Eng., Professor Emeritus at McMaster University, Dr. Frank Haberberger, GM Opel and Herr Ernst Sperling, GM Opel, Mr. Rusty Helm, GM, Mr. Bryan Swift, P.Eng., GM Canada and Ms. Tammy Giroux, GM Canada. Thanks to my family, Matt, Brock and Bonnie for their encouragement, patience and support.

This work is dedicated to the memory of Mrs. Olga Jaroslava Yates (Kandra).

LIST OF TERMS

ACS	Applied Coating Solids
APHEA	Air Pollution and Health – A European Approach Study
API	Air Pollution Index
AQCD	Air Quality Criteria Document
AQG	WHO Air Quality Guidelines
AQI	Air Quality Index
ASAP	Anti Smog Action Plan (Ontario)
BACT	Best Available Control Technology (US)
BAT	Best Available Techniques (Europe)
BATEA	Best Available Technology Economically Achievable (Canada)
BREF	Best Available Technology Reference Document
CAA	Clean Air Act (US)
CAFE	Clean Air for Europe
CCME	Canadian Council of Ministers of the Environment
CEPA	Canadian Environmental Protection Act, 1999
CFR	Code of Federal Registry (US)
CVMA	Canadian Vehicle Manufacturers Association
CWS	Canada Wide Standards
EC	Environment Canada
EPA	Environmental Protection Act (Ontario)
GM	General Motors
GMCL	General Motors of Canada Limited
HAPS	Hazardous Air Pollutants (US)
IMECA	The Metropolitan Index of the Quality of Air (Mexico)
LAER	Lowest Achievable Emission Rate (US)
LRTAP	Long-range Transboundary Air Pollution
MACT	Maximum Achievable Control Technology (US)
NAA	Non-Attainment Area (US)
NAAQO	National Ambient Air Quality Objective (Canada)
NAAQS	National Ambient Air Quality Standard (US)
NAFTA	North American Free Trade Agreement
NH_3	Ammonia
NMMAPS	US National Morbidity, Mortality and Air Pollution Study
NMVOC	Non-methane volatile organic compounds
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
NO_X	Nitrogen Oxides
NPRI	National Pollutant Release Inventory (Canada)
NSPS	New Source Performance Standard
O_3	Ozone
OAQPS	Office of Air Quality Planning and Standards (US)

OEM	Original Equipment Manufacturers
OMA	Ontario Medical Association
PEMA	Pollution Emission Management Area
PM	Particulate matter
PM_{10}	Fine particulates with an aerodynamic diameter of less than 10 μm
$PM_{2.5}$	Fine particulates with an aerodynamic diameter of less than 2.5 μm
PSD	Prevention of Significant Air Quality Deterioration
RBLC	RACT/BACT/LAER Clearinghouse (US)
RTO	Regenerative Thermal Oxidizer
SO_2	Sulphur dioxide
TEMM	Tripartite Environment Ministers Meeting (China, Korea, Japan)
TOMA	Tropospheric Ozone Management Area
UNECE	United Nations Economic Commission for Europe
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds
WHO	World Health Organization

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Introduction and Study Objectives

Smog, the mixture of air pollutants that can often be seen as a haze in the air, is considered to be a serious health concern by a number of jurisdictions around the world including Canada and Ontario.

The two main ingredients of smog are ground-level (or tropospheric) ozone and fine particulate matter. Ozone is created by the reaction of volatile organic compounds (VOC) and nitrogen oxides (NO_X) in the presence of sunlight. Particulate matter (PM) results from primary sources, such as dust, and from secondary sources created by the reactions of nitrogen oxides, sulphur oxides, volatile organic compounds and ammonia in the atmosphere. The following equations represent the associated governing relationships:

$$\textbf{Ozone + PM = Smog} \quad (1.1)$$

$$\textbf{VOC + NO}_\textbf{X}\textbf{ + Sunlight = Ozone} \quad (1.2)$$

The Province of Ontario is embarking on a program to assess VOC emissions from a number of industrial sectors with the intent of establishing a policy for further reduction. A significant source of anthropogenic VOC emissions is solvent use. Of particular interest to this study is the solvent use and resultant VOC emissions from the surface coating (painting) operations in the manufacture of automobiles and light duty trucks by original equipment manufacturers (OEM) in Ontario.

The objective of this project report is to briefly summarize the concern with smog and its precursors, to quantify the anthropogenic sources of VOC emissions including the contribution from the automotive manufacturing sector, and to summarize relevant regulatory and policy initiatives related to the control of emissions from the automotive manufacturing sector. Another objective is to identify and recommend best management practices that could be useful to the automotive sector and the Ontario Ministry of the Environment for the development of future policy.

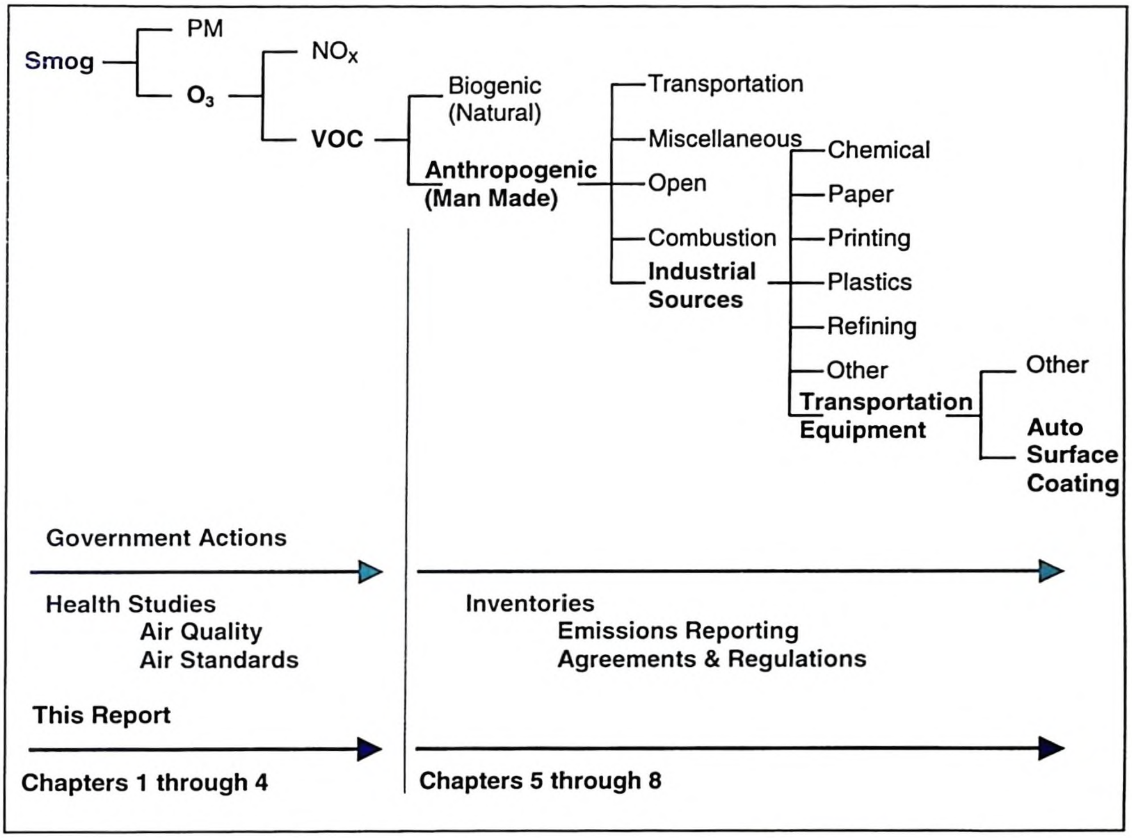
1.1 Structure of Report

This report is divided into eight sections. The first four sections discuss the history of smog and legislation, health impacts of smog, definition of VOC, air quality and air standards and include chapters: (1) Introduction, (2) Background and Literature Review, (3) Air Quality, and (4) Analysis of Regulatory Air Standards. The last four sections discuss the anthropogenic (manmade) sources of VOC emissions, automotive surface coating standards, the automotive sector and surface coating processes, emissions from surface coating, and surface coating best practices and include chapters: (5) Sources of VOC, (6) Analysis of Regulatory Standards Applied to Industry, (7) Automotive

Manufacturing Sector and Best VOC Management Practices, and (8) Summary, Conclusions and Recommendations.

Figure 1.1 provides a road map to the structure of this report.

Figure 1.1 Road Map for this Report



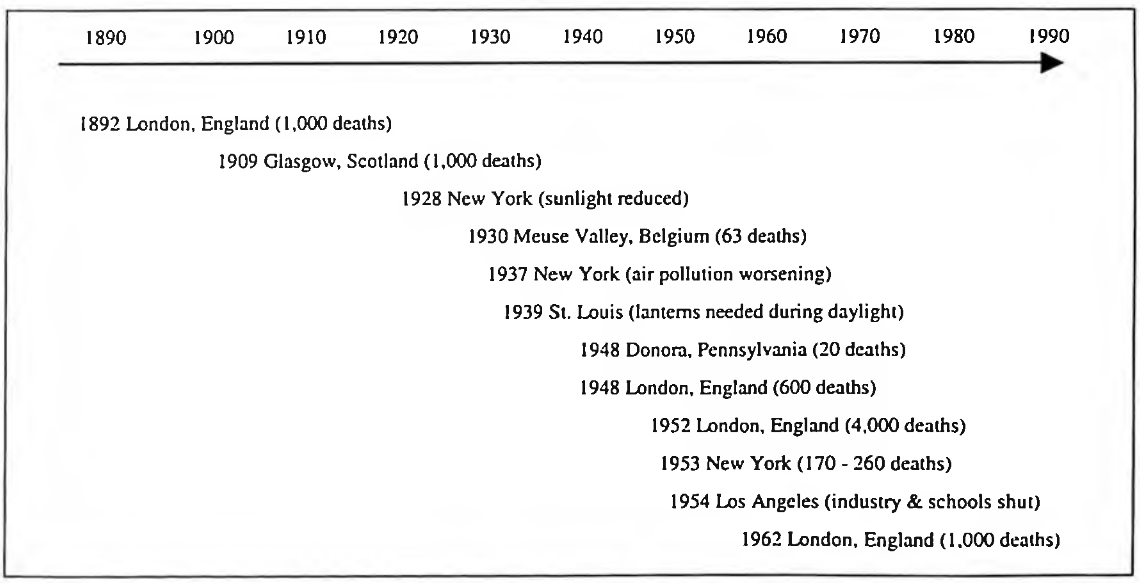
2 Background and Literature Review

This section will briefly review the history of significant smog events and their relationship to the development of significant historical regulatory initiatives. This section will also briefly review the health impacts of smog, in particular the health effects of its two main constituents: ozone and particulate. Finally, this section will provide definitions for volatile organic compounds, which are precursors to the formation of ozone. They are also recognized as a significant emission from the painting processes in the manufacture of automobiles and light duty trucks.

2.1 Brief History of Smog

The term "smog" was first used by H. A. Des Voeux in 1905 to describe the conditions of sooty fog (fog intensified by smoke) that occurred frequently over British urban areas. It was popularized in 1911 when Des Voeux presented a report to the Manchester Conference on deaths that occurred in Glasgow and Edinburgh in the fall of 1909 as a consequence of smoke-laden fogs (MetOffice, 2005), (Radford, 2005). Figure 2.1 provides the chronology of significant smog events (Radford, 2005).

Figure 2.1 Timeline of Significant Smog Events



The "Great Smog" of 1952 in London, England occurred one century after Charles Dickens used the term "London particular" in *Bleak House* (published in 1853) describing London's fogs (MetOffice, 2005).

...I asked him whether there was a great fire anywhere? For the streets were so full of ***dense brown smoke*** *that scarcely anything was to be seen.*

"Oh, dear no, miss," he said. "This is a ***London particular.****"*
I had never heard of such a thing.
"A fog, miss," said the young gentleman.
"Oh, indeed!" said I... (from Bleak House, Charles Dickens, 1853)

On Friday, December 5, 1952 the smog that covered London brought premature death to an estimated 4,000 people (MetOffice, 2005). While considered the most significant smog event, the smog of 1952 was not the first, nor the last.

Earlier smog events were often related to particulate matter and sulphurous emissions primarily from coal combustion. Modern smog events are related to particulate matter and photochemical reactions.

A report prepared for the City of Toronto estimates that approximately 1,700 premature deaths and between 3,000 and 6,000 hospital admissions each year are associated with air pollution related to smog (Pengelly, 2004).

2.2 Brief History of Legislation

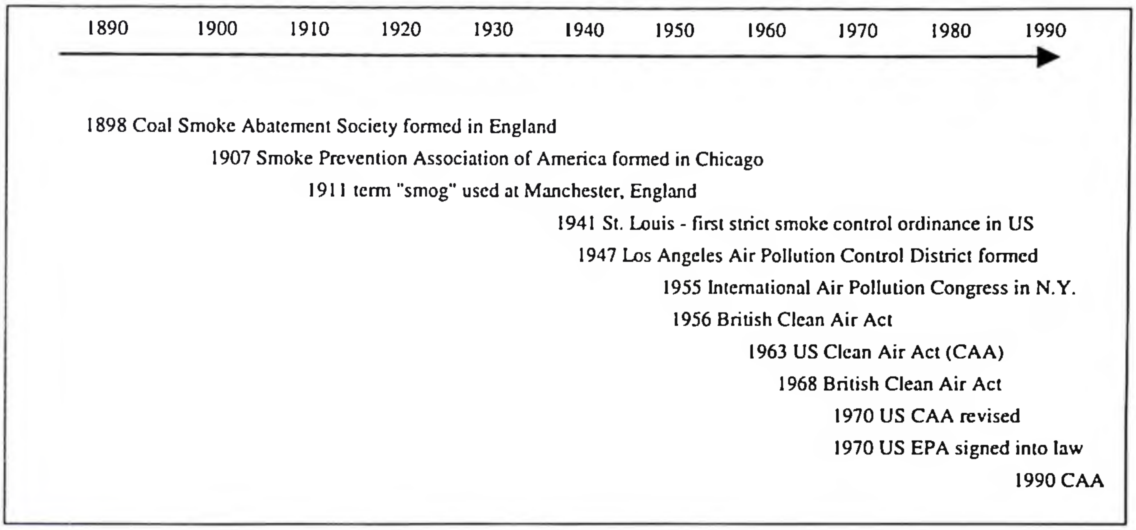
At the turn of the 20^{th} century "smoke abatement/prevention" societies/associations were formed in England and the United States of America (US). Following the Great Smog of 1952, the British Clean Air Act was established in 1956. The USA Clean Air Act was established in 1963.

The USA Environmental Protection Agency (EPA) was signed into law in 1970 and the USA Clean Air Act was significantly revised in 1990. Figure 2.2 provides the chronology of significant historical regulatory initiatives, many of which were in response to the smog events listed in Figure 2.1 (Radford, 2005).

Canada has also taken steps to address smog and its precursors. Canada signed the United Nations Economic Commission for Europe (UNECE) 1979 Geneva Convention on Long-range Transboundary Air Pollution (LRTAP), the UNECE 1991 Protocol concerning the Control of Emissions of Volatile Organic Compounds, and the UNECE 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone.

Canada has also signed the Air Quality Agreement (1991) and Ozone Annex (2000) with the US. The Canadian Environmental Protection Act (CEPA, 1999) has declared VOC, O_3, NO, NO_2, and particulate matter (PM_{10}) to be toxic, and Ontario's Anti-Smog Action Plan (ASAP) established in 1996 aims to have industry voluntarily reduce air pollutants that contribute to smog.

Figure 2.2 Timeline of Significant Regulatory Events



2.3 Health Impacts of Smog

There are numerous studies spanning several decades and many jurisdictions, which have linked health effects to poor air quality. Toxicological studies, controlled human exposure studies and epidemiological studies on the health effects of exposure to the constituents of smog (ozone, particulates and others), and increased mortality (premature deaths) and morbidity (illness and hospital admissions) have been cited in the body of work. This section will briefly summarize some of the current information available from the World Health Organization (WHO), Europe, the US and Canada.

2.3.1 World Health Organization

The World Health Organization (WHO) is the United Nations agency for health governed by the 192 member states (WHO, 2005). WHO research, publications and guidelines are a respected source of information on health issues including those related to air pollution.

Ozone: The WHO Air Quality Guideline (AQG) references a number of human clinical and epidemiological studies on the health effects of exposure to ozone, and it states that associations have been demonstrated between daily ozone levels and mortality and hospital admissions. A WHO working group established to review the most recent scientific evidence on the adverse health effects of particulate matter, ozone and nitrogen dioxide concluded that recent epidemiological studies have strengthened the evidence that there are short-term ozone effects on mortality and respiratory morbidity (WHO, 2003).

Particulates: The WHO concludes that "the weight of evidence from numerous epidemiological studies on short-term responses points clearly and consistently to associations between concentrations of particulate matter and adverse effects on human health at low levels of exposure commonly encountered in developed countries" (AQG, 2000). However, the AQG states that the available information for particulate matter does not allow a guideline value to be made below which no effect would be observed. The WHO working group concluded that fine particulate matter ($PM_{2.5}$) is strongly associated with mortality and hospital admissions and referenced the US National Morbidity, Mortality, and Air Pollution Study (NMMAPS) and the Air Pollution and Health a European Approach (APHEA) study, among other sources, as providing the scientific evidence (WHO, 2003).

2.3.2 Europe

A cost-benefit analysis for Clean Air for Europe (CAFE) has calculated the total health impacts for the 25 members of the European Union (EU25) for the baseline 2000 to 2020 (CAFE-CBA, 2005). The report studied the mortality and morbidity by ozone and particulates and is based on 1997 meteorological data.

Ozone: In 2000, approximately 21,000 premature deaths (acute) are estimated to have occurred in EU25 as a result of ozone concentrations (CAFE-CBA, 2005).

Particulates: In 2000, approximately 288,000 premature deaths (chronic) are estimated to have occurred in EU25 as a result of particulate concentrations. Particulate concentrations have a greater impact than ozone concentrations. Also, PM concentrations result in more cases of annual morbidity effects than ozone (CAFE-CBA, 2005).

2.3.3 United States

Ozone: The US EPA published an Air Quality Criteria Document (AQCD) for ozone in 1996 that provided the scientific basis for the current National Ambient Air Quality Standard (NAAQS) for ozone set in 1997. In January 2005, the US EPA published a revised AQCD (first external review draft) to take into account the large number of new scientific studies that have been conducted since 1996. The AQCD considered a large number of toxicological, controlled human exposure and epidemiological studies in their review. It referenced epidemiological studies conducted in the US, Canada, Europe, Asia, Latin America and Australia. The AQCD concludes that "the toxicology suggests that there is a plausible mechanism for the epidemiologic findings" and "the newly available epidemiological studies support the general conclusion that ozone is causally related to respiratory-related mortality and morbidity" (Ozone, 2005).

Particulates: The US EPA published an AQCD for particulate matter in 1996 that provided the scientific basis for the current NAAQS for particulate matter set in

1997. The AQCD was revised in October 2004 to take into account the large number of new scientific studies that have been conducted since 1996. On January 31, 2005, the US EPA Office of Air Quality Planning and Standards (OAQPS) published a draft Staff Paper, which evaluated the key studies and scientific information contained in the AQCD. The Staff Paper, considering the scientific evidence and associations between ambient concentrations of particulate matter, in particular fine particulates ($PM_{2.5}$), and mortality and hospital visits, recommends that the fine particulate NAAQS be lowered (Particulate, 2005).

2.3.4 Canada

Scientific studies indicate that there are significant health effects associated with particulate matter and ozone including chronic bronchitis, asthma, and premature deaths. Environmental effects include reduced visibility due to particulates and crop damage and greater vulnerability to disease in some tree species due to ozone.

The Canadian Government Order adding ozone and its precursors to the List of Toxic Substances in Schedule 1 of CEPA, 1999 states that "particulate matter and ground-level ozone are the main ingredients of smog and cause serious health effects for Canadians including thousands of premature deaths, hospital admissions and emergency room visits every year" (CanadaGazette, 2005).

Ozone: In 1998, ozone was identified as a priority for Canada Wide Standards (CWS). This resulted in the federal, provincial, and territorial health and environment departments agreeing that the Science Assessment Document would form the basis for the development of a CWS for ozone (NAAQO Ozone, 1999). The Science Assessment Document states that "there is sufficient evidence to conclude an association exists between ambient levels of ozone and human mortality, respiratory hospitalizations and several other health endpoints" (NAAQO, Ozone Science, 1999).

Particulates: The Science Assessment Document for particulates forms the basis for the CWS for particulate (NAAQO, Particulate 1999). The addendum to the Science Assessment Document states that "there is no clear evidence of a "threshold" level for the positive associations between particulate matter and both daily mortality and hospitalization rates. That is, any increase in ambient particulate matter is associated with a potential increase in mortality and hospitalization rates", and "the weight of evidence from the epidemiology studies indicates that exposures experienced by populations in developed countries are of sufficient adverse health consequences to have an impact on public health" (NAAQO PM Addendum, 1999).

A report prepared for Toronto Public Health estimates that approximately 1,700 non-traumatic mortalities and 3,000 to 6,000 excess hospital admissions are related to air pollution in Toronto each year (Pengelly, 2004).

2.4 Definition of Volatile Organic Compounds

The definition of VOC is somewhat dependent on the particular jurisdiction, as will be briefly discussed below.

2.4.1 Europe

The European Union (EU) defines VOC as "any organic compound having at 293.15°K a vapour pressure of 0.01 kPa or more, or having a corresponding volatility under the particular condition of use. For the purpose of the Directive, the fraction of creosote which exceeds this value of vapour pressure at 293.15°K shall be considered a VOC. Organic compound shall mean any compound containing at least the element carbon and one or more of hydrogen, halogens, oxygen, sulphur, phosphorus, silicon or nitrogen, with the exception of carbon dioxide and inorganic carbonates and bicarbonates" (1999/13/EC, 1999).

2.4.2 United States

The US EPA defines VOC as "any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions. This includes any such organic compound other than the following [for list see Appendix 1], which have been determined to have negligible photochemical reactivity" (EPA VOC, 2005).

2.4.3 Canada

Canada has added VOC to the List of Toxic Substances in Schedule 1 of CEPA, 1999 under subsection 90(1) of the Act published on June 9, 2001 and defines VOC as "volatile organic compounds that participate in atmospheric photochemical reactions, excluding the following [for list see Appendix 2]" (CEPA-Toxic, 2005).

The Canadian Council of Ministers of the Environment (CCME) defines VOC in their New Source Performance Standards and Guidelines for the Reduction of Volatile Organic Compound Emissions from Canadian Automotive OEM Coating Facilities as "any organic compound which participates in atmospheric photochemical reactions. That is, any organic compound other than the following [for list see Appendix 3] which have been excluded because of their negligible photochemical reactivity". It is important to note that acetone is also excluded (CCME, 1995).

Ontario defines VOC as "any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions and has a vapour pressure of 0.01 kPa or greater at 25°C [298°K]. The following compounds are not included as VOC because of their negligible photochemical reactivity [for list see Appendix 4]" (Reg.127, 2005).

2.5 Literature Review

An extensive review of literature was undertaken for the preparation of this report. Literature sources include government websites, corporate websites, and non-governmental organization websites, which are listed in the Reference section of this report. Since this area is dynamic and evolving, the literature review focused around website-related materials.

2.6 Summary

Smog (ground-level ozone and particulates) and smog precursors are considered by Canada and Ontario, as well as many other jurisdictions around the world, to be a serious health concern.

For the automotive manufacturing sector, VOC (a precursor to ozone) are generally recognized as any organic compound that participates in atmospheric photochemical reactions and that are found in paint formulations and related products, excluding methane and acetone. A common definition among jurisdictions would be helpful in ensuring consistent comparisons of VOC emissions and paint shop performance.

The following section will discuss current ambient air quality related issues.

3 Air Quality

Section 3 will discuss ambient ground level ozone concentrations (and to a much lesser degree particulate concentrations) found in Europe, Asia and North America. An analysis of regulatory ambient air standards will be discussed in Section 4.

To illustrate the visual effect of smog on air quality, Figures 3.1 and 3.2 demonstrate the difference between a clear day and a smog event (Particulate, 2005).

Figure 3.1 $PM_{2.5}$ = 2.5 μg/m^3

Figure 3.2 $PM_{2.5}$ = 65 μg/m^3

Regional air quality is measured and reported by many jurisdictions worldwide. Municipalities, regions and countries report on daily air quality (usually as an air quality index or air pollution index) as well as providing near real-time data, historical data and long-term trends for many if not all of the criteria air contaminants including ozone and particulates. The following sections briefly describe some of the data available in Europe, Asia and North America.

3.1 Europe

Smog Warners Data Exchange provides daily ozone maps with data provided by members of the European Environment Agency Technical Working Group on Data Exchange and Forecasting for Ozone Episodes in North-West Europe (Smog Warners, 2005). Maximum hourly ozone concentrations are indicated on the maps. Concentrations of ozone greater than 90 ppb are above the population information threshold, while concentrations greater than 120 ppb are above the population warning value.

The United Kingdom (UK) National Air Quality Information Archive provides hourly concentrations and daily maximums for monitoring stations located within sixteen regions (AirNow International, 2005), (UK Air Quality, 2005).

In Germany, current and historical air quality information on the five criteria air contaminants (O_3, PM, NO_X, SO_2 and CO) is provided by the German Länder and the Federal Environmental Agency (German Air Quality, 2005). The number of days of particulate matter and ozone exceedances at each station is also provided. Note that the PM_{10} maximum daily limit is 50 µg/m³ (24-hour average) and the limit may not be exceeded more than 35 days per year. The ozone maximum daily limit is 60 ppb (8-hour average).

3.2 Asia

China monitors air quality at 84 major cities. The highest pollution index reading of 451 for Beijing in 2004 occurred on February 19 and was due to PM_{10}, which corresponds to a concentration greater than 500 $\mu g/m^3$ (24-hour average) (AirNow International, 2005), (China, 2005). Hong Kong has 14 stations measuring ambient particulate matter (PM_{10}). The highest 24-hour PM_{10} reading was 257 $\mu g/m^3$ and the annual average was 81 $\mu g/m^3$ in 2003. Ozone is measured at 11 stations. The highest 1-hour value concentration was 303 $\mu g/m^3$ (151 ppb) in 2003. Most readings of ozone and particulate matter in 2003 met the Hong Kong's air quality criteria (AirNow International, 2005). Japan and Korea also provide near real-time air quality data (AirNow International, 2005), (Korea, 2005).

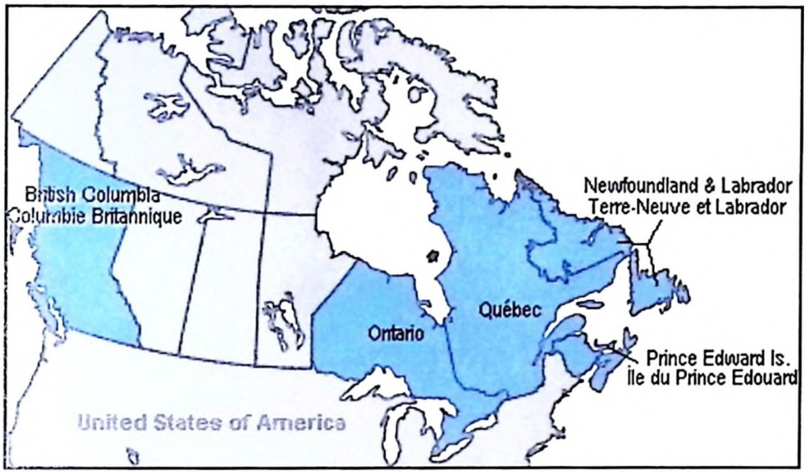
3.3 North America

In the US, a cross-agency government website (AirNow, 2005) provides current and historical air quality index information, ozone and particulate matter concentrations for each state, as well access to a number of webcams and descriptions of recent pollution episodes.

Air quality in the Mexico City Metropolitan Area is provided in near real-time for ozone and particulate matter. Maximum 1-hour ozone concentrations less than 216 $\mu g/m^3$ (110 ppb) and 24-hour PM_{10} concentrations less than 150 $\mu g/m^3$ represent good air quality (less than 100 IMECA units) (AirNow International, 2005) (Mexico, 2005).

Canada, in cooperation with US federal and state governments, can now produce maps of near real-time readings of ozone in Eastern Canada and Eastern US, Vancouver-Puget Sound and Western Canada and Western US on the AirNow website. "Canadian data are provided by participating provinces to Environment Canada's Meteorological Service of Canada, where they are collated and transferred to the US EPA in South Carolina, which creates the merged maps. Information on ozone levels in other provinces may be added later" (AirNow, 2005). Figure 3.3 shows the AirNow map available for Canada.

Figure 3.3 AirNow Map Archives for Canada



As an example of the data provided for Canada on the AirNow website, Figure 3.4 shows the peak ozone concentrations (in ppb) for Eastern Canada and the Eastern US for June 8, 2004 (AirNow, 2005).

The maximum ozone concentrations (1-hour average) in Southern Ontario were as high as 100 ppb. Particulate concentrations for Canada are not yet available on the website.

Figure 3.4 Peak Ozone Values for Eastern Canada and US for June 8, 2004

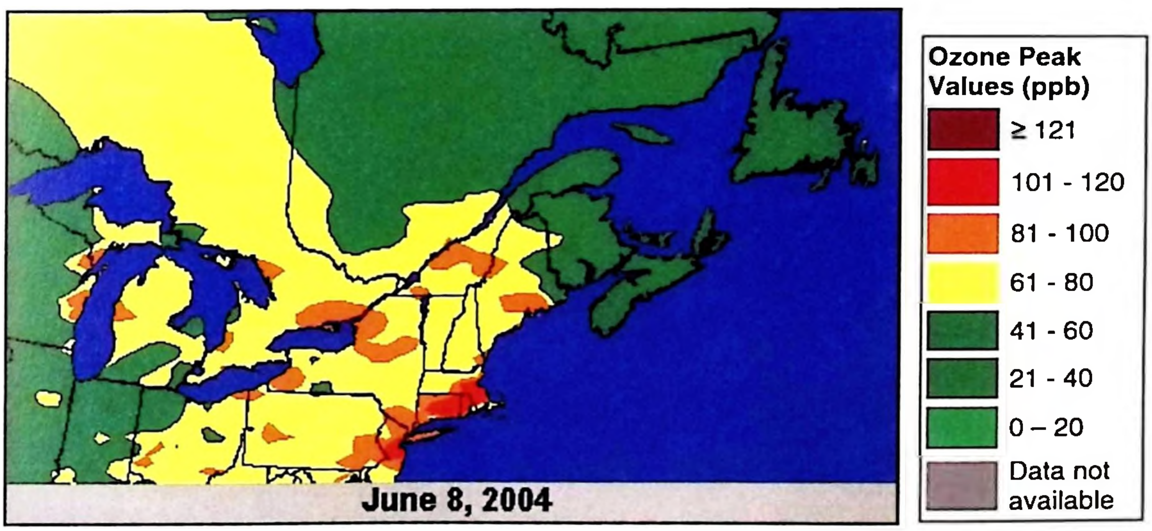


Figure 3.5 shows the Canadian and US 2002 fourth highest maximum daily 8-hour ozone concentrations and also shows the locations and density of air monitoring stations (Ozone Annex Review, 2004).

Figure 3.5 Canada - US Air Stations & Ozone Concentrations for 2002

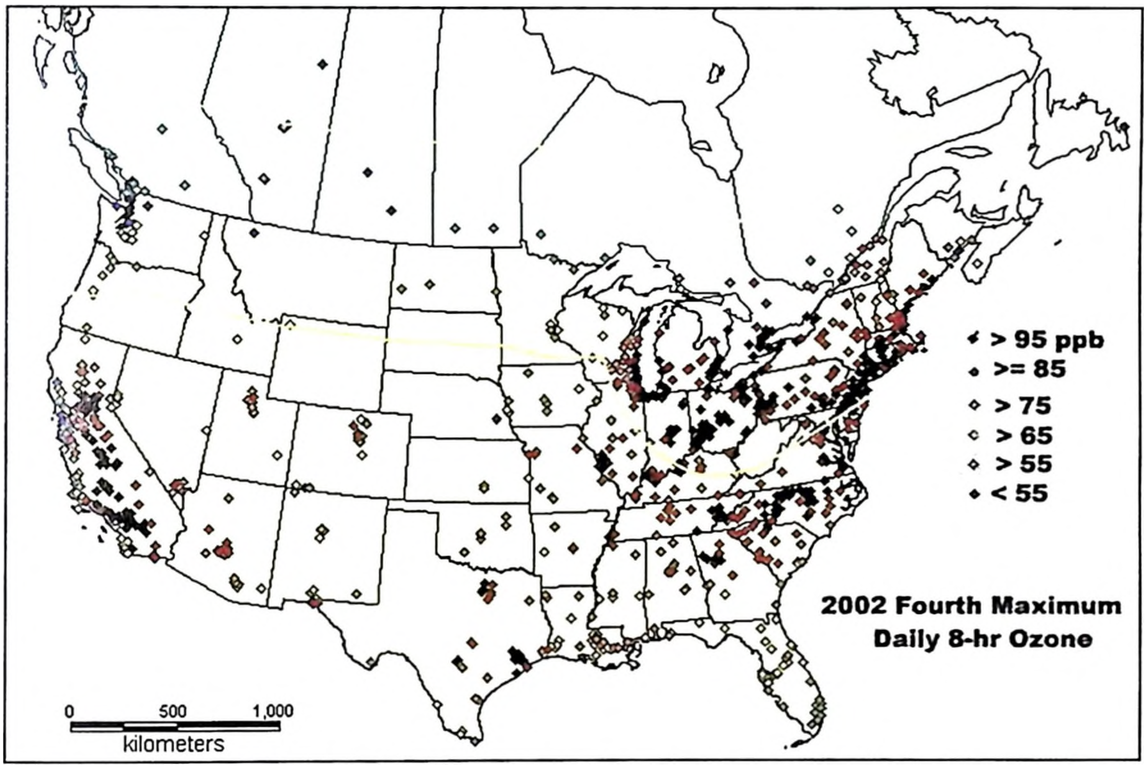
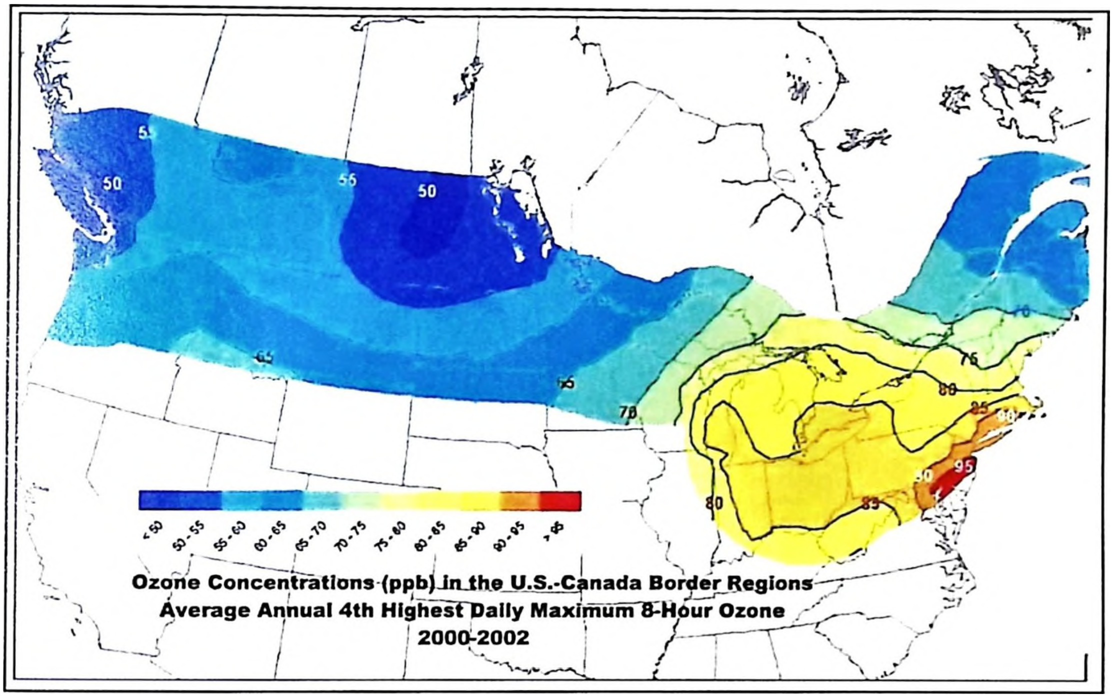


Figure 3.6 provides the same information as Figure 3.5 presented as ozone concentration contours, indicating that Southern Ontario was exposed to a fourth highest daily maximum 8-hour concentration of between 85–90 ppb (Ozone Annex Review, 2004).

Ozone concentrations within 500 km of the border have been trending between 60–70 ppb and 70–90 ppb at Canadian and US sites, respectively (annual 4th highest daily 8-hour average measurements between 1993 and 2002) (Ozone Annex Review, 2004).

Figure 3.6 Canada and US Ozone Concentrations (ppb) for 2002



In 2002, Canada had 69 measurement sites for $PM_{2.5}$. Of these, 27 recorded a 98th percentile daily maximum $PM_{2.5}$ concentration above 30 $\mu g/m^3$. The 98th percentile daily maximum $PM_{2.5}$ concentration in Ontario ranged from 23-41 $\mu g/m^3$ and 14 out of 21 measurement sites had 98th percentile concentrations greater than 30 $\mu g/m^3$ (PM-Ozone Report, 2004).

In 2002, Canada had 154 measurement sites for ozone. Of these, 84 recorded a 4th highest daily maximum 8-hour concentration of ozone that was above 65 ppb. Of the 84, 39 were recorded in Ontario. The 4th highest daily maximum 8-hour ozone concentrations in Ontario ranged from 59-108 ppb and 39 out of 41 measurement sites had the 4th highest daily maximum 8-hour concentrations greater than 65 ppb (PM-Ozone Report, 2004).

Ontario also provides near real-time and historical air quality information (Air Quality Index) for 32 locations, primarily cities located in Southern Ontario (Air Ontario, 2005). The Air Quality Index (AQI) is an indicator of air quality based on hourly pollutant measurements of some or all of the criteria air contaminants. A review of the data indicates that the predominant cause of the AQI readings are ozone concentrations followed by fine particulate ($PM_{2.5}$) concentrations.

3.4 Summary

Near real-time and historical air quality data are available in many jurisdictions in Europe, Asia, and North America. Air Quality Ontario (Air Ontario, 2005) provides near real-time and historical data. The website provides an Air Quality Index value and indicates which pollutant (ozone or particulate) is contributing to the reading. Air Now (AirNow, 2005) is a cross-agency US website that includes Environment Canada and the Ontario Ministry of the Environment as partner agencies. The website provides near real-time and historical ozone data for western and eastern Canada and the US.

A 2002 Canadian summary of ambient $PM_{2.5}$ and ozone concentrations reported that the 98^{th} percentile daily maximum $PM_{2.5}$ concentration in Ontario ranged from 23-41 $\mu g/m^3$, and that the 4^{th} highest daily maximum 8-hour ozone concentrations in Ontario ranged from 59-108 ppb (PM-Ozone Report, 2004).

Ambient air standards have been developed by government agencies in response to their concern regarding the health effects of smog and smog precursors discussed in Chapter 2, and the current ambient air concentrations of ozone and particulate matter discussed in this Chapter. An analysis of regulatory ambient air standards will be discussed in the next section.

4 Analysis of Regulatory Air Standards

This section will review selected ambient air standards in Europe, Asia, the US and Canada as they relate to ground-level ozone and particulate matter emissions. Sources of VOC emissions including those from the automobile and light duty truck manufacturing sector in Canada will be discussed in Section 5.

4.1 World Health Organization

The WHO Air Quality Guidelines are the international reference on the adverse health effects of exposure to different air pollutants. The ambient air AQG for ozone is 60 ppb based on an 8-hour average (AQG, 2000). The AQG states that the available information for particulate matter does not allow a guideline value to be made below which no effect would be observed; therefore, the AQG provides dose response values for particulate matter instead of an air standard.

4.2 The 1979 Geneva Convention on Long-range Transboundary Air Pollution

The United Nations Economic Commission for Europe (UNECE) 1979 Geneva Convention on Long-range Transboundary Air Pollution is the first international legally binding agreement to manage air pollution on a regional basis. The Convention is in response to environmental concerns of the 1960's and an emerging understanding of the relationship between sulphur emissions in continental Europe and the acidification of Scandinavian lakes. In the 1970's, several studies confirmed that air pollution could travel thousands of kilometers before deposition and damage occurred. The Convention entered into force in 1983 and has been ratified by 49 governments, including Canada and the US (LRTAP, 1979). According to Mr. Pierre Pinault, Transboundary Air Issues, Environment Canada, Canada's signing and ratification reflected Canada's early concern of sulphur emissions and acidification of lakes largely as a result of US air emissions and the Canadian Government's support for what was at the time primarily a European initiative (phone interview conducted on March 24, 2005). The LRTAP includes eight specific protocols:

1. The 1984 Protocol on Monitoring of Long-range Transmission of Air Pollutants
2. The 1985 Protocol on the Reduction of Sulphur Emissions by at least 30%
3. The 1988 Protocol concerning the Control of Nitrogen Oxides Fluxes
4. The 1991 Protocol concerning the Control of Emissions of VOC
5. The 1994 Protocol on Further Reduction of Sulphur Emissions
6. The 1998 Protocol on Heavy Metals
7. The 1998 Protocol on Persistent Organic Pollutants
8. The 1999 Protocol to Abate Acidification, Eutrophication & Ozone

The 1991 and 1999 Protocols which address VOC emissions and ground level ozone, respectively, will be discussed in more detail in the following sections.

4.2.1 The UNECE 1991 Protocol

This 1991 Protocol entered into force in September 1997. It has been signed by 23 governments, including Canada and the US, and has been ratified by 21 governments. Canada and the US have not ratified this protocol (VOC Protocol, 1991). Mr. Pierre Pinault, Transboundary Air Issues, Environment Canada, indicated that it is unlikely that Canada would ratify this protocol at this time (phone interview conducted on March 24, 2005). Difficulty in accurately establishing baseline VOC emissions and the current Air Quality Agreement with the US were cited as contributing reasons.

Note that this Protocol defines VOC as "all organic compounds of anthropogenic nature, other than methane, that are capable of producing photochemical oxidants by reactions with nitrogen oxides in the presence of sunlight." Note, under this definition, VOC are often referred to as non-methane VOC or NMVOC.

The Protocol calls for the "control and reduction of VOC emissions in order to reduce transboundary fluxes and the fluxes of the resulting secondary photochemical oxidant products so as to protect human health and the environment from adverse effects" (VOC Protocol, 1991). In order to meet these requirements, the Protocol states that each Party shall control and reduce its national annual emissions of VOC in any one of the following three ways:

1. Reduce national annual emissions of VOC by at least 30% by 1999, using 1988 as a base or any other annual level between 1984 and 1990 (selected by US).
2. The same reduction as (1) within a Tropospheric Ozone Management Area (TOMA) and ensuring that by 1999 total national emissions do not exceed 1988 levels (selected by Canada).
3. Where emissions in 1988 did not exceed certain levels, Parties may opt for stabilization at that level of emission by 1999.

Note that Canada has identified the Lower Fraser Valley in British Columbia and the Windsor-Quebec Corridor as Tropospheric Ozone Management Areas or TOMAs.

4.2.2 The UNECE 1999 Protocol

The 1999 Protocol was adopted on November 30, 1999 (Ozone Protocol, 1999). It has been signed by 31 governments, including Canada and the US, and it has been ratified by 14 governments (it has not been ratified by Canada). With the ratification by the US on December 3, 2004, the Protocol is only two ratifications away from coming into force. Mr. Pierre Pinault, Transboundary Air Issues, Environment Canada, indicated that it is likely that Canada will ratify this protocol within a few years (phone interview conducted on March 24, 2005). The objective of the Protocol is to control and reduce emissions of sulphur, NO_X, VOC and ammonia that are caused by anthropogenic activities and are likely to cause adverse effects on human health, natural ecosystems, materials and crops.

Note that the 1999 Protocol states that the critical level of ozone for human health is represented by the WHO Air Quality Guideline (60 ppb, 8-hour average), for Canada critical levels are identified as per the CWS for ozone (65 ppb, 8-hour average, to be met by 2010) and for the US critical levels are identified as per the NAAQS for ozone (80 ppb, 8-hour average and 120 ppb, 1-hour average).

4.3 European Union (EC) Air Quality

European Union (EU) environmental law on air pollution is divided into three categories: air quality, motor vehicles and industry. The following selected environmental laws on air quality (directives and communications) are presented below:

- Directive 96/62/EC ambient air quality assessment and management
- Directive 1999/30/EC relating to limit values for SO_2, NO_2, NO_X, PM and lead
- Directive 00/69/EC relating to limits on carbon monoxide and benzene
- Directive 2002/3/EC relating to ozone in ambient air
- COM/2001/0245 Clean Air for Europe (CAFE) Programme
- Directive 2001/81/EC national emission ceilings

Directives 96/62/EC, 1999/30/EC, 2002/3/EC, COM/2001/0245, and 2001/81/EC will be briefly discussed in the following sections.

4.3.1 Directive 96/62/EC

This directive is the enabling legislation that establishes the basic principles that make it possible to set ambient air quality objectives, establishes common methods and criteria for assessing air quality, and provides for the collection and dissemination of information on air quality (96/62/EC, 1996). The directive requires that the European parliament establish limit values and alert thresholds for specified pollutants. The objectives of the directive are established through “daughter” directives, two of which are discussed below.

4.3.2 Directive 1999/30/EC

This is the first "daughter" directive of 96/62/EC; it establishes ambient air limits for SO_2, NO_2, PM_{10} and lead (1999/30/EC, 1999). The PM_{10} concentration limit is 50 $\mu g/m^3$, (24-hour) not to be exceeded more than 35 times per year and 40 $\mu g/m^3$ (annual average).

4.3.3 Directive 2002/3/EC

This is the third "daughter" directive of 96/62/EC; it sets an ozone concentration target value for 2010 (60 ppb, 8-hour) not to be exceeded on more than 25 days per calendar year averaged over three years. The directive also sets an information threshold (90 ppb, 1-hour) and an alert threshold (120 ppb, 1-hour) for ambient air concentrations of ozone (2002/3/EC, 2002). The long-term objective in this directive is to comply with the WHO guidelines for ozone. Where target values are not met, member states must develop action plans to reduce ozone concentrations in ambient air.

4.3.4 COM/2001/0245

The Clean Air for Europe (CAFE, 2001) program establishes a long-term, integrated strategy to address air pollution and to protect against its effects on human health and the environment. The CAFE program will focus on particulate matter and ground level ozone.

4.3.5 Directive 2001/81/EC

This directive sets national emission ceilings for SO_2, NO_X, VOC and NH_3 to be achieved by the end of 2010 (NEC, 2001). The overriding objective is to reduce ground-level ozone and acidification by reaching the ceiling values. Total VOC emissions from the EU15 member states must be reduced from 1990 levels of approximately 14.5 million tonnes to 6.5 million tonnes by 2010. Each EU15 member state is assigned a VOC emission ceiling to be attained by 2010. For example, Germany's ceiling VOC emission limit is 0.995 million tonnes in 2010. The directive also provides ceiling values for the new members to the EU.

4.4 Canada - US Air Quality Agreement (1991)

Canada and the US signed the Air Quality Agreement on March 13, 1991 (AQA, 1991), (CAN-US, 2005). The purpose of the Agreement is to establish a practical instrument to address shared concerns regarding transboundary air pollution. The object is to control transboundary air pollution. Annex 1 of the Agreement sets specific reduction objectives for SO_2 and NO_X emissions from stationary and mobile sources. This Annex also sets requirements for both countries to prevent air quality deterioration and to protect visibility, particularly in parks. In Annex 2 of the Agreement, both countries agree to coordinate their air pollution monitoring activities and they agree to cooperate and exchange information.

4.4.1 Ozone Annex to the Air Quality Agreement (2000)

In 2000 Canada and the US amended the Air Quality Agreement (Ozone Annex, 2000) to include for the reduction of the transboundary flow of tropospheric ozone and precursor emissions (NO_X and VOC). A new Annex 3 was added to the Agreement, which included specific objectives for the control and reduction in anthropogenic emissions of NO_X and VOC from mobile and stationary sources in both countries. The long-term goal of the Annex is that ozone concentrations in ambient air not exceed the Canada Wide Standard (CWS) and the US National Ambient Air Quality Standards (NAAQS) for ozone.

Each country designated a Pollution Emission Management Area (PEMA) to which the requirements of the Annex would apply. For Canada the PEMA extends from the east shore of Lake Superior to Quebec City. For the USA the PEMA extends from Wisconsin in the mid-west to Kentucky in the south to the northeast coast (Figure 4.1) (Canadian Progress, 2004).

Figure 4.1 Canada and US – Pollution Emission Management Area (PEMA)

The Canadian PEMA includes central and southern Ontario and southern Quebec and represents approximately 50% of the population of Canada. The US PEMA includes 18 states and the District of Columbia and represents approximately 40% of the population of the US. The Canadian PEMA is very similar to the Windsor-Quebec corridor TOMAs established under the UNECE 1991 Protocol.

4.4.2 The US Clean Air Act

The Clean Air Act (CAA) was passed in 1963 and revised in 1970 to include a national air pollution control program. The most significant amendments occurred in 1990, which are referred to as the 1990 Clean Air Act (CAA, 1990). The amendments addressed "three major threats to the nation's environment and to the health of millions of Americans: acid rain, urban air pollution, and toxic air emissions" and also established a national permitting program and improved enforcement (CAA, 1990). The CAA requires EPA to set NAAQS, which it has done for six principal criteria air pollutants - ozone, particulate matter, carbon monoxide, sulfur dioxide, nitrogen oxides, and lead (NAAQS, 2005). The ozone and particulate standards are discussed below.

The 8-hour NAAQS for ozone is 80 ppb. To achieve this standard, the 3-year average of the 4^{th} highest daily maximum 8-hour average ozone concentration at each monitor must not exceed 80 ppb. The 1-hour NAAQS for ozone is 120 ppb. Note that the 1-hour standard will not apply to an area one year after the effective date of the designation of that area for the 8-hour ozone NAAQS. The 24-hour $PM_{2.5}$ NAAQS is 65 $\mu g/m^3$. To achieve this standard, the 3-year average of the 98^{th} percentile of 24-hour concentrations at each monitor must not exceed 65 $\mu g/m^3$. The annual average $PM_{2.5}$ NAAQS is 15 $\mu g/m^3$. To achieve this standard, the 3-year arithmetic mean concentration must not exceed 15 $\mu g/m^3$. The 24-hour PM_{10} NAAQS is 150 $\mu g/m^3$. The annual average PM_{10} NAAQS is 50 $\mu g/m^3$.

4.4.3 National Ambient Air Quality Objectives & Canada Wide Standards

The Canadian National Ambient Air Quality Objective (NAAQO) for ozone of 82 ppb, 1-hour average, was established in 1976 and confirmed in 1989. The NAAQO for total suspended particulate is 70 and 120 $\mu g/m^3$, based on annual and 24-hour averages, respectively. In January 1998, the CCME (with the exception of Quebec) signed the Canada-Wide Accord on Environmental Harmonization and Canada-Wide Standards. The Environment Ministers made a decision that air standards will be developed through NAAQO or CWS, not both. As a result, future development of ozone and particulate matter standards will be through the CWS process.

In June 2000, the federal, provincial and territorial governments, except Quebec, signed the CWS for particulate matter and ozone (CWS, 2005). For fine particulate matter ($PM_{2.5}$) the CWS is 30 $\mu g/m^3$, 24-hour averaging time, based on the 98^{th} percentile annual ambient measurement, averaged over 3 consecutive years, to be achieved by 2010. For ozone, the CWS is 65 ppb, 8-hour averaging time, based on the 4^{th} highest annual ambient measurement, averaged over 3 consecutive years, to be achieved by 2010.

4.4.4 Ontario Anti Smog Action Plan (ASAP)

Under the Anti Smog Action Plan (ASAP), Ontario has made a commitment to reduce provincial emissions of NO_X and VOC by 45% by 2015, from 1990 baseline levels (ASAP, 2002). This reduction in NO_X and VOC is required in order to achieve a 75% reduction in the number of ozone exceedances of Ontario's 1-hour ozone ambient air quality criteria (AAQC) of 80 ppb. Ontario is assuming comparable US reductions of NO_X and VOC to be achieved through the Ozone Annex. Reductions in sulphur dioxide as part of the Countdown Acid Rain program are also included in the ASAP, as well as a 10% reduction target for particulate emissions by 2015, from 1990 baseline levels.

The aim of ASAP is to achieve these reductions (summarized in Table 4.1) through voluntary actions taken by industry.

It is important to note that under the CWS, Ontario has accepted that the 45% reduction in VOC emissions will be achieved by 2010 subject to successful negotiations with the US for similar reductions, and that this will represent Ontario's efforts towards achieving the CWS for ozone. Remaining ambient ozone concentrations above the CWS will be considered attributable to the transboundary flow from the US, which will be the responsibility for Canada to address through bilateral negotiations.

Table 4.1 ASAP Reduction Targets by 2015 from 1990 Levels

NOx	VOC	SO_2	PM
45%	45%	50%	10%

4.5 Summary

Ambient air standards have been developed by government agencies in response to the health effects of smog and smog precursors discussed in Chapter 2 and ambient concentrations of ozone and particulate matter discussed in Chapter 3. In this Chapter, an analysis of various regulatory ambient air standards has been presented and is summarized below.

The European Union has established Directives for air quality including particulate matter standards and target values for ozone concentrations with the long-term objective to meet WHO air quality guidelines and national emission ceilings for VOC emissions by 2010.

Canada and the US amended the Air Quality Agreement (Ozone Annex, 2000) to include the reduction in the transboundary flow of ozone and precursor emissions (NO_X and VOC). The US Clean Air Act is the enabling legislation that establishes National Ambient Air Quality Standards (NAAQS) for criteria contaminants including ozone and particulate matter. The Canadian Council of Ministers of the Environment (CCME) has endorsed the Canada Wide Standards (CWS) for ozone and PM_{10} to be achieved by 2010. The Ontario Ministry of the Environment's Anti Smog Action Plan (ASAP) established a 45% reduction target for VOC emission by 2015 from 1990 levels and seeks to achieve these targets through the voluntary action of industrial emitters.

A review of ozone and particulate ambient air standards for a number of jurisdictions in Europe, Asia and North America is provided in Appendix 5 and summarized below:

- 1-hour ozone standards range from 60 ppb (Japan, and China residential areas) to 120 ppb (US and Hong Kong). Canada and Ontario's 1-hour ozone standards are 82 and 80 ppb, respectively.
- 8-hour ozone standards range from 60 ppb (WHO, EU target, Japan, and China residential areas) to 80 ppb (US and Mexico). Canada's 8-hour ozone standard is 65 ppb (to be achieved by 2010).
- Of the jurisdictions studied, there are two 24-hour $PM_{2.5}$ standards, the US at 65 $\mu g/m^3$ and Canada's at 30 $\mu g/m^3$ (to be achieved by 2010). [The US is the only jurisdiction (of those researched) that has an annual $PM_{2.5}$ standard at 15 $\mu g/m^3$.] (Mexico has proposed the same 24-hour and annual $PM_{2.5}$ standards as the US).
- 24-hour PM_{10} standards range from 50 $\mu g/m^3$ (EU, and China residential areas) to 250 $\mu g/m^3$ (China industrial areas). Canada and Ontario's PM standard is 120 $\mu g/m^3$ for total suspended particulates.
- Annual PM_{10} standards range from 40 $\mu g/m^3$ (EU and China residential areas) to 150 $\mu g/m^3$ (China industrial areas). Canada and Ontario's PM standards are 70 and 60 $\mu g/m^3$ respectively for total suspended particulates. Japan is the only jurisdiction (of those researched) with a 1-hour PM_{10} standard of 200 $\mu g/m^3$.

It is important to note that there is a continuous process, particularly in Europe and North America, of collecting data on ambient concentrations of PM and ozone, reviewing new science on health effects, setting policy and revising air standards as required.

A review of the 2002 Canadian summary of ambient $PM_{2.5}$ and ozone concentrations, reported in Chapter 3, indicates that daily maximum $PM_{2.5}$ concentrations in Ontario exceed the 24-hour $PM_{2.5}$ standard of 30 $\mu g/m^3$ (the Ontario range was 23-41 $\mu g/m^3$), and that the 8-hour ozone concentrations exceed the 8-hour ozone standard of 65 ppb (the Ontario range was 59-108 ppb). However, it is important to note that the Canadian particulate and ozone standards are to be achieved by 2010. The next section will discuss the sources of VOC emissions.

5 Sources of Volatile Organic Compounds

Sources of VOC emissions in US, Canada and Ontario including VOC emissions from Ontario's automobile and light duty truck manufacturing sector will be discussed in this section.

5.1 Canada - US

VOC emissions for Canada and the US presented at the Canada-US Air Quality Agreement Ozone Annex Review for 2002 are shown in Figures 5.1 and 5.2 (Ozone Annex Review, 2004), (CAN-US, 2005). In the US, VOC emissions from solvent use are approximately 4.2 million tonnes out of a total of 15.2 million tonnes of VOC released. In Canada, VOC emissions from solvent use are approximately 0.47 million tonnes out of a total of 2.7 million tonnes of VOC released. The most significant difference between Canada and the US is that in Canada most of the VOC emissions are from the industrial sector. Industrial sources contribute approximately 1.4 million tonnes of VOC emissions in the US (9%) and 1.0 million tonnes of VOC emissions in Canada (37%). This is the result of the proportionally higher contribution of VOC from upstream oil and gas production in Canada, which accounts for approximately 75% of Canada's industrial total.

Figure 5.1 2002 US VOC Emissions

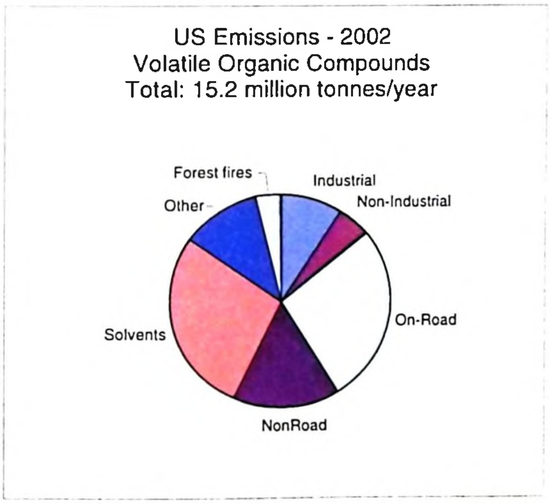
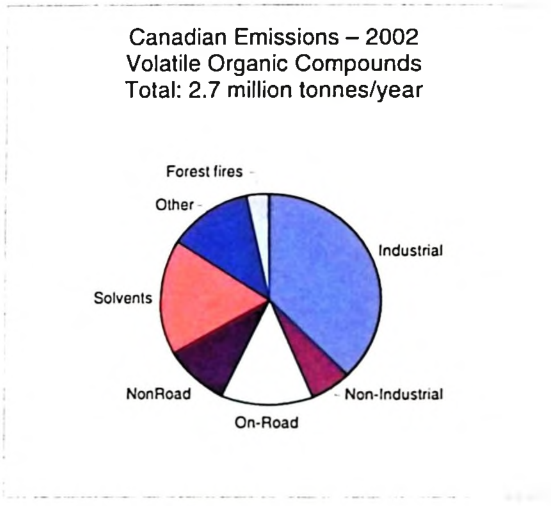
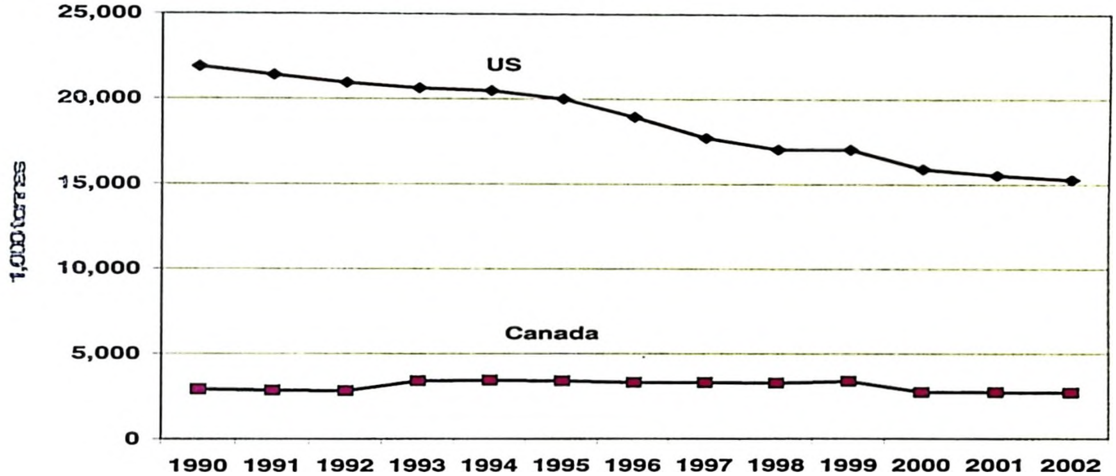


Figure 5.2 2002 Canadian VOC Emissions



In the US, VOC emissions have been trending down from a value of 21.9 million tonnes released in 1990 to a value of 15.2 million tonnes in 2002. Canadian VOC emissions have remained steady at just under 3 million tonnes released per year (Figure 5.3) (Ozone Annex Review, 2004).

Figure 5.3 Canada – US VOC Emissions Trend



5.2 Canada - Ontario

Under the Ozone Annex of the Canada-US Air Quality Agreement, each country designated a Pollution Emission Management Area (PEMA) to which the provisions of the Annex apply (see Figure 4.1).

Of the approximately 2.61 million tonnes of anthropogenic VOC released in Canada in 2002 (forest fires contribute approximately 88,000 tonnes), the Canadian PEMA (southern Ontario and southern portions of Quebec) contributed 0.973 million tonnes and are forecast to be 35% lower than 1990 levels by 2010 (Table 5.1) (Canadian Progress, 2004).

It is of interest to note that the biogenic (natural) VOC emissions for Canada are estimated to be 14.682 million tonnes released in 2000, which is significantly more than the anthropogenic sources (EC VOC, 2005).

Table 5.1 Canadian PEMA VOC Emissions[1]

	PEMA VOC Emissions (ktonnes)				% Change	
Sector/Year	**1990**	**2002**	**2007**	**2010**	**1990 to 2007**	**1990 to 2010**
Industrial sources	180.4	154.4	130.8	132.2	-27%	-27%
Non industrial fuel combustion	216.2	129.8	130.5	132.0	-40%	-39%
Electric Power Generation	0.8	0.8	0.8	0.8	-7%	-7%
On-road transportation	350.7	157.5	103.9	83.3	-70%	-76%
Non-road Transportation	156.9	156.7	147.6	139.6	-6%	-11%
Solvent Utilization	352.2	299.9	298.8	300.2	-15%	-15%
Other Anthropogenic Sources	70.0	74.0	76.4	77.4	9%	10%
Forest Fires	0.0	0.0	0.0	0.0	-	-
TOTAL	1,327	973	889	866	-33%	-35%
Total w/o Forest Fires	1,327	973	889	866	-33%	-35%

In 2002, VOC emissions in the Ontario portion of the Canadian PEMA were 0.651 million tonnes and are forecasted to be 36% lower than 1990 levels by 2010 (Table 5.2) (Canadian Progress, 2004).

Table 5.2 Ontario PEMA VOC Emissions[1]

	ON PEMA VOC Emissions (ktonnes)				% Change	
Sector/Year	**1990**	**2002**	**2007**	**2010**	**1990 to 2007**	**1990 to 2010**
Industrial sources	135.9	103.6	75.8	75.2	-44%	-45%
Non industrial fuel combustion	118.2	80.4	80.4	80.4	-32%	-32%
Electric Power Generation	0.8	0.8	0.8	0.8	0%	0%
On-road transportation	225.5	90.8	58.7	47.1	-74%	-79%
Non-road Transportation	103.8	104.9	98.1	92.7	-6%	-11%
Solvent Utilization	248.4	231.1	226.3	226.3	-9%	-9%
Other Anthropogenic Sources	39.6	39.4	39.8	39.8	0%	0%
Forest Fires	0.0	0.0	0.0	0.0	-	-
TOTAL	872	651	580	562	-34%	-36%
Total w/o Forest Fires	872	651	580	562	-34%	-36%

VOC emissions for Canada, published by Environment Canada (EC) in their December 2004 report on Criteria Air Contaminant Emissions (CAC, 2004) were 2.75 million tonnes in 2000, just slightly greater than the 2002 VOC emission total for Canada of 2.7 million tonnes (Table 5.3). Industrial emissions of VOC accounted for 0.99 million tonnes, almost identical to the 2002 releases. Note that upstream oil and gas accounted

[1] Note: "Source is Environment Canada - Pollution Data Branch, May 2004. The Tables include provincial input and all reduction measures except Tier 4 Off-Road. These estimates have not been reconciled with the Ontario Drive Clean program, specific technical data and other initiatives, and may therefore differ from future Ontario Ministry of the Environment estimates" (Canadian Progress, 2004).

for 0.74 million tonnes of the industrial total, leaving approximately 0.25 million tonnes for other industrial sources. Ontario VOC emissions were 0.65 million tonnes in 2000 (Table 5.4), which is approximately the same as the 2002 Ontario PEMA VOC emissions.

Table 5.3 2000 VOC Emissions for Canada (tonnes)

Source	Tonnes[1]
Industrial	992,547
Fuel Combustion	158,686
Transportation	727,142
Miscellaneous	552,987
Open Sources	234,267
Total	**2,665,629**

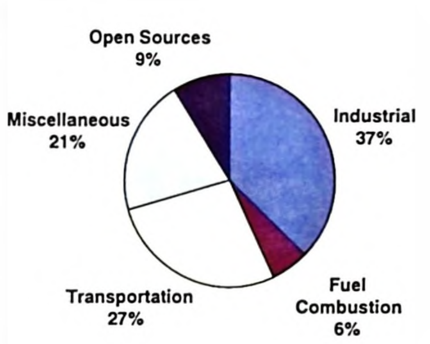
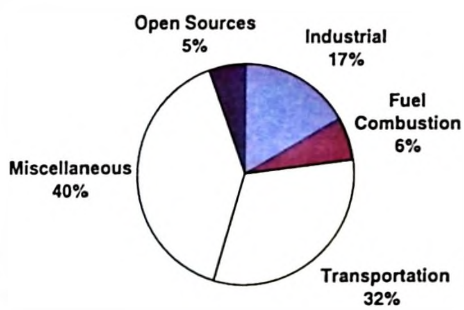


Table 5.4 2000 VOC Emissions for Ontario (tonnes)

Source	Tonnes[2]
Industrial	108,796
Fuel Combustion	40,236
Transportation	204,961
Miscellaneous	259,814
Open Sources	35,363
Total	**649,170**



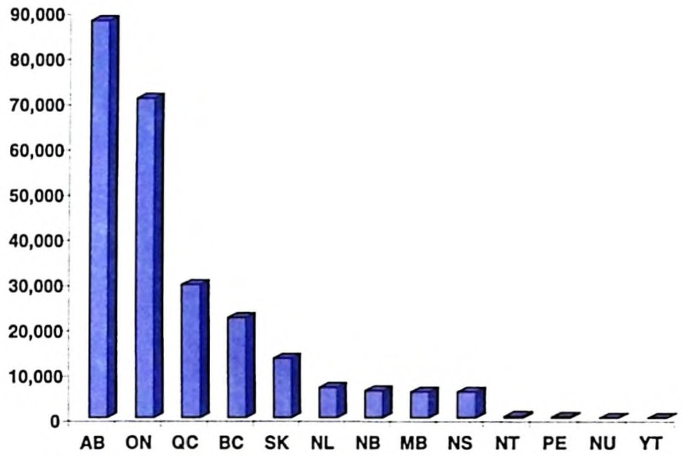
The Canadian National Pollutant Release Inventory (NPRI) established under the Canadian Environmental Protection Act (CEPA 1999) requires companies to report information on releases and transfers of listed pollutants to the Government of Canada on an annual basis. EC has posted preliminary information for the 2003 NPRI (NPRI, 2003). It is important to note that the data is preliminary and has not been reviewed or analyzed by EC. Therefore, slight corrections can be expected as EC completes their analysis. VOC emissions reported from 1,772 industrial reporting facilities in Canada total 249,037 tonnes (0.25 million tonnes) (Table 5.5), which is the same as the 2000 CAC data (minus the upstream oil and gas VOC emissions).

[1] Year 2000 Releases were published in December, 2004. In Industrial Sources, upstream oil and gas account for 739,760 tonnes. Fuel combustion is from non-industrial sources. Forest fires have been excluded from open sources (CAC, 2004).

[2] Same as Note 1 above, however, upstream oil and gas account for 742 tonnes (CAC, 2004).

Table 5.5 2003 NPRI VOC Emissions by Province

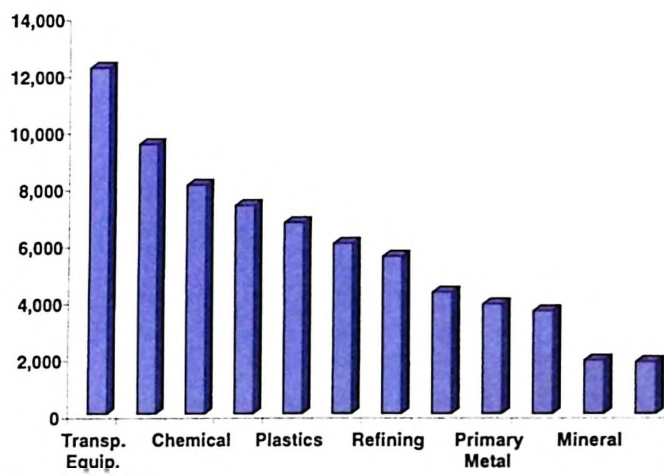
Province	Tonnes
Alberta	87,906
Ontario	70,765
Quebec	29,583
British Columbia	22,244
Saskatchewan	13,269
Newfoundland	6,846
New Brunswick	6,078
Manitoba	5,825
Nova Scotia	5,808
Northwest Territories	451
Prince Edward Island	248
Nunavut	14
Yukon	0
Total	**249,037**



The industrial sector in Ontario accounts for 70,764 tonnes and VOC emissions from the manufacturing of transportation equipment accounts for 12,182 tonnes (Table 5.6).

Table 5.6 2003 NPRI Ontario VOC Emissions by Industrial Sector

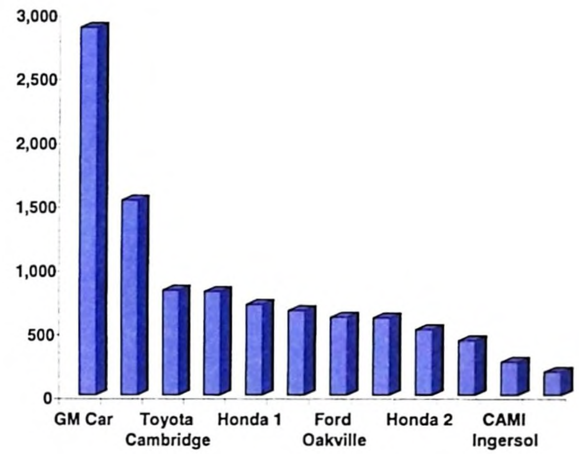
Industrial Sector (CAD 2-D SIC Code)	Tonnes
Transport. Equip.(32)	12,182
All Other	9,487
Chemical (37)	8,051
Paper Products (27)	7,328
Plastic Products (16)	6,735
Printing (28)	5,992
Refining (36)	5,529
Fabricated Metal (30)	4,274
Primary Metal (29)	3,852
Wood (25)	3,619
Mineral (35)	1,883
Food Industries (10)	1,833
Total	**70,764**



Of the 12,182 tonnes of VOC emissions released from manufacturing of transportation equipment (Table 5.6) Ontario's automotive sector accounts for 10,082 tonnes (Table 5.7) almost all of which are from surface coating operations.

Table 5.7 2003 VOC Emissions for Ontario's Automotive Sector

Manufacturer	Tonnes
GM Oshawa Car	2,887
GM Oshawa Truck	1,533
Toyota Cambridge	827
Ford St. Thomas	818
Honda Alliston 1	715
DCX Brampton	669
Ford Oakville	615
DCX Windsor	611
Honda Alliston 2	522
Ford Oakville Truck	433
CAMI Ingersol	265[1]
DCX Windsor Truck	187
Total	**10,082**



5.3 Summary

VOC emissions from the surface coating of automobiles and light duty trucks compared to Canadian and Ontario total anthropogenic sources are presented in Table 5.8. VOC emissions from automotive surface coating in Ontario represent approximately 1.5% of Ontario's anthropogenic total and less than 0.5% of Canada's anthropogenic total. Section 6 will discuss regulatory standards applied to automotive surface coating.

Table 5.8 Relative Contribution to Anthropogenic VOC Emissions

Contribution	VOC Emissions kt/yr
Canada anthropogenic	2,666
Ontario anthropogenic	649
Ontario industry	71
Ontario transportation equipment	12
Ontario auto surface coating	10

[1] Note that the 2003 preliminary NPRI data lists CAMI as emitting 520 tonnes of VOC. However, CAMI over reported and the value should read 265 tonnes. This has been reported to EC, but not corrected on the NPRI database to-date (Tammy Giroux, Senior Analyst, GMCL, March 16, 2005). This does marginally affect other totals, which have not been corrected.

6 Analysis of Regulatory Standards Applied to Industry

This section will review selected laws in Europe, the US and Canada as they relate to the regulatory control of VOC emissions from automobile and light duty truck surface coating.

6.1 United Nations Economic Commission for Europe

As mentioned in Section 4, the United Nations Economic Commission for Europe (UNECE) 1979 Convention on Long-range Transboundary Air Pollution (LRTAP) is the first international legally binding agreement to manage air pollution on a regional basis. Two of the Convention's protocols deal specifically with emissions from automotive surface coating and will be discussed below.

6.1.1 The UNECE 1991 Protocol

In September 1997, the 1991 Protocol on the Control of Emissions of Volatile Organic Compounds entered into force. As discussed in Section 4, the Protocol specifies three options for emission reduction targets that have to be chosen upon signature or ratification. Canada chose to reduce emissions in the TOMAs. However, Canada has not ratified the Protocol.

Two years after coming into force, each Party shall apply appropriate national or international emission standards to new stationary sources based on the best available technologies which are economically feasible, taking into consideration Annex II. Five years after coming into force, in those areas in which national or international tropospheric ozone standards are exceeded or where transboundary fluxes originate, each Party shall apply the best available technologies that are economically feasible to existing stationary sources in major source categories, taking into consideration Annex II.

Annex II, Control Measures for Emissions of Volatile Organic Compounds from Stationary Sources provides guidance in identifying best available technologies to enable Parties to meet the obligations of the Protocol (VOC Protocol, 1991).

The Annex identifies major anthropogenic stationary sources of NMVOC emissions as:

1. Use of solvents
2. Petroleum industry
3. Organic chemical industry
4. Small-scale combustion,
5. Food industry
6. Iron and steel industry
7. Handling and treatment of wastes
8. Agriculture

The following industrial sources of solvent use are cited as the largest contributors to NMVOC emissions:

1. Industrial surface coating
2. Paper surface coating
3. Car manufacturing
4. Commercial painting
5. Printing
6. Metal degreasing
7. Dry-cleaning
8. Flat wood paneling

The Annex states that there is rapid and ongoing development of low-solvent or solvent-free paints, and that these are among the most cost-effective solutions to reduce VOC emissions. Many plants have selected a combination of low-solvent paints and adsorption/incineration abatement technologies for VOC reduction. The Annex also notes that VOC emissions from automotive surface coating have been reduced to 60 g/m2 in several countries and that it is technically possible to reduce VOC emissions from new plants to levels below 20 g/m^2.

For automotive surface coating, the Annex lists the following VOC emission reduction and control measures for consideration:

1. Water-based systems, high solids coatings or powder coatings
2. Activated carbon adsorption
3. Thermal or catalytic incineration with heat recovery

6.1.2 The UNECE 1999 Protocol (Gothenberg Protocol)

Annex VI of the Gothenberg Protocol provides VOC emission limit values for stationary sources (Ozone Protocol, 1999). The Annex lists VOC emission limit values for automotive surface coating (Table 6.1). Note that the Annex states that the automotive surface coating VOC emission limits do not apply to Canada and the US. For Canada, the Annex states that the CCME New Source Performance Standards and Guidelines for the Reduction of Volatile Organic Compound Emissions from Canadian Automotive Original Equipment Manufacturer (OEM) Coating Facilities, August 1995 applies. For the US, the Annex states that the Surface Coating for Automobile and Light Duty Trucks 40 CFR, Part 60, Subpart MM applies.

Table 6.1 VOC Limits for Automotive Surface Coating

	Emission Limit (g/m^2)	
	New	**Existing**
Cars	45	60
Truck Cabins	55	75
Vans and Trucks	70	90

6.2 European Union

As discussed in Section 4, EU environmental law on air pollution is divided into three categories: air quality, motor vehicles and industry. EU environmental requirements for industry will be discussed briefly in this section.

The industry category includes the following EU directives:

- Directive 1999/13/EC emission limits of VOC due to the use of organic solvents
- Directive 96/61/EC integrated pollution prevention and control
- Draft Best Available Technology Reference Document (BREF) on Surface Treatment using Organic Solvents

6.2.1 Directive 1999/13/EC

This directive applies to approximately 20 industrial processes that use volatile organic solvents (1999/13/EC, 1999). For most of the activities identified, the directive specifies a consumption threshold above which the provisions of the directive apply. Member States must take measures to ensure that all new installations comply with the provisions of this directive. Also, all new installations not already covered by Directive 96/61/EC (integrated pollution prevention and control) must be registered or authorized before being put into service. Annex II of the directive provides VOC emission limits for automotive surface coating in g/m^2 (provided in Appendix 6). Note that the EC surface coating limits of this directive are the same as the UNECE 1999 Protocol surface coating limits (described in simple terms in Table 6.1). Also note that the painted surface area is defined as the total electrophoretic coating area and may be calculated as 2-times the weight of the product divided by the average thickness of the sheet metal times the density of the sheet metal. (The painted surface area is also referred to as the elpo "dipped" surface and includes both outer and inner surface areas of the automotive body being dipped in the elpo tank.)

6.2.2 Directive 96/61/EC

The purpose of the integrated pollution prevention and control directive is to prevent or reduce emissions to air, water and land through a comprehensive system of permits applied mainly to industrial activities (96/61/EC, 1996). New installations are required to have a permit and they are expected to use best available techniques (BAT) for the control of emissions. Existing facilities will be required to comply by 2007. Guidance on what constitutes a BAT for various industrial sectors is provided in BAT reference documents (BREFs).

6.2.3 Draft BREF on Surface Treatment using Organic Solvents

The Draft BREF (BREF, 2004) describes that the surface coating process in the automotive sector has the following components:

- Pretreatment (degreasing/phosphate)
- Electrocoat
- Sealing
- Primer
- Topcoat (basecoat and clearcoat)

The BREF indicates that electrocoat, primer and topcoat account for approximately 80% of all VOC emissions from the automotive surface coating process.

Note that the Draft BREF states that in Europe, VOC emissions from 65 automotive paint shops range between approximately 5 and 106 g/m^2 (the median value is approximately 45-48 g/m^2). The average VOC emissions from German automotive paint shops are assumed to be in the 35-45 g/m^2 range and that for many automotive paint shops in Europe VOC emissions range between 60 and 120 g/m^2 (BREF, 2004). This will be discussed in more detail in Section 7.

The BREF states that substitution of solvent-based paints with water-based or powder coatings, paint application technologies and VOC abatement should be considered in the determination of BAT for the automotive surface coating sector, and lists the following for consideration:

Substitution of Solvent- Based Paints

- Water-based paints (electrocoat, primer and basecoat)
- Powder coatings (primer and clearcoat) (note that powder primer is employed in North America, and powder clearcoat is employed at one facility in Europe)
- Powder slurry (not typically employed, possibly at one facility in Europe).

Paint Application Methods

- Immersion (applies to electrocoat)
- Conventional high and low pressure spraying
- High volume low pressure spraying
- Electrostatic atomizing spraying
- Electrostatically assisted high rotation bells

Abatement

- Adsorption
- Oxidation (recuperative, catalytic, and regenerative)

6.3 Ozone Annex to the Canada-US Air Quality Agreement (2000)

As previously discussed in Section 4, Canada and the US amended the Air Quality Agreement in 2000 (Ozone Annex or Annex 3) to include for the reduction of transboundary flows of tropospheric ozone and precursor emissions (NO_X and VOC). Annex 3 includes specific objectives for the control and reduction in anthropogenic emissions of NO_X and VOC. Both countries agree that the long term goal is that atmospheric concentrations for ozone not exceed Canada Wide Standard (CWS) and US National Ambient Air Quality Standards (NAAQS).

Annex 3 also sets specific objectives for the control and reduction of NO_X and VOC for mobile and stationary sources for both countries. Sections of the Annex that are relevant to the automotive manufacturing sector are Part III paragraph A.3 for Canada and paragraph B.3 for the US, which state:

- Canada shall control and reduce its emission of VOC as per the CCME New Source Performance Standards and Guidelines for the Reduction of Volatile Organic Compound Emissions from Canadian Original Equipment Manufacturers (OEM) Coating Facilities (August 1995).
- The US shall require major new VOC and NO_X sources in the PEMA to meet New Source Performance Standards as required by 40 CFR Part 60, including Subpart MM.

6.4 The US Clean Air Act

The Clean Air Act (CAA) was passed in 1963 and revised in 1970 to include a national air pollution control program. The most significant amendments occurred in 1990, which are referred to as the 1990 Clean Air Act (CAA, 1990). As discussed in Section 4, the amendments included the establishment of a national permitting program.

Two types of permits are issued under the CAA, operating permits and construction permits. Usually permits are issued by the state environmental agency; however, in some cases the EPA is the permitting authority. Title V of the CAA requires that all major sources (any source that emits or has the potential to emit 100 tons or more per year of any criteria air pollutant) obtain an operating permit. The CAA also requires that new major stationary sources and major modifications to stationary sources obtain a permit before starting construction. Construction permits in nonattainment areas, defined as an area where the air quality exceeds the NAAQS, are referred to as NAA permits. Permits in attainment areas are referred to as prevention of significant air quality deterioration (PSD) permits. Best Available Control Technology (BACT) is the emission control level required for sources in attainment areas. The Lowest Achievable Emission Rate (LAER) is required on sources in nonattainment areas.

Under the CAA, EPA is required to regulate large facilities that emit one or more of 188 listed hazardous air pollutants (HAPS). Large facilities are those that have the potential to emit 10 tons/year or more of a listed pollutant or 25 tons/year or more of a combination of pollutants. These facilities will require that maximum achievable control technology (MACT) be employed.

6.4.1 New Source Performance Standards

New Source Performance Standards (NSPS) are emission standards established under the CAA for criteria pollutants emitted from stationary sources. For surface coating in the automobile and light duty truck manufacturing sector, VOC emissions standards are specified in Title 40: Protection of Environment, Part 60: Standards of Performance for New Stationary Sources, Subpart MM: Standards of Performance for Automobile and Light Duty Truck Surface Coating Operations (Title 40, Part 60, Subpart MM).

Subpart MM requirements apply to the prime-coat (electrodeposition or elpo), guide-coat (surfacer or primer) and topcoat (basecoat and clearcoat) surface coating operations in automobile and light duty truck assembly plants. The requirements apply to construction, reconstruction and modifications occurring after October 5, 1979, and state that no owner or operator shall discharge VOC emissions greater than the following standards listed in Table 6.2 expressed as kg of VOC per liter of applied coating solids (ACS) (Subpart MM, 2005).

Table 6.2 US EPA New Source Performance Standards for Automotive Surface Coating

Process	Standard (kg of VOC / L of ACS)	Standard (lb of VOC / gal of ACS)
Electrodeposition	0.17	1.41
Primer	1.4	11.64
Topcoat	1.47	12.22

6.4.2 Prevention of Significant Air Quality Deterioration - BACT Determination

The determination of Best Available Control technology (BACT) for New Source Review under the Prevention of Significant Air Quality Deterioration (PSD) requires that the following steps be completed as part of the permitting process:

1. Identify all control technologies
2. Eliminate technically infeasible options
3. Rank remaining control technologies by cost effectiveness
4. Evaluate the most effective controls and document the results
5. Select BACT

To assist State and local regulators in making control technology determinations, and industries and consultants when they are preparing air permits and researching control options, and public and environmental groups when they are reviewing and commenting on permits, the US EPA Clean Air Technology Center maintains a database called the RACT/BACT/LAER Clearinghouse (RBLC). The RBLC database contains information about recent control technology determinations and lists the current best available technologies permitted in the US. Although specific criteria governing RACT, BACT, LAER, or NSPS varies, the general underlying approach is to require the best abatement technology possible on all major existing, new, or modified sources (RBLC, 2005).

A review of RBLC (RBLC, 2005) for VOC emission limits for surface coating in the automotive sector indicates that paint shops with the best performance are achieving the following:

- Electrodeposition: BACT Coating Limits range between 0.04 – 0.23 pounds VOC emitted per gallon of applied coating solids. This is being achieved with water-based paint and abating curing oven emissions and in some cases dip tanks.
- Primer: BACT Coating Limits range between 0.0 – 6.3 pounds VOC emitted per gallon of applied coating solids. This is being achieved with powder (virtually zero VOC emissions for powder prime), water-based or solvent-borne paints and abatement.
- Topcoat: BACT Coating Limits range between 5.2 – 8.2 pounds VOC emitted per gallon of applied coating solids. This is being achieved with a combination of water-based or solvent-borne paint and abatement.

Detailed permit requirements have been summarized for 11 automotive facilities and is provided in Appendix 7. Table 6.3 summarizes the NSPS and BACT VOC emission limits for surface coating in the automotive sector.

Table 6.3 US EPA NSPS versus BACT VOC Emission Limits

Process	NSPS (Standard) (lb of VOC / gal of ACS)	BACT Permit Limits (lb of VOC / gal of ACS)
Electrodeposition	1.41	0.04 – 0.23
Primer	11.64	0 – 6.3
Topcoat	12.22	5.2 – 8.2

6.5 Canada

6.5.1 CCME New Source Performance Standards and Guidelines

In 1991, the CCME developed a plan for the management of NO_X and VOC in recognition of the impact of smog on human health. As part of the plan, CCME published more than 16 codes of practice/guidelines for the reduction of NO_X and VOC from various sectors or sources. One of these codes of practice, the CCME New Source Performance Standards and Guidelines for the Reduction of Volatile Organic Compound Emissions from Canadian Auto OEM Coating Facilities sets out VOC emission limits in g/m^2 for automotive surface coating (Table 6.4) (CCME, 1995).

Table 6.4 CCME Performance Standards - VOC Emission Limits

	New Source Limits (g/m^2)	Existing Source Limits (g/m^2)	
	Final (1997)	Interim (2000)	Final (2005)
Automobiles	55	65	55
Passenger vans and sport utility vehicles	60	70	60
Light duty trucks and vans	75	80	75

The new source performance standards VOC limits are based on Best Available Control Technology Economically Achievable.

Similar to EC directive 1999/13/EC, the painted surface area is defined as the total vehicle body area (this is understood in the industry to mean the total electrophoretic surface area, as in directive 1999/13/EC, or the electrodeposition or elpo coating area) and may be calculated as 2-times the weight of the body divided by the average sheet metal thickness times the density of the sheet metal.

6.5.2 Ontario Anti Smog Action Plan (ASAP) Progress Report, August 2000

This first progress report (August 2000) highlights actions taken to date to reduce smog and smog precursors in Ontario. It also highlights voluntary actions taken by industry, including those by the automotive manufacturing sector highlighted below.

> *"Member companies of the Canadian Vehicle Manufacturers' Association [CVMA] have a successful record of significant environmental achievement through defined voluntary action, over and above regulation. The Ontario government Anti-Smog Action Plan provides a valuable partnership mechanism for the automotive industry to carry out its smog reducing initiatives effectively and efficiently while working towards the mutual goal of significant air quality improvement in this province: Mark Nantais, President Canadian Vehicle Manufacturers' Association"*, (ASAP, 2000)

> *"Automotive assembly facilities in Ontario have implemented projects aimed at reducing VOC emissions from their surface coating facilities, and these facilities are developing and implementing programs to meet the CCME New Source Performance Standards and Guidelines for the Reduction of Volatile Organic Compound Emissions from Canadian Auto OEM Coating Facilities, August 1995."* (ASAP, 2000)

> *"Five automotive companies, the CVMA and the MOE have drafted a Memorandum of Understanding ... the companies agree to achieve the standards set out in the [CCME] New Source Performance Standards and Guidelines for the Reduction of Volatile Organic Compound Emissions from Canadian Automotive OEM Coating Facilities by 2005 ... More than half of the 15 assembly plants have already achieved the VOC emission standard. In addition, companies participating in the Canadian Automotive Manufacturing Pollution Prevention Project have reported on VOC emission reductions of 4,500 tonnes per year."* (ASAP, 2000)

VOC reduction case studies from the CVMA Pollution Prevention 5th Progress Report are included in the 2000 ASAP progress report and have been summarized in Table 6.5 (ASAP, 2000).

Table 6.5 Summary of Voluntary VOC Reduction Projects (5th Report)

Facility	Description	VOC reduced (t/year)
DaimlerChrysler Bramalea Assembly	Conversion to water-borne basecoat paints	143
Ford Ontario Truck Assembly	Paint shop replacement	400
GM Oshawa Truck Assembly	Reduced paint purge	200
DaimlerChrysler Windsor Assembly	Solvent management program	430
Ford Oakville Assembly	Colour coat automation	65

6.5.3 Ontario Anti Smog Action Plan (ASAP) Progress Report, August 2002

The second progress report highlights progress made in reducing smog and smog precursors since the first report in 2000. It also highlights the voluntary actions taken by industry including those by the automotive manufacturing sector.

The report states that the CVMA member companies, through their Pollution Prevention project, have achieved a 32% reduction in VOC in 1999 from 1992 baseline levels in spite of increasing production levels over the same time period. These reductions have been achieved as a result of equipment upgrades, process modifications, material substitutions, and effective environmental management systems, which, according the CVMA 7th Progress Report, have resulted in a 5,000 tonne reduction in VOC per year (ASAP, 2002).

6.5.4 Canadian Automotive Manufacturing Pollution Prevention Project

The CVMA Pollution Prevention Project dates back to 1992 and is a co-operative effort between the participating members companies (DaimlerChrysler, Ford and GM), the federal Department of the Environment and the Ontario Ministry of the Environment to document voluntary actions taken by the member companies to reduce pollutants.

The results of the 8th annual progress report are summarized in Table 6.6 (CVMA, 2005).

Table 6.6 Summary of Voluntary VOC Reduction Projects (8th Report)

Facility	Description	Results
DaimlerChrysler Pillette Assembly (full size vans)	Paint application using electrostatic robots	▪ 5% reduction in paint consumption ▪ reduced VOC emissions by 25t/yr ▪ achieve VOC emission of 47 g/m^2 ▪ saving $250,000/year
Ford Oakville Assembly (minivans)	Improved spray nozzle & paint application technologies in 2001, 1-coat replaced 2-coat basecoat	▪ reduced paint & solvent usage ▪ reduced VOC emissions by 77t/yr ▪ achieve VOC emission of 30 g/m^2
GM Oshawa Truck Plant (full size pickup trucks)	Installed electrostatic rotary bell for water borne basecoat application "Aquabell" in 2002	▪ 20% improved transfer efficiency ▪ reduced VOC emissions by 60 t/yr ▪ saved 300,000 liters of paint ▪ saved $5,000,000 per year
DaimlerChrysler Windsor Assembly (minivans)	High pressure water blasting of elpo carriers replaced solvent borne cleaners	▪ eliminated 2-butoxyethanol ▪ reduced VOC emissions by 26 t/yr
DaimlerChrysler Windsor Assembly (minivans)	High pressure water blasting of spray booths replaced solvent borne cleaners	▪ reduced VOC emissions by 69 t/yr ▪ saved $90,000/year on solvent

6.5.5 Ontario Air Permitting

Ontario has jurisdiction over the issuance of air permits (Certificates of Approval) under the Ontario Environmental Protection Act (O.EPA, 1990) and Regulation 346 (Reg.346, 2005) administered by the Ontario Ministry of the Environment (MOE, 2005). While there is no specific permitting requirement for VOC emissions in Ontario, the permitting regime does require that the maximum ½-hour concentration for each contaminant emitted from a facility must meet a ½-hour point of impingement standard ($\mu g/m^3$). Therefore, the facility must demonstrate compliance with speciated VOC air standards (i.e., xylene and toluene) in addition to NO_X, SO_2, PM, and any other contaminant emitted. This is usually assessed through the use of air dispersion modeling specified in Regulation 346. The air permit must be issued before construction. Recently, however, Ontario has been issuing Comprehensive Certificates of Approval (Air) that allow limited operational flexibility including the ability to make changes to processes and emissions including construction under the provisions of the permit. The operational flexibility is valid for 5 years, at which time a review of the permit is required to extend the operational flexibility.

6.6 Summary

The UNECE has established two Protocols for the control of VOC emissions: the 1991 Protocol to abate ground level ozone and the 1999 Protocol establishing VOC emission limits. The 1999 Protocol establishes VOC emission limits for automotive surface coating expressed as grams of VOC per square meter surface painted, g/m^2.

The EU has established Directives to control air emissions from industry. For the automotive manufacturing sector, Directive 1999/13/EC establishes VOC emission limits automotive surface coating expressed as g/m^2 (same limits as the UNECE 1999 Protocol) and Directives 1999/13/EC and 96/61/EC require that new facilities be registered or permitted. The EC has also published a draft reference document on Best Available Techniques (BREF) for automotive surface coating.

Canada and the US amended the Air Quality Agreement (Ozone Annex) to include for the reduction in the transboundary flow of ozone and precursor emissions. Pertinent to the automotive sector, the Annex states that Canada shall control VOC emissions as per the CCME new source performance standards, and the US shall require major new sources to meet surface coating standards in 40 CFR Part 60, Subpart MM.

The US Clean Air Act establishes a construction and operating permitting system that requires that New Source Performance Standards (NSPS) and Best Available Control Technology (BACT) limits for VOC emissions from automotive surface coating are met for new installations.

The CCME published new source performance standards and guidelines for automotive surface coating that sets out VOC emission limits in g/m^2. The Ontario MOE ASAP progress reports have identified the Canadian automotive sector as voluntarily implementing significant VOC reductions initiatives since 1992 as part of the voluntary CVMA Pollution Prevention Project. Ontario air permitting, while not directly regulating VOC emissions, does impose ½-hour maximum point of impingement limits on each speciated VOC released from a facility.

A review of VOC emission limits for automotive surface coating is summarized in Tables 6.7 and 6.8. The two approaches used (g/m^2 or kg/L of ACS [lb/gallon of ACS]) are not directly comparable. Section 7 will describe the automotive sector and best management practices for VOC control from automotive surface coating.

Table 6.7 Summary of VOC Emission Limits for Automotive Surface Coating

	VOC Emission Limits (g/m²)		
	Cars	Truck cabins, vans and SUVs	Trucks and vans
UNECE & EC - New	45	55	70
UNECE & EC - Existing (2007)	60	75	90
Germany – New & Existing	35[1]	45	70
Taiwan	110	na[2]	na
Mexico - New	55	60	75
Mexico - Existing (1999)	85	90	100
Mexico - Existing (2006)	55	60	75
Canada - New (1997)	55	60	75
Canada - Existing (2005)	55	60	75

Table 6.8 US NSPS versus BACT VOC Emission Limits for Surface Coating

Process	NSPS (Standard) (kg of VOC/L of ACS)	BACT Permit Limits (kg of VOC/L of ACS)
Electrodeposition	0.17	0.01 – 0.03
Primer	1.40	0.00 – 0.76
Topcoat	1.47	0.62 – 0.98

[1] Facility Permit values can be higher than the Standard depending on when the permit was issued.
[2] "na" means information was mot available during writing of this report

7 Automobile and Light Duty Truck Manufacturing and Best VOC Management Practices

Globally automobile and light duty truck manufacturing is the world's biggest industry employing 8 million people, producing approximately 60 million vehicles in 2004 and generating approximately $US 1.5 trillion in annual sales. Global production capacity is approximately 70 million vehicles per year (McAlinden, 2004). This overcapacity is putting pressure on an already very competitive business. This section will describe the automobile and light duty truck sector, identify best VOC management practices and suggest best practices for Ontario.

7.1 Global Manufacturing

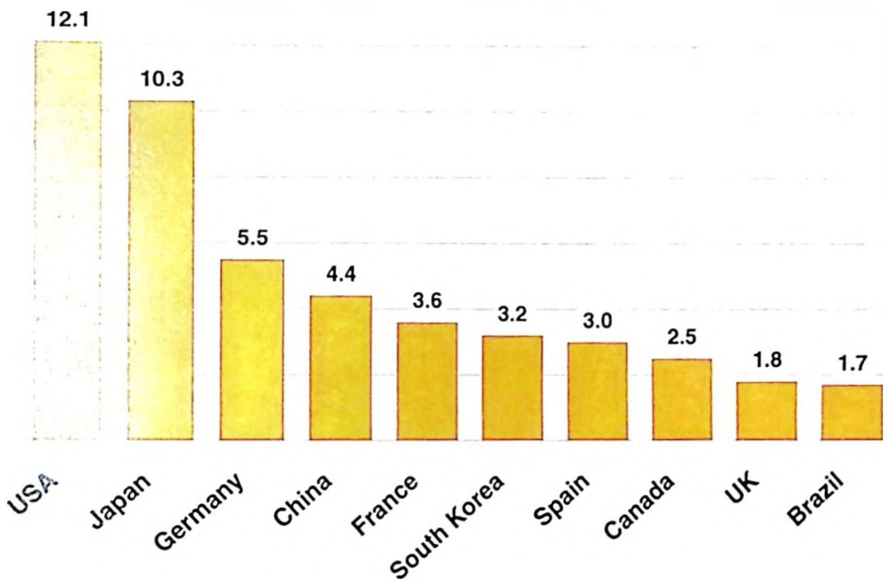
Global manufacturing is roughly split equally between North America, Europe and Asia. North America produced approximately 16.2 million vehicles per year in 2003. The US is the largest producer in North America and largest in the world at approximately 12.1 million vehicles per year. Europe produced approximately 20 million vehicles per year in 2003. Germany is the largest producer in Europe at approximately 5.5 million vehicles per year. Asia produced approximately 17.9 million vehicles per year in 2003. Japan is the largest producer in Asia at approximately 10.3 million vehicles per year and the second largest producer in the world, behind the US. The rest of the world produced approximately 6.4 million vehicles per year in 2003. The 10 largest automobile manufacturing countries in 2003 are shown in Figure 7.1 (VDA, 2005).

China has seen the largest growth in the last 3 years. China moved from 8^{th} position in 2001 (behind Canada) with approximately 2.3 million vehicles produced to 4^{th} position in 2002 with approximately 3.3 million units produced and has increased production to 4.4 million vehicles produced in 2003 (VDA, 2005).

Canadian production has fallen from approximately 3 million vehicles produced in 2000 to approximately 2.5 million vehicles produced in 2004 (VDA, 2005) (CAPC, 2005). Canadian production is predicted to increase to 2.66 million vehicles in 2005 (Keenan, 2005). However, production is forecast to decline over time to an estimated 2.4 million vehicles produced in 2011 (CSM, 2005).

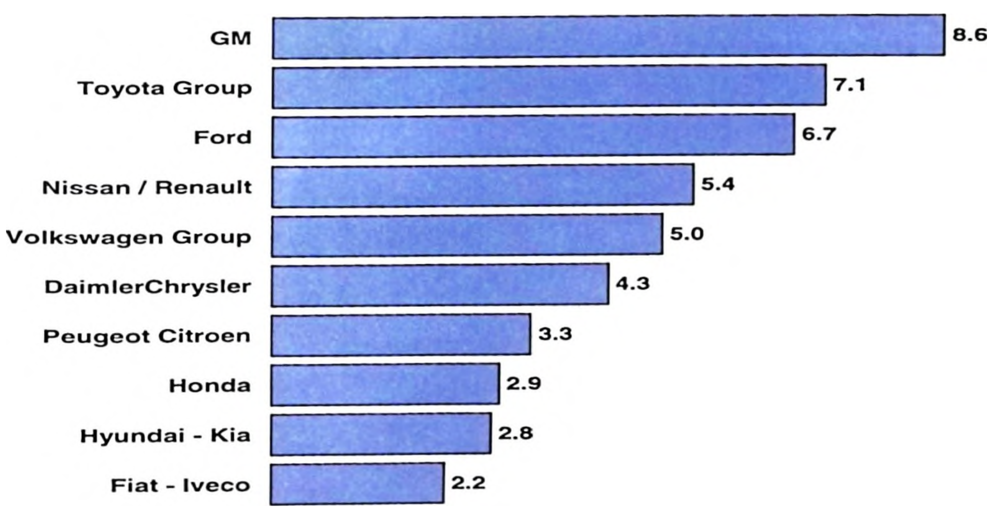
General Motors is the world's largest manufacturer of automobiles and light duty trucks at 8.6 million vehicles produced in 2003, followed by the Toyota Group at approximately 7.1 million vehicles produced in 2003 and Ford at approximately 6.7 million vehicles produced in 2003. Of the 8.6 million vehicles that GM produced in 2003, approximately 5.3 million were produced in North America and approximately 1.8 million were produced in Europe.

Figure 7.1 10 Largest Automobile Manufacturing Countries in 2003 Production in Million Units



Toyota produced approximately 3.5 million vehicles in Japan, approximately 1.3 million vehicles in North America, approximately 0.5 million vehicles in Europe, and approximately 0.5 million vehicles in Asia (excluding Japan) in 2003. The 10 largest manufacturers in 2003 are shown in Figure 7.2 (compiled from data made available on corporate and industry web pages).

Figure 7.2 10 Largest Automobile Manufactures in the World in 2003 Production in Million Units



7.2 Canadian Manufacturing

There are six automobile and light duty truck manufacturers in Canada operating 12 assembly plants all located in Ontario between Windsor and Oshawa. The six manufacturers, CAMI, DaimlerChrysler, Ford, General Motors, Honda, and Toyota will be briefly discussed in this section.

CAMI Automotive

CAMI is a joint venture between Suzuki Motor Corporation and General Motors of Canada Limited. CAMI began assembling vehicles in approximately 158,000 m^2 of floor space in their facility in Ingersol in 1989. CAMI has a production capacity of approximately 250,000 vehicles per year and is currently producing the GM Equinox (CAMI, 2005).

DaimlerChrysler Canada

DaimlerChrysler has assembly facilities in Windsor and Brampton. The Windsor assembly plant, built in 1928, produces the Dodge Grand Caravan, Chrysler Town & Country and Chrysler Pacifica in approximately 372,000 m^2 of floor space. Their Brampton assembly plant, built in 1986, produces the Chrysler 300 and Dodge Magnum in approximately 274,000 m^2 of floor space (DaimlerChrysler, 2005).

Ford Motor Company

Ford has assembly facilities in Oakville and St. Thomas. The Oakville assembly plant produces the Freestar minivan. The plant opened in 1953 and has approximately 360,000 m^2 of floor space. The St. Thomas assembly plant produces the Crown Victoria and Grand Marquis. The plant opened in 1967 and has approximately 242,000 m^2 of floor space (Ford, 2005). The Oakville Truck Plant is currently closed; however, it is expected to re-open.

General Motors of Canada

General Motors has three assembly plants in Oshawa. The Car 1 assembly plant produces the Chevrolet Impala and Monte Carlo. The Car 2 assembly plant produces the Buick Allure and Pontiac Grand Prix. The facility, opened in 1953, occupies approximately 687,500 m^2 of floor space producing approximately 600,000 vehicles per year. The Truck assembly plant builds the Chevrolet Silverado, GMC Sierra and Sierra Denali full-size, light duty pick-up trucks. The 1965 facility occupies approximately 288,000 m^2 of floor space producing approximately 300,000 vehicles per year (GM, 2005).

Honda of Canada Manufacturing

Honda has two assembly plants located in Alliston. Total production capacity is approximately 390,000 units annually. Plant 1 started production in 1986 and currently produces Honda Civic Sedan and Acura 1.7 EL. Plant 2 started production in 1998 and currently produces Honda Odyssey, Acura MDX and Honda Pilot SUV (Honda, 2005).

Toyota Motor Manufacturing Canada

Toyota began assembling vehicles in Cambridge in 1986. Today they assemble the Corolla, Matrix and Lexus RX 330, and have an annual capacity of approximately 250,000 vehicles in their north and south facilities (Toyota, 2005).

The automotive and light duty truck manufacturers in Ontario have an annual production capacity of approximately 2.8 million vehicles per year (Table 7.1).

Table 7.1 Summary of Ontario Vehicle Manufacturers

Manufacturer[1]	Production Capacity[2]
General Motors and CAMI (4)	1,150,000
Ford (2)	460,000
DaimlerChrysler (2)	550,000
Honda (2)	390,000
Toyota (2)	280,000
Total	**2,830,000**

7.3 Automotive Surface Coating

This section will describe the surface coating process, paint technology, VOC emissions from surface coating and best available technologies for surface coating and abatement of VOC emissions.

7.3.1 Surface Coating Process Description

Automobile and light duty truck surface coating, or painting, consists of four primary processes; phosphating, electrodeposition, primer and topcoat. Each will be discussed briefly in this section.

[1] Number of assembly plants shown in brackets.
[2] Approximate production capacity (vehicles/year).

Phosphate: The zinc phosphate process includes multiple cleaning stages, an activating rinse, zinc phosphate, sealant rinse, and multiple deionized water rinses. The phosphate process prepares the body for the following paint processes and provides the first layer of corrosion protection. This process is not considered a source of VOC emissions.

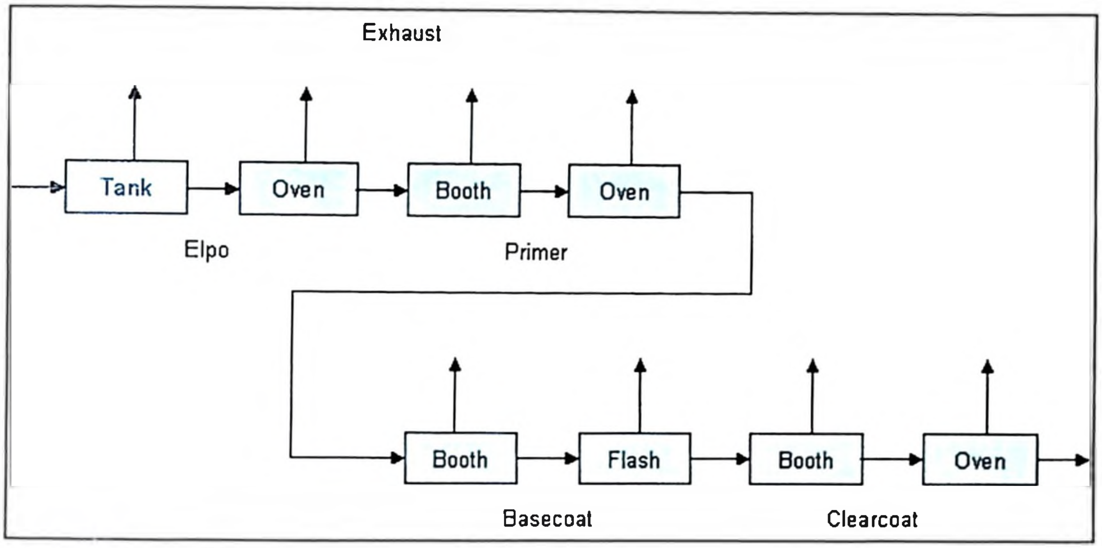
Electrodeposition: This process, also known as electrocoat, e-coat, elpo or prime coat, applies a corrosion resistant primer to the body. Typically, the body is submerged in a lead free water-based paint/water bath in a dip tank. Electrical charges in the paint and body are used to deposit the paint onto the body. This process is considered a low contributor to VOC emissions from the paint shop. New installations in North America typically abate the emissions from the dip tank and curing oven. Considering the low VOC emissions from the painting process, abatement is typically installed to control odours and toxic emissions.

Primer: This process, also known as primer-surfacer, surfacer or guidecoat, applies the layer of paint that joins the corrosion-protected body to the topcoat paint layers. The primer smoothes out surface irregularities, improves stone-chip performance, and helps to protect the body from visible and UV light. Primers can be solvent-borne, water-borne or powder. VOC emissions can range from virtually zero, for powder coatings, to fairly significant for water-borne and solvent-borne coatings. New installations in North America typically abate the emissions from the spray booth and curing oven if solvent-borne or water-borne primers are used. Powder coatings do not require abatement.

Topcoat: This term applies to the last painting process that provides the colour (basecoat) and final gloss and protection (clearcoat). Basecoat paint provides the colour and can be either water-borne or solvent-borne. VOC emissions from the basecoat process can be significant. Clearcoat provides the last layer of paint and provides the high gloss finish appearance, etch and scratch resistance, and environmental protection. Clearcoats are typically solvent-borne (one plant in Germany use a powder/slurry and one uses a powder clearcoat). The application of clearcoat paints are typically the largest source of VOC emissions from an automotive paint shop. New installations in North America typically abate the emissions from the basecoat heated flash (intermediate curing ovens), automatic zones of the spray booth and topcoat ovens.

The electrodeposition, primer and topcoat processes described above are shown diagrammatically in Figure 7.3 without any abatement of emissions.

Figure 7.3 Simple Schematic of Paint Shop Process



7.3.2 Paint Technology

In terms of paint technology, paints can be classified into three broad categories:

- Water-based paints
- Solvent-borne paints
- Powder paints

Note that there can be significant variation within each category, such as low solids, high solids, and slurry.

In general, today's newer paint shops are using lead-free, water-based paints for electrodeposition, water or powder-based paints for primer, and water or solvent-based paints for topcoat. Some examples of paint technologies being used worldwide, compiled from data provided by the US EPA and corporate and industry websites, is provided in Table 7.2. The review of paint shops indicates that the paints commonly used in the US are water-based primer, water-based basecoat, and solvent-borne clearcoat paints. Newer GM paint shops in the US are using powder primer. The GM Opel plant in Eisenach is the only plant using water-based paints for the primer, basecoat and clearcoat. The BMW plant in Dingolfing is the only plant currently using a powder clearcoat, and the DaimlerChrysler plant in Sindelfingen is the only plant using a powder/slurry clearcoat. For GM of Canada, the evolution of paint technology and paint shop technology is partially revealed by Table 7.2 – from water/solvent/solvent with no abatement in early-1980 to water/water/solvent in mid-1980 to powder/water/solvent with significant abatement in 2006.

Table 7.2 Examples of Various Paint Technologies

Country	Manufacturer/Plant	Primer	Basecoat	Clearcoat
US	Hyundai, Alabama (2004)[1]	Water	Water	Solvent
	Honda, Alabama (2002)	Water	Water	Solvent
	Nissan, MS (2001)	Water	Water	Solvent
	GM Delta, MI (2001)	Powder	Water	Solvent
	GM, OK (1999)	Powder	Water	Solvent
	GM, Flint (1999)	Water	Solvent	Solvent
	BMW, SC (1999)	Water	Water	Solvent
	Ford, Michigan (1998)	Water	Water	Solvent
Canada	GM Car 1 & 2 (early-1980's)[2]	Water	Solvent	Solvent
	GM Truck (mid-1980's)	Water	Water	Solvent
	GM Car 1 & 2 (2006)	Powder	Water	Solvent
Europe	GM Opel Antwerp (1984)[3]	Water	Solvent	Solvent
	GM Opel Azambuja (2000)	Water	Water	Solvent
	GM Opel Bochum (1986)	Water	Water	Solvent
	GM Opel Eisenach (1992)	Water	Water	Water
	GM IBC - Luton	Solvent	Solvent	Solvent
	GM Ellesmere Port (1990)	Water	Solvent	Solvent
	GM Poland (1998)	Water	Water	Solvent
	GM Opel Rüsselsheim (1992)	Water	Water	Solvent
	GM Saab Trollhättan	Water	Water	Solvent
	GM Zaragoza (1982)	Water	Solvent	Solvent
	DaimlerChrysler Sindelfingen	Water	Water	Powder/Slurry
	BMW Dingolfing	Water	Water	Powder

[1] For US Plants, the date in brackets represents the Air Permit date.
[2] For Canadian Plants, the date in brackets represents the approximate date of installation.
[3] For European Plants, the date in brackets is the date of the last major upgrade to the paint shop.

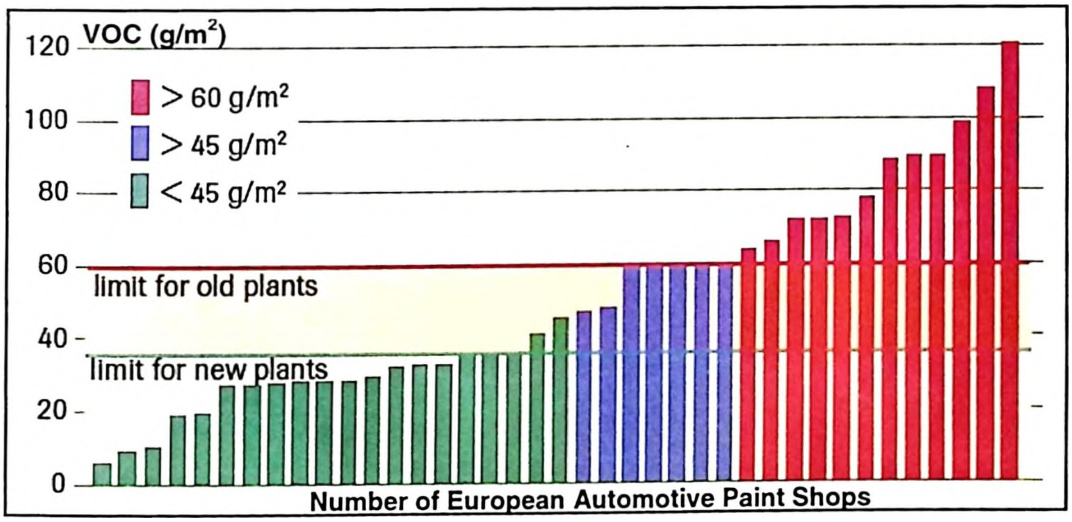
7.3.3 VOC Emissions from Surface Coating

Through advancements in paint technology, such as water-borne paints, powder paints, and higher solids/lower VOC paints, application technology (such as electrostatic bell applicators increasing transfer efficiencies), abatement technology, and improvements in cleaning and maintenance practices, the emissions of VOC from automotive surface coating have dramatically reduced over the past 10 – 15 years.

To illustrate this, VOC emissions from automotive painting operations in Germany were reduced by approximately 50% between 1990 and 2002, from approximately 24,000 tonnes released in 1992 to approximately 12,500 tonnes released in 2002, even though production increased by approximately 10% during the same period (VDA, 2005). Similar VOC reductions, approximately 37% on a mass basis and approximately 47% on a surface area basis (i.e., VOC in g/m^2 coated surface) from 1992 to 2002, have been found in Ontario's automotive paint shops (CVMA data[1]).

VOC emissions from European automotive paint shops range from a low of less than 10 g/m^2 to a high of approximately 120 g/m^2 as indicated in Figure 7.4 (VDA, 2005), (BREF, 2004). The Figure also indicates that for the automotive paint shops in Europe, approximately 50% will not meet the new standard of 45 g/m^2 for 2007 (VDA, 2005), (BREF, 2004).

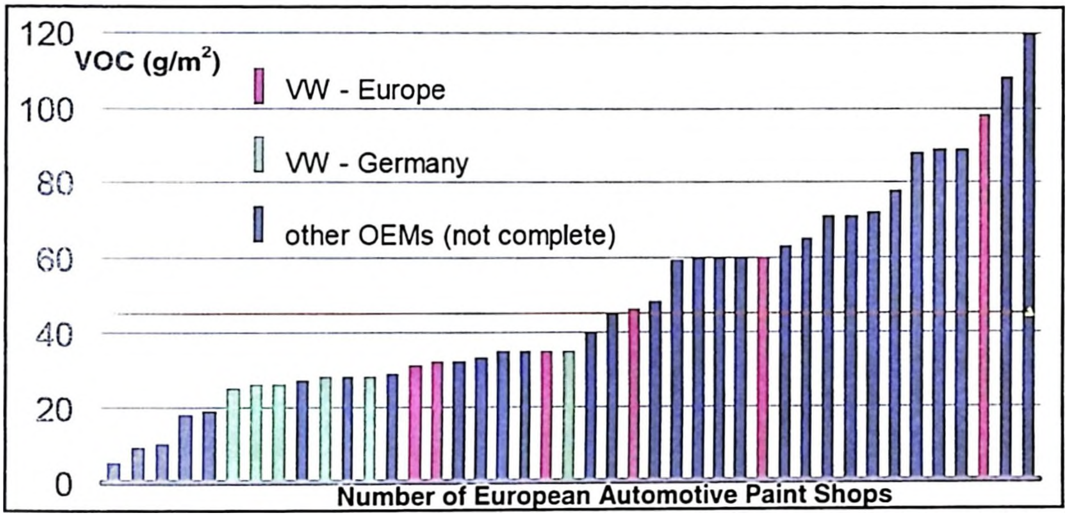
Figure 7.4 VOC Emissions from European Automotive Paint Shops



[1] Plant specific data are confidential – only industry aggregated data is used.

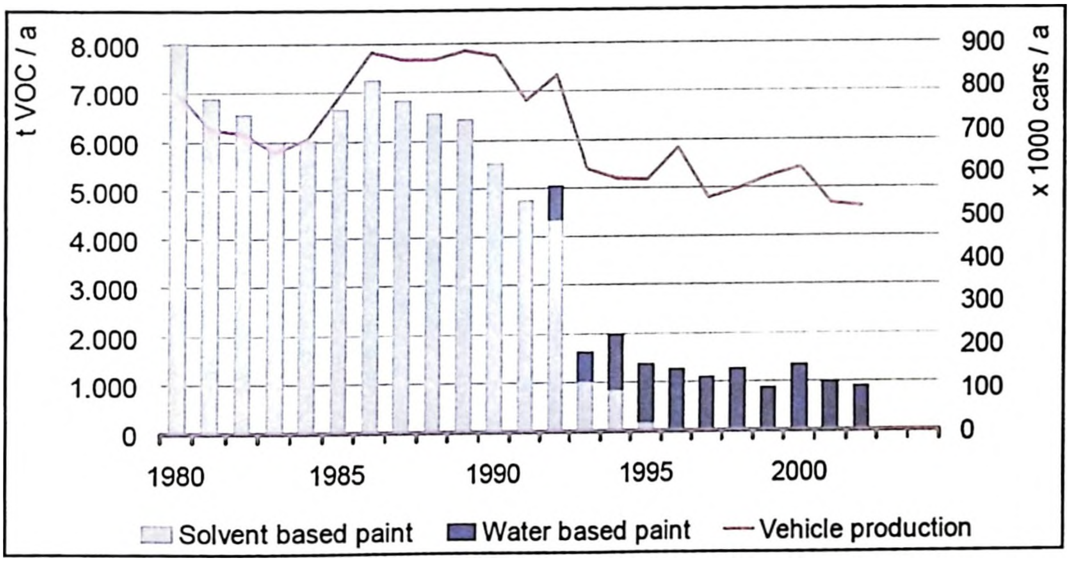
The same information presented by Volkswagen (VW, 2003) indicates that of the 12 Volkswagen paint shops operating in Europe, 10 currently meet the 2007 standard (Figure 7.5). The lowest VOC emission rate for a European VW automotive paint shop is approximately 25 g/m^2, while the highest emission rate is just under 100 g/m^2.

Figure 7.5 VOC Emissions from Volkswagen Automotive Paint Shops



The Volkswagen facility at Wolfsburg dramatically reduced VOC emissions by changing to water-based paints in the mid-1990's (Figure 7.6). In 2002, the facility was emitting just under 1,000 tonnes per year of VOC while producing approximately 560,000 vehicles per year (VW, 2003). This calculates to approximately 1.8 kg/vehicle.

Figure 7.6 VOC Emissions from Volkswagen Paint Shop Wolfsburg



The Draft EU BREF reports that in Europe, VOC emissions from 65 automotive paint shops range between approximately 5 and 106 g/m^2 (the median value is approximately 45-48 g/m^2). The average VOC emissions from German automotive paint shops are assumed to be in the 35-45 g/m^2 range and this corresponds to an average solvent consumption of approximately 2.5 to 4 kg/vehicle. This roughly calculates to an average painted surface area of 71-89 m^2. While the BREF reports that the BMW plant in Dingolfing, the Opel plant in Eisenach and the DaimlerChrysler plant in Rastatt have VOC emissions that are approaching 10 g/m^2, it also states that for many automotive paint shops in Europe VOC emission range between 60 and 120 g/m^2 (BREF, 2004).

A comparison of VOC emissions from automotive paint shops by region, company and plant is presented in Table 7.3. Data were generally obtained through corporate and/or industry websites (GM data for Oklahoma, Oshawa and Europe were obtained from websites and GM sources). The base year for comparison is 2002 or 2003 as indicated in Table 7.3. Surface areas, when provided or calculated from the available data, ranged from 85 m^2 to 142 m^2. This is higher than the calculated surface area range from the BREF data (BREF, 2004). However, this is expected to some degree to account for larger North American vehicles. Where surface area is not known or cannot be calculated, it has been assumed to be 100 m^2. This is felt to be a reasonable assumption for comparative purposes. Individual plants included for comparison all represent large production volume shops. The smallest is the GM IBC (Isuzu) facility in Lutton, England at 84,000 vehicles produced in 2003.

A review of the data indicates Nissan's average VOC emission rate across all facilities is reported to be 45 g/m^2. Volvo reports that they have achieved an emission rate of 23 g/m^2. This is as a result of their facility in Göteborg, Sweden achieving 16 g/m^2 and their facility in Ghent, Belgium achieving 25 g/m^2. GM's facilities in Germany have VOC emissions ranging from 26 – 39 g/m^2 and their Saab facility in Sweden is achieving 23 g/m^2. Toyota's facilities in Europe (3 plants) are reported to average 36 g/m^2 and they report that their facilities in the US achieved an average emission rate of 22 g/m^2. Ford's North American facilities reportedly achieved an average emission rate of 29 g/m^2. Honda's three facilities in Japan are reported to average 33 g/m^2. The GM facility in Oklahoma has an emission rate calculated at 11 g/m^2.

World class performance would appear to be a VOC emission rate in the 20's and 30's (g/m^2), which is found in each region: Europe, Asia and North America.

Table 7.3 Examples of VOC Emissions by Region, Company and Plant[1]

Region	Plant	Units ('000s)	VOC (t)	kg/ unit	Area (m^2)	VOC (g/m^2)	Comments
Global	Nissan (2003)	2,812	*12,654*	*4.5*	*100*	45	
	Volvo (2003)	413	744	2.22	**97**	23	
	Peugeot-Citroën (02)	3,309	*18,597*	5.62	*100*	*56*	
Europe	Toyota	414	1,665	4.02	**112**	36	For 3-plants
	Fiat, Italy (2003)	800	*5,758*	*7.2*	*100*	72	
	BMW (2002)	1,090	3,521	3.23	*100*	*32*	Germany total
	BMW Dingolfing	281	721	2.57	*100*	*26*	Germany
	DaimlerChrysler (02)	484	526	1.11	**108**	10	Sindelfingen Plant
	Ford Jaguar (2002)	130	*780*	6.0	*100*	*60*	England
	Volvo Göteborg (03)	166	*266*	*1.6*	*100*	16	Sweden
	Volvo Ghent (2003)	154	*385*	*2.5*	*100*	25	Belgium
	Opel (2003)	947	5,890	6.22	*100*	*62*	
	VW Wolfsberg (2002)	560	1,000	1.8	**86**	21	Germany
	VW Wolfsberg (2003)	515	1,202	2.33	**86**	27	Germany
	Mercedes Car Group	1,300	*1,561*	1.2	*100*	*12*	Estimated
	GM Azambuja	167	*701*	*4.2*	*100*	42	Portugal
	GM Opel Bochum	286	*744*	*2.6*	*100*	26	Germany
	GM Opel Eisenach	127	*394*	*3.1*	*100*	31	Germany
	GM Rüsselsheim	124	*484*	*3.9*	*100*	39	Permit is 40 g/m^2
	GM Vauxhall (2003)	130	*787*	6.05	*100*	*61*	Ellesmere Port
	GM IBC (Isuzu) (03)	84	759	9.08	**101**	90	Lutton (vans)
	GM Saab (2000)	114	*280*	2.46	*100*	23	Trollhättan
	Peugeot-Citroën (03)	1,922	*10,244*	5.33	*100*	*53*	France only
North America	Toyota (2003)	1,375	*3,025*	*2.2*	*100*	22	
	Ford (2003)	3,778	*10,985*	*2.9*	*100*	29	
	GM (2003)	5,433	*21,732*	4.0	*100*	*40*	
	Chrysler Group	2,481	*6,699*	2.7	*100*	*27*	Est. from graph
	GM OKC (2004)	134	125	0.93	**85**	11	
	GM Osh. Truck (03)	322	1,533	4.76	**109**	44	
	GM Oshawa Car (03)	618	2,887	4.7	**142**	33	
	GM Oshawa Car (06)	618	1,316	2.13	**142**	15	Estimated for 2006
Asia	Honda (2003)	1,171	*3,864*	*3.3*	*100*	33	3 plants in Japan
	Nissan Kyushu (2003)	--	--	*2.0*	*100*	20	
	Toyota Altona (2003)	114	538	4.74	**103**	46	Australia
	Toyota Tsutsumi (03)	--	--	*4.1*	*100*	41	Japan

[1] Values in "**bold**" are calculated surface area (in m^2) from data provided. Values in "*italics*" and "underlined" are calculated assuming a painted surface area of 100 m^2.

In 2002, VOC emissions for automobile manufacturing in Ontario ranged from 23–43 g/m^2 (this was a significant reduction from 1992 when the range was 40–85 g/m^2). For light duty trucks, vans and sport utility vehicles, the VOC emissions in 2002 ranged from 19–46 g/m^2 (this is also a significant reduction from 1992 when the range was 50–95 g/m^2) and is not appreciably different than the emissions from automobile manufacturing (CVMA data[1]).

Specific VOC emission rates (in g/m^2) for each assembly plant in Ontario are not available. However, emission rates can be estimated based on publicly available NPRI data on total VOC released per facility in 2003 (Table 5.7), publicly available production volumes for 2003 and by making an assumption that the total VOC released are from painting operations, and by making an estimate of the painted surface area of the vehicle mix at each facility.

The Ontario automotive sector produced approximately 2.5 million vehicles in 2003 making Canada the eighth largest producer in the world. VOC emissions released from the sector in 2003 equaled 10,082 tonnes (Table 5.7) which is approximately 14% of Ontario industrial VOC emissions (from reportable facilities) or 1.5% of Ontario's total anthropogenic VOC emissions.

On average, VOC emissions from Ontario automobile surface coating are conservatively estimated to be 4.4 kg per vehicle or 37 g/m^2. The range is from 29–40 g/m^2, which is within the range of the CVMA data. On average, VOC emissions from Ontario light duty truck surface coating are conservatively estimated to be 3.6 kg per vehicle or 36 g/m^2. Note the range is from 25-48 g/m^2, which is just slightly higher than the range of the CVMA data. A summary is provided in Table 7.5.

VOC emissions from Ontario automobile surface coating are significantly less than the CCME criteria of 55 g/m^2. VOC emissions from light duty truck surface coating are significantly less than the CCME criteria of 60/75 g/m^2. VOC emissions from Ontario automotive manufacturers are also lower than the new standards in Europe (i.e., 45 g/m^2 for automobiles) which become effective in 2007 for existing facilities. Also, VOC emissions from Ontario automotive manufacturers, on average, almost meet the most stringent European standard of 35 g/m^2 found in Germany.

---

[1] Plant specific data are confidential – only industry ranges are used.

Table 7.4 2003 VOC Emissions (g/m²) for Ontario's Automotive Sector

Plant	Product	Annual Production	Estimated Area (m^2)	VOC Emissions		
				tonnes	kg/unit	g/m²
Automobiles						
GM Oshawa Car	Mid-size car	618,149	120[1]	2,887	4.7	39
Toyota Cambridge	Mid-size car	234,982	120	827	3.5	29
Ford St. Thomas	Full-size car	174,681	120	818	4.7	39
Honda Alliston 1	Mid-size car	171,446[2]	120	715	4.2	35
DCX Brampton	Full size car	140,349	120	669	4.8	40
Totals / Averages		**1,339,607**	**120**	**5,916**	**4.4**	**37**
Light Duty Trucks						
GM Oshawa Truck	Truck	321,895	100[3]	1,533	4.8	48
Ford Oakville	Minivan	286,748	100	1048[4]	3.7	37
DCX Windsor	Minivan	306,020	100	798[5]	2.6	26
Honda Alliston 2	Small SUV	207,874	100	522	2.5	25
CAMI Ingersol[6]	Small SUV	42,516	100	265	6.2	62
Ford Oakville Truck	Truck	--				
DCX Windsor Truck	Truck	--				
Totals / Averages		**1,165,053**	**100**	**4,166**	**3.6**	**36**
Grand Totals / Averages		**2,504,660**	**111**	**10,082**	**4.0**	**36**

[1] GMCL estimates that the surface area of a mid-size vehicle is 142 m^2 – therefore, 120 m^2 is conservatively assumed for all automobiles.

[2] Only total production for Honda (Plant 1 & 2 combined) was available - split between Plant 1 & Plant 2 was forced to make total cars & total trucks equal OICA data.

[3] GMCL estimates that the surface area of a light duty truck is 109 m^2 – therefore, 100 m^2 is conservatively assumed for all trucks, vans and SUVs.

[4] Only total production for Ford trucks was available – therefore, VOC emissions for both Plants (minivan and truck) are rolled into one value.

[5] Only total production for DaimlerChrysler trucks was available – therefore, VOC emissions for both Plants (minivan and truck) are rolled into one value.

[6] Production at CAMI was significantly below capacity and CAMI was beta testing new product – therefore, purging and maintenance cleaning skewed VOC emissions higher than anticipated for normal production.

7.3.4 Best Available Technology

The US EPA publishes a list of automotive paint shops representing Best Available Control Technology (BACT) (Appendix 7), (RBLC, 2005). In the US, BACT in the newer shops appears to be: (1) water-borne primer, water-borne basecoat and solvent-borne clearcoat with ovens abated with regenerative thermal oxidizers (RTOs) and automatic zones of the clearcoat spray booths abated with carbon concentrators and RTOs, or (2) powder prime, water-borne basecoat and solvent-borne clearcoat with ovens abated with RTOs and automatic zones of clearcoat spray booths abated with carbon concentrators and RTOs.

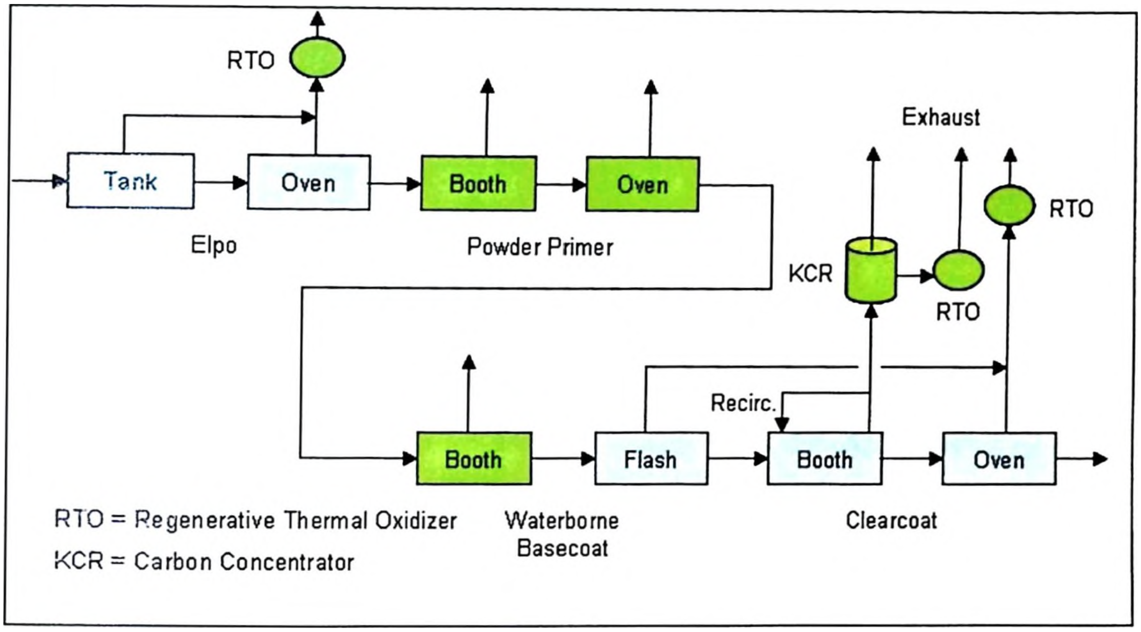
The European experience with Best Available Techniques (BAT) is not as mature as the US experience. New installations in EU25 are expected to employ BAT, and existing facilities will be required to comply by 2007. Guidance on what constitutes a BAT for various industrial sectors is provided in BAT reference documents (BREFs). The draft BREF for automotive surface coating states that substitution of solvent-based paints, paint application methods and abatement should be considered, and also lists technologies which would be applicable in Europe as well as in North America.

Canada and Ontario do not have a specific requirement to apply BAT. However, it is implied in the VOC emissions limits for surface coating in the CCME New Source Performance Standards and Guidelines for the Reduction of Volatile Organic Compound Emissions from Canadian Auto OEMs.

General Motors is currently replacing its existing Oshawa Car plant paint shop as the existing shop reaches the end of its economic life. The new paint shop, currently under construction and scheduled to be operational in 2006, is expected to reduce VOC emissions to less than approximately 15 g/m^2, establishing a new bench mark for the province that will represent Ontario BAT when operational in 2006. This facility, constructed to the new GM template for North America, will achieve this significant reduction in VOC emissions through the use of powder prime, water-borne basecoat, and electrostatic bell paint application of paint and abatement of ovens, heated flash and the automatic zones of the clearcoat spray booth. Figure 7.7 provides a simplified schematic of the new GM Oshawa BAT paint shop.

GM reported that the new paint shop represents an investment of $US 650 million (note that it is equivalent to two large automotive paint shops as it is servicing the Oshawa Car Plants 1 and 2) and has argued that the most cost-effective environmental improvements can only be made at the replacement of a paint shop at the end of its economic life (normally 20-25 years).

Figure 7.7 Simple Schematic of GM Oshawa BAT Paint Shop Process



7.4 Summary

Ontario's automotive sector has significantly reduced VOC emissions since the early 1990's. They have accomplished this largely on voluntary initiatives. VOC emissions from automotive surface coating at Ontario's OEMS currently meet CCME surface coating criteria and would meet European standards for new shops (existing shops have until 2007 to comply). GM's new paint shop for Oshawa Car Plants 1 and 2 will represent the Ontario BAT when operational in 2006 (it is effectively a US BACT configuration). Section 8 will provide a summary, conclusions and recommendations.

8 Summary, Conclusions and Recommendations

Smog (in simple terms, the combination of ground level ozone and particulates) is considered by Canada and Ontario, as well as many other jurisdictions around the world, to be a serious health concern. In response, governments have established regulations and programs to control and reduce the emission of particulates and the ozone precursors (oxides of nitrogen and volatile organic compounds). The painting process in the manufacture of automobile and light duty trucks is viewed as a significant source of VOC emissions. The Ontario Ministry of the Environment is currently reviewing industrial sources of VOC emissions including those from automotive manufacturing in order to set policy for future reductions. This project report contains a review of the pertinent issues including regulatory standards and best practices, and it contains recommendations for best practices for VOC management for the automotive sector in Ontario.

Air Quality: Near real-time air quality data are available in many jurisdictions in Europe, North America, and Asia to inform citizens of local air quality and to alert citizens to "smog" days. In 2002, Southern Ontario was exposed to 4^{th} highest daily maximum 8-hour ozone concentrations from 59-108 ppb.

Air Standards: 8-hour ozone standards range from 60 ppb (WHO, EU target, Japan, and China residential areas) to 80 ppb (US). Canada's 8-hour ozone standard is 65 ppb (to be achieved by 2010). The Ontario ambient air ozone concentrations described above significantly exceed the 8-hour ozone CWS of 65 ppb (to be achieved by 2010).

Sources of VOC Emissions: Canadian anthropogenic emissions of VOC are approximately 2,600 kt per year. Ontario contributes approximately 650 kt per year. Ontario industry contributes approximately 71 kt per year, and Ontario's six (6) automobile and light duty truck manufacturers account for approximately 10 kt per year. This represents approximately 1.5% of Ontario's anthropogenic total.

Surface Coating Standards: Canada and Europe have VOC surface coating standards for the automotive painting operations expressed as a function of surface area coated (i.e. for cars the European standard is 45 g/m^2 and the Canadian guideline is 55 g/m^2). The US New Source Performance Standard (NSPS) is expressed as a function of the volume of applied coating solids (ACS) (i.e. for cars and light duty trucks the topcoat standard is 1.47 kg/L ACS). The two approaches cannot be directly compared. In addition to the NSPS, the US also requires that new or modified paint shops meet BACT, resulting in more stringent VOC limits than the NSPS. Europe has just introduced a BACT concept effective in 2007. Canada has no such requirement although the CCME new source performance standard (i.e. 55g/m^2 for cars) is based on BAT economically achievable.

Automotive Sector: Canada ranks eighth in global automotive production at approximately 2.5 million cars and light duty trucks produced annually. All of Canada's manufacturing is located in Southern Ontario. VOC emissions from European automotive paint shops range from less than 10 g/m^2 to a high of 120 g/m^2 and approximately 50% of the paint shops today do not meet the 2007 standard of 45 g/m^2. The US NSPS and BACT programs, while having different standards, are expected to produce similar, if not lower emissions. For example, Ford reports that its North American operations achieved an average of 29 g/m^2 in 2003. While facility-specific data are not available, VOC emissions from Canadian manufacturers are estimated to be approximately 36 g/m^2 for cars, light duty trucks, vans and SUVs, which meets the CCME limits, European limits, and is almost equal to the most stringent European standard of 35 g/m^2 in Germany. The new GM Car Plant paint shop will represent the BAT facility for Ontario at 15 g/m^2 when operational in 2006. Table 8.1 summarizes graphically the similarities and differences among the various competitive automotive manufacturing jurisdictions worldwide.

Table 8.1 Summary by Region[1]

Description		NAFTA			Europe				Asia		
		US	CA	ME	GE	UK	FR	SP	JA	CH	KO
Smog Related Air Standards											
Ozone Standards	1-hour	X	X	X					√	√	X
	8-hour	X	X	X	√	√	√	√			X
$PM_{2.5}$ Standards	24-hour	X	√	x[2]							
	Annual	X		x[2]							
PM_{10} Standards	24-hour	X	x[3]	X	√	√	√	√	x[3]	√	X
	annual	X	x[3]	X	√	√	√	√		√	X
Transboundary Air Agreements											
International Agreements		X	X		X	X	X	X			
Regional Agreements		X	X	X	X	X	X	X	x[4]	x[4]	x[4]
Air Pollution Monitoring and Reporting											
Real-Time Air Pollution Data		X	X	X	X	X	X	X	X	X	X
Air Emission Reporting		X	X	X	X	X	X	X	X	na	X
Requirements Related to Automotive Manufacturing											
Air Permitting		X	X	X	X	X	X	X	na	na	na
BAT Requirements		√	x[5]	na	x[6]	x[6]	x[6]	x[6]	na	na	na
VOC Coating Standards (g/m^2)			X	X	√	X	X	X	na	na	na
VOC Coating Standards (kg/L ACS)		X							na	na	na

[1] Table Legend: √ = most stringent requirement of jurisdictions surveyed, X = requirements are met, x = requirements effectively met, "na" = information is not readily available

[2] Proposed standard in Mexico

[3] Canada and Japan have standards on Total Suspended Particulate

[4] Developing Regional Initiatives through TEMM (TEMM, 2005)

[5] CCME Coating Guidelines (CCME, 1995) indicates that VOC limits are based on BATEA

[6] Existing facilities in EU to implement BAT in 2007

8.1 Conclusions

Smog events continue to occur in Southern Ontario and maximum ozone concentrations exceed the Canada Wide Standards. Ontario's automotive sector, while perceived as a significant contributor to VOC emissions at 10 kt per year, contributes only 1.5% of Ontario's 650 kt annual emissions. Canada's current VOC guideline for automotive surface coating at 55 g/m^2 is less stringent than Europe's new standard at 45 g/m^2 or Germany's at 35 g/m^2. However, Canadian manufacturers have made significant reductions since the early 1990's and are now achieving VOC emissions, on average, approximately equal to 36 g/m^2. GM's new paint shop for its Oshawa Car Plant is expected to achieve approximately 15 g/m^2 in 2006. Therefore, it can be concluded that through a combination of voluntary (ASAP), regulatory (air permitting), and corporate initiatives (emission objectives and a common "template" design for new paint shops), Ontario's automotive manufacturers are achieving VOC emission performance found in the most stringent European jurisdiction (Germany) and with new installations (GM Oshawa) are approaching US EPA BACT standards.

8.2 Recommendations

The Ontario Ministry of the Environment should continue with its current approach of using the ASAP program and air permitting to control VOC emissions from Ontario's automotive manufacturers. Through voluntary actions, the sector has demonstrated significant VOC reductions, and the current performance of the sector is equal to, if not better than, competitive jurisdictions worldwide. This is remarkable considering this performance has been achieved in the spirit of cooperation and good operations without excessive regulations.

The Ontario Ministry of the Environment should consider, in consultation and cooperation with the Canadian Council of Ministers of the Environment (CCME) and the automotive manufacturing sector, updating the New Source Performance Standards and Guidelines for the Reduction of VOC Emissions from Canadian Automotive OEM Coating Facilities (1995) as the document is now 10 years old, and the new facility and existing facility emission requirements have become the same in 2005.

This project work provides the automotive sector in Ontario and the Ontario Ministry of the Environment with a better understanding of the competitive nature of the global automotive manufacturing business as well as Canada's and Ontario's position in the world with respect to the management of VOC. It also demonstrates the effectiveness of voluntary actions in this sector and clearly states the performance of the Ontario automotive sector compared to competing jurisdictions. It is hoped that the consideration of these findings will assist in developing sound and effective policy for future VOC reductions from the Ontario automotive sector.

References

Acid Rain, Air Pollution and Health, Environmental Fact Sheet No. 9, June 2001, Swedish NGO Secretariat on Acid Rain, Sweden (**AcidRain, 2005**) http://www.acidrain.org/

Acid Rain, Swedish NGO Secretariat on Acid Rain, Göteborg, Sweden (**Acid Rain, 2005**) http://www.acidrain.org/

AirNow, International Air Quality (**AirNow International, 2005**) http://www.epa.gov/airnow/where/world.html

AirNow, On-line Air Quality Information for the US and Canada (**AirNow, 2005**) http://www.epa.gov/airnow/index.html or http://www.airnow.gov/

Air Quality Agreement, Canada-US, 1991 (**AQA, 1991**) http://www.ijc.org/rel/agree/air.html

Air Quality Guidelines for Europe, Second Edition, 2000, WHO Regional Office of Europe (**AQG, 2000**) http://www.euro.who.int/air/Activities/20020620_1

Air Quality Management District, California South Coast (**AQMD, 2005**) www.aqmd.gov

Air Quality Monitoring Network In Hong Kong, Air Services Group, Environmental Protection Department, The Government of the Hong Kong Special Administrative Region, A report on the results from the Air Quality Monitoring Network, 2003 (**AQMN, 2003**)

Air Quality Ontario, On-line Air Quality Information (**Air Ontario, 2005**) http://www.airqualityontario.com/

Anti-Smog Action Plan (Ontario): Progress through Partnership 2000 (**ASAP, 2000**) http://www.ene.gov.on.ca/envision/air/smog/asap2000.htm

Anti-Smog Action Plan (Ontario): Progress through Partnership 2002 (**ASAP, 2002**) http://www.ene.gov.on.ca/envision/air/smog/asap2002.htm

Association des Constructeurs Européens d' Automobiles (European Automobile Manufacturers Association) European Automobile Industry Report, 2004 (**ACEA, 2005**) www.acea.be

Best Available Techniques Reference Document on Surface Treatment using Organic Solvents, EC Integrated Pollution Prevent and Control Draft, May 2004 **(BREF, 2004)** http://www.jrc.es/pub/english.cgi/d1039871/The%20first%20draft%20BREF%20on%20Surface%20Treatment%20using%20solvents%20-%203.6%20Mb

Black Triangle Region, Common Report on Air Quality in 2002 **(BTR, 2002)** www.umweltbundesamt.de/uba-info-daten-e/index.htm

BMW Corporate Website **(BMW, 2005)** http://www.bmwgroup.com

BMW Dingolfing Environmental Report, 2003 **(BMW, 2003)** http://www.bmw-werk-dingolfing.de/dingolfing/htdocs/deutsch/downloads/Umwelterklaerung_2003.pdf

CAFE CBA: Baseline Analysis 2000 to 2020, AEA Technology Environment, UK, January 25, 2005, Pye, S., and Watkins, P. **(CAFE-CBA, 2005)** http://www.iiasa.ac.at/docs/HOTP/Mar05/cafe-cba-baseline-results.pdf

CAMI Automotive **(CAMI, 2005)** http://www.cami.ca/

Canada Gazette, Order Adding Toxic Substances to Schedule 1 to the CEPA, 1999 **(CanadaGazette, 2005)** http://canadagazette.gc.ca/partII/2003/20030702/html/sor229-e.html

Canada-US Air Links **(CAN-US, 2005)** http://www.ec.gc.ca/pdb/can_us/canus_links_e.cfm#pm

Canada Wide Standards for Particulate and Ozone **(CWS, 2005)** http://www.ccme.ca/initiatives/standards.html?category_id=59

Canadian Automotive Partnership Council, A Canadian Auto Strategy, October 2004 **(CAPC, 2005)** http://capcinfo.ca/english/news/news-nouvelles_oct26_04.html

Canadian Progress to Implement the Ozone Annex, Air Quality Committee, June 11, 2004, Québec City, Air Quality Committee **(Canadian Progress, 2004)**

Canadian Vehicle Manufacturers Association **(CVMA, 2005)** http://www.cvma.ca

CCME New Source Performance Standards and Guidelines for the Reduction of Volatile Organic Compound Emissions from Canadian Auto OEM Coating Facilities, August 1995 **(CCME, 1995)** www.ccme.ca

CEPA Toxic Substances List - Updated Schedule 1 as of March 9, 2005 **(CEPA-Toxic, 2005)** http://www.ec.gc.ca/CEPARegistry/subs_list/Toxicupdate.cfm

China State Environmental Protection Agency **(China, 2005)** http://www.sepa.gov.cn/ or http://www.zhb.gov.cn/english/

Clean Air Act as amended 1990, US EPA **(CAA, 1990)** http://www.epa.gov/oar/oaq_caa.html/

Clean Air for Europe, Baseline Scenarios, October 2004 **(CAFE, 2004)** http://europa.eu.int/comm/environment/air/cafe/general/keydocs.htm

Clean Air for Europe (CAFE) Programme: Towards a Thematic Strategy for Air Quality EC COM (2001) 245 final, 04.05.2001, Brussels, Communication from the Commission **(CAFE, 2001)** http://europa.eu.int/eur-lex/en/com/pdf/2001/com2001_0245en01.pdf

Criteria Air Contaminant Emissions (2000) for Canada, Environment Canada, December 2004 **(CAC, 2004)** www.ec.gc.ca/pdb/cac/ape_tables/canada2000_e.cfm

CSM Worldwide, Farmington Hills, Michigan, USA **(CSM, 2005)** www.csmauto.com

DaimlerChrysler Canada **(DaimlerChrysler Canada, 2005)** http://www.daimlerchrysler.ca/EN/HOME_FLASH/1,,EN-HOME_FLASH,.html

DaimlerChrysler **(DaimlerChrysler, 2005)** http://www.daimlerchrysler.com/dccom

DuPont Powder Coatings **(DuPont, 2005)** http://www.dupontpowder.com/

EC Council Directive 1999/13/EC, March 11, 1999, Limitation of Emissions of Volatile Organic Compounds due to the use of Organic Solvents **(1999/13/EC, 1999)** http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=31999L0013&model=guichett

EC Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air **(1999/30/EC, 1999)** http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=31999L0030&model=guichett

EC Council Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management **(96/62/EC, 1996)** http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=31996L0062&model=guichett

EC Directive 2002/3/EC of the European Parliament and of The Council of 12 February 2002, relating to ozone in ambient air **(2002/3/EC, 2002)** http://europa.eu.int/eur-lex/pri/en/oj/dat/2002/l_067/l_06720020309en00140030.pdf

Ecology Center of Ann Arbor, Comments on Permit Number 209-0090, Hyundai Assembly Plant, September 19, 2002 (Ecology, 2005) www.ecocenter.org

Ecology Center of Ann Arbor, Comments on Permit Number 895-93A, Ford Michigan Truck Plant, May 7, 1998 **(Ecology, 2005)** www.ecocenter.org

Environment Canada **(EC, 2005)** www.ec.gc.ca

Environment Canada, Volatile Organic Compounds - 2000 Emissions **(EC VOC, 2005)** www.ec.gc.ca/pdb/cac/ape_tables/voc2000_e.cfm

EPA -US, Title 40, Part 51, Subpart F, Section 51.100 (Definitions), (s) Volatile Organic Compounds (VOC), **(EPA VOC, 2005)**, http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=80cda0a184f3631df464dfba44e2b1c4&rgn=div5&view=text&node=40:2.0.1.1.2&idno=40#40:2.0.1.1.2.3.8.1

Europa, A Comparison of EU Air Pollution Legislation with Other Countries, January 2004 **(Europa, 2005)** http://europa.eu.int/comm/enterprise/environment/reports_studies/index.htm

Ford Corporate Citizens Report 2003 - 2004 **(Ford, 2005)** http://www.ford.com

Ford Motor Company **(Ford, 2005)** http://www.ford.com/en/default.htm

General Motors **(GM, 2005)** http://www.gm.com/

General Motors, Corporate Environmental Repots **(GM Environment, 2005)** http://www.gm.com/company/gmability/environment/

German Air Quality Data, German Länder and the Federal Environmental Agency **(German Air Quality, 2005)** http://www.env-it.de/luftdaten/start.fwd

German Air Quality Control 2010, National Programme, August 2002 **(German NEC, 2005)** http://www.umweltbundesamt.de

GM 2004 Corporate Responsibility Report, 2004 Responsibility Report **(GMResponsibilty, 2005)** http://www.gm.com/company/gmability/sustainability/reports/04/600_environment/663na_emi.html

Health Effects of Ground level Ozone, Ontario Medical Association **(Health, 2005)** www.oma.org/phealth/health.htm

Honda Environmental Annual Report **(Honda, 2005)** http://world.honda.com/environment/2004report/

Japanese Ministry of the Environment **(Japan, 2005)** http://www.env.go.jp/en/index.html or http://www.env.go.jp/index.html

Keenan, G., Ontario Passes Michigan in Auto Production, January 10, 2005, The Globe and Mail **(Keenan, 2005)**

Korea (Republic of), Ministry of Environment **(Korea, 2005)** http://www.me.go.kr/ or http://eng.me.go.kr/user/index.html or http://airmap.nier.go.kr/airinfo/

Long-range Transboundary Air Pollution, UNECE, 1979 Geneva Convention **(LRTAP, 1979)** http://www.unece.org/env/lrtap/welcome.html or http://www.unece.org/env/lrtap/lrtap_h1.htm

McAlinden, S. P., Global Economic Challenges to the Auto Industry, Center for Automotive Research, September 14, 2004, GM Environmental Conference, Detroit **(McAlinden, 2004)**

Met Office, United Kingdom **(MetOffice, 2005)** www.metoffice.gov.uk

Meteorological Service of Canada (MSC) - Smog **(MSC, 2005)** http://www.msc.ec.gc.ca/saib/smog/smog_e.html

Mexican Official Standards (O_3, CO, SO_2, NO_2, PST, PM_{10}, & Lead), **(Mexico, 2005)**, http://www.sma.df.gob.mx/simat/pnnormasalud.htm

Mexico City, Air Quality in the Metropolitan Area **(Mexico, 2005)** http://www.sima.com.mx/valle_de_mexico/mexico.htm

Ministry of the Environment - Ontario **(MOE, 2005)** www.ene.gov.on.ca

Multilateral Environmental Agreements **(MEA, 2005)** http://www.unescap.org/drpad/vc/orientation/M3anx_MEAs.htm

National Ambient Air Quality Objectives for Ground Level Ozone, Health Canada, July 1999 **(NAAQO Ozone, 1999)** http://www.hc-sc.gc.ca/hecs-sesc/air_quality/publications/ground-leve_ozone.htm

National Ambient Air Quality Objectives for Ground Level Ozone, Science Assessment Document, Health Canada, July 1999 (**NAAQO Ozone Science, 1999**) http://www.hc-sc.gc.ca/hecs-sesc/air_quality/publications/ground_level_ozone/part1/toc.htm

National Ambient Air Quality Objectives for Particulate Matter, Addendum to the Science Assessment Document, Health Canada and Environment Canada, July 1998 (**NAAQO PM Addendum, 1999**) http://www.hc-sc.gc.ca/hecs-sesc/air_quality/publications/particulate_matter_science_assessment/addendum/toc.htm

National Ambient Air Quality Objectives for Particulate Matter, Health Canada, July 1999 (**NAAQO PM, 1999**) http://www.hc-sc.gc.ca/hecs-sesc/air_quality/publications/particule_matter.htm

National Ambient Air Quality Standards, US EPA (**NAAQS, 2005**) http://www.epa.gov/air/criteria.html

National Emission Ceilings, EC Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001, on national emission ceilings for certain atmospheric pollutants (**NEC, 2001**) http://europa.eu.int/eur-lex/pri/en/oj/dat/2001/l_309/l_30920011127en00220030.pdf

National Pollutant Release Inventory, 2003 Preliminary Version Release, Environment Canada (**NPRI, 2003**) www.ec.gc.ca/pdb/npri/early_release/index_e.cfm

Nissan Environmental Report, 2004 (**Nissan, 2005**) http://www.nissan-global.com/EN/COMPANY/CSR/SUSTAINABILITY2004/AWARD/

Nissan Motor Company Limited, 2004 Environmental Report (**Nissan, 2004**) http://www.nissan-global.com/EN/ENVIRONMENT/LIBRARY/ER/index.html

NOM-121-ECOL-1997, Mexican Automotive Surface Coating Standards (**NOM-121**) http://www.sma.df.gob.mx/bibliov/download/archivos/semarnap_nom_121_ecol_1997.pdf

OECD, Environmental Performance Reviews (1st Cycle), Conclusions and Recommendations 32 countries (1993-2000), November 2000 (**OECD Performance, 2005**) http://www.oecd.org/dataoecd/19/56/2432829.pdf

OECD, Organization for Economic Co-operation and Development (**OECD, 2005,** http://www.oecd.org/home/

Ontario Environmental Protection Act, 1990 (**O. EPA, 1990**) http://www.e-laws.gov.on.ca/DBLaws/Statutes/English/90e19_e.htm

Ontario Medical Association, Air Quality/Smog Issues (**OMA, 2005**) http://www.oma.org/phealth/smogmain.htm

Ontario Medical Association, Toronto, Ontario (**OMA, 2005**) www.oma.org

Opel Corporate Responsibility Report 2003/4 (**OPEL, 2005**) http://www.gm.com/company/gmability/sustainability/reports/04/800_regional/opel_crr_121704.pdf

Organic Compounds, UNECE, 1991 Protocol concerning the Control of Emissions of Volatile Organic Compounds (**VOC Protocol, 1991**) http://www.unece.org/env/lrtap/vola_h1.htm

Organisation Internationale des Constructeurs d'Automobiles (International Organization of Motor Vehicle Manufacturers), Paris (**OICA, 2005**) http://www.oica.net/

Ozone Air Quality Criteria, First External Draft, US EPA, Jan., 2005 (**Ozone, 2005**) cfpub.epa.gov/ncea/cfm/recordisplay.cfm?PrintVersion=True&deid=114523

Ozone Annex, Progress Report 2004, Canada - US Air Quality Agreement (**Ozone Annex, 2005**) http://www.ec.gc.ca/pdb/can_us/2004CanUs/section1b_e.html

Ozone Annex Review, Scavo, K., US EPA, and Puckett, K., EC, US - Canada Air Quality Agreement Ozone Annex Review, 2002 Emissions and Ambient Air Quality Benchmark (**Ozone Annex Review, 2004**)

Ozone Annex to the 1991 Air Quality Agreement, Canada-US (**Ozone Annex, 2000**) http://www.ec.gc.ca/air/can_usa_e.html

Ozone, UNECE, 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone, (**Ozone Protocol, 1999**) http://www.unece.org/env/lrtap/multi_h1.htm

Particulate Matter – Ozone, National Summary of Ambient $PM_{2.5}$ and Ozone Report for 2002 prepared for the Joint Action Implementation Coordinating Committee by Environment Canada, September, 2004 (**PM-Ozone Report, 2004**) http://www.ccme.ca/assets/pdf/jaicc_2002_ntnl_smry_e.pdf

Particulate Matter, Review of the National Ambient Air Quality Standards for Particulate Matter, Policy Assessment of Scientific and Technical Information, OAQPS Staff

Paper – Second Draft, ES EPA, January 2005 (**Particulate, 2005**) http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_cr_sp.html

Pengelly, L. D., et al, Air Pollution-Related Burden of Illness in Toronto: 2004 Update, Technical Report prepared for the City of Toronto, March 2004 (**Pengelly, 2004**) www.city.toronto.on.ca/health/hphe/pdf/air_and_health_burden_technical.pdf

Peugeot, PSA-Peugeot-Citroen, Environmental Stewardship 2003 (**Peugeot, 2005**) http://www.psa-peugeot-citroen.com/document/publication/Environmmental_Stewardship_20031087477742.pdf

RACT/BACT/LAER Clearinghouse, Technology Transfer Network Clean Air Technology Center, US EPA (**RBLC, 2005**) http://cfpub.epa.gov/rblc/htm/bl02.cfm

Radford University, Environmental History Timeline, East Main Street, Radford, VA (**Radford, 2005**) www.radford.edu

Regulation 127, Airborne Contaminant Discharge - Monitoring and Reporting, Step By Step Guideline for Emission Calculation, Record Keeping and Reporting for Airborne Contaminant Discharge, Ontario Ministry of the Environment Revised: May 2004, (**Reg.127, 2005**) http://www.ene.gov.on.ca/envision/gp/4099e02.pdf

Regulation 346, General – Air Pollution, Ontario (**Reg.346, 2005**) http://www.e-laws.gov.on.ca/DBLaws/Regs/English/900346_e.htm

Saab Environmental Report 2001 (**Saab, 2001**) http://www.saab.com.tr/main/pdf/GLOBAL_en_environmental_report.pdf

Shanghai Environment Online - English Version (**Shanghai, 2005**) http://www.envir.online.sh.cn/eng/

Sindelfingen Plant, DaimlerChrysler Environmental Report 2003 (**Sindelfingen, 2003**) http://www.daimlerchrysler.com/Projects/c2c/channel/documents/278816_sindelfingen_ue2003.pdf

Smog Warners Data Exchange (**Smog Warners, 2005**) http://www.aeat.co.uk/netcen/airqual/forecast/smogwarners/

Smog, The 1952 London Smog, UK Met Office (**Smog, 1952**) http://www.metoffice.gov.uk/health/features/200302/pea_soup.html

Subpart MM, US EPA, Title 40, Part 60, Standards of Performance for Automobile and Light Duty Truck Surface Coating Operations **(Subpart MM, 2005)** http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=b829ed04b944f8f57288119f85bdeb8b&rgn=div5&view=text&node=40:6.0.1.1.1&idno=40#40:6.0.1.1.1.52

Toyota **(Toyota, 2005)** http://www.toyota.co.jp/en/index.html

Toyota North America 2004 Environmental Report **(Toyota NA, 2005)** http://www.toyota.com/about/environment/news/images/04envrep-all.pdf

Tripartite Environment Ministers Meeting **(TEMM, 2005)** http://www.temm.org/docs/main.html

UK, National Air Quality Information Archive **(UK Air Quality, 2005)** http://www.airquality.co.uk/archive/index.php

Umwelt Bundes Amt, German Federal Environmental Agency **(UBA, 2005)** http://www.umweltbundesamt.de

UNECE, September 2003, Modelling and Assessment of Health Impacts of Particulate Matter and Ozone, Working Group on Effects **(UNECE, 2003)** Modelling and assessment of health impacts of particulate matter and ozone

UNECE, September 2004, Modelling and Assessment of Health Impact of Particulate Matter and Ozone, Working Group on Effects **(UNECE, 2004)** Modelling and assessment of the health impact of particulate matter and ozone

Vauxhall Sustainability Review 2003 **(Vauxhall, 2005)** http://vauxhall.co.uk/companyInformation/reports.jhtml

Verband der Automobilindustrie (VDA) 2004 Annual Report, Germany **(VDA, 2005)** www.vda.de

Volkswagen AG Environmental Report 2003/2004 **(VW, 2004)** http://www.mobility-and-sustainability.com/

Volkswagen, Paint Shop Technology at Volkswagen, Technical Progress and Environmental Protection, Dr. M. Mrowietz, Brussels, 24-25 November 2003 **(VW, 2003)** http://europa.eu.int/comm/enterprise/environment/events/env_performance/presentations/air_emissions_mrowietz.pdf

Volvo Citizenship Report 2003, Volvo Car Corporation (**Volvo, 2003**) www.volvocars.com/AboutVolvo/CorporateCitizenship/

World Health Organization (WHO), (**WHO, 2005**), http://www.who.int/en/

World Health Organization Working Group, Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide, Germany, January 2003 (**WHO, 2003**) http://www.euro.who.int/document/e79097.pdf

World Health Organization Working Group, Health Aspects of Air Pollution in Europe, WHO, June 2004 (**WHO, 2004**) http://www.euro.who.int/air/Activities/20040621_1

Appendices

Appendix 1 US EPA Definition of VOC

As of 12/29/2004 - 40 CFR 51.100(s) - Definition – "Volatile organic compounds (VOC)" means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions. This includes any such organic compound other than the following, which have been determined to have negligible photochemical reactivity:

- methane
- ethane
- methylene chloride (dichloromethane)
- 1,1,1-trichloroethane (methyl chloroform)
- 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113)
- trichlorofluoromethane (CFC-11)
- dichlorodifluoromethane (CFC-12)
- chlorodifluoromethane (HCFC-22)
- trifluoromethane (HFC-23)
- 1,2-dichloro 1,1,2,2-tetrafluoroethane (CFC-114)
- chloropentafluoroethane (CFC-115)
- 1,1,1-trifluoro 2,2-dichloroethane (HCFC-123)
- 1,1,1,2-tetrafluoroethane (HFC-134a)
- 1,1-dichloro 1-fluoroethane (HCFC-141b)
- 1-chloro 1,1-difluoroethane (HCFC-142b)
- 2-chloro-1,1,1,2-tetrafluoroethane (HCFC-124)
- pentafluoroethane (HFC-125)
- 1,1,2,2-tetrafluoroethane (HFC-134)
- 1,1,1-trifluoroethane (HFC-143a)
- 1,1-difluoroethane (HFC-152a)
- parachlorobenzotrifluoride (PCBTF)
- cyclic, branched, or linear completely methylated siloxanes
- acetone
- perchloroethylene (tetrachloroethylene)
- 3,3-dichloro-1,1,1,2,2-pentafluoropropane (HCFC-225ca)
- 1,3-dichloro-1,1,2,2,3-pentafluoropropane (HCFC-225cb)
- 1,1,1,2,3,4,4,5,5,5-decafluoropentane (HFC 43-10mee)
- difluoromethane (HFC-32)
- ethylfluoride (HFC-161)
- 1,1,1,3,3,3-hexafluoropropane (HFC-236fa)
- 1,1,2,2,3-pentafluoropropane (HFC-245ca)

- 1,1,2,3,3-pentafluoropropane (HFC-245ea)
- 1,1,1,2,3-pentafluoropropane (HFC-245eb)
- 1,1,1,3,3-pentafluoropropane (HFC-245fa)
- 1,1,1,2,3,3-hexafluoropropane (HFC-236ea)
- 1,1,1,3,3-pentafluorobutane (HFC-365mfc)
- chlorofluoromethane (HCFC-31)
- 1-chloro-1-fluoroethane (HCFC-151a)
- 1,2-dichloro-1,1,2-trifluoroethane (HCFC-123a)
- 1,1,1,2,2,3,3,4,4-nonafluoro-4-methoxy-butane (C4F9OCH3 or HFE-7100)
- 2-(difluoromethoxymethyl)-1,1,1,2,3,3,3-heptafluoropropane ((CF3)2CFCF2OCH3)
- 1-ethoxy-1,1,2,2,3,3,4,4,4-nonafluorobutane (C4F9OC2H5 or HFE-7200)
- 2-(ethoxydifluoromethyl)-1,1,1,2,3,3,3-heptafluoropropane ((CF3)2CFCF2OC2H5)
- methyl acetate
- 1,1,1,2,2,3,3-heptafluoro-3-methoxy-propane (n-C3F7OCH3 or HFE-7000)
- 3-ethoxy-1,1,1,2,3,4,4,5,5,6,6,6-dodecafluoro-2-(trifluoromethyl) hexane (HFE-7500)
- 1,1,1,2,3,3,3-heptafluoropropane (HFC 227ea)
- and methyl formate (HCOOCH3)
- and perfluorocarbon compounds which fall into these classes:
  (i) cyclic, branched, or linear, completely fluorinated alkanes,
  (ii) cyclic, branched, or linear, completely fluorinated ethers with no unsaturations,
  (iii) cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations, and
  (iv) sulfur containing perfluorocarbons with no unsaturations and with sulfur bonds only to carbon and fluorine.

Appendix 2 Canadian Definition of VOC

Volatile organic compounds as defined in the Annex of the *Canada Gazette* Notice entitled: *Notice of intent to recommend that ozone and its precursors (nitrogen oxides [nitric oxide and nitrogen dioxide] and volatile organic compounds) be added to the List of Toxic Substances in Schedule 1 to the Canadian Environmental Protection Act, 1999 under subsection 90(1) of the Act* published on June 9, 2001. (Toxic Substances List - Updated Schedule 1 as of August 13, 2003.). Volatile organic compounds that participate in atmospheric photochemical reactions, excluding the following:

a. methane;
b. ethane;
c. methylene chloride (dichloromethane);
d. 1,1,1-trichloroethane (methyl chloroform);
e. 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113);
f. trichlorofluoromethane (CFC-11);
g. dichlorodifluoromethane (CFC-12);
h. chlorodifluoromethane (HCFC-22);
i. trifluoromethane (HFC-23);
j. 1,2-dichloro-1,1,2,2-tetrafluoroethane (CFC-114);
k. chloropentafluoroethane (CFC-115);
l. 1,1,1-trifluoro-2,2-dichloroethane (HCFC-123);
m. 1,1,1,2-tetrafluoroethane (HFC-134a);
n. 1,1-dichloro-1-fluoroethane (HCFC-141b);
o. 1-chloro-1,1-difluoroethane (HCFC-142b);
p. 2-chloro-1,1,1,2-tetrafluoroethane (HCFC-124);
q. pentafluoroethane (HFC-125);
r. 1,1,2,2-tetrafluoroethane (HFC-134);
s. 1,1,1-trifluoroethane (HFC-143a);
t. 1,1-difluoroethane (HFC-152a);
u. parachlorobenzotrifluoride (PCBTF);
v. cyclic, branched or linear completely methylated siloxanes;
w. acetone;
x. perchloroethylene (tetrachloroethylene);
y. 3,3-dichloro-1,1,1,2,2-pentafluoropropane (HCFC-225ca);
z. 1,3-dichloro-1,1,2,2,3-pentafluoropropane (HCFC-225cb);
   (z.1) 1,1,1,2,3,4,4,5,5,5-decafluoropentane (HFC 43-10mee);
   (z.2) difluoromethane (HFC-32);
   (z.3) ethylfluoride (HFC-161);
   (z.4) 1,1,1,3,3,3-hexafluoropropane (HFC-236fa);
   (z.5) 1,1,2,2,3-pentafluoropropane (HFC-245ca);
   (z.6) 1,1,2,3,3-pentafluoropropane (HFC-245ea);
   (z.7) 1,1,1,2,3-pentafluoropropane (HFC-245eb);

(z.8) 1,1,1,3,3-pentafluoropropane (HFC-245fa);
(z.9) 1,1,1,2,3,3-hexafluoropropane (HFC-236ea);
(z.10) 1,1,1,3,3-pentafluorobutane (HFC-365mfc);
(z.11) chlorofluoromethane (HCFC-31);
(z.12) 1-chloro-1-fluoroethane (HCFC-151a);
(z.13) 1,2-dichloro-1,1,2-trifluoroethane (HCFC-123a);
(z.14) 1,1,1,2,2,3,3,4,4-nonafluoro-4-methoxy-butane ($C_4F_9OCH_3$);
(z.15) 2-(difluoromethoxymethyl)-1,1,1,2,3,3,3-heptafluoropropane (($CF_3)_2CFCF_2OCH_3$);
(z.16) 1-ethoxy-1,1,2,2,3,3,4,4,4-nonafluorobutane ($C_4F_9OC_2H_5$);
(z.17) 2-(ethoxydifluoromethyl)-1,1,1,2,3,3,3-heptafluoropropane (($CF_3)_2CFCF_2OC_2H_5$);
(z.18) methyl acetate and perfluorocarbon compounds that fall into the following classes, namely,

i. cyclic, branched or linear completely fluorinated alkanes,
ii. cyclic, branched, or linear completely fluorinated ethers with no unsaturations,
iii. cyclic, branched or linear completely fluorinated tertiary amines with no unsaturations, or
iv. sulfur containing perfluorocarbons with no unsaturations and with sulfur bonds only to carbon and fluorine.

Appendix 3 CCME Guideline Definition of VOC

Any organic compound which participates in atmospheric photochemical reactions. That is, any organic compound other than the following, which have been excluded because of their negligible photochemical reactivity:

- methane,
- ethane,
- methyl chloroform,
- methylene chloride,
- CFC-113 (trichlorotrifluoroethane),
- CFC -114 (dichlorotetrafluoroethane),
- CFC-115 (chloropentafluoroethane),
- CFC-11 (trichlorofluoromethane),
- CFC-12 (dichlorodifluoromethane),
- CFC-22 (chlorodifluoromethane),
- FC-23 (trifluoromethane),
- HCFC-123 (dichlorotrifluoroethane),
- HCFC-141b (dichlorofluoroethane),
- HCFC-142b (chlorodifluoroethane), and
- HFC-134a (tetrafluoroethane).

Note for the purpose of this standard, acetone has been excluded.

Appendix 4 Ontario Definition of VOC

Ontario Regulation 127/01 - Airborne Contaminant Discharge Monitoring and Reporting - Step By Step Guideline. For the purposes of this Guideline, volatile organic compounds (VOC) are defined as any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions and has a vapour pressure of 0.01 kPa or greater at 25°C. The following compounds are not included as VOC because of their negligible photochemical reactivity:

- methane; ethane; methylene chloride (dichloromethane);
- 1,1,1-trichloroethane (methyl chloroform); 1,1,2-trichloro-1,2,2- trifluoroethane (CFC-113);
- trichlorofluoromethane (CFC-11); dichlorodifluoromethane (CFC-12);
- chlorodifluoromethane (HCFC-22);
- trifluoromethane (HFC-23);
- 1,2- dichloro 1,1,2,2-tetrafluoroethane (CFC-114);
- chloropentafluoroethane (CFC-115);
- 1,1,1-trifluoro 2,2-dichloroethane (HCFC-123);
- 1,1,1,2- tetrafluoroethane (HFC-134a);
- 1,1-dichloro 1-fluoroethane (HCFC-141b);
- 1-chloro 1,1-difluoroethane (HCFC-142b);
- 2-chloro-1,1,1,2- tetrafluoroethane (HCFC-124);
- pentafluoroethane (HFC-125);
- 1,1,2,2- tetrafluoroethane (HFC-134);
- 1,1,1-trifluoroethane (HFC-143a);
- 1,1- difluoroethane (HFC-152a);
- parachlorobenzotrifluoride (PCBTF);
- cyclic, branched, or linear completely methylated siloxanes;
- acetone;
- perchloroethylene (tetrachloroethylene);
- 3,3-dichloro-1,1,1,2,2-pentafluoropropane (HCFC-225ca);
- 1,3-dichloro-1,1,2,2,3-pentafluoropropane (HCFC-225cb);
- 1,1,1,2,3,4,4,5,5,5-decafluoropentane (HFC 43-10mee);
- difluoromethane (HFC-32);
- ethylfluoride (HFC-161);
- 1,1,1,3,3,3-hexafluoropropane (HFC-236fa);
- 1,1,2,2,3-pentafluoropropane (HFC-245ca);
- 1,1,2,3,3-pentafluoropropane (HFC-245ea);
- 1,1,1,2,3-pentafluoropropane (HFC-245eb);
- 1,1,1,3,3-pentafluoropropane (HFC-245fa);
- 1,1,1,2,3,3-hexafluoropropane (HFC-236ea);
- 1,1,1,3,3-pentafluorobutane (HFC-365mfc);

- chlorofluoromethane (HCFC-31);
- 1-chloro-1-fluoroethane (HCFC-151a);
- 1,2-dichloro-1,1,2-trifluoroethane (HCFC-123a);
- 1,1,1,2,2,3,3,4,4-nonafluoro-4-methoxy-butane (C4F9OCH3);
- 2-(difluoromethoxymethyl)-1,1,1,2,3,3,3-heptafluoropropane ((CF3)2CFCF2OCH3);
- 1-ethoxy-1,1,2,2,3,3,4,4,4-nonafluorobutane (C4F9OC2H5);
- 2-(ethoxydifluoromethyl)-1,1,1,2,3,3,3-heptafluoropropane ((CF3)2CFCF2OC2H5);
- methyl acetate and perfluorocarbon compounds which falls into these classes:
  (i) Cyclic, branched, or linear, completely fluorinated alkanes;
  (ii) Cyclic, branched, or linear, completely fluorinated ethers with no unsaturations;
  (iii) Cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations; and
  (iv) Sulphur containing perfluorocarbons with no unsaturations and with sulphur bonds only to carbon and fluorine.

Owing to the numerous VOC species, it is not possible to give an all inclusive list of atmospherically important VOC. A list of VOC compounds based on Carter's 23 list of ozone forming potential contaminants, not including those in the forementioned USEPA exclusion list, is available from the Ministry of the Environment's Public Information Centre upon request.

Appendix 5 Summary of Ozone & Particulate Air Standards

Jurisdiction	Ozone	$PM_{2.5}$	PM_{10}	Averaging Time/Comments
WHO				1-hour
	60 ppb			8-hour
				24-hour – WHO recommends dose response
				Annual– WHO recommends dose response
EU				1-hour
	60 ppb			8-hr - 2010 target not to be exceeded > 25 days/yr
			50 $\mu g/m^3$	24-hr, not to be exceeded > 35 times per year
			40 $\mu g/m^3$	Annual
Japan	60 ppb		200 $\mu g/m^3$	1-hour
				8-hour
			100 $\mu g/m^3$	24-hour – TSP daily average of 1-hour value
				Annual
China (Residential Areas)	60 ppb			1-hour
				8-hour
			50 $\mu g/m^3$	24-hour
			40 $\mu g/m^3$	Annual
China (Commercial Areas)	80 ppb			1-hour
				8-hour
			150 $\mu g/m^3$	24-hour
			100 $\mu g/m^3$	Annual
China (Industrial Areas)	100 ppb			1-hour
				8-hour
			250 $\mu g/m^3$	24-hour
			150 $\mu g/m^3$	Annual
Korea	100 ppb			1-hour
	60 ppb			8-hour
			150 $\mu g/m^3$	24-hour
			70 $\mu g/m^3$	Annual
Hong Kong	240 $\mu g/m^3$			1-hour
				8-hour
			180 $\mu g/m^3$	24-hour
			55 $\mu g/m^3$	Annual
US EPA NAAQS	120 ppb			1-hour (235 $\mu g/m^3$)
	80 ppb			8-hr (4th highest value in 3-yr aver.)(157$\mu g/m^3$)
		65 $\mu g/m^3$	150 $\mu g/m^3$	24-hour
		15 $\mu g/m^3$	50 $\mu g/m^3$	Annual
Mexico Norm	110 ppb			1-hour
	80 ppb			8-hour (5th maximum in a year)
		65 $\mu g/m^3$	150 $\mu g/m^3$	24-hour ($PM_{2.5}$ is proposed)
		15 $\mu g/m^3$	50 $\mu g/m^3$	Annual ($PM_{2.5}$ is proposed)
Canada EC / HC NAAQO	82 ppb			1-hour
				8-hour
			120 $\mu g/m^3$	24-hour (total suspended particulate (TSP))
			70 $\mu g/m^3$	Annual (total suspended particulate (TSP))
Canada CCME CWS				1-hour
	65 ppb			8-hour (by 2010) 4th highest ave. over 3 yrs
		30 $\mu g/m^3$		24-hour (by 2010) 98th percentile ave. 3 yrs
				Annual
Ontario AAQC	165 $\mu g/m^3$			1-hour (or 80 ppb)
				8-hour
			120 $\mu g/m^3$	24-hour (TSP < 44 μm)
			60 $\mu g/m^3$	Annual (TSP < 44 μm)

Appendix 6 Directive 1999/13/EC - The Vehicle Coating Industry

The total emission limit values are expressed in terms of grams of solvent emitted in relation to the surface area of product in square metres and in kilograms of solvent emitted in relation to the car body.

The surface area of any product dealt with in the table below is defined as follows:

- the surface area calculated from the total electrophoretic coating area, and the surface area of any parts that might be added in successive phases of the coating process which are coated with the same coatings as those used for the product in question, or the total surface area of the product coated in the installation.

The surface of the electrophoretic coating area is calculated using the formula:

$$\frac{2 \times \text{total weight of product shell}}{\text{average thickness of metal sheet} \times \text{density of metal sheet}}$$

This method shall also be applied for other coated parts made out of sheets.

Computer aided design or other equivalent methods shall be used to calculate the surface area of the other parts added, or the total surface area coated in the installation.

The total emission limit value in the table below refers to all process stages carried out at the same installation from electrophoretic coating, or any other kind of coating process, through to the final wax and polish of topcoating inclusive, as well as solvent used in cleaning of process equipment, including spray booths and other fixed equipment, both during and outside of production time. The total emission limit value is expressed as the mass sum of organic compounds per m^2 of the total surface area of coated product and as the mass sum of organic compounds per car body.

Activity (solvent consumption threshold in tonnes/year)	Production threshold (refers to annual production of coated item)	Total emission limit value	
		New	Existing
Coating of new cars (> 15)	> 5 000	45 g/m^2 or 1,3 kg/body + 33 g/m^2	60 g/m^2 or 1,9 kg/body + 41 g/m^2
	≤ 5 000 monocoque or > 3 500 chassis-built	90 g/m^2 or 1,5 kg/body + 70 g/m^2	90 g/m^2 or 1,5 kg/body + 70 g/m^2
Coating of new truck cabins (> 15)	≤ 5 000 > 5 000	65 g/m^2 55 g/m^2	85 g/m^2 75 g/m^2
Coating of new vans and trucks (> 15)	≤ 2 500 >2 500	90 g/m^2 70 g/m^2	120 g/m^2 90 g/m^2
Coating of new buses (> 15)	≤ 2 000 >2 000	210 g/m^2 150 g/m^2	290 g/m^2 225 g/m^2

Vehicle coating installations below the solvent consumption thresholds in the table above shall meet the requirements for the vehicle refinishing sector in Annex IIA.

Appendix 7 Selected US Auto Plants Having BACT for VOC

Plant	Units/Yr	Ecoat	Primer	Topcoat
Hyundai Alabama 2004 (1)	300,000	- Water based - RTO controlling oven - 0.13 lb/gal ACS (3)	- Water based - RTO controlling oven - 4.1 lb/gal ACS (3)	- Water based basecoat - Solvent -based clearcoat - RTO controlling oven & auto zones of clearcoat booth - 5.2 lb/gal ACS (2)
Honda Alabama 2002	195,000	- Water based - RTO controlling oven - 0.13 lb/gal ACS	- Water based - RTO controlling oven - 4.1lb/gal ACS	- Water based basecoat - Solvent-based clearcoat - RTO controlling oven & auto zones of clearcoat booth - 5.2 lb/gal ACS
GM Delta Township MI 2001	91/hour	- Dip tank & oven controlled by thermal oxidation - 0.04 lb/gal ACS	- Powder - "0" VOC emissions	- Waterborne basecoat - Solvent-borne clearcoat - heated flash & topcoat ovens controlled by RTO, auto zones of cc booth controlled by carbon conc. & RTO - 5.42 lb/gal ACS
Nissan MS 2001	500,000	- Waterborne - Oven controlled by RTO - 0.13 lb/gal ACS	- Waterborne - Oven controlled by RTO - 4.1 lb/gal ACS	- Waterborne basecoat - Solvent-borne clearcoat - Auto zones of cc controlled by carbon adsorption & RTO - Topcoat ovens controlled by RTO - 5.2 lb/gal
GM Lansing Grand River, MI 2000	211,603	- Dip tank & oven controlled by thermal oxidation - 0.04 lb/gal ACS	- Automatic spray section & oven controlled w/ carbon concentrator & RTO - 5.2 lb/gal ACS	- Waterborne basecoat - Solvent-borne clearcoat - Carbon concentrator & RTO control of BC flash-off & auto zone of cc booths - 5.2 lb/g ACS
GM LA 2000	373,560	- Thermal oxidizer - 0.04 lb/gal ACS	- Powder - "0" VOC emissions	- Concentrator & RTO - 6.61 lb/gal ACS
GM OK 1999		- Dip tank & oven controlled by thermal oxidization - 0.13 [0.04 check] lb/gal ACS	- Powder - "0" VOC emissions	- Waterborne basecoat - Carbon adsorption & RTO - 5.3 lb/gal ACS
GM Flint Michigan 1999	70,000	- Waterborne - Dip tank & oven controlled w/ carbon and thermal oxidizer - 0.04 lb/gal ACS	- Solvent borne - 100% capture flash & ovens, 85% in booths w/ carbon conc. & RTO - 3.46 lb/gal ACS	- Solvent borne - 100% capture on ovens & flash-off, 85% in booths, control by carbon concentrator / thermal oxidizer - 5.5 lb/gal ACS
BMW SC 1999	25/hour	- Waterborne - Thermal incineration for oven - 0.22 lb/gal ACS	- Waterborne - Thermal incineration for underbody & primer oven - 0.5 lb/ gal ACS	- Waterborne basecoat - Thermal incineration - 6.24 lb/gal ACS
Ford Dearborn Michigan 1998 & 2000	80/hour	- Water-based - control of tank and curing oven by RTO - 0.04 lb/gal ACS	- Waterborne - No booth control - Carbon absorbers & RTO on ovens - 6.3 lb/gal ACS	- Waterborne basecoat / oven controlled by RTO - Clearcoat auto-bell section controlled by carbon wheel & RTO / oven controlled - 6.5 lb/gal ACS
Toyota Indiana 1996	360,000	- Ovens controlled by thermal oxidizer (RTO) - 0.23 lb/gal ACS	- RTO on oven & carbon adsorption & RTO for auto zones of booth - 2.37 lb/gal ACS	- RTO on ovens & carbon & RTO on auto zones of BC/CC booth (Plant 1) – RTO on ovens & carbon & RTO on auto zones of CC booth (Plant 2) - 8.2 – 5.2 lb/gal ACS (Plants 1/2)