CCME

Canadian Council of Ministers of the Environment | Le Conseil canadien des ministres de l'environnement

CANADA-WIDE STANDARD FOR BENZENE
2010 FINAL REPORT
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PN 1467

The Canadian Council of Ministers of the Environment (CCME) is the primary, minister-led intergovernmental forum in Canada for collective action on environmental issues of national, and international concern.

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Summary

Benzene is a clear, and usually colourless, liquid with a gasoline-like odour. Under typical ambient conditions, some liquid benzene will evaporate and exist in the ambient air as a gas. Benzene is listed on Schedule 1 (list of toxic substances) of the *Canadian Environmental Protection Act, 1999* (CEPA 1999).

To reduce the exposure of Canadians to benzene, the Canadian Council of Ministers of the Environment (CCME) (except the Province of Québec[1]) endorsed the Canada-wide Standard (CWS) for Benzene, Phase 1 in June 2000, and Phase 2 in September 2001. Phase 1 of the CWS called for a 30% reduction in national benzene emissions, from 50.86 kilotonnes (kt) in 1995 to 35.6 kt by the end of the year 2000. Phase 2 of the CWS required a further 6 kt (12%) reduction in emissions, to be achieved by the end of the year 2010. The combined Phase 1 and Phase 2 of the CWS are equivalent to a 42% reduction in emissions relative to the base year of 1995.

Both CWS were achieved by the end of 2003. In fact, by the end of 2003 a 63.3% reduction in emissions had been achieved relative to 1995 (from 50.86 kt to 18.65 kt). Emissions reductions continued after 2003, falling to 14.56 kt in 2008 (the latest available figures), which represents a 71.4% reduction from 1995. National average ambient concentrations of benzene also decreased in urban locations. In the urban locations considered, the annual average ambient concentrations decreased to 0.93 µg/m3 in 2009 (from 3.60 µg/m3 in 1994), which represents a 74% reduction. In the rural locations considered, the ambient benzene concentrations remained relatively stable.

The majority of the benzene emissions reductions have come from transportation (on-road vehicles) and the upstream oil and gas sectors (natural gas dehydrators). Two factors that have likely played a major role in these emission reductions are the introduction of the federal *Benzene in Gasoline Regulations* and the implementation of best management practices by the Canadian Association of Petroleum Producers and Directive 039 issued by the Energy Resources Conservation Board and Alberta Environment.

The reduction in ambient levels is a positive step forward in reducing the risk of exposure of Canadians to benzene, as desired by CCME. Considering the increasing number of vehicles on the road and expansions in other sectors that potentially emit benzene, pursuing continuous improvements on recent achievements will remain a challenge. CCME will monitor benzene emission trends and ambient levels and revisit the need to take further actions in the future if needed.

[1] Québec is not a signatory to the Canada-wide Accord on Environmental Harmonization or the agreement on Canada-wide Standards. However, Québec strives to meet environmental standards whose limits are similar to those in the Canada-wide Standards.

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1. INTRODUCTION

Benzene is a clear, and usually colourless, liquid with a gasoline-like odour. Under typical ambient conditions, some liquid benzene will evaporate and exist in the ambient air as a gas. Benzene is listed on Schedule 1 (list of toxic substances) of the *Canadian Environmental Protection Act, 1999* (CEPA 1999).

Benzene is also listed as a carcinogenic agent to humans (*Group 1* substance) by the *International Agency for Research on Cancer* (IARC) of the World Health Organization. CAREX Canada,[2] a multidisciplinary team of researchers based at the School of Environmental Health at the University of British Columbia, states that benzene is considered a "non-threshold toxicant," where adverse effects may occur at any level of exposure. It also ranks benzene as Group A (immediate high priority) for both occupational and environmental settings. This assessment was based on the carcinogenicity and other toxic properties of the substance, the prevalence of exposure in Canada, and the feasibility of assessing exposure. CAREX is developing estimates of the number of Canadians exposed to known, probable and possible carcinogens in workplace and community environments, including benzene. These estimates, once completed, will provide significant support for targeting exposure reduction strategies and cancer prevention programs.

To reduce the exposure of Canadians to benzene, the Canadian Council of Ministers of the Environment (CCME) (except the Province of Québec[3]) endorsed the Canada-wide Standard (CWS) for Benzene, Phase 1 in June 2000, and Phase 2 in September 2001, with both phases calling for reductions in national emissions of benzene.

The 2008 update report[4] on the benzene CWS stated that the Phase 1 and Phase 2 emissions reductions targets for benzene had both been achieved as of 2003, with the Phase 2 reductions achieved seven years ahead of schedule. This 2010 progress report documents the further progress made in reducing emissions of benzene as of 2008.

Background information on the Phase 1 and Phase 2 benzene CWS is provided in section 2 of this report. Section 3 provides the national benzene emissions for the period 1995 to 2008, and section 4 provides the national ambient concentrations of benzene at urban and rural locations in Canada. A brief conclusion is provided in section 5.

[2] http://www.carexcanada.ca/en/benzene/

[3] Québec is not a signatory to the Canada-wide Accord on Environmental Harmonization or the agreement on Canada-wide Standards. However, Québec strives to meet environmental standards whose limits are similar to those in the Canada-wide Standards.

[4] http://www.ccme.ca/assets/pdf/benzene_08_report_final_e.pdf

2. BACKGROUND ON THE BENZENE PHASE 1 AND PHASE 2 CWS

Phase 1 of the CWS for benzene[5] was endorsed in June 2000. In Phase 1, ministers committed to reduce the 1995 national total emissions of benzene from major source sectors by 30% by the end of 2000. Initial sectors for consideration under Phase 1 included natural gas dehydrators, transportation (vehicles and fuels), refineries, chemical manufacturing, and steel mills.

The Phase 2 CWS for benzene[6] was endorsed in September 2001. In Phase 2, environment ministers committed to a further 6 kt reduction in emissions from existing sources to be achieved by the end of 2010, and to promote the application of best management practices for new and existing facilities.

The 1995 national emissions of benzene were first estimated at 58.4 kt as reported in the *Companion Document*[7] to the benzene CWS Phase 2. Because the emission compilation methods evolved over the years, the 1995 national emissions were revised to 50.86 kt in the 2001 Annual Progress Report,[8] mostly due to a revision in the emissions from residential wood combustion (e.g. woodstoves, fireplaces).

Based on the revised 1995 national emissions of benzene (50.86 kt), the 30% reductions required under Phase 1 corresponds to a 15.26 kt reduction in emissions, a reduction to 35.6 kt, by the end of 2000. The further 6 kt emission reductions to be achieved under Phase 2 required national emissions to be reduced to 29.6 kt by the end of 2010. The combined Phase 1 and 2 CWSs correspond to a 42% reduction in emissions from 1995.

3. NATIONAL BENZENE EMISSIONS

Some of the uses of benzene, as reported by CAREX Canada, include the following: as raw material for the production of chemicals including ethylbenzene (for styrene), cumene (for phenol and acetone), and cyclohexane (for nylon and synthetic fibres); and for use in the manufacturing of rubbers, lubricants, dyes, detergents, drugs, and pesticides. Benzene was also formerly added to gasoline as an octane enhancer and anti-knock agent (along with toluene and xylene). However, in Canada, benzene is generally no longer added to gasoline, but does occur naturally in crude oil and gasoline.

Individual jurisdictions have pursued emission reductions of benzene through specific actions related to components of the oil and gas (natural gas dehydrators), transportation, petroleum refining, chemical manufacturing, and steel manufacturing sectors. National emissions from these and other sectors are reported in Table 1 and Figure 1 (note that the vertical axis in Figure 1 is logarithmic).

[5] http://www.ccme.ca/assets/pdf/benzene_std_june2000_e.pdf
[6] http://www.ccme.ca/assets/pdf/benzene_cws_phase2_e.pdf
[7] http://www.ccme.ca/assets/pdf/benzene_companion_e.pdf
[8] http://www.ccme.ca/assets/pdf/bzph1ntnlsmry_15jan02_e.pdf

Table 1 and Figure 1 indicate substantial national reductions in benzene emissions between 1995 and 2008 (latest available emission inventory), with reductions occurring across all sectors, except for residential wood combustion (e.g. wood stoves, fireplaces) where national emissions showed a marginal increase.

Between 1995 and 2003, national emissions of benzene decreased by 63.3%[9], from 50.86 kt in 1995 to 18.65 kt in 2003. Therefore, the Phase 1 CWS which called for a 30% reduction in emissions by 2000, and the combined Phase 1 and 2 CWSs which called for an equivalent 42% reduction by 2010, were both achieved between 2000 and 2003. Emissions continued to decrease after 2003, decreasing to 14.56 kt by 2008, which equates to a 22% reduction relative to 2003 emissions and 71.4% reduction relative to 1995.

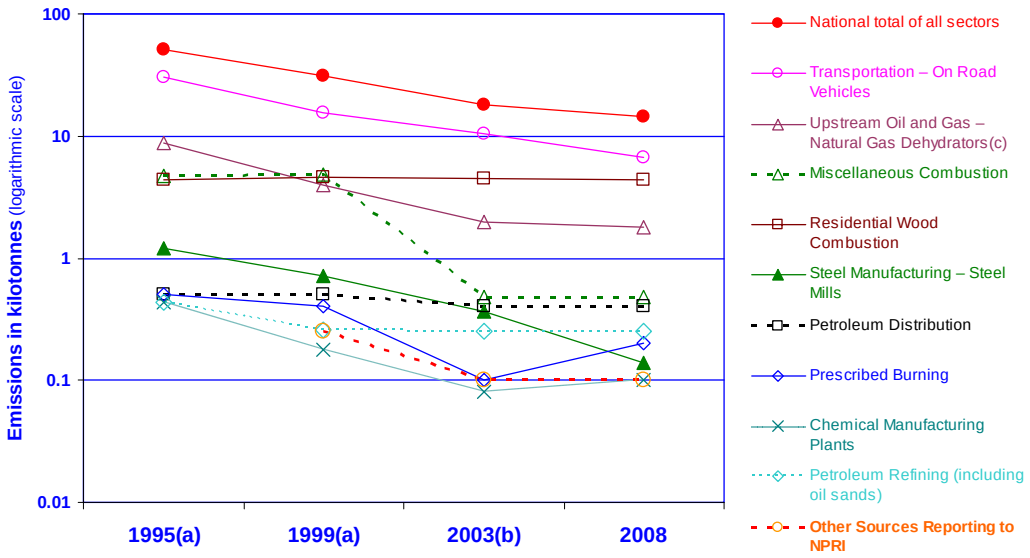
Table 1: National benzene emissions in Canada from 1995 to 2008

					Percent reductions between:	
	1995[a] (kt)	1999[a] (kt)	2003[b] (kt)	2008 (kt)	1995 and 2003	1995 and 2008
Transportation – On Road Vehicles	30	15.6	10.38	6.66	65.4	77.8
Natural Gas Dehydrators[c] – Upstream Oil and Gas	8.74	4.01	1.99	1.8	77.2	79.4
Steel Manufacturing – Steel Mills	1.2	0.72	0.37	0.14	69.2	88.3
Petroleum Distribution	0.5	0.5	0.4	0.4	20.0	20.0
Petroleum Refining (including oil sands)	0.44	0.26	0.25	0.25	43.2	43.2
Chemical Manufacturing Plants	0.44	0.18	0.08	0.1	81.8	77.3
Residential Wood Combustion[e]	4.34	4.56	4.5	4.43	-3.7	-2.1
Miscellaneous Combustion	4.7	4.8	0.48	0.48	89.8	89.8
Prescribed Burning	0.5	0.4	0.1	0.2	80.0	60.0
Other Sources Reporting to NPRI		0.25	0.1	0.1		60.0[d]
National Total	**50.86**	**31.28**	**18.65**	**14.56**	**63.3**	**71.4**

a) *"Benzene Canada-wide Standard Phase 1- National Summary Annual Progress Report", CCME, 2002.*
b) *"Canadian Benzene Emissions Inventory for 2003", ChemInfo, 2006.*
c) *"Status Report – Benzene Emissions from Glycol Dehydrators", CAPP, 2005.*
d) Indicated percentage change is between 2008 and 1999.
e) The reported emissions from residential wood combustion for 2003 differ from the emissions reported in the 2008 update report because of changes in the emission quantification methodologies.

[9] The 2008 progress update reported a 67% decrease. The difference between the two reports is mostly due to the adjustment in emissions from residential wood combustion as mentioned in footnote (e) of Table 1.

Figure 1: National benzene emissions in Canada from 1995 to 2008



(a) *Benzene Canada-wide Standard Phase 1- National Summary Annual Progress Report*, CCME, 2002.
(b) *"Canadian Benzene Emissions Inventory for 2003"*, ChemInfo, 2006.
(c) *Status Report – Benzene Emissions from Glycol Dehydrators,* CAPP, 2005

On a mass basis, the largest reductions in emissions occurred in the transportation sector (on-road vehicles), where emissions decreased from 30 kt in 1995 to 6.66 kt in 2008. The reduction in emissions from the transportation sector is a result of the implementation of the federal *Benzene in Gasoline Regulations.* These regulations came into force on July 1, 1999 following the acceptance by CCME of the recommendations by the federal-provincial Task Force on Cleaner Vehicles and Fuels that benzene in gasoline be reduced to 1% by volume through a federal regulation. Despite the large reductions in emissions from the transportation sector, benzene emissions from this sector remain one of the largest sources of benzene in Canada, followed by residential wood combustion.

The second largest absolute reductions in emissions occurred in the upstream oil and gas sector (more specifically from natural gas dehydrators), where emissions decreased from 8.74 kt in 1995 to 1.8 kt in 2008. The reductions in emissions from natural gas dehydrators is largely attributable to the implementation of *The Best Management Practices for Control of Benzene Emissions from Glycol Dehydrators*[10] of the Canadian Association of Petroleum Producers, and Directive 039[11] (*Revised Program to Reduce Benzene Emissions from Glycol Dehydrators*) issued by the Energy Resources

[10] http://www.capp.ca/getdoc.aspx?DocId=105760&DT=PDF
[11] http://www.ercb.ca/docs/documents/directives/Directive039.pdf

Conservation Board and Alberta Environment. Similarly, reductions in other sectors came from the minimizing emissions through the application of best available pollution prevention and control techniques for new and expanding facilities as called for in the benzene Phase 2 CWS.

On a percentage basis, the largest reductions between 1995 and 2008, with the exception of miscellaneous combustion sources, occurred in steel manufacturing, with an 88.3% reduction. There is high uncertainty in the estimation of emissions from miscellaneous combustion sources, which includes pulp and paper, wood products, landfills and general combustion sources. The reduction in emissions from miscellaneous combustion sources may be due to change in the emissions estimation methodology instead of actual reductions in emissions.

Prescribed burning is the only sector from Table 1 for which the emissions are estimated to have increased between 2003 and 2008. It should be noted, however, that the number and the area of the prescribed burnings can vary greatly from year to year. The application of prescribed burning is an essential tool in environmental stewardship. Since 2000, there has been a renewed interest in its application, especially with respect to ecosystem restoration activities. The judicious use of prescribed burning can also be an effective tool in helping to mitigate catastrophic wildfire risk and can create greater resiliency in forest and rangelands in response to changes in climate. Prescribed burnings are often in relatively remote locations, but if conducted near population centres exposure can be mitigated through management and planning.

4. NATIONAL AMBIENT BENZENE CONCENTRATIONS

Benzene Measurement Methodology

Gaseous benzene and other volatile organic compounds (VOC) are measured as part of the National Air Pollution Surveillance (NAPS) network. The NAPS network is operated cooperatively by federal, provincial, territorial and municipal monitoring agencies through a Memorandum of Understanding[12], with Environment Canada maintaining a central database of all the air quality measurements made at NAPS monitoring sites. The collection of routine VOC samples began in 1989 at a few locations across Canada, with the network gradually expanding over the years

VOC samples are collected automatically by drawing ambient air into Summa-polished canisters over a 24 hour period (midnight to midnight) for urban samples, and over a midday 4-hour period for rural samples.[13] The samples are sent to Environment Canada where a suite of VOCs are analyzed, including benzene.

[12] http://www.gazette.gc.ca/rp-pr/p1/2010/2010-04-24/pdf/g1-14417.pdf

[13] Since benzene concentrations fluctuate during the day, annual averages for urban and rural sites are not directly comparable because the calculations are based on different sampling periods.

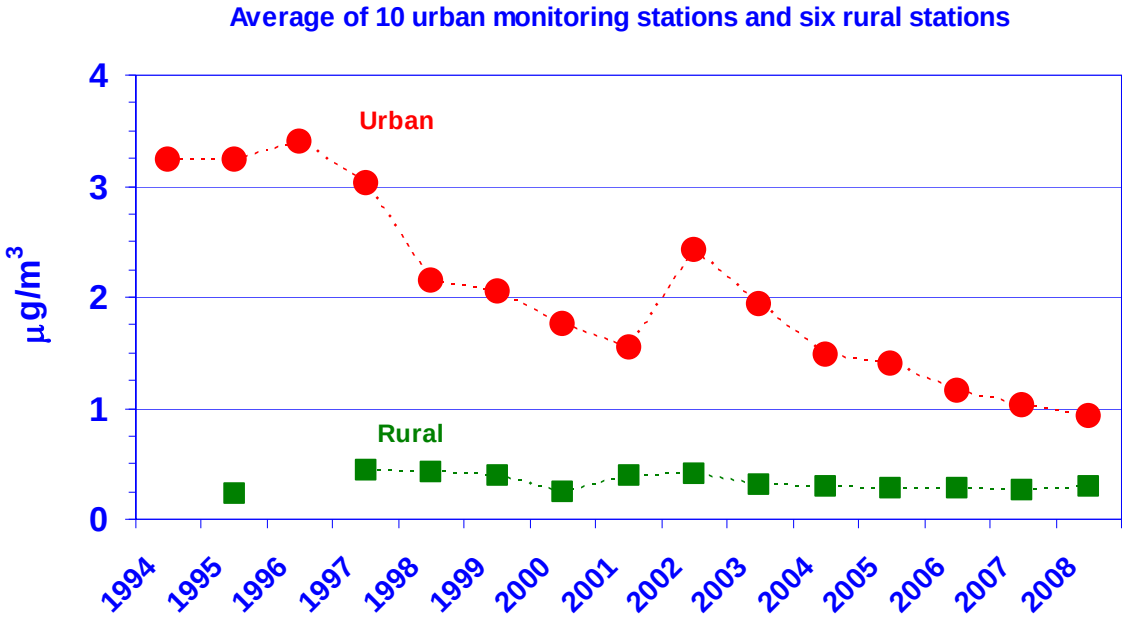
National Annual Average Ambient Benzene Concentrations, 1994 to 2009

This section discusses the annual average ambient concentrations of benzene for the sixteen year period from 1994 to 2009.

Figure 1 presents the annual average ambient benzene levels for ten urban stations and six rural air monitoring trend stations (presented in the Appendix A)[14] for the sixteen year period. Overall, at the urban locations the annual average benzene concentrations decreased by 0.2 µg/m^3 per year. Between 1994 and 2009, there was an approximate decrease of 74%, from 3.6 µg/m^3 to 0.9 µg/m^3, approaching levels observed in rural areas. Annual average levels at the rural stations remained steady over this 16 year period at approximately 0.3 µg/m^3.

The decrease in the ambient concentrations of benzene at the urban stations considered is likely a reflection of the reductions in emissions from the transportation sector with the coming into force of the *Benzene in Gasoline Regulations*. Other emission reduction initiatives implemented at a more local level (such as Montréal's By-Law 90, which addresses the emissions from the petrochemical and the chemical industries), may have also contributed to the observed decreases at selected stations.

Figure 2: Annual average ambient benzene concentrations, 1994 to 2009



[14] Benzene concentrations in this report may differ slightly from previous reports because of the more stringent criteria used for the selection of trend sites. An annual and seasonal (summer and winter) data completeness criterion of 75% was applied based on a 1-in-6 day sampling schedule for the selection of trend sites. All of the trend sites had at least 75% data completeness in 2009. Outliers were not removed from the dataset. The annual mean for a given year was obtained by averaging the annual mean (arithmetic average) concentrations for trend sites for the given year. There was no interpolation of missing data. No special statistical or analysis techniques were used.

The much lower average ambient concentrations of benzene measured at the rural stations reflects the smaller impact from the transportation sector in these locations due to the presence of fewer vehicles in rural areas compared to urban centers.

5. CONCLUSIONS

National emissions of benzene decreased by 63%, from 50.86 kt in 1995 to 18.65 kt, in 2003. The emissions further decreased to 14.56 kt by 2008, which represents a 71.4% reduction from the 1995 emissions and a 22% reduction from the 2003 emissions. The Phase 1 and Phase 2 CWSs were therefore both achieved by 2003, and emissions reductions continued until 2008 (the end of the current reporting period).

Most of the reductions in emissions came from the transportation sector (on-road vehicles), with a decrease in emissions of 77.8% between 1995 and 2008, and from natural gas dehydrators with a decrease in emissions of 79.4%. The reduction in emissions from the transportation sector is a result of the implementation of the *Benzene in Gasoline Regulations*. The reduction in emissions from natural gas dehydrators is largely attributable to the implementation of best management practices by the Canadian Association of Petroleum Producers and Directive 039 issued by the Energy Resources Conservation Board and Alberta Environment. Reductions were also recorded in most other sectors (except for residential wood combustion), and these were likely driven by the Phase 2 CWS which calls for the minimization of emissions through the application of best available pollution prevention and control techniques for new and expanding facilities.

The reduction in benzene emissions is reflected in the reduction in the ambient concentrations of benzene at the urban stations considered. At these stations, the annual average ambient concentrations of benzene were about 74% less in 2009 compared to 1994.

The reductions in ambient levels are a positive step forward in reducing the risk of exposure of Canadians to benzene, as desired by CCME. Considering the increasing number of vehicles on the road and the expansion of other sectors that potentially emit benzene, pursuing continuous improvements on recent achievements will remain a challenge. CCME will monitor benzene emission trends and ambient levels and revisit the need to take further actions in the future if needed.

Appendix A

List of the urban and rural NAPS air monitoring trend stations used for the calculation of the annual averages in Figure 1.

URBAN AIR MONITORING STATIONS

NAPS ID	CITY	ADDRESS	LATITUDE	LONGITUDE
50103	MONTREAL	1050 A, BOUL. SAINT-JEAN-BAPTISTE	45.64125	-73.499363
50121	LONGUEUIL	8361 RUE OCEANIE - BROSSARD	45.44306	-73.46861
50115	MONTREAL	1001 BOUL DE MAISONNEUVE OUEST	45.50083	-73.57528
60104	OTTAWA	RIDEAU & WURTEMBURG	45.43433	-75.676
60512	HAMILTON	ELGIN & KELLY	43.25778	-79.86167
70119	WINNIPEG	65 ELLEN STREET	49.89795	-97.14665
90130	EDMONTON	10255 - 104th STREET	53.54449	-113.49893
90227	CALGARY	611-4th STREET S.W.	51.04778	-114.07556
90121	EDMONTON	17 STREET & 105 AVENUE	53.54823	-113.36811
100111	METRO VAN - PORT MOODY	MOODY & ESPLANADE PORT MOODY	49.28083	-122.84917

RURAL AIR MONITORING STATIONS

NAPS ID	CITY	ADDRESS	LATITUDE	LONGITUDE
30501	KEJIMKUJIK	NATIONAL PARK	44.433611	-65.205833
54102	SUTTON	MONT SUTTON/ROUND TOP RIDGE	45.088611	-72.556944
54401	SAINT-ANICET	1128 DE LA GUERRE	45.11667	-74.28333
55201	LEMIEUX	1290 RTE DES ATOCAS	46.30361	-72.06083
62601	SIMCOE	EXPERIMENTAL FARM	42.856896	-80.270282
64401	EGBERT	EGBERT	44.231111	-79.783056