AIR POLLUTION EMISSIONS AND CONTROL:

LIGHT DUTY VEHICLES

Environmental Protection Service
Environment Canada

Report EPS 2/TS/4
July 1984

Comments

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Cat. No. En 49/2-4 E/F
ISBN 0-662-53284-8
BEAUREGARD PRESS LIMITED

ABSTRACT

In Canada, light duty vehicles are the principal man-made emission source of oxides of nitrogen, carbon monoxide, and hydrocarbons. The contribution of these emissions both directly and indirectly - through secondary atmospheric processes - to the air pollutant burden in and around urban centres and to long range transport impacts is described, as well as the projected decrease in these emissions that would result from applying more stringent emission standards to light duty vehicles. The economic implications of more stringent standards to the purchase and operating costs of light duty vehicles are also considered.

RÉSUMÉ

Au Canada, de toutes les sources résultant de l'activité humaine, les véhicules automobiles légers sont la principale source d'oxydes d'azote, de monoxyde de carbone et d'hydrocarbures. La contribution, tant directe qu'indirecte (résultant de procédés atmosphériques secondaires), de ces émissions à la pollution atmosphérique urbaine et suburbaine et à la pollution par transport à distance est décrite dans cette publication. On y retrouve aussi des estimés de la diminution des quantités émises advenant l'application de normes d'émissions plus strictes pour les véhicules automobiles légers. Finalement, les implications économiques de ces normes plus strictes quant au coûts d'achat et d'opération des véhicules automobiles légers sont exposées.

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1 INTRODUCTION

Environment Canada, in co-operation with the Department of Transport, is currently conducting an analysis of the implications of introducing more stringent emission standards in Canada for new light duty vehicles (1); light duty vehicles (LDV's) in this context refer to gasoline- and diesel-powered automobiles and light duty trucks. The present Canadian new-vehicle emissions standards have remained unchanged since 1975 and the standards under consideration are the same as those adopted by the United States in 1981 (see Section 4). The purpose of this report is to summarize information presented in other reports related to this review and to outline the background data and rationale relevant to the proposed changes.

Three primary air pollutants are present in the exhaust emissions from LDV's; these are carbon monoxide (CO), hydrocarbons (HC), and NO_x, where NO_x refers to the sum of nitric oxide and nitrogen dioxide. In addition, the evaporation of gasoline from a vehicle's fuel tank and carburetor also results in hydrocarbon emissions. It has been estimated (2) that, in 1980, LDV's in Canada emitted 4 719 000 tonnes of CO, 460 000 tonnes of HC, and 356 000 tonnes of NO_x, or about 45%, 23%, and 20% respectively of total Canadian man-made emissions of these pollutants.

These LDV-related pollutants are also emitted from natural sources. For example, in Canada, natural CO emissions are estimated to be 260 000 tonnes per year (3), and natural emissions of NO_x have been variously estimated to be one million (4) and 2.7 million tonnes per year (5). Using the more recent of these natural emissions estimates (4), LDV's in Canada are responsible for about 12% of total (man-made plus natural) Canadian emissions of NO_x. However, it should be noted that whereas natural NO_x and CO emissions are widely distributed across the country, man-made emissions are usually concentrated in urban areas, a situation that is reflected in the much higher ambient-air concentrations of NO_x and CO in cities (NO_x, 0.023 ppm; CO, 1.3 ppm (6)) than in clean, unpolluted rural air (NO_x, 0.001 ppm (4); CO 0.25 ppm (7)).

The hydrocarbons emitted from gasoline-powered vehicles include hydrocarbon compounds such as methane, ethane, acetylene, propylene, and benzene, as well as oxygen-containing compounds such as aldehydes, ketones, esters, acids and phenols (8). As air pollutants, CO and NO_x are known to cause adverse effects on health, vegetation, and personal comfort and well-being (9); however, the extent to which hydrocarbon emissions from LDV's cause direct environmental problems is not known. Nevertheless, they do give rise indirectly to significant adverse effects (9), through the key role that they play in the

formation of photochemical oxidants (10, 11). These oxidants are produced in the atmosphere through a series of complex, interrelated reactions between NO_x and reactive hydrocarbons* in the presence of sunlight (12). Although carbon monoxide has also been shown to take part with NO_x in similar photochemical reactions, its presence does not lead to significant oxidant formation when hydrocarbons are present (13). Secondary pollutants formed in the photochemical reactions include ozone, N-nitroso compounds, and peroxyacetylnitrate as well as nitric acid and inorganic nitrates (14). Ozone usually represents about 90% of the total oxidants, and because it can be measured more readily than other photochemical oxidants, its concentration is used as an indicator or surrogate for all oxidant compounds. As with NO_x and CO, ambient-air concentrations of ozone in, and downwind of, urban centres are higher than those in unpolluted air (15).

In general, air pollutant emissions from LDV's affect environmental quality in three ways. The emissions of NO_x contribute significantly to the acid deposition problem, while the combination of NO_x and HC emissions contribute to the formation of ozone and photochemical oxidants. Finally, the three primary pollutants (CO, NO_x, and HC) and the secondary pollutant ozone, contribute to the ambient air pollution burden in our cities.

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* The reactivity of a particular hydrocarbon is measured by its effect on the rate of ozone formation in sunlight in the presence of NO_x and air. Highly reactive organic compounds include olefins and aldehydes whereas, for example, methane, ethane, and benzene have small or negligible reactivities.

2 AIR POLLUTANT EMISSIONS

2.1 Emissions of NO_x, CO, and HC in Canada

Estimated 1980 Canadian emissions of NO_x, HC and CO are given in Tables 1, 2 and 3(2). It may be noted from these tables that a wide variety of sources contribute to the national totals; nevertheless, for each pollutant, LDV's in the transportation sector are the largest single-source group and the discussion that follows will focus on transportation and LDV'S.

2.2 Transportation Sector

2.2.1 Sector Description. For present purposes, the transportation sector in Canada may be divided into two groups: light duty vehicles and 'other transportation'. This latter group consists of medium- and heavy-duty gasoline-powered trucks, heavy-duty diesel trucks, off-road mobile sources (rail, marine, and air transport) and other miscellaneous sources which use gasoline.

2.2.2 Historical Emissions. The emissions of NO_x, CO, and HC in Canada and eastern Canada between 1974 and 1980 are summarized in Tables 4 and 5. The methodology used to derive the transportation-sector emissions is given in Appendix 1.

On a national basis, between 1974 and 1980, the transportation sector accounted for about 60% of NO_x emissions, 75-85% of CO emissions, and 40-53% of the HC emissions (Table 4). For all three pollutants, LDV's were the largest emission source in the transportation sector, and their contribution to the total transportation sector emissions over this period averaged about 35% for NO_x, and 66% for CO and HC. In the other transportation group, heavy-duty diesel trucks and "off-road" diesel engines were also important contributors to the emissions of NO_x, whereas heavy-duty and medium-duty gasoline trucks were important contributors to CO and HC emissions. While NO_x emissions from LDV's remained relatively constant between 1974 and 1980, both CO and HC emissions from LDV's decreased significantly.

Between 1974 and 1980, the emissions of CO, NO_x, and HC in eastern Canada closely resembled those nationally (Table 5). As a region, however, eastern Canada contributed about two-thirds of the national emissions from LDV's and about half of the national emissions from other transportation sources for all three pollutants.

TABLE 1 1980 NO_x* EMISSIONS IN CANADA

Sector/Source	Emissions (kilotonnes)	% of Total
Power Generation		
- Ontario Hydro	101.3	5.8
- Nova Scotia Power	31.0	1.8
- New Brunswick Power	16.6	1.0
- Alberta plants	52.9	3.0
- Other	27.6	1.6
Fuel Combustion		
- Petroleum Refineries	34.9	2.0
- Natural Gas Processing	129.4	7.4
- Other Industrial		
- residual oil	50.4	2.9
- other fuels	53.6	3.1
- Commercial	36.5	2.1
- Residential (incl. fuelwood)	50.1	2.9
Transportation		
- LDV	355.7	20.4
- MDGT** HDGT HDDT	209.9	12.0
- Off-highway mobile (air, marine, rail)	180.1	10.3
- Other diesel (e.g. mining, forestry)	176.6	10.1
- Other gasoline	149.6	8.6
Other Industrial		
- Non-ferrous smelters	9.9	0.6
- Petroleum refineries	5.6	0.3
- Tar sands	24.4	1.4
- Other	23.0	1.3
Miscellaneous	23.2	1.3
TOTAL	1 742.3	

* NO_x reported as NO_2

** MDGT; medium-duty gasoline trucks, HDGT; heavy-duty gasoline trucks, HDDT; heavy-duty diesel trucks.

TABLE 2 1980 HC EMISSIONS IN CANADA

Sector/Source	Emissions (kilotonnes)	% of Total
Industrial Processes		
- Petroleum refining	134.0	6.8
- Petrochemicals	211.4	10.7
- Other	226.8	11.5
Power Generation	5.8	0.3
Fuel Combustion		
- Natural gas processing	45.4	2.3
- Other	15.9	0.8
Transportation		
- LDV	460.2	23.3
- MDT HDGT HDDT	140.5	7.1
- Off-highway mobile (air, marine, rail)	86.8	4.4
- Other	109.7	5.5
Miscellaneous		
- Gas/diesel marketing	235.7	11.9
- Coatings application	141.6	7.2
- Solvents use	76.7	3.9
- Other	87.9	4.4
TOTAL	1 978.4	

TABLE 3 1980 CO EMISSIONS IN CANADA

Sector/Source	Emissions (kilotonnes)	% of Total
Industrial Processes		
- Iron & Steel (incl. coke)	269.4	2.6
- Petroleum Refining	173.6	1.7
- Aluminum Manufacturing	149.0	1.4
- Carbon Black	112.0	1.1
- Other	81.9	0.8
Power Generation	20.3	0.2
Fuel Combustion		
- Fuelwood	392.7	3.8
- Other	68.3	0.7
Transportation		
- LDV	4 719.2	45.1
- MDT HDGT HDDT	1 716.0	16.4
- Off-highway mobile (air, marine, rail)	304.3	2.9
- Other	1036.5	9.9
Miscellaneous		
- Slash Burning	1 040.6	9.9
- Other	385.1	3.7
TOTAL	10 469.4	

TABLE 4 NATIONAL EMISSIONS OF NITROGEN OXIDES, HYDROCARBONS AND CARBON MONOXIDE (kilotonnes)

	1974			1976			1978			1980		
Sources/Pollutants	NO_x	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x	HC	CO
LDV	334	751	7 056	355	591	6 241	374	578	6 101	356	460	4 719
Other Transportation	569	259	2 936	654	327	3 298	679	303	3 180	716	337	3 057
Stationary	618	899	1 867	703	1 006	1 742	723	1 224	2 012	670	1 181	2 693
TOTAL	1 521	1 909	11 859	1 712	1 924	11 281	1 776	2 105	11 293	1 742	1 978	10 469

TABLE 5 EASTERN CANADA* EMISSIONS OF NITROGEN OXIDES HYDROCARBONS AND CARBON MONOXIDE (kilotonnes)

	1974			1976			1978			1980		
Sources/Pollutants	NO_x	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x	HC	CO
LDV	230	519	4 859	240	401	4 207	247	385	4 031	234	305	3 091
Other Transportation	291	127	1 343	334	173	1 525	350	144	1 352	351	179	1 519
Stationary	385	627	1 077	399	699	1 194	414	688	1 392	361	626	1 646
TOTAL	906	1 273	7 279	973	1 273	6 926	1 011	1 217	6 775	946	1 110	6 256

* Ontario, Quebec and Atlantic Provinces

2.2.3 Projected Emissions. The projected emissions of CO, NO_x, and HC from the transportation sector until the end of the century are based on two scenarios:

- maintenance of current Canadian emissions standards for LDV's, i.e., a status quo situation; and
- adoption of 1981 U.S. emissions standards in Canada by 1987.

In calculating the status quo projections for the transportation sector, the following assumptions were made:

1) no change in current emissions standards, tampering rate, speed distribution or vehicle age distribution;
2) (vehicle population) x (vehicle miles travelled) increases at a rate of 1.5% per year for LDV's and all medium-duty and heavy-duty trucks from 1980 onwards; and
3) emissions from other transportation sources are based on a fuel usage forecast (16) prepared by the Department of Energy, Mines and Resources, and trend analysis of historical emission data developed by Environment Canada.

Figure 1 gives the projected national emissions of NO_x from LDV's, other transportation sources, and stationary sources (17) until the end of the century. Under the status quo scenario, it is expected that NO_x emissions from LDV's will remain roughly constant at the 1980 level of about 350 kt/year; similarly NO_x emissions from stationary sources are not expected to change significantly from about 700 kt/year (17). However, NO_x emissions from other transportation sources are expected to increase from 716 kt in 1980 to 1039 kt in the year 2000.

By adopting 1981 U.S. emission standards for LDV's in 1987, it is estimated that in the year 2000, NO_x emissions from LDV's will be reduced by about 45% (173 kt) from the status quo level; this will reduce the projected total national emissions of NO_x by 8% in the year 2000. This reduction would only begin then to arrest the NO_x emissions increase from the transportation sector as a whole.

Under the status quo scenario, HC emissions from the transportation sector are expected to continue to decrease from the mid-1970 levels until about 1990 and then start to increase gradually again to the year 2000 (Figure 2). Hydrocarbon emissions from LDV's follow a similar pattern, accounting for about 280 kt of the 724 kt due to transportation in the year 2000. The introduction of the U.S. standard will reduce HC emissions from LDV's by about 50% from the status quo level for the year 2000, and the total HC burden from the transportation sector by about 18% (from 724 kt to 591 kt).

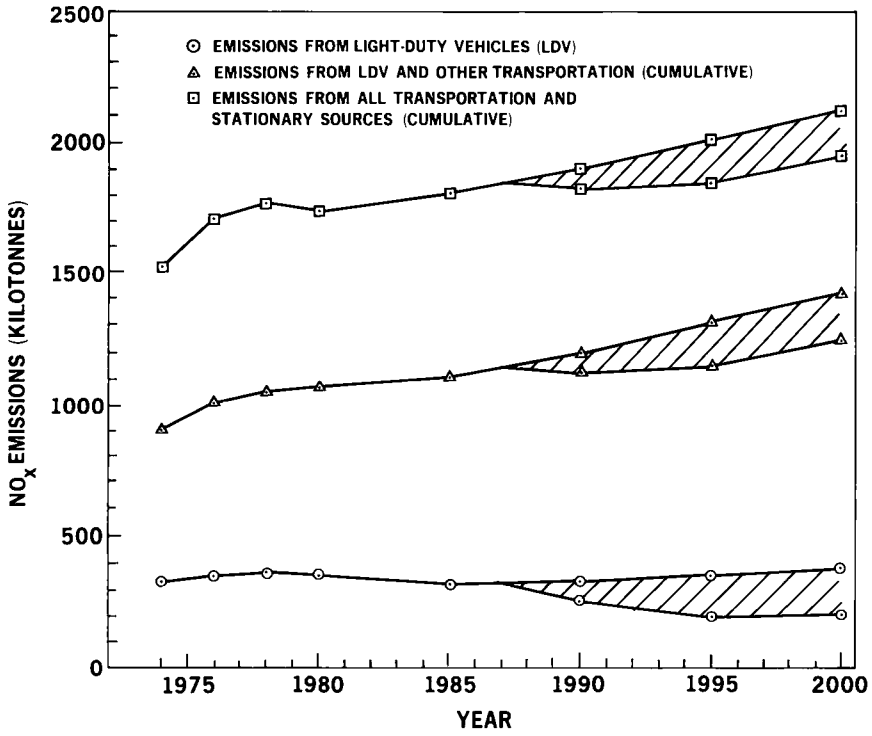

FIGURE 1 NO_X HISTORICAL AND PROJECTED NATIONAL EMISSIONS

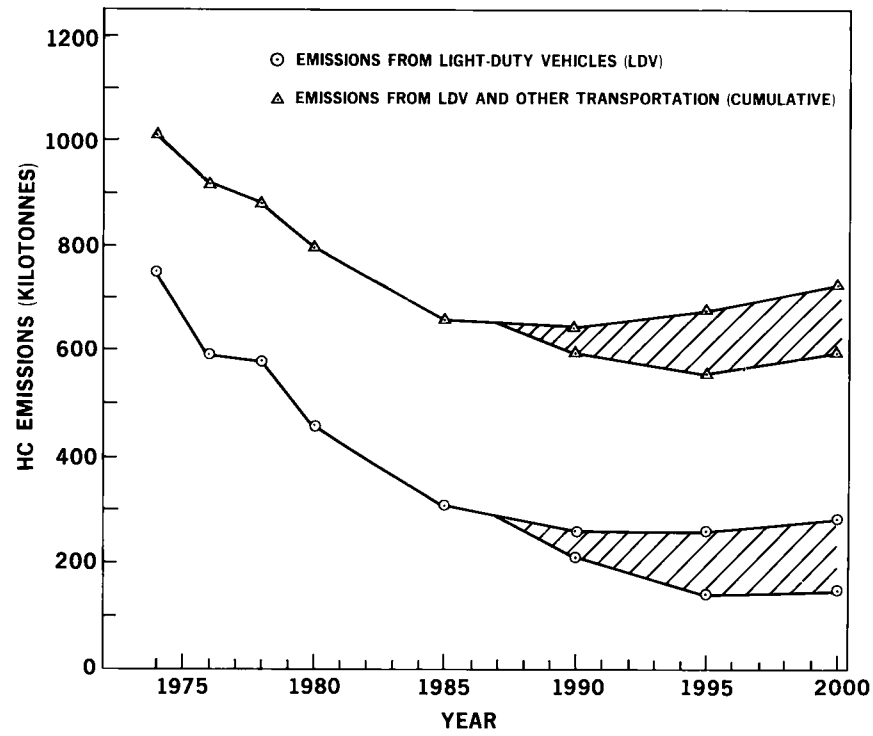

FIGURE 2 HC HISTORICAL AND PROJECTED NATIONAL EMISSIONS

The situation for CO is similar to that for HC; the status quo emissions initially decrease until about 1985 and then increase to the year 2000, reaching about 8.2 million tonnes for the transportation sector (Figure 3). Carbon monoxide emissions from LDV's reach a minimum of about 3.8 million tonnes in 1985 and increase to about 4.6 million tonnes in the year 2000. Adoption of the U.S. emission standard will reduce the LDV emissions to about 2.2 million tonnes (roughly 50% of status quo level) in the year 2000 and reduce the overall emissions of CO from the transportation sector in that year by about 30%.

Although the contribution of stationary sources to HC and CO emissions is not depicted in Figures 2 and 3, it is expected that theses sources will not play a significantly different role than that observed historically. Transportation will still remain the major sector contributing to CO emissions; however, for HC, the situation could be somewhat altered, resulting from closures that are taking place in the petroleum refining and petrochemical sectors.

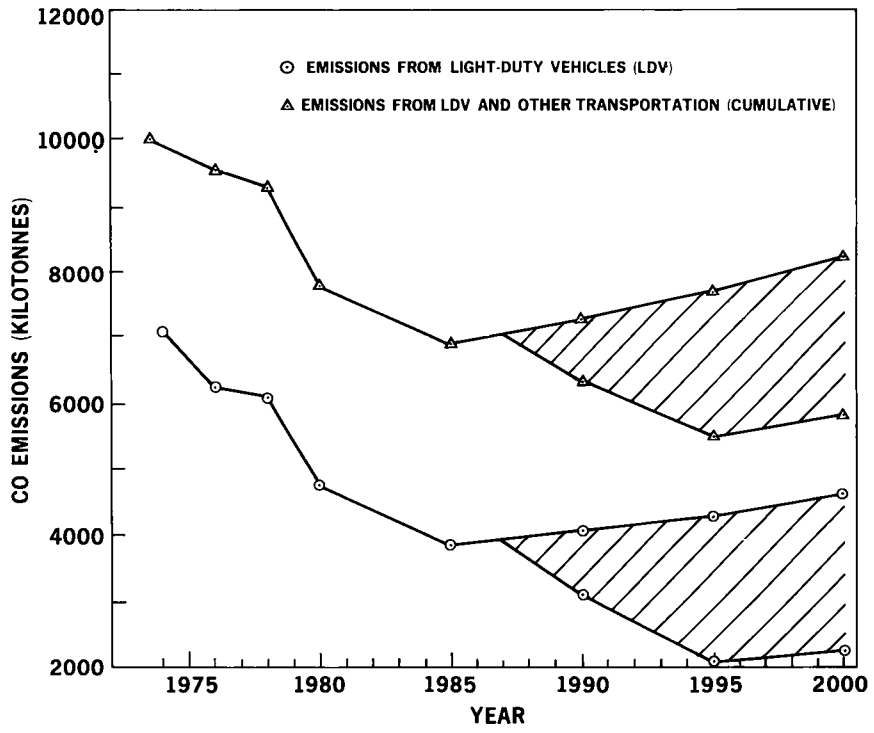

FIGURE 3 CO HISTORICAL AND PROJECTED NATIONAL EMISSIONS - TRANSPORTATION

For eastern Canada (Ontario, Quebec and the Atlantic provinces), it is projected that under status quo conditions, the contribution of transportation sources to NO_x, HC, and CO emissions will continue to be similar to that found historically, i.e., for all three pollutants, LDV's will contribute about two-thirds of national LDV emissions and, in turn, other transportation will account for about half of the national emissions in this sector. However, by adopting the U.S. standards for LDV's in 1987, it is estimated that by the year 2000 the emission of NO_x, HC, and CO in eastern Canada will be reduced by roughly 50% of their status quo levels in that year. Similarly, for the transportation sector as a whole, the emissions of NO_x, HC, and CO will be reduced by about 15%, 20%, and 33%, respectively. Under this scenario, it is estimated that the proposed LDV emissions standards will result, in the year 2000, in a reduction in the total NO_x emissions from all sources in eastern Canada of approximately 8%.

2.3 NO_x Emissions in Eastern Canada

To provide perspective on the contribution of LDV's to NO_x emissions in eastern Canada, the mass and percent of total emissions of NO_x from various sectors in this region are given in Table 6.

TABLE 6 NO_x EMISSIONS IN EASTERN CANADA* (1980)

Sector	NO_x Emissions (kilotonnes)	% of total
Non-ferrous Smelters	8	0.8
Power Generation	159	16.8
Fuel Combustion	171	18.1
Transportation		
LDV's	234	24.7
MDGT, HDGT, HDDT	111	11.7
Off-road Sources	100	10.6
Other	140	14.8
Other Industrial	23	2.4
TOTAL	946	100

* Ontario, Quebec and the Atlantic Provinces.

3 ENVIRONMENTAL QUALITY IN CANADA

3.1 NO_x Emissions and Acid Precipitation

While it is known that the ionic composition of acid precipitation is variable in both space and time, studies have shown that in the northeastern United States and eastern Canada, on an annual basis, sulphates contribute about 65% and nitrates 35% of precipitation acidity (18, 19). Atmospheric models are not yet available to provide a detailed, quantitative relationship between NO_x emissions and acid deposition; however, on the simplifying assumption that the nitrate contribution to acid precipitation can be linearly related to NO_x emissions then, from Table 6, the contribution of LDV's, which are the largest individual source of NO_x emissions in the transportation sector, would be about 9% of precipitation acidity.

Available information indicates that nitrates are formed more rapidly than sulphates in the atmosphere and that they are also deposited closer to the source of emissions (20). Therefore it may be concluded that significant reductions in NO_x emissions in Canada will result in corresponding reductions in nitrate deposition in this country. This is unlike the situation with SO_2 emissions, where it is necessary to rely in part on emission reductions in the United States in order to achieve targeted sulphate loadings in this country.

During the growing season, nitrates can undergo assimilative uptake by either terrestial or aquatic plants as an essential plant nutrient, thereby serving to neutralize the acidity of the nitric acid deposition. Under normal growth conditions it can be expected that the major portion of available nitrate will be assimilated. However, during the period of biological inactivity in the winter months, sulphates and nitrates accumulate in the snowpack. In the early spring, when the snowpack begins to melt, a sudden pulse of acidity is released into the watershed in only a few days of spring melt. This is commonly referred to as the "spring shock effect". It occurs during the sensitive life stages of many aquatic species and can cause death or deformation of fish, fry and other amphibians. Studies in Norway and Sweden, the northern United States and eastern Canada have documented this pH depression or net increase in the hydrogen ion content of the surface waters.

Many factors affect this spring shock in any given year; these include the amount of snowfall, daily temperature fluctuations (freeze-thaw conditions), geological formations and terrestial make-up of the area, as well as the mass emissions of the precursor pollutants.

While much emphasis has been placed on reducing sulphur dioxide emissions, NO_x emissions must also be viewed with concern due to their contribution to the pH depression associated with the snowpack melt episodes. This depression, when imposed on the surface waters where the acidity has already been increased due to excess sulphates, results in levels of acidity that may be critical and occur at sensitive life stages of many aquatic organisms, even though the long-term average acidity may be tolerated by a normal biological habitat.

3.2 Air Quality

3.2.1 Measurement. Air quality in Canada is monitored on a continuous basis by the National Air Pollution Surveillance (NAPS) Network and by provincial air monitoring networks. The NAPS Network is a federal-provincial co-operative network established to provide urban air quality data and to determine air quality trends across Canada for both levels of government. Provincial air monitoring networks, on the other hand, vary in size and scope and are designed to meet specific local and regional needs, within a given province, for air quality information.

3.2.2 National Ambient Air Quality Objectives. The prescription of national ambient air quality objectives (NAAQO's) for Canada is provided for under the mandate of the Clean Air Act; these objectives are based on three levels of ambient air quality:

- the maximum desirable level, which defines the long-term goal for air quality and provides a basis for an anti-degradation policy for the unpolluted parts of the country and for the continuing development of control technology;
- the maximum acceptable level, which is intended to provide adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well-being; and
- the maximum tolerable level, which denotes a time-based concentration of an air contaminant beyond which, due to a diminishing margin of safety, appropriate action is required to protect the health of the general population.

Recommendations to the Minister of the Environment to publish ambient-air concentrations for these objectives for a given pollutant are made by the Federal-Provincial Committee on Air Pollution, and are based on a thorough review of environmental and health effects associated with the presence of the given pollutant in ambient air. Data of the type given in Reference 9 form an important component in setting the various air-quality-objective concentrations.

The NAAQO's for the LDV-related pollutants, carbon monoxide, nitrogen dioxide, and ozone, are given in Table 7. A NAAQO for hydrocarbons has not been established.

3.3 Current/Historical Air Quality Data

3.3.1 Ozone. Valid ozone data from the complete NAPS Network are only available since 1979 and annual mean ozone concentrations for the period 1979-82 are given in Table 8. No significant changes occurred during that period, in which about 30% of the stations exceeded the annual maximum acceptable level.

The percentage of NAPS readings in a given year (1979 to 1982) that exceed the maximum acceptable 24-hour ozone concentration are given in Table 9 for various cities across Canada. It should be noted that for cities in which there is more than one NAPS station, the data from all the stations have been given as a city average, and that (to avoid biases) only stations having sufficient data to calculate a valid annual mean are included in Table 9. It is apparent from this table that readings higher than the 24-hour maximum acceptable concentration are the rule rather than the exception.

In a similar manner, the rate per monitoring station that the maximum acceptable and maximum tolerable one-hour NAAQO's for ozone were exceeded between 1977 and 1982 is given in Table 10 for various cities and regions in Canada. These rates are derived from measurements made at NAPS stations in urban centres (supplemented by municipal data for Montreal and Vancouver), and at provincial stations in rural and urban areas in Ontario. The number of monitoring stations is given for each year for which data are available. No overall trend is apparent in ozone concentrations and year-to-year variability is governed to a large extent by meteorological factors (15). However, a preliminary analysis of 1983 NAPS data indicates that the rates at which the one-hour maximum acceptable NAAQO for ozone were exceeded at most stations in Ontario will be greater than for any year since 1978.

The ozone data from monitoring stations in Vancouver, Ontario, Montreal-Quebec City, and New Brunswick-Nova Scotia have been analysed using consistent criteria for the definition of ozone episodes. The terminology for episode types and the number of occurrences of each type are given in Table 11, while Table 12 presents the annual number of episode days, by region, from 1977 to 1982.

Based on the number of exceedances per station of the NAAQO one-hour acceptable level, and on the number of episode days per year, Canada can be roughly divided into four zones of ozone impact.

TABLE 7 NATIONAL AMBIENT AIR QUALITY OBJECTIVES FOR CARBON MONOXIDE, NITROGEN DIOXIDE, AND OZONE

Air Contaminant	Maximum Desirable Level	Maximum Acceptable Level	Maximum Tolerable Level
Carbon Monoxide			
Average 8-hour concentration	5 ppm	13 ppm	17 ppm
Average 1-hour concentration	13 ppm	31 ppm	-
Oxidants (ozone)			
Annual arithmetic mean	-	0.015 ppm	-
Average 24-hour concentration	0.015 ppm	0.025 ppm	-
Average 1-hour concentration	0.05 ppm	0.08 ppm	0.15 ppm
Nitrogen Dioxide			
Annual arithmetic mean	0.03 ppm	0.05 ppm	-
Average 24-hour concentration	-	0.11 ppm	0.16 ppm
Average 1-hour concentration	-	0.21 ppm	0.53 ppm

TABLE 8 ANNUAL MEAN OZONE CONCENTRATIONS: 1979-1982

Year	Number of Stations	Average of Annual Mean	Percentage of Stations with Annual Mean Less than Values Shown (ppm O_3)			
			90%	75%	50%	25%
1979	39	0.015	0.020	0.018	0.015	0.012
1980	41	0.016	0.021	0.020	0.016	0.012
1981	35	0.015	0.020	0.018	0.015	0.012
1982	40	0.016	0.021	0.019	0.016	0.013

(a) The southern portions of Ontario and Quebec (specifically the corridor stretching from Windsor to Quebec City).

Exceedances per station of the one-hour acceptable air quality objective ranged from 15 to 190 per year and episode days were 16 to 40 per year over the period of data record. Mean growing season ozone concentrations ranged from 0.04 to 0.05 ppm in southern Ontario.

(b) Vancouver and lower Fraser Valley

Exceedances per station of the one-hour acceptable air quality objective ranged from 21 to 45 per year and episode days averaged 35 per year.

(c) Nova Scotia and New Brunswick

Exceedances per station of the one-hour acceptable air quality objective ranged from 8 to 16 per year and episode days averaged 5 per year.

(d) The remainder of Canada

Exceedances of the one-hour acceptable air quality objective for ozone have occurred at almost all urban ozone monitoring sites in the NAPS network. Based on Ontario data, exceedances in many rural areas of Canada downwind of these urban centres would also be expected.

TABLE 9 PERCENTAGE OF 24-HOUR OZONE CONCENTRATIONS EXCEEDING MAXIMUM ACCEPTABLE LEVEL FOR VARIOUS CANADIAN CITIES

	1979		1980		1981		1982	
	No. of Stations	%	No. of Stations	%	No. of Stations	%	No. of Stations	%
Saint John, N.B.	(1)	INV	(1)	34.1	(1)	14.8	(1)	32.9
Montreal, Que.	(7)	11.1	(8)	11.7	(5)	10.7	(6)	18.8
Quebec City, Que.	(1)	1.8	(1)	1.8	(2)	3.4	(2)	18.8
Ottawa, Ont.	(2)	14.7	(3)	16.0	(3)	7.9	(3)	12.1
Windsor, Ont.	(1)	17.4	(1)	28.8	(1)	26.7	(1)	23.3
Toronto, Ont.	(7)	10.0	(7)	11.3	(5)	10.3	(7)	9.5
Sudbury, Ont.	(1)	16.2	(1)	6.8	(1)	10.0	(1)	11.0
London, Ont.	(1)	15.2	(1)	21.8	(1)	25.3	(1)	31.4
Sarnia, Ont.	(1)	40.5	(1)	33.7	(1)	29.6	(1)	39.1
Cornwall, Ont.	(1)	36.9	(1)	40.6	(1)	35.9	(1)	32.0
St. Catherines, Ont.	(1)	20.5	(1)	25.3	(1)	24.0	(1)	33.1
Winnipeg, Man.	(2)	17.1	(2)	24.4	(2)	11.3	(1)	9.2
Regina, Sask.	(1)	23.2	(1)	37.1	(1)	INV	(1)	25.6
Edmonton, Alta	(2)	19.0	(2)	11.9	(2)	15.9	(2)	24.1
Calgary, Alta.	(1)	44.3	(2)	19.6	(2)	16.6	(2)	23.8
Vancouver, B.C.	(4)	6.6	(4)	7.0	(1)	3.0	(3)	4.5
Victoria, B.C.	(1)	11.7	(1)	INV	(1)	INV	(1)	11.0

INV: INVALID (A valid annual mean cannot be computed because of insufficient data)

TABLE 10 EXCEEDANCES PER STATION OF THE OZONE ONE-HOUR MAXIMUM ACCEPTABLE AND MAXIMUM TOLERABLE AIR QUALITY OBJECTIVES IN SELECTED CANADIAN CITIES AND REGIONS: 1977 to 1982

	1977			1978			1979			1980			1981			1982(d)		
City/Region	(1) NO.	(2) ACC	(3) TOL	NO.	ACC	TOL	NO.	ACC	TOL	NO.	ACC	TOL	NO.	ACC	TOL	NO.	ACC	TOL
Toronto (a)	6	14	0	6	78	0	6	30	<1	6	26	0	6	22	0	7	10	0
Montreal (a)	-	-	-	-	-	-	9	29	<1	9	15	0	9	21	<1	9	19	<1
Vancouver (a)	-	-	-	10	26	1	10	21	1	11	25	1	10	46	6	10	8	0
Edmonton (a)	-	-	-	2	4	0	3	10	<1	3	0	0	3	16	0	2	7	0
Winnipeg (b)	-	-	-	-	-	-	2	0	0	2	3	0	2	0	0	2	0	0
Calgary (b)	-	-	-	-	-	-	3	9	1	2	1	0	2	2	0	2	6	0
Ottawa (b)	-	-	-	-	-	-	2	12	0	3	18	0	3	0	0	3	8	0
Southwestern Ontario (c)	6	185	9	7	155	13	8	70	3	7	100	2	-	-	-	-	-	-
West Central Ontario (c)	4	87	2	4	188	11	6	43	2	6	87	1	-	-	-	-	-	-
Central Ontario (c)	4	52	3	5	130	7	4	74	7	4	34	2	-	-	-	-	-	-
Southeastern Ontario (c)	2	23	0	3	155	11	3	20	0	1	26	0	-	-	-	-	-	-
Northeastern Ontario (c)	1	14	0	1	38	0	1	15	0	1	7	0	-	-	-	-	-	-

(1) NO. = Number of Monitoring Stations
(2) ACC = Maximum Acceptable One-Hour Air Quality Objective
(3) TOL = Maximum Tolerable One-Hour Air Quality Objective

(a) Davis, C.S. et al., Final Report: Proposed Automobile Emissions Standards, Concord Scientific Corp., Report to Environment Canada (1984).
(b) Environment Canada, National Air Pollution Surveillance, Annual Summaries for 1979, 1980, 1981, and 1982.
(c) Mukammel, E., Report on Oxidant Climatology of Ontario, Atmospheric Environment Service Report (1984).
(d) All 1982 data from NAPS Annual Summary for 1982.

- = Not Available

TABLE 11 NUMBER OF OCCURRENCES OF VARIOUS OZONE EPISODES

Region	No. of Stations*	Time Period	Station Episodes(1)	Episode Days(2)	Areal Episodes(3)	Persistent Episodes(4)
New Brunswick-Nova Scotia	3-7	1979-1982	20	20	0	1
Montreal Region Quebec City	10-12	1979-1982	131	65	16	4
Southwestern Ontario	6-8	1977-1980	347	159	36	20
West Central Ontario	4-6	1977-1980	288	137	26	2
Central Ontario	4-5	1977-1980	173	100	21	8
Southeastern Ontario	1-3	1977-1980	78	58	4	5
Northeastern Ontario	1	1977-1980	13	12	0	2
Vancouver GVRD	10-11	1978-1981	237	139	21	5

* Number of stations reporting valid data vary from year to year.

Definitions

(1) Station Episode: Ozone concentration greater than one-hour maximum acceptable level for three or more consecutive hours.

(2) Episode Day: A day on which at least one station episode occurs.

(3) Areal Episode: The occurrence on the same day of three or more station episodes in a specified geographic area.

(4) Persistent Episode: The occurrence of an areal episode on two or more consecutive days.

3.3.2 Carbon Monoxide. Annual mean carbon monoxide concentrations, as measured at NAPS stations over a ten-year period beginning in 1973, are given in Table 13. These data indicate that carbon monoxide concentrations decreased significantly from 1973 to 1976, but that there has been no consistent trend since then.

Analyses of recent NAPS data for one-hour and eight-hour carbon monoxide concentrations show that these concentrations were almost always less than the applicable maximum acceptable levels. However, exceedances of these levels, and also the eight-hour maximum tolerable level, did occur in a small percentage of the

TABLE 12 OZONE EPISODE DAYS BY YEAR IN SELECTED REGIONS IN CANADA: 1977 - 1982

Region	No. of Stations*	Number of Episode Days in Year						
		1977	1978	1979	1980	1981	1982	Total
New Brunswick - Nova Scotia	3-7	NA	5	2	11	1	1	20
Montreal-Quebec City	10-12	NA	NA	15	9	20	21	65
Southwestern Ontario	6-8	46	56	36	21	NA	NA	159
West Central Ontario	4-6	34	49	23	31	NA	NA	137
Central Ontario	4-5	16	46	26	12	NA	NA	100
Southeastern Ontario	1-3	3	45	5	5	NA	NA	58
Northeastern Ontario	1	2	6	3	1	NA	NA	12
Vancouver - GVRD	10-11	NA	29	30	41	39	NA	139

* Number of stations reporting valid data varies from year to year.
NA - Not Available

observations at a few stations located in high-density traffic areas (e.g. in Montreal, Toronto, and Edmonton). The variation between 5 a.m. and 8 p.m. in one-hour CO concentrations, averaged over all NAPS stations from 1974 to 1982 (Figure 4), illustrates very clearly the impact of motor vehicle emissions on ambient air quality in Canada. It may be noted that a bimodal concentration - time distribution shown in this figure is associated with the morning and evening rush hours.

3.3.3 Nitrogen Dioxide. Annual mean concentrations of nitrogen dioxide, as measured by the NAPS Network from 1977-82, are given in Table 14. These data indicate that, from 1977 to 1981, there was a significant decrease in nitrogen dioxide concentations, but since then there has been no significant change.

Recent NAPS data for one-hour and 24-hour nitrogen dioxide concentrations are similar to the short-term carbon monoxide concentrations in that there were occasional exceedances of the maximum acceptable and maximum tolerable levels at

TABLE 13 ANNUAL MEAN CARBON MONOXIDE CONCENTRATIONS: 1973-1982

Year	Number of Stations	Average of Annual Mean	Percentage of Stations with Annual Mean Less than Values Shown (ppm CO)			
			90%	75%	50%	25%
1973	10	2.7	4.3	3.3	2.5	2.1
1974	18	2.4	5.0	3.0	2.2	1.2
1975	22	1.9	2.8	2.4	1.7	1.3
1976	29	1.6	2.4	1.9	1.4	0.9
1977	33	1.6	2.3	1.9	1.4	0.9
1978	40	1.5	2.8	2.0	1.3	0.8
1979	42	1.7	3.2	2.0	1.5	1.0
1980	43	1.5	2.8	1.8	1.4	0.9
1981	36	1.5	2.3	1.6	1.4	0.9
1982	41	1.3	2.2	1.9	1.6	0.9

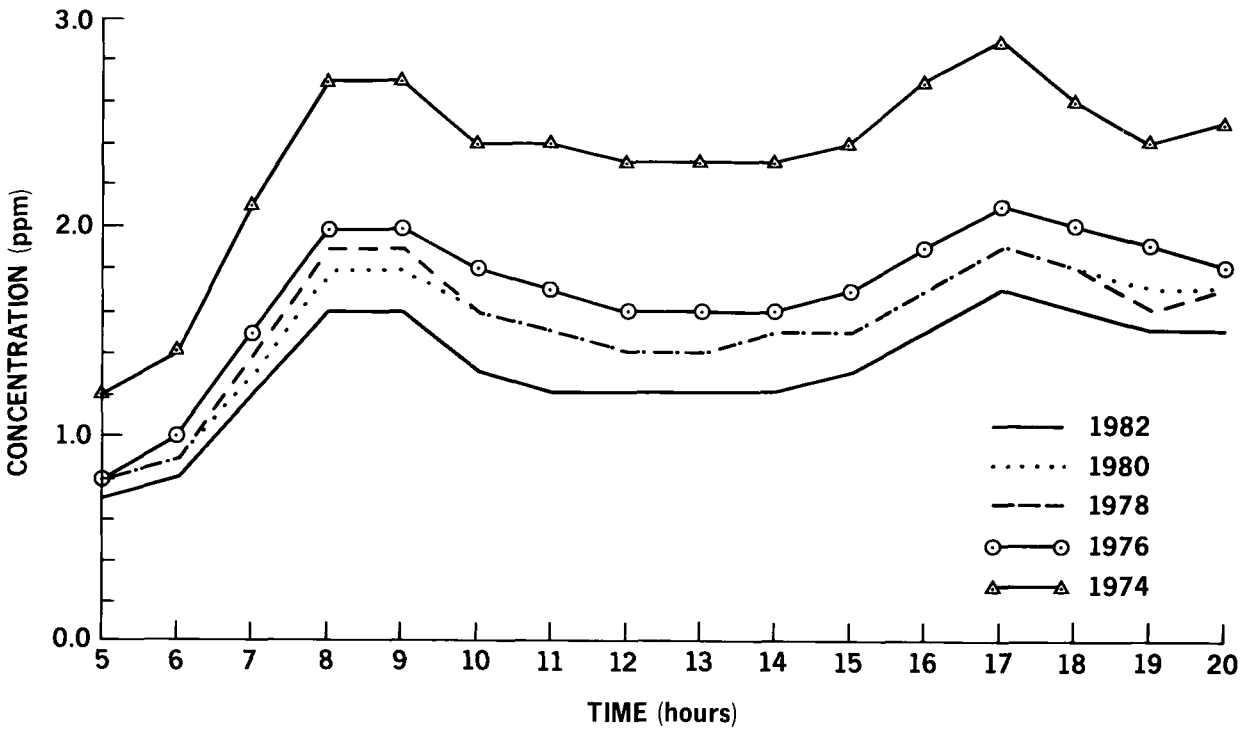

FIGURE 4 HOURLY MEAN CONCENTRATION OF CARBON MONOXIDE FOR ALL NAPS STATIONS

TABLE 14 ANNUAL MEAN NITROGEN DIOXIDE CONCENTRATIONS; 1977-1982

Year	Number of Stations	Average of Annual Mean	Percentage of Stations with Annual Mean Less than Values Shown (ppm NO_2)			
			90%	75%	50%	25%
1977	27	0.031	0.044	0.034	0.027	0.021
1978	33	0.029	0.04	0.035	0.029	0.02
1979	34	0.026	0.034	0.031	0.027	0.019
1980	43	0.025	0.037	0.031	0.023	0.019
1981	36	0.023	0.032	0.029	0.022	0.016
1982	41	0.023	0.034	0.027	0.022	0.018

stations located in high-density traffic areas. The urban-air concentrations of NO and NO_2 during the course of the day also follow a bimodal traffic-related pattern similar to that for CO (15).

3.3.4 Hydrocarbons. Data on the ambient-air concentration of hydrocarbons in Canada are available only for Toronto (11 years of data) and Edmonton (9 years of data); an analysis of these data (21) indicates that no discernible trend in concentrations was identifiable for either city over the measurement period.

4 AUTOMOTIVE INDUSTRY CONSIDERATIONS

4.1 Emission Standards

Canadian and United States light-duty motor vehicle emissions standards are given in Table 15. It may be noted that current Canadian standards allow significantly higher emissions of all pollutants than the U.S. standards.

TABLE 15 VEHICLE EMISSION STANDARDS (g/km)

Year	Hydro-carbons	Carbon Monoxide	Oxides of Nitrogen	Diesel Particulates	Evaporative Hydrocarbons
Passenger Cars					
1975 to 1985 Canada Gasoline & Diesel	1.22	15.5	1.9	NA	2.0g/Test(1)
1981 U.S. Gasoline & Diesel	0.25	2.1(4)	0.62(3)	NA	2.0g/Test(2)
1984 U.S. Gasoline & Diesel	0.25	2.1	0.62(3)	0.37	2.0g/Test(2)
Light Duty Trucks					
1975 to 1985 Canada Gasoline & Diesel 0-6000 pounds GVWR	1.22	15.5	1.9	NA	2.0g/Test(1)
1981 U.S. Gasoline & Diesel 0-8500 pounds GVWR	1.04	11.2	1.63	NA	2.0g/Test(2)
1984 U.S. Gasoline & Diesel 0-8500 pounds GVWR	0.49	6.2	1.43	0.37	2.0g/Test(2)

(1) Cannister test (carbon trap)
(2) SHED test (sealed housing evaporative determination)
(3) NO_x standard waived to 0.93 g/km for diesel or innovative technology
(4) CO Standard waived to 4.35 g/km.

4.1.1 Passenger Cars - Gasoline. Current Canadian emission standards can be met without the use of catalyst technology (22) whereas the current U.S. standards require the

use of a three-way catalyst system with electronic engine controls. Canadian NO_x standards are usually met through use of exhaust gas recirculation (EGR).

New vehicles sold in Canada are fitted with four different emission control systems: non-catalyst (20%), oxidation catalyst (63%), three-way catalyst (15%) or special systems (2%). Vehicles equipped with catalyst systems require lead-free fuel for proper system operation and durability.

Under laboratory conditions passenger vehicles with three-way catalyst-control systems show equivalent or slightly improved fuel economy when compared to similarly equipped vehicles with Canadian emission control systems (23).

4.1.2 Passenger Cars - Diesel. In Canada, diesel-powered passenger cars are subject to the same emission standards as gasoline powered cars. Little, if any, additional emission control equipment need be installed on diesel-powered cars sold in Canada to meet the 1981 U.S. standard (22) which has no requirement for particulate emissions.

Diesel-powered passenger cars, equipped with EGR to meet the U.S. 1981 passenger car standard, could suffer a small (less than 5%) fuel economy penalty. At present, diesel-powered cars in Canada represent less than 5% of new car sales (22).

4.1.3 Light Duty Trucks - Gasoline. Canadian emission standards for automobiles also apply to light-duty trucks up to 6000 pounds (2720 kg) gross vehicle weight rating (GVWR). It is reported (22) that the U.S. 1981 standard for light-duty trucks up to 8500 pounds (3850 kg) GVWR can be met without catalysts; however, as is the case with passenger cars, many manufacturers fit their vehicles with oxidation catalysts. As a result, such trucks require lead-free fuel for proper emission control system performance.

The fuel economy of light duty trucks marketed in Canada and the U.S. appears to be identical (22).

4.1.4 Evaporative Emissions. Most manufacturers use the current U.S. hydrocarbon evaporative control system, which meets the 2 gram per test SHED (sealed housing evaporative determination) requirement. In a few instances some models may have to be upgraded (22).

4.1.5 North American LDV Production. As would be anticipated, because of the dominance of the U.S. market, the major portion of LDV's produced in North America is equipped to meet U.S. emission standards. For example, in 1983, about 92% of the 10 million LDV's produced in North America were so equipped. Similarly, of the 7.8 million passenger cars produced in that year, approximately 90% were equipped to meet the U.S.

standards; this includes the 70% of Canadian passenger car production (968 000) which was exported to the U.S.

4.2 Technology and Costs to Meet Proposed Standards; Passenger Cars

4.2.1 Incremental Retail Price Equivalent. In response to a survey of domestic manufacturers and selected importers, industry was uniform in stating that a closed-loop, three-way catalyst system would be required to meet the proposed emission standards; that is, the same system as currently used on United States models (22).

Ford, Chrysler, and several of the importers provided price estimates. Ford estimated an incremental retail price equivalent of $175 to replace the current emission control system with one that will meet the proposed standards. Chrysler estimated a $210 incremental retail price equivalent to upgrade its 2.2-litre engine family from an oxidation catalyst system to a three-way catalyst system. The incremental retail price equivalent estimates provided by importers ranged from $155 (Volkswagen) to $940 (Renault). The two largest importers, Toyota and Honda, each with about 6 percent of the market, reported incremental retail price equivalents that generally fall in the $350-$550 range, depending on the engine family and emission control system configuration (25).

General Motors declined to provide estimates of the costs to upgrade its current emission control systems to meet the proposed standards. Over 90 percent of General Motors passenger cars sold in Canada are equipped with carburetors and oxidation catalysts. General Motors indicated that, to meet the proposed standards, it would probably use its current U.S. federal emission control system with "some refinement anticipated". The major changes from the current systems would be to use carburetors with electronic feedback control and three-way oxidation catalysts. From U.S. Environmental Protection Agency (EPA) cost data (26, 27), the estimated incremental retail price equivalents would be $30 to $100 and $80 to $140 for the catalyst and the hardware, respectively. Therefore, the incremental retail price equivalent for General Motors passenger cars would be $110 to $240.

4.2.2 Average Incremental Retail Price Equivalent. To calculate the average cost to the consumer, it is assumed that the market shares held by domestic manufacturers and importers will remain at 1983 levels during 1987-1996. The average incremental retail price equivalent (R.P.E.) would then be the weighted average of the manufacturers' and importers' estimates discussed above.

The market shares (28) and incremental R.P.E. for General Motors, Chrysler, Ford and 'all others' are shown in Table 16. The weighted average of these data is $235 per car.

TABLE 16 AVERAGE INCREMENTAL RETAIL PRICE EQUIVALENT

Company	Market Share %	Incremental Retail Price Equivalent ($ Cdn 1983)
General Motors	38	175
Chrysler	16	210
Ford	15	175
All Others	31	350
	Weighted Average:	235

4.2.3 Disaggregation of Retail Price Equivalent. The retail price equivalent estimates can be disaggregated into their component parts using the Lindgren equation (26) as modified by Pilorusso and DeKany (22) to take into account the application of the Canadian federal sales tax.

DeKany and Pilorusso showed disaggregated retail price equivalents for two markup factors, 2.7 and 1.93. (The markup factor is a composite of parts manufacturer's, vehicle assembler's and dealer's markups). The lower markup factor, 1.93, is based upon the EPA's analysis of actual cost data and, probably, more accurately reflects true costs and markups (25).

Table 17 shows the component parts (as percentages) and the corresponding R.P.E. per car. As can be seen from this table, 60% of the R.P.E. is made of cost at the manufacturing level and the remaining 40% is made of various markups, federal tax, and research and development costs.

It is considered that research and development costs are no longer an attributable component to the R.P.E. because the current technology has been in place in the U.S. for four years. Furthermore, it is not known how much of the incremental R.P.E. will be passed on to the consumer or, conversely, how much will be absorbed by the manufacturer. This is because the price of a new car is dependent on many factors, other than just parts and assembly costs (e.g., desired return on investment, pricing policies, economic climate, market conditions, market share, import restrictions). If it is assumed that only the vehicle assembler cost is passed on to car buyers, then, since the average price of new passenger cars in 1983 was $10 721 (29), this additional cost would represent a 1.3% increase in the price of a new car. In the final analysis, market forces or marketing strategies are more likely to determine new car prices than hardware costs, particularly considering the small costs involved.

TABLE 17 COMPONENTS OF THE R.P.E.'s

Component	Percent	R.P.E. per Car
Plant Manufacturing		
. material	31.4	74
. labour	9.6	23
. plant overhead	3.8	9
Sub Total:	44.8	105
Component vendor markup	10.3	24
Tooling expense	2.9	7
Assembly, engine and body modification	2.0	5
Total - Vehicle assembler Cost	60.0	141
Vehicle Assembler Markup	13.8	32
Federal Sales Tax	6.6	16
Dealer markup	13.8	32
Research and development	5.7	13
Total R.P.E.	100%	$235

4.2.4 Lead Time Considerations. Pilorusso and DeKany (22) report that manufacturers of vehicles which conform to current U.S. standards could supply similar emission control systems in Canada within 12 to 18 months. The few manufacturers who would be required to redesign and certify completely new or substantially modified systems could require up to 36 months.

As noted previously, about 15% of new cars sold in Canada are already equipped with U.S.-specific control technology. Typically, about 950 000 new cars are sold in Canada and about 9 million in the U.S. annually. The auto trade pact permits the free movement of new cars and new car parts across the Canada/U.S. border. In 1983 about 70% of the cars manufactured in Canada were sold in the U.S. (31, 32). These were all equipped with U.S.-specific emission control equipment. Only about 5% of U.S. new car production was sold in Canada. While most of that 5% was produced with Canadian-specific emission control equipment, it is evident that the car manufacturers should be able to provide cars to meet more stringent emissions standards in Canada in less than two years.

5 REFINERY INDUSTRY CONSIDERATIONS

As vehicles equipped with catalytic converters have entered the motor vehicle fleet in Canada, lead-free gasoline's share of annual gasoline consumption has increased from about 6% in 1975 to 45% in 1983. Under status quo or natural lead phase-down conditions, it is projected that this demand for lead-free gasoline will continue to increase until 1990, when it will stabilize at about 70% of total gasoline demand (24). At that time, the residual 30% leaded-fuel demand will be for cars and trucks that are designed to operate on leaded gasoline.

At present, about 20% of the new passenger cars sold in Canada employ emission control technology that is able to meet current Canadian emission standards without the use of catalytic converters; these cars operate on leaded fuel. However, this leaded-fuel technology is not adequate to meet the standards under consideration. In order to meet these standards, this segment of the new vehicle fleet would have to be equipped with catalyst technology and to operate on lead-free fuel. This fuel requirement will result in a progressive increase in demand for lead-free fuel which is incremental to that forecast under the natural phase-down projection. Assuming that the proposed standards are introduced in 1987, it is estimated that by 1996 the demand for lead-free fuel will have increased from 70% to 90% of total gasoline demand.

To meet this increased demand, the refinery industry will need to provide additional capacity to produce lead-free gasoline. An estimate of the capital and operating costs involved has been made in a study conducted by Monenco (33). This study, which was commissioned by Environment Canada and carried out with the co-operation of the Department of Energy, Mines and Resources and the Petroleum Association for Conservation of the Canadian Environment (PACE), also estimated the costs to the industry if the octane-enhancing additive MMT (methyl cyclopentadienyl manganese tricarbonyl) is no longer used in lead-free gasoline. Although this additive is currently used in Canada, it is not permitted in the U.S. because studies there in the late 1970's indicated that its presence in gasoline prejudiced the attainment of the HC emission standard. According to Monenco, the capital and operating costs resulting from the removal of MMT and a 70/30 to 90/10 shift in grade split (lead-free/leaded) are $494 million and $42 million/year, respectively. If MMT is retained, the respective costs are $68 million and $19 million/year. Assuming that the capital expenditures are made over the 10-year period during which the incremental demand for lead-free gasoline will occur, then the production costs over the lead-free pool may be estimated as about 0.3

cents/litre without MMT and less than 0.1 cent per litre if it remains as a fuel additive. The vehicle maintenance savings that accrue to the motorist from the use of lead-free fuel compared to leaded fuel are discussed elsewhere (34, 35).

Canadian car manufacturers report no significant durability or maintenance problems with cars equipped to meet U.S. emissions standards when operating on Canadian fuels containing MMT. Technological improvements also have been and continue to be made which minimize the potential impact of MMT-containing fuels. Therefore removal of MMT is not considered to be a prerequisite to the attainment of the 0.25 g/km hydrocarbon standard.

6 CONCLUSIONS

Light duty vehicles are the largest single man-made source of NO_x, HC, and CO emissions in Canada and contribute significantly to the urban air concentrations of these pollutants. In addition, the NO_x and HC emissions undergo various reactions in the atmosphere that lead to the formation of nitric acid and ozone, compounds that play important roles in acid precipitation and in health/agricultural impacts, respectively. Although there are numerous man-made sources of NO_x, HC and CO emissions, LDV's are nevertheless unique in that they are not only the major individual source of all three pollutants, but that they also offer the opportunity for more stringent control of these pollutants simultaneously using technology that is already proven and in widespread use in North America. Thus, whereas current Canadian emission standards for LDV's have remained unchanged since 1975, the standards under consideration have been in force in the U.S. since 1981. In 1983, cars equipped to meet these latter standards represented about 90% (7 million) of all cars built in North America, and about 70% of cars manufactured in Canada, which were exported to the U.S. and equipped to meet the U.S. standard. Thus, the simple adoption of the U.S. standard in Canada should not have a major impact on the car manufacturing industry; implementation should require only a relatively short lead-time. It is further estimated that, on a sales-weighted basis, the average cost to the manufacturers to equip cars to meet these standards in Canada would be about $140 per car.

At present, mathematical models capable of predicting the environmental improvements to be expected from more stringent LDV emission standards are not available and therefore it is not possible to estimate the monetary value of the environmental and health benefits to be anticipated from the decreased emissions. Indeed, there is scientific debate on the most appropriate control strategy to address the ozone problem in Canada; namely whether to control both NO_x and HC emissions, or to directly control one or the other of these precursor pollutants. Nevertheless, despite the current lack of quantitative emissions/effects relationships and of a detailed understanding of atmospheric chemistry processes, HC and NO_x emissions are unambiguously recognized as playing a major role in the formation of ozone, and NO_x emissions as contributing to the acid precipitation phenomenon. It is therefore considered prudent to adopt a control strategy that will reduce these precursor emissions to the maximum possible extent. A necessary first step in this strategy can be achieved by adopting the U.S. emission standards for LDV's which, it is estimated, will result in reductions (from

the 1980 levels) of 45% or more for LDV emissions of NO_x, CO, and HC in Canada by the year 2000. This action will limit projected status-quo increases in NO_x emissions and hence reduce the contribution of LDV's to acid precipitation; it should also lead to a general improvement in ambient air quality in and around urban centres and to decreasing the LDV contribution to ambient ozone concentrations and to regional ozone episodes.

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APPENDIX

Methodology for Estimating Transportation Sector Emissions

The assumptions and methodologies used to determine historical NO_X, HC and CO emissions from the transportation sector in Canada and eastern Canada are given in detail in References 1 to 3. In brief, they consist of the following.

1) Emission factor estimates for automobiles, light-duty gasoline trucks, medium-duty gasoline trucks, and heavy-duty gasoline and diesel trucks are based on the following factors:*

   a) New vehicle performance data for the years 1972 and earlier are based on U.S. EPA MOBILE 2 Base Emission Rates (BER) (4).

   b) New vehicle performance data for 1973-83 passenger cars are based on the results of compliance testing performed at the Vehicle Emission Test Laboratory of Environment Canada.

   c) In-use degradation for the fleet is derived from various estimates of tampering, misfuelling and maladjustment according to the emission control technology being utilized.

   d) For light-duty trucks, it is assumed that all trucks up to 1983 were built to perform to U.S. emission limits.

   e) All medium-duty and heavy-duty truck emission and age distribution factors have been taken from U.S. EPA MOBILE 2.

2) Road motor vehicles registration data were taken from Statistics Canada publications (5).

3) Distribution of the truck population is based on historical survey data collected by the Ontario Ministry of Transportation and Communications (6). Environment Canada then applied the same distribution for each truck type for each province.

4) Distances travelled by each vehicle type noted in 1) are based on historical survey data collected by Environment Canada (7). The same distance travelled was used for all years up to 1980.

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* These factors have been modified to incorporate the best data currently available and may not reflect the values found in the historical documents under references 1, 2, and 3. Consequently the emission estimates differ from what appears in those documents, especially in the case of CO.

5) Data for other transportation sources and stationary sources have been taken from references 1 to 3 and 8 and aggregated into the categories presented in Tables 4 and 5. Forest fires have been excluded from the aggregate emission totals.

References

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