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Surveillance of environmental & occupational exposures for cancer prevention

INDICATORS OF EXPOSURE TO KNOWN AND SUSPECTED CARCINOGENS IN THE ENVIRONMENT

DATA PRIORITIES AND RECOMMENDATIONS

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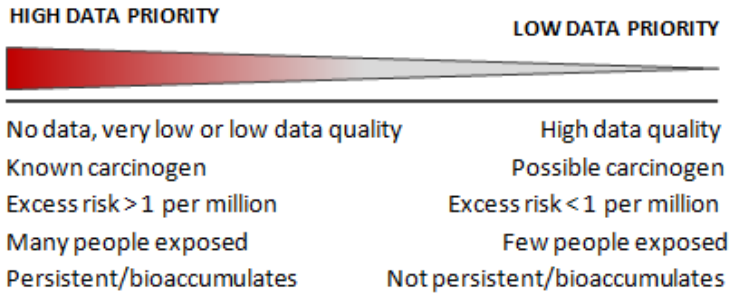
Executive Summary

The goal of CAREX Canada's environmental exposure research is to help reduce the future incidence of cancer by providing resources to support actions that reduce or eliminate Canadians' exposure to known and suspected carcinogens in non-occupational settings.[1] To meet this goal, we developed indicators of lifetime excess cancer risk due to potential exposure to 33 known or suspected carcinogens (Table 1) via five exposure pathways (outdoor air, indoor air, indoor dust, drinking water, and foods/beverages), using measured data circa 2006.

Lifetime excess cancer risk indicates the maximum number of *additional* cases of cancer would be expected to occur in a group of people if they are all exposed to a specific known or suspected carcinogen throughout their entire life. Most often, this excess risk is stated as a proportion, for example, 2 additional cases per million people. In Canada and the United States, lifetime excess cancer risks greater than 1 to 100 per million people may be prioritized for additional investigation, either by collecting additional data or conducting detailed risk assessments.

The objective of this report is to provide an overview of the data we found to support the calculation of the lifetime excess cancer risk indicators, to identify and prioritize data gaps, and to provide recommendations for addressing high priority data gaps.

For each substance and exposure pathway, priorities for specific data gaps were subjectively assessed as high, moderate or low using the following framework:



Priorities are based on the judgement of CAREX Canada staff[2], and apply nationally. Different priorities may exist regionally or locally, depending on the unique sources of known or suspected carcinogens and datasets that were not publicly available or readily accessible to the CAREX Canada staff. In addition to identifying priorities for specific substance-exposure pathways (see Table 1 for overview), we also identified several high priority data gaps that apply across drinking water, food and beverages, and consumer products pathways.

[1] More information on potential exposures in occupational settings is available at http://www.carexcanada.ca/en/occupational_approach/

[2] CAREX staff biographies are available at http://www.carexcanada.ca/en/team/

High priority:

- **Treated drinking water.** Drinking water quality monitoring is under the jurisdiction of local governments, and there is no national (or sometimes even provincial) database that synthesizes these results. The lack of a standard set of substances being tested, and changes in analytical methods over time pose significant challenges to understanding exposure levels and geographic patterns in Canadians' exposure to known or suspected carcinogens via treated drinking water.

  Recommendation – improve access to data on measured levels of known and suspected carcinogens in treated drinking water: Measured levels of a standard list of contaminants in treated drinking water could be synthesized into publicly available national (or at least, provincial) databases or reports on a regular basis for exposure surveillance purposes.

- **Privately sourced drinking water.** Privately sourced drinking water (from wells or surface water) is sent by individuals for lab testing, and results may not be reported to local jurisdictions. A substantial number of Canadians drink privately sourced water, especially in the Maritime provinces.

  Recommendation – improve access to data on measured levels of known and suspected carcinogens in privately sourced drinking water: Lab test results from private drinking water systems could be anonymized and made public in order to increase our understanding of exposure levels in the Canadian population not served by municipal systems.

- **Lack of standardization in food lists between studies.** Neither Canada nor the US conducts food monitoring programs that directly measure levels of known or suspected carcinogens in foods and beverages in conjunction with the amount consumed. Programs focus either on measuring contaminants or substances of concern, OR on documenting types and amounts of foods eaten, but do not use fully comparable food lists. This makes it difficult in some cases to associate measured levels with consumption levels.

  Recommendation – enhance the integration of existing data collection efforts for exposure surveillance purposes: An ongoing population-based survey that includes dietary intake AND analysis of foods as eaten for a standard set of substances including known and suspected carcinogens.

- **Lack of concentration and use frequency data for consumer products.** While consumer products are typically thought to be safe in Canada, there is currently no system in place that would allow ongoing and comprehensive exposure surveillance for a standard set of substances and products.

  Recommendation – establish a comprehensive reporting system for known and suspected carcinogens in consumer products for exposure surveillance purposes: Federal and provincial governments could require manufacturers to report concentration levels present in products, and explore ways to work with either retailers or market survey companies to track frequency of use statistics**.**

- **Outdoor Air** - **Diesel engine exhaust (known carcinogen)**. Assuming 18 percent of measured fine particulates in outdoor air is from diesel engine exhaust, the average lifetime excess cancer risk associated with measured levels in 2006 is 35 per million. A potentially high number of Canadians are exposed.

  Recommendation – refine current estimates of Canadians potential exposure to diesel engine exhaust: Use detailed heavy duty traffic volume data in conjunction with targeted monitoring to establish regionally representative ratios of elemental carbon/total fine particulates, and inform analyses of residential proximity to roads with heavy duty traffic.

- **Outdoor Air – Asbestos (known carcinogen).** Levels of asbestos in outdoor air are rarely measured in Canada. US data from the 1990's suggests that asbestos is frequently detected in outdoor air, and levels are higher in urban areas. These data suggest an average lifetime excess cancer risk of approximately 2.5 per million. Canadian data from known asbestos mining areas suggests lifetime excess cancer risk can be much higher (up to 1,270 per million).

  Recommendation - increase our understanding of Canadians' exposure to asbestos in outdoor air: Conduct a national survey in urban areas (potentially via the National Air Pollution Surveillance monitoring system), and targeted monitoring in areas known or suspected to be influenced by mining, asbestos processing, or naturally occurring deposits.

- **Indoor Air** - **Diesel engine exhaust (known carcinogen)**. No data on levels of diesel engine exhaust infiltrating to indoor air were found, but assuming 60 percent of fine particulates in outdoor air infiltrates to indoor air, and 18 percent of that is due to diesel engine exhaust, the average lifetime excess cancer risk based on 2006 data is 300 per million.

  Recommendation – provide evidence for reducing exposures: In addition to improving estimates of outdoor levels of diesel engine exhaust, and conducting residential proximity analyses (see outdoor air recommendation), collect additional information on the effectiveness of air filters in removing fine particulates in a variety of housing types.

- **Indoor Air – Asbestos (known carcinogen)**. Indoor levels of asbestos are rarely measured in Canada. US data, gathered in the 1990s, from a survey of buildings thought to be contaminated with asbestos (but not undergoing renovation or remediation) suggests the average lifetime excess cancer risk is 11 per million.

  Recommendation - increase our understanding of Canadians' exposure to asbestos in indoor air: A comprehensive monitoring study, designed to include buildings known to contain materials with asbestos, buildings that have been remediated, and newer buildings without contaminated materials. The study should include measures of both indoor and outdoor levels at locations in urban and rural areas, as well as near potentially contaminated sites (mining sites, historic vermiculite processing plants, and naturally occurring deposits).

Moderate priority:

We did not make recommendations for moderate priority data issues; however, increased data collection is required for the following substances and exposure pathways to confirm the prevalence and level of exposure:

- Indoor air: arsenic, cadmium, hexavalent chromium, and nickel; benzo[a]pyrene, 1,3-butadiene and polychlorinated biphenyls (PCBs).
- Indoor dust: benzo[a]pyrene
- Food and beverages: arsenic, benzo[a]pyrene, 2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD), polychlorinated biphenyls (PCBs), dichloroacetic acid (DCA)

Low Priority:

A number of data issues were assessed as low priorities (Table 1). This assessment is generally due to the likelihood of relatively few Canadians being exposed, lifetime excess cancer risk indicators being well below 1 per million (even though data were limited), and/or the identification of new studies (post 2006) that may address data gaps. These may still be of higher priority in specific regions or locations with known sources.

Not Priority:

For many substances and pathways, we found sufficient data to estimate lifetime excess cancer risk, on average, for Canadians circa 2006. Continuing to collect data and/or conduct new studies will be key to establishing trends in potential exposure to these substances.

> **NOTE:** Substances identified as 'not priority' for data collection may be priorities for exposure reduction. For known carcinogens with moderate to high data quality and lifetime excess cancer risks above 1 per million, targeted programs should be developed to raise awareness and/or reduce environmental concentrations.

Table 1. Overview of priorities for data collection or improvement by substance
(not including consumer products)

IARC 1 - KNOWN CARCINOGENS	Outdoor Air	Indoor Air	Indoor Dust	Drinking Water*	Food & Beverage*
Arsenic and compounds (inorganic)	NOT PRIORITY	MODERATE	LOW	NOT PRIORITY	MODERATE
Asbestos	HIGH	HIGH	--	--	--
Benzene	NOT PRIORITY	NOT PRIORITY	--	NOT PRIORITY	LOW
Benzo[a]pyrene	NOT PRIORITY	MODERATE	MODERATE	LOW	MODERATE
1,3-Butadiene	NOT PRIORITY	MODERATE	--	LOW	LOW
Cadmium and cadmium compounds	NOT PRIORITY	MODERATE	--		--
Chromium (hexavalent)	LOW	MODERATE	LOW	NOT PRIORITY	LOW
Diesel engine exhaust	HIGH	HIGH	--	--	--
Formaldehyde	NOT PRIORITY	NOT PRIORITY	--	--	--
Nickel and nickel compounds	NOT PRIORITY	MODERATE	--	--	--
Polychlorinated biphenyls	LOW	MODERATE	LOW	LOW	MODERATE
Radon	NOT PRIORITY	NOT PRIORITY	--	--	--
2,3,7,8-Tetrachlorodibenzo-para-dioxin	NOT PRIORITY	LOW	LOW	LOW	MODERATE
IARC 2A - PROBABLE CARCINOGENS					
Lead and lead compounds	NOT PRIORITY	NOT PRIORITY	LOW	NOT PRIORITY	NOT PRIORITY
Tetrachloroethylene	NOT PRIORITY	NOT PRIORITY	NOT PRIORITY	NOT PRIORITY	LOW
IARC 2B - POSSIBLE CARCINOGENS					
Acetaldehyde	NOT PRIORITY	NOT PRIORITY	--	--	--
Benz[a]anthracene	NOT PRIORITY	LOW	NOT PRIORITY	LOW	LOW
Benzo[b]fluoranthene	NOT PRIORITY	LOW	NOT PRIORITY	LOW	LOW
Benzo[k]fluoranthene	NOT PRIORITY	LOW	NOT PRIORITY	LOW	LOW
Bromodichloromethane	--	--	--	NOT PRIORITY	LOW
Chloroform	NOT PRIORITY	LOW	--	NOT PRIORITY	LOW
Chlorothalonil	NOT PRIORITY	LOW	LOW	LOW	LOW
Chrysene	NOT PRIORITY	LOW	NOT PRIORITY	LOW	LOW
Dichloroacetic acid	NOT PRIORITY	NOT PRIORITY	NOT PRIORITY	NOT PRIORITY	MODERATE
Dichloromethane	NOT PRIORITY	LOW	--	LOW	LOW
Dichlorvos	LOW	NOT PRIORITY	LOW	NOT PRIORITY	LOW
Ethylbenzene	NOT PRIORITY	NOT PRIORITY	--	NOT PRIORITY	LOW
Indeno(1,2,3-cd)pyrene	NOT PRIORITY	LOW	NOT PRIORITY	LOW	LOW
Lindane	NOT PRIORITY	LOW	LOW	NOT PRIORITY	LOW
MX	--	--	--	LOW	LOW
N-nitrosomethylethylamine	--	--	--	NOT PRIORITY	LOW
Pentachlorophenol	LOW	LOW	LOW	NOT PRIORITY	LOW
2,4,6-trichlorophenol	--	--	--	NOT PRIORITY	LOW

* Many data are collected for drinking water, but are not readily accessible. Similarly, many data are collected for foods and beverages, but are difficult to integrate.

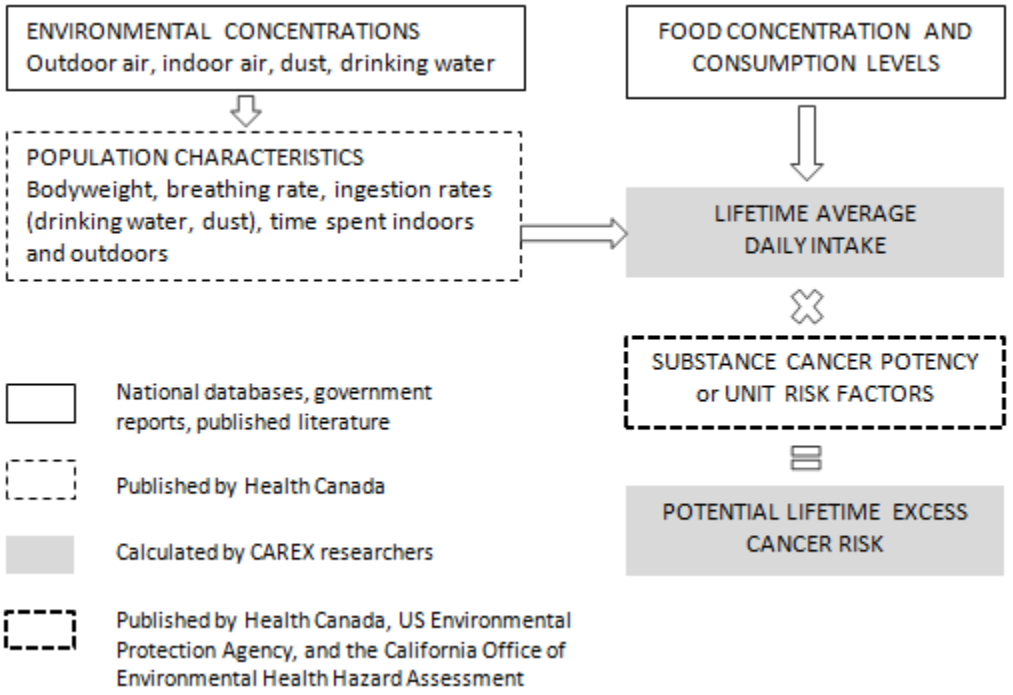
1.0 Introduction

The goal of CAREX Canada's environmental research is to help reduce the future incidence of cancer by providing resources to support actions that reduce or eliminate Canadians' exposure to known and suspected carcinogens in non-occupational settings. In keeping with this goal, we developed the following guiding principles for environmental exposure surveillance information:

- should be national in scope, while incorporating regional variation when appropriate;
- should enable surveillance over time (at the least, establish a benchmark and develop information that can be refreshed over time to identify trends); and
- should support prioritization by making information comparable across exposure pathways and among substances.

Using these guidelines, we adopted a risk assessment-based approach to develop population-level indicators of potential exposure. These indicators incorporate measured levels of the known and suspected carcinogens in each applicable exposure pathway and use standard assumptions about inhalation and ingestion rates (Figure 1). **For each substance and exposure pathway, we calculated potential lifetime excess cancer risk using measured levels circa 2006 as an indicator of Canadians' potential exposure.**

Figure 1. Approach for developing indicators of exposure*



*Note- radon is calculated using lifetime total dose, asbestos is calculated using lifetime average hourly concentration

Lifetime excess cancer risk indicates the maximum number of *additional* cases of cancer that would be expected to occur in a group of people if they are all exposed to a specific known or suspected carcinogen throughout their entire life. Most often, this excess risk is stated per million people (for example, 2 per million). In Canada and the United States, lifetime excess cancer risks greater than 1 to 100 per million may be prioritized for additional investigation, either by collecting additional data or conducting detailed risk assessments.[3,4]

For each substance and exposure pathway, the Environmental Team identified useful data by:

- Systematically reviewing selected known and suspected carcinogens (Table 1) to identify key exposure pathways (outdoor air, indoor air, indoor dust, drinking water, foods and beverages, and consumer products).
- Performing comprehensive internet searches for publicly available databases and peer-reviewed literature containing measured data for each substance and relevant exposure pathways.
- Consulting with various federal and provincial departments to identify internal data sources.
- Conducting meetings, evaluations and costs assessments for commercially available data sets.
- Developing scientific advisory groups for outdoor air, indoor air and dust, and drinking water to review available data and generate ideas for filling data gaps.

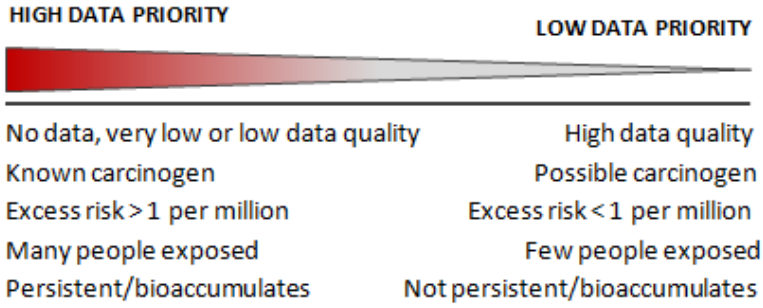
Whenever possible, we used concentration data from publicly available and ongoing national or provincial monitoring programs (either online or as summarized in government reports). When these were not available, we used data from peer-reviewed journal articles reporting results from studies conducted in 2000 or more recently in Canada, the US or northern European countries, and with sample durations of at least 24 hours.

In this report, we summarize the results of our search for data to support the development of the lifetime excess cancer risk indicators. In the process, we identify important data issues, and provide recommendations for addressing high priority data issues. The priorities identified are national in scope – regional or local issues may result in different priorities.

Each section of the report covers a specific exposure pathway and provides a brief synopsis of the data used or evaluated. When possible, we also provide a table summarizing the data source and quality for each substance, and a set of high (with associated recommended actions), moderate and low data priorities. Data quality assessments are subjective, and are meant to indicate how well the average

[3] Health Canada (2010). Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0. Federal Contaminated Site Risk Assessment in Canada.
[4] US EPA Waste and Cleanup Risk Assessment: Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (http://www.epa.gov/oswer/riskassessment/baseline.htm).

measured level identified actually represents the average national level. Data priorities are subjectively assessed as high, moderate or low using the following framework:



2.0 Outdoor Air

Data Synopsis: We primarily used data from the National Air Pollutants Surveillance (NAPS) program run by Environment Canada, which provides regularly measured levels for a wide range of pollutants in outdoor air[5]. The data are collected and quality checked using scientifically accepted methods by Environment Canada staff before being made available to the public. When NAPS data were not available, we used government reports or peer-reviewed literature.

Tables 2a, 2b and 2c provide a summary of sources of measured data identified for each substance in outdoor air, and an assessment of data quality with respect to representing the 'average' Canadian measured level circa 2006.

Table 2a. Summary of Data Quality in Outdoor Air – Known Carcinogens

IARC Group 1 Known Carcinogen	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Asbestos (Fibre)	2.5 (1,267)	**Very Low**	Asbestos in outdoor air is not regularly measured in Canada or the US. We used an outdoor air average concentration based on one comprehensive study from the US, conducted in the 1990s.
Diesel engine exhaust	34.6 (61.6)	**Very Low**	Total fine particulates are regularly measured at 177 monitoring stations across Canada. The amount of fine particulates attributable to diesel engine emissions is not measured directly. Our estimate assumes that 18% of total fine particulates are generated by diesel engines.
Polychlorinated biphenyls	0.1 (0.3)	**Very Low**	Polychlorinated biphenyls are measured in outdoor air at only 8 NAPS monitoring stations in Southern Ontario using accepted protocols, and reported as either total PCBs (including all congeners) or as total equivalent PCBs. Total toxic equivalent levels were used for our indicator.
Chromium (hexavalent) (Metal)	0.1 (0.2)	**Low**	Total chromium is regularly measured at 13 NAPS monitoring stations across Canada. Hexavalent chromium is not measured directly. Our estimate assumes 5 percent of measured chromium is hexavalent chromium.
Arsenic and compounds (inorganic)	0.3 (0.6)	**Moderate**	Total arsenic is regularly measured in outdoor air at 13 NAPS monitoring stations across Canada.
Benzo[a]pyrene (PAH)	0.01 0.04)	**Moderate**	Benzo[a]pyrene is regularly measured in outdoor air at 18 NAPS monitoring stations across Canada.

[5] Air quality data are also collected regionally by the British Columbia Ministry of Environment, Metro Vancouver, and the City of Montreal, but typically focus on particulate matter, ozone and greenhouse gases.

Table 2a. Summary of Data Quality in Outdoor Air – Known Carcinogens Continued

IARC Group 1 Known Carcinogen	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Cadmium (Metal)	0.1 (0.25)	**Moderate**	Cadmium is regularly measured in outdoor air at 13 NAPS monitoring stations across Canada.
Formaldehyde (VOC)	1.6 (3.1)	**Moderate**	Formaldehyde is regularly measured in outdoor air at 15 NAPS monitoring stations across Canada.
Nickel compounds (Metal)	0.05 (0.2)	**Moderate**	Nickel is regularly measured in outdoor air at 13 NAPS monitoring stations across Canada.
Radon	277	**Moderate**	Radon in outdoor air was measured in a number of Canadian cities in 1990-1991. While we do not expect levels to change over time given outdoor levels of radon are a product of geology and soil moisture, data from areas not previously measured may affect the estimate of average levels.
TCDD - dioxin	0.003 (0.005)	**Moderate**	2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD) is measured in outdoor air at 16 NAPS monitoring stations across Canada.
Benzene (VOC)	1.9 (7.9)	**High**	Benzene is regularly measured in outdoor air at 53 NAPS monitoring stations across Canada.
1,3-Butadiene (VOC)	1.3 (10.9)	**High**	1,3-butadiene is regularly measured in outdoor air at 53 NAPS monitoring stations across Canada.

Table 2b. Summary of Data Quality in Outdoor Air – Probable Carcinogens

IARC Group 2A Probable Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Lead (Inorg. compounds) (Metal)	0.002 (0.007)	**Moderate**	Lead is regularly measured in outdoor air at 13 NAPS monitoring stations across Canada using accepted protocols.
Tetrachloroethylene (VOC)	0.1 (1.3)	**High**	Tetrachloroethylene is regularly measured in outdoor air at 53 NAPS monitoring stations across Canada using accepted protocols.

Table 2c. Summary of Data Quality in Outdoor Air – Possible Carcinogens

IARC Group 2B Possible Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Dichlorovos	0.003 (0.02)	**Very Low**	One Canadian study in St. Damase, Quebec, was identified, but dichlorvos was not detected in outdoor air. Data from a US study in Iowa indicated infrequently detected low levels.
Pentachlorophenol	0.001 (0.1)	**Very Low**	A study measuring pentachlorophenol levels outside of homes and daycares in the US (NC and OH) in 2000-2001 was used for our indicators.
Acetaldehyde (VOC)	0.2 (0.3)	**Low-Moderate**	Acetaldehyde is regularly measured in outdoor air at 15 NAPS monitoring stations across Canada using accepted protocols.
Benz[a]anthracene (PAH)	0.0002 (0.0008)	**Moderate**	Benz[a]anthracene is regularly measured in outdoor air at 18 NAPS monitoring stations across Canada using accepted protocols.
Benzo[b]fluoranthene (PAH)	0.005 (0.02)	**Moderate**	Benzo[b]fluoranthene is regularly measured in outdoor air at 18 NAPS monitoring stations across Canada using accepted protocols
Benzo[k]fluoranthene (PAH)	0.001 (0.004)	**Moderate**	Benzo[k]fluoranthene is regularly measured in outdoor air at 18 NAPS monitoring stations across Canada using accepted protocols.
Chlorothalonil	0.00008 (0.0002)	**Moderate**	Six Canadian studies were identified, all reporting low mean and median measured values.
Chrysene (PAH)	0.0004 (0.002)	**Moderate**	Chrysene is regularly measured in outdoor air at 18 NAPS monitoring stations across Canada using accepted protocols.
Indeno[1,2,3-cd]pyrene (PAH)	0.002 (0.007)	**Moderate**	Indeno[1,2,3-cd]pyrene is regularly measured in outdoor air at 18 NAPS monitoring stations across Canada using accepted protocols
Lindane	0.004 (0.07)	**Moderate**	Ten recent Canadian studies were identified, with similar low average levels. Mean and maximum levels were a magnitude higher in agricultural areas.
Chloroform (VOC)	0.2 (0.4)	**High**	Chloroform is regularly measured in outdoor air at 53 NAPS monitoring stations across Canada using accepted protocols.
Dichloromethane (VOC)	0.04 (0.1)	**High**	Dichloromethane is regularly measured in outdoor air at 52 NAPS monitoring stations across Canada using accepted protocols
Ethylbenzene (VOC)	0.09 (0.5)	**High**	Ethylbenzene is regularly measured in outdoor air at 53 NAPS monitoring stations across Canada using accepted protocols.

High Priority Data Issues:

- **Asbestos (IARC Group 1 - known carcinogen, very low data quality, average LECR 2.5 per million).** Asbestos in outdoor air is not regularly measured in Canada, but may be present near asbestos mining activities (historic or active)[6], historic vermiculite processing sites[7], naturally occurring asbestos deposits[8], and more generally in urban environments (released from weathering of vehicle brake pads, asbestos containing cement, and other products)[9]. We found only one Canadian study, conducted in 1984 in Quebec towns associated with asbestos mines, which used the recommended measurement method. Based on data from a national US study conducted in the 1990s, lifetime excess cancer risk associated with typical asbestos levels in outdoor air ranged from 0.31 to 2.53 per million. The Canadian data suggest a lifetime excess cancer risk of as high as 1,270 per million in active mining towns.
    - **A national survey in urban areas (potentially via the NAPS system), and targeted monitoring in areas known or suspected to be influenced by mining, processing, or naturally occurring deposits would be required to fully understand Canadians' exposure to asbestos via outdoor air.**

- **Diesel engine exhaust (IARC Group 1 - known carcinogen, very low data quality, average LECR 34.6 per million).** Diesel engine exhaust is not measured directly by NAPS. Assuming that 18 percent of total fine particulate matter is due to diesel engine exhaust[10], the LECR associated with average measured levels at 177 NAPS sites is approximately 35 per million. Importantly, a large proportion of the Canadian population may be exposed to diesel engine exhaust as it is widespread in urban areas and in proximity to roadways. Measuring diesel engine exhaust in outdoor air is difficult, as it is made up of many different substances. The level of elemental carbon in fine particulate matter has been used as an indicator of diesel engine exhaust; however, it is not a unique tracer and may also indicate the presence of other sources such as wood burning, forest fires, and coal or oil fueled power plants[11].
    - **More useful information on the potential exposure of Canadians to diesel engine exhaust might be developed using detailed heavy duty traffic volume data in conjunction with targeted monitoring to establish regionally representative ratios of elemental carbon/total fine particulates, and analyses of residential proximity to roads with heavy duty traffic.**

[6] LaJoie P et al. (2003). Asbestos Fibres in Indoor and Outdoor Air: The Situation in Quebec. Institut National du Sante Publique du Quebec. ISBN 2-550-43778-0.
[7] Kelly J et al. (2006). Community Exposure to Asbestos from a Vermiculite Exfoliation Plant in NE Minneapolis. Inhalation Toxicology. 18: pp 941-947.
[8] US EPA website – Naturally Occurring Asbestos: Clear Creek Management Area: http://www.epa.gov/region09/toxic/noa/clearcreek/index.html
[9] Lee R et al. (2008). Airborne asbestos in buildings. Regulatory Toxicology and Pharmacology 50: pp 218-225.
[10] Maykut NN, Lewtas J, Kim E, Larson TV: **Source Apportionment of PM2.5 at an Urban IMPROVE Site in Seattle, Washington.** *Environ Sci Technol* 2003, **37:**5135-5142.
[11] Schauer J (2003). Evaluation of elemental carbon as a marker for diesel particulate matter. Journal of Exposure Analysis and Environmental Epidemiology 13 (6): pp 443-453.

Moderate Priority Data Issues:

- None

Low Priority Data Issues:

- **Hexavalent chromium (IARC Group 1 – known carcinogen, low data quality, average LECR 0.1 per million).** Hexavalent chromium is not measured directly by NAPS. Lifetime excess cancer risk, assuming five percent of the maximum total chromium measured at NAPS sites in 2006 is less than 1 per million; however, this assumption should be validated.

- **PCBs (IARC Group 1 - known carcinogen, very low data quality, average LECR 0.1 per million).** PCBs in outdoor air are measured at only 8 sites in southern Ontario. While PCBs have been banned from manufacture in or import to Canada since 1977, they are persistent in the environment and tend to accumulate in animals, with higher levels observed in humans and other animals at the top of the food chain.[12] For this reason, the most important exposure pathway for PCBs is generally recognized to be via food.

- **Pentachlorophenol (IARC Group 2b – possible carcinogen, very low data quality, average LECR 0.003 per million).** Pentachlorophenol is infrequently measured in outdoor air. It is used primarily as a heavy-duty wood preservative for utility poles, railway ties, fence posts, etc. Pentachlorophenol is persistent and bioaccumulative. An early screening level exposure assessment conducted for the Canadian Soil Quality Guideline for Pentachlorophenol[13] identifies food as the most significant exposure pathway (ranging from 92 to 97 percent of average daily intake), so exposure via food pathways may be more important to track than those via outdoor air.

- **Dichlorvos (IARC Group 2b – possible carcinogen, very low data quality, average LECR 0.001 per million).** Dichlorvos is infrequently measured in outdoor air. Dichlorvos is not used on outdoor crops and is not persistent or bioaccumulative in the environment. Canadians are more likely to be exposed via the use of pest strips in indoor environments.

[12] Health Canada (2005). It's Your Health – PCBs. http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/environ/pcb-bpc-eng.php
[13] Canadian Council of Ministers of the Environment (1997). Canadian Soil Quality Guidelines for Pentachlorophenol: Environmental and Human Health. www.ccme.ca/assets/pdf/pn_1272_e.pdf.

3.0 Indoor Air

Data Synopsis: No national or regional databases containing standardized data on concentrations of known or suspected carcinogens in indoor air were identified. We obtained average measured levels from peer-reviewed literature, many of which are based on studies conducted by Health Canada scientists or academic researchers.

Tables 3a, 3b and 3c provide a summary of sources of measured data identified for each substance in indoor air, and an assessment of data quality with respect to representing the 'average' Canadian measured level circa 2006.

Table 3a. Summary of Data Quality in Indoor Air – Known Carcinogens

IARC Group 1 Known Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Arsenic and compounds (inorganic)	--	Gap	No recent data or studies identified using appropriately accurate analytical methods.
Cadmium	--	Gap	No recent data or studies identified using appropriately accurate analytical methods.
Chromium (hexavalent)	--	Gap	No recent data or studies identified using appropriately accurate analytical methods.
TCDD - dioxin	--	Gap	No recent data or studies were identified.
Asbestos	11 (10,640)	Very Low	Only one Canadian study identified, conducted in 2003-2004 in Thetford PQ, the site of an active asbestos mine. The indoor air average concentration used is based on one comprehensive study from the US, conducted in the 1990s.
Benzo[a]pyrene	0.2 (3.3)	Very low	One recent US study identified (New York City). Agrees reasonably well with a smaller US study in Chicago. A small Canadian study near an aluminum smelter reported a similar mean for 10 homes without oil heating, but a lower mean for 3 homes with oil heating.
Diesel engine exhaust	300 (536)	Very low	No studies measuring fine particulates in indoor air due to diesel engine emissions were identified. The estimate assumes that 60 percent of outdoor diesel engine exhaust ends up indoors (via open doors, windows, and infiltration through leaks in building walls).
Polychlorinated biphenyls	4.5 (9.1)	Very low	One recent Canadian study was identified (ON), but does not report the total toxic equivalent of PCBs in indoor air (only congeners with 3 to 7 chlorines).
1,3-Butadiene	23.4 (--)	Low	Two Canadian studies identified (Windsor ON and Ottawa ON) with geometric mean in the first study being similar to 50th percentile level reported in the second study. These results are similar to means reported in non-wood burning homes in Sweden in 2003.

Table 3a. Summary of Data Quality in Indoor Air – Known Carcinogens Continued

IARC Group 1 Known Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Nickel compounds	0.9 (1.7)	Low	One recent Canadian study identified (ON). The reported medians are not very similar to several older US studies using the same analytical method.
Formaldehyde	487 (1,257)	Low-moderate	Three recent Canadian studies were identified (PEI, PQ, and SK) with good agreement among studies.
Benzene	78 (812)	Moderate	Four recent Canadian studies identified (Regina SK, Northern AB, Quebec, and Windsor ON). Mean levels available from SK study comparable to medians, geometric means and 50th percentile levels measured in other Canadian and a number of US studies.
Radon	23,655 (--)	Moderate - High	Indoor radon levels have been measured in thousands of homes across Canada over the past 30 years, and the results suggest levels can vary widely depending on geological characteristics and building structure conditions. New data from ongoing studies may affect the estimate of average levels.

Table 3b. Summary of Data Quality in Indoor Air – Probable Carcinogens

IARC Group 2A Probable Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Lead (Inorganic compounds)	0.03 (--)	Low	Measures are for total lead only. One recent Canadian study identified (ON). The reported medians are similar to several older US studies using the same analytical method, although the Canadian maximum is lower than those reported in the US studies.
Tetrachloroethylene	6.3 (1,223)	Low-moderate	One recent Canadian study was identified (PQ). Geometric mean reported is similar to four recent US studies, although maximum reported is higher than those in the US studies.

Table 3c. Summary of Data Quality in Indoor Air – Possible Carcinogens

IARC Group 2B Possible Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Dichlorvos	--	Gap	No recent data or studies were identified.
Benz[a]anthracene	0.001 (0.01)	Very low	One recent US study identified (New York City). Levels reported agree reasonably with a smaller US study in Chicago, but are higher than those in an older Canadian study using a small sample of homes near an aluminum smelter in Quebec.
Benzo[b]fluoranthene	0.03 (0.3)	Very low	One recent US study identified (New York City). The mean agrees with a small older Canadian study near an aluminum smelter, but the maximum is higher than that reported in a smaller US study in Chicago.
Benzo[k]fluoranthene	0.01 (0.15)	Very low	One recent US study identified (New York City). Agrees reasonably well with a smaller US study in Chicago. A small Canadian study near an aluminum plant reported a similar mean for 10 homes without oil heating, but a lower mean for 3 homes with oil heating.
Chloroform	1.6 (65.8)	Very low	One recent US study identified (three cities in Michigan), reported mean is 10 times lower than another US study using a similar sample duration.
Chlorothalonil	-- (0.04)	Very Low	No Canadian studies identified. A US study (Cape Cod, MA) found infrequent detections (17% of 90 samples) of chlorothalonil at low levels.
Chrysene	0.002 (0.02)	Very low	One recent US study identified (New York City). Some agreement with a smaller US study in Chicago.
Indeno[1,2,3-cd]pyrene	0.06 (0.2)	Very low	One recent US study identified (New York City). Agrees reasonably well with a smaller US study in Chicago. A small Canadian study near an aluminum plant reported a similar mean for 10 homes without oil heating, but a lower mean for 3 homes with oil heating.
Lindane	-- (39.3)	Very Low	No Canadian studies were identified. Data from a US study (Cape Cod, MA) reported detection of lindane in 1 of 90 samples.
Pentachlorophenol	0.04 (1.9)	Very Low	One Canadian study identified which detected maximum concentrations a magnitude lower than two US studies.
Dichloromethane	1.4 (--)	Low	One recent Canadian study was identified (Windsor ON).
Acetaldehyde	65 (292)	Low-moderate	Three recent Canadian studies were identified (Windsor ON, PEI, and Regina SK). Average of means reported in the PEI and Regina SK studies is relatively similar to means reported in US studies.
Ethylbenzene	6.1 (56.5)	Low-moderate	Two recent Canadian studies were identified (Northern AB and Quebec). Reported medians agreed well with means and medians reported in a number of US studies.

High Priority Data Issues:

Asbestos (IARC Group 1 – known carcinogen, very low data quality, average LECR 11 per million). Asbestos in indoor air is not systematically measured in Canada. Asbestos may be present in indoor air when old building or insulation materials containing asbestos degrade or are disturbed, such as during repairs or renovations. Our estimate of lifetime excess cancer risk is based on levels measured in a US survey conducted in the 1990s of 752 buildings (including schools, universities, public and commercial buildings, and residences) that were thought to be contaminated with asbestos, but were not undergoing renovations or remediation. In addition, asbestos from outdoor air may infiltrate to indoor air, which may be of higher concern in areas where asbestos mining occurred, near historic vermiculite processing sites, near naturally occurring geological deposits containing asbestos, or more generally in urbanized areas due to weathering of automotive brake pads and other asbestos containing products. We found only one Canadian study reported measured levels of asbestos indoors, in an active asbestos mining town, with measured levels high enough to result in a maximum excess lifetime cancer risk of over 10,000 per million.

- **A better understanding of asbestos levels normally present in indoor air would be provided by a comprehensive monitoring study, designed to include buildings known to contain materials with asbestos, and newer buildings without contaminated materials. The study should include measures of both indoor and outdoor levels at locations in urban and rural areas, as well as near potentially contaminated sites (mining sites, historic vermiculite processing plants, and naturally occurring deposits).**

- **Diesel engine exhaust (IARC 1 – known carcinogen, very low data quality, average LECR 300 per million).** Indoor levels of diesel engine exhaust are due entirely to infiltration from outdoors. For this estimate, we assume 18 percent of outdoor fine particulate matter is from diesel exhaust[14], and that 60 percent[15] of indoor fine particulates are from outdoor sources. Given the amount of time people typically spend at home indoors, urban dwellers, especially those living in close proximity to heavy truck routes, may have relatively high exposures.
  - **In addition to improving estimates of outdoor levels of diesel engine exhaust, and conducting residential proximity analyses (see outdoor air recommendation), additional information on the effectiveness of air filters in removing fine particulates in a variety of housing types could provide evidence for reducing exposures.**

[14] Maykut NN, Lewtas J, Kim E, Larson TV: **Source Apportionment of PM2.5 at an Urban IMPROVE Site in Seattle, Washington.** *Environ Sci Technol* 2003, **37:**5135-5142.
[15] Hystad PW, Setton EM, Allen RW, Keller PC, Brauer M: **Modeling residential fine particulate matter infiltration for exposure assessment.** *Journal Of Exposure Science & Environmental Epidemiology* 2009, **19:**570-579.

Moderate Priority Data Issues

- **Arsenic (inorganic), cadmium, hexavalent chromium (IARC Group 1 – known carcinogens, data gaps)** and **nickel (IARC Group 1 – known carcinogen, low data quality, average LECR 0.9 per million)**. Sources of metals in indoor air are related primarily to combustion or organic materials, for example, tobacco or coal, and infiltration of outdoor sources. Assuming 60 percent infiltration of outdoor air, average measured outdoor levels result in indoor lifetime excess cancer risks of 1 to 2.3 per million for arsenic (max 4.7 per million), 0.15 to 1.0 per million for cadmium (max 2.2 per million), and 0.13 to 1.1 for hexavalent chromium (max 1.9 per million). In homes with indoor sources, lifetime excess cancer risk indicators could be well above 1 per million.

- **Benzo[a]pyrene (IARC Group 1 – known carcinogen, very low data quality, average LECR 0.2 per million)**. Benzo[a]pyrene has not been measured frequently in indoor air in Canada, but reported data suggest that lifetime excess cancer risk is well below 1 per million (with maximum level reported resulting in 3.3 per million). There is evidence that indoor levels of benzo[a]pyrene are highly correlated with outdoor levels, suggesting few indoor sources[16]; however wood burning for residential heating, cooking (especially grilling or burning) and tobacco smoke contribute benzo[a]pyrene to indoor air, which may elevate lifetime excess cancer risk in homes with these sources.

- **1,3 Butadiene (IARC Group 1 – known carcinogen, low data quality, average LECR 23.4 per million).** Although there are not many data for 1,3-butadiene in Canadian homes, several studies provide similar results, and these agree with a Swedish study. Levels may be higher in homes burning wood for heating purposes and could result in higher lifetime excess cancer risk.

- **PCBs (IARC Group 1 – known carcinogens, very low data quality, average LECR 4.5 per million)**. PCBs are persistent and bioaccumulative in the environment. While it is typically recognized that ingestion of contaminated foods is the dominant exposure pathway, reported levels in the one Canadian study identified resulted in lifetime excess cancer risk in excess of 1 per million. Recent evidence also suggests that PCBs in indoor air, related to emissions from existing flexible sealants and some paints may also be important contributors to levels in dust and food.[17]

[16] Naumova Y, Eisenreich S, et al. (2002). Polycyclic Aromatic Hydrocarbons in the Indoor and Outdoor Air of Three Cities in the U.S. Environmental Science and Technology 36, pp. 2552-2559.
[17] Zhu X, Diamond M, Robson M, and Harrad S. (2011) Sources, Emissions, and Fate of Polybrominated Diphenyl Ethers and Polychlorinated Biphenyls Indoors in Toronto, Canada. Environmental Science and Technology (45) pp 3268-3274.

Low Priority Data Issues

- **TCDD (IARC Group 1- known carcinogen, data gap).** TCDD (2,3,7,8- tetrachlorodibenzo-para-dioxin) is known to be persistent and bioaccumulative in the environment, and is emitted during combustion of organic materials. No data suitable for calculating lifetime excess cancer risk due to inhalation of TCDD in indoor air were identified, generally due to a lack of standardized measurement and reporting. For example, studies differ widely in which dioxin congeners are measured and reported, and some combine many congeners into one measure. Ingestion of contaminated food is the dominant exposure pathway.

- **Benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, indeno[1,2,3-cd]pyrene (IARC Group 2B – possible carcinogens, very low data quality, average LECRs ranging from 0.001 to 0.03 per million).** These polycyclic aromatic hydrocarbons (PAHs) are also related strongly to outdoor levels from combustion sources. Measured levels in a small study conducted in New York suggest lifetime excess cancer risks area well below 1 per million.

- **Chloroform (2B – possible carcinogen, very low data quality, average LECR 1.6 per million)**. Chloroform in indoor air may be due to infiltration of outdoor emissions from industrial sources, (although the maximum level measured outdoors in Canada in 2006 results in a lifetime excess cancer risk of only 0.4 per million), as well as volatilization from chlorinated water during showering, dish and clothes washing.

- **Chlorothalonil (IARC Group 2B – possible carcinogen, very low data quality, maximum LECR 0.04 per million).** Chlorothalonil is not used indoors, is not persistent or bioaccumulative, and the maximum measured level reported in a US study results in a lifetime excess cancer risk of well below 1 per million.

- **Dichlorovos (IARC Group 2B – possible carcinogen, data gap)**. Dichlorvos is not persistent or bioaccumulative; however, exposure may occur when indoor sources are present, such as pest strips, sprays or flea collars.

- **Lindane (IARC Group 2B – possible carcinogen, very low data quality, maximum lifetime excess cancer risk 39 per million)**. Lindane has never been produced in Canada, and most uses were discontinued in 2002, although it is still used in some prescription medicines (lice shampoo). One US study reported detecting lindane in one out of 90 homes. It is, however, persistent and bioaccumulative, and exposure may still occur via ingestion of contaminated foods.

- **Pentachlorophenol (IARC Group 2B – possible carcinogen, very low data quality, average LECR 0.04 per million).** Pentachlorophenol was used as wood preservative so exposure via indoor air could occur from treated wood used for building materials. The maximum measured level in indoor air in a Canadian study results in a lifetime excess cancer risk of 1.9 per million.

4.0 Indoor Dust

Data Synopsis: There are no national-level databases containing standardized data on concentrations of substances in indoor dust in Canada. We obtained average measured levels from peer-reviewed literature.

Tables 4a, 4b and 4c provide a summary of sources of measured data identified for each substance in indoor dust, and an assessment of data quality with respect to representing the 'average' Canadian measured level circa 2006.

Table 4a. Summary of Data Quality in Indoor Dust – Known Carcinogens

IARC Group 1 Known Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Arsenic and compounds (inorganic)	--	Gap	No recent data or studies were identified using appropriately accurate analytical methods.
TCDD - dioxin	--	Gap	No recent data or studies were identified.
Chromium (hexavalent)	1.2 (3.5)	Very Low	One recent US study (New Jersey) reported on hexavalent chromium specifically in a relatively large sample (120 homes).
Polychlorinated biphenyls	0.4 (1.1)	Very Low	One recent Canadian study was identified (ON), but reports only PCB congeners with 3 to 7 chlorines.
Benzo[a]pyrene	23 (306)	Low	One recent Canadian study was identified (Ottawa, ON).
Benzene		n/a	Exposure via dust is negligible.
Radon		n/a	Exposure via dust is negligible.
Formaldehyde		n/a	Not carcinogenic via ingestion.
1,3-Butadiene		n/a	Exposure via dust is negligible.
Asbestos		n/a	Exposure via dust is negligible.
Nickel compounds		n/a	Not carcinogenic via ingestion.
Cadmium		n/a	Not carcinogenic via ingestion.
Diesel engine exhaust		n/a	Exposure via dust is negligible.

Table 4b. Summary of Data Quality in Indoor Dust – Probable Carcinogens

IARC Group 2A Probable Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Lead (Inorg. compounds)	1.0 (2.0)	Very Low	One recent UK study was identified using appropriately accurate analytical method.
Tetrachloroethylene		n/a	Exposure via dust is negligible.

Table 4c. Summary of Data Quality in Indoor Dust – Possible Carcinogens

IARC Group 2B Possible Carcinogens	LECR per million average (maximum)	Data Quality	Notes
Dichlorvos	--	Gap	No recent data or studies were identified
Chlorothalonil	-- (0.006)	Very Low	No recent Canadian data or studies were identified. Data from a US study (Cape Cod, MA) report detection in 2 percent of 119 samples.
Lindane	-- (0.9)	Very Low	No recent Canadian data or studies were identified. Data from a US study (Cape Cod, MA) report detection in 40 percent of 119 samples.
Pentachlorophenol	0.01 (2.7)	Very Low	No recent Canadian data or studies were identified. Two US studies were identified.
Benzo[b]fluoranthene	3.8 (15.4)	Low	One recent Canadian study identified (Ottawa, ON). No other comparable studies were identified.
Benzo[k]fluoranthene	1.3 (15.0)	Low	One recent Canadian study identified (Ottawa, ON). No other comparable studies were identified.
Chrysene	0.3 (2.8)	Low	One recent Canadian study identified (Ottawa, ON). No other comparable studies were identified.
Indeno[1,2,3-cd]pyrene	2.4 (26.4)	Low	One recent Canadian study identified (Ottawa, ON). No other comparable studies were identified.
Benz[a]anthracene	1.1 (15.4)	Low	One recent Canadian study identified (Ottawa, ON). No other comparable studies were identified.
Acetaldehyde		n/a	Not carcinogenic via ingestion.
Ethylbenzene		n/a	Exposure via dust is negligible.
Dichloromethane		n/a	Exposure via dust is negligible.
Chloroform		n/a	Exposure via dust is negligible.

High Priority Data Issues:

- None

Moderate Priority Data Issues:

- **Benzo[a]pyrene (IARC Group 1 – known carcinogen, low data quality, average LECR 23 per million).** One Canadian study was identified that measured polycyclic aromatic hydrocarbons (PAHs) including benzo[a]pyrene, and reported levels that result in an average lifetime excess cancer risk well above 1 per million. Ingestion of dust may be a particularly important exposure pathway during childhood.

Low Priority Data Issues:

- **Arsenic (inorganic) (IARC Group 1 – known carcinogen, data gap), hexavalent chromium (IARC Group 1 – known carcinogen, very low data quality, average LECR 1.2 per million) and lead (IARC Group 2A – probable carcinogen, very low data quality, average LECR 1.0 per million).** Metals in house dust have not been studied extensively in Canada circa 2006, although the recently completed Canadian House Dust Study[18], based on a nationally representative survey of urban homes conducted in 2007 to 2010 should address these gaps.

- **TCDD (IARC Group 1 – known carcinogen, data gap**). TCDD may be present in house dust, but ingestion via foods is the most significant exposure pathway, accounting for approximately 99 percent of total intake[19].

- **PCBs (IARC Group 1 – known carcinogens, very low data quality, average LECR 0.4 per million).** Ingestion of PCBS in house dust is generally considered to make a low contribution to exposure via ingestion of dust (~ 1 percent of total exposure).

- **Chlorothalonil (IARC Group 2B – possible carcinogen, very low data quality, maximum LECR 0.006 per million).** Chlorothalonil is not used indoors, is not persistent or bioaccumulative, and the maximum measured level reported in a US study results in a lifetime excess cancer risk of well below 1 per million.

- **Dichlorvos (IARC Group2B – possible carcinogen, data gap).** Dichlorvos is not persistent or bioaccumulative; however, exposure may occur when indoor sources are present, such as pest strips, sprays or flea collars.

- **Lindane (IARC Group 2B – possible carcinogen, very low data quality, maximum LECR 0.9 per million).** It is unlikely that lindane levels in indoor dust will increase, given current uses are limited to some prescription medicines (lice shampoo). It is, however, persistent and bioaccumulative, and exposure may still occur via ingestion of contaminated foods.

- **Pentachlorophenol (IARC Group 2B – possible carcinogen, very low data quality, maximum LECR 2.7 per million).** Pentachlorophenol was used as wood preservative so exposure via indoor dust could occur from treated wood used for building materials. The maximum measured level in indoor air in a Canadian study results in a lifetime excess cancer risk of 1.9 per million.

[18] More information is available at: http://www.hc-sc.gc.ca/ewh-semt/contaminants/dust-poussiere-eng.php
[19] Travis C and Hattemer-Frey H. (1991). Human exposure to dioxin. The Science of the Total Environment. 104 pp 97-127.

5.0 Drinking Water

Data Synopsis: There are no national-level databases containing standardized data on drinking water quality in Canada. Monitoring treated drinking water quality is the jurisdiction of individual municipalities and/or regional districts across Canada, making it difficult to develop a comprehensive national database. Discussions with representatives of the Federal Provincial Territorial Committee on Drinking Water identified the difficulties inherent in trying to integrate treated drinking water quality data due to a lack of standardization in the contaminants monitored, as well as sample collection and analysis methods, and changes in methods over time. In addition, while many jurisdictions do report on water quality, they typically provide only number of times guidelines or standards are exceeded, rather than the actual concentrations measured. Data for drinking water from private systems (wells or surface water sources) are not generally available across Canada, as it is up to individuals to have their water tested and there is no requirement to report results to any government office. Some provinces have digital data for wells and surface water intakes, but no water quality data associated.

Additional data sources identified but not used include:

- *Environment Canada Municipal Water and Wastewater Survey (MWWS), 2004* –This survey is incomplete for the Canadian population, but provides a preliminary indicator of populations potentially exposed to disinfection byproducts[20].
- *Statistics Canada Survey of Drinking Water Plants* - This survey was initially conducted for the years 2005-2007. Published results pertain only to infrastructure (volumes treated, etc.), and not to measured levels of contaminants[21]. Future surveys may identify levels of disinfection byproducts, and potentially some known or suspected carcinogens.
- *Health Canada Tap Water Survey* – results for this survey were to be released in 2011, but are not yet available. This survey should provide data on measured levels of disinfection byproducts and some other contaminants that may be known or suspected carcinogens[22].

We used average levels measured in Ontario Drinking Water Surveillance Programs (DWSP), an easily accessible online compilation of provincial treated drinking water testing results, to represent typical Canadian levels circa 2006[23]. A review of published government reports compiled by Health Canada to support the formation of drinking water guidelines[24] was also conducted to compare how well the Ontario data represented other regions in Canada.

[20] Available at: http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=ED7C2D33-1
[21] Available at: http://www.statcan.gc.ca/pub/16-403-x/2009001/part-partie1-eng.htm
[22] Information available at: http://www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/tap_water-eau_robinet-eng.php#a4
[23] Avaialble at: http://www.ene.gov.on.ca/environment/en/monitoring_and_reporting/drinking_water_surveillance_program/STDPROD_076064.html
[24] Available at: http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/index-eng.php#tech_doc

Tables 5a, 5b and 5c provide a summary of sources of measured data identified for each substance in drinking water, and an assessment of data quality with respect to representing the 'average' Canadian measured level circa 2006.

Table 5a. Summary of Data in Drinking Water – Known Carcinogens

IARC Group 1 Known Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
1,3-Butadiene	--	Gap	1,3-butadiene was not measured in Ontario DWSP in 2006. No recent Canadian studies were identified.
Benzo[a]pyrene	--	Gap	Only two samples in the Ontario DWSP were analyzed for benzo[a]pyrene. No other data or studies were identified.
Polychlorinated biphenyls	--	Gap	Only one sample was tested for PCBs in the Ontario DWSP in 2006. No other data were identified.
TCDD - dioxin	--	Gap	TCDD was not measured in Ontario DWSP in 2006. No recent data or studies were identified.
Arsenic and compounds (inorganic)	89 (467)	Moderate	Total arsenic was detected in at least 75 percent of samples (n=328) from the Ontario DWSP in 2006; a national review of data up to 2002 reported higher levels.
Chromium (hexavalent)	12.9 (86.2)	Moderate	Chromium was detected in all samples (n=329) from the DWSP in 2006. Our estimate assumes that 100 percent of total chromium in drinking water is hexavalent.
Benzene	-- (2.9)	Moderate-High	Benzene was not detected in any samples (n=343) from the Ontario DWSP in 2006, given a detection limit of 0.05 µg/L. A national review of drinking water data reported infrequent detection of higher levels.
Asbestos		n/a	Exposure via drinking water is negligible.
Cadmium		n/a	Not carcinogenic via ingestion.
Diesel engine exhaust		n/a	Not present in drinking water.
Formaldehyde		n/a	Not carcinogenic via ingestion.
Nickel compounds		n/a	Not carcinogenic via ingestion.
Radon		n/a	Exposure via drinking water is negligible.

Table 5b. Summary of Data in Drinking Water – Probable Carcinogens

IARC Group 2A Probable Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Lead (Inorg. compounds)	0.15 (6.7)	Moderate	Lead was detected in at least 75% of samples (n=330) from the Ontario DWSP in 2006.
Tetrachloroethylene	0.08 (2.5)	Moderate	Tetrachloroethylene was detected in less than 25 percent of samples (n=343) from the Ontario DWSP in 2006.

Table 5c. Summary of Data in Drinking Water – Possible Carcinogens

IARC Group 2B Possible Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Dichlorvos	-- (5.3)	Low	Dichlorvos was not detected in any samples of treated drinking water (n=67) based on data from the Ontario DWSP in 2006.
Lindane	-- (0.09)	Low	Lindane was not detected in any samples of treated water (n=76) from the Ontario DWSP in 2006. One study in Alberta measured a maximum of 0.0026 ug/L.
Pentachlorophenol	-- (0.03)	Low	Pentachlorophenol was not detected in any samples (n=54) of treated drinking water from the Ontario DWSP in 2006.
2,4,6-trichlorophenol	-- (0.04)	Low	2,4,6-trichlorophenol was not detected in any samples (n=69) of water in distribution systems from the Ontario DWSP in 2006.
Benz[a]anthracene	--	Gap	Only 2 samples were analyzed for benzo[a]anthracene in Ontario in 2006. No recent data or studies identified.
Benzo[b]fluoranthene	--	Gap	Only 2 samples were analyzed for benzo[b]fluoranthene in Ontario in 2006. No recent data or studies were identified.
Benzo[k]fluoranthene	--	Gap.	Only 2 samples were analyzed for benzo[k]fluoranthene in Ontario in 2006. No recent data or studies identified.
Chlorothalonil	--	Gap	Chlorothalonil was not measured in Ontario drinking water in 2006. No Canadian studies were identified.
Chrysene	--	Gap	Only 2 samples were analyzed for chrysene in Ontario in 2006. No recent data or studies were identified.
Dichloromethane	--	Gap	No recent Canadian data or studies were identified.
Indeno[1,2,3-cd]pyrene	--	Gap	Only 2 samples were analyzed for indeno[1,2,3-cd]pyrene in Ontario in 2006. No recent data or studies were identified.
MX		Gap	No recent data or studies were identified.
Bromodichloromethane	19.2 (127.6)	Moderate	All samples (n=343) from the Ontario DWSP contained bromodichloromethane in 2006.
Chloroform	23.5 (117.5)	Moderate	All samples (n=343) from the Ontario DWSP contained chloroform in 2006.
Dichloroacetic acid	20.1 (81.5)	Moderate	Dichloracetic acid was detected in at least 75 percent of samples (n=329) from the Ontario DWSP in 2006.
Ethylbenzene	0.02 (0.5)	Moderate	Ethylbenzene was detected in fewer than 25 percent of samples (n=343) from the Ontario DWSP in 2006.
N-nitroso methylethylamine	-- (0.6)	Moderate	No samples (n=160) from the Ontario DWSP contained n-nitrosomethylethylamine in 2006.
Acetaldehyde		n/a	Not carcinogenic via ingestion.
Nickel		n/a	Not carcinogenic via ingestion.

High Priority Data Issues:

- **Measured levels in treated drinking water systems**. Health Canada staff undertake reviews of measured levels in support of developing and updating Guidelines for Canadian Drinking Water Quality documents and frequently report regional data gathered via personal communications with provincial counterparts.
    - **Measured levels of contaminants in treated drinking water could be synthesized into publicly available national (or at least, provincial) databases or reports on a regular basis for exposure surveillance purposes.**

- **Measured level in private drinking water systems.** Statistics Canada Households and the Environment Survey reports that in 2009, 11 percent of Canadians received drinking water from private wells or surface water; however, the percentages were much higher in Prince Edward Island (39 percent), Nova Scotia (39 percent), and New Brunswick (51 percent)[25].
    - **Lab test results from private drinking water systems could be anonymized and made public in order to increase our understanding of exposure levels in the Canadian population not served by municipal systems, particularly in the Maritime provinces.**

Moderate Priority Data Issues:

- None

Low Priority Data Issues:

- **1,3-butadiene (IARC Group 1 – known carcinogen, data gap)**. Major sources of 1,3-butadiene in Canada are combustion-related emissions, and when emitted to air, 1,3-butadiene is expected to remain in air and not enter the hydrological cycle. The potential for exposure via drinking water is therefore very low in Canada. The National Pollutant Release Inventory records no releases of 1,3-butadiene to water in Canada in 2006 to 2011[26].

- **TCDD (IARC Group 1 – known carcinogen, data gap)**. Evidence suggests that < 0.01% of exposure is via drinking water[27], with ingestion of contaminated foods being the most significant exposure pathway for this persistent and bioaccumulative carcinogen.

- **PCBs (IARC Group 1 – known carcinogens, data gap)**. As many PCBs adsorb to sediments in water, they are not typically present in drinking water at levels of concern. Given the

[25] Statistics Canada CANSIM Table 153-0062.
[26] Emissions statistics available at: http://www.ec.gc.ca/pdb/websol/querysite/query_e.cfm
[27] National Toxicology Program (2011). 12th Report on Carcinogens. US Department of Health and Human Services.

persistence and bioaccumulative nature of PCBs, ingestion of contaminated food is the most important exposure pathway.

- **Benzo[a]pyrene (IARC Group 1 – known carcinogen, data gap) and benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene and indeno[1,2,3-cd]pyrene (IARC Group 2B – possible carcinogens, data gap)**. Combustion of organic material is the main source of PAHs in outdoor and indoor air, and these 5 to 7 ring PAHs are most likely to partition to soil and sediment, then enter the food chain. Contaminated water does not contribute substantially to total exposure, and evidence suggests that for non-smokers, food intake is the most important exposure pathway, with drinking water contributing less than inhalation of air[28].

- **Chlorothalonil (IARC Group 2B – possible carcinogen, data gap)**. Chlorothalonil is not persistent or bioaccumulative, and was not detected in any of 1,377 samples from national domestic well survey (1991 – 2004) in US[29].

- **Dichloromethane (IARC Group2B – possible carcinogen, data gap)**. Dichloromethane has been known to occur in surface water, groundwater, treated drinking water, and bottled well water[30], but has recently been reported to be infrequently detected at low levels in Canada[31].

- **MX (IARC Group 2B – possible carcinogen, data gap)**. MX is a byproduct of drinking water chlorination, and has been detected in treated drinking water in the US. The World Health Organization Drinking Water Guidelines report that MX levels in treated water in Finland, the UK, the US, and Japan are well below levels of concern for health[32].

[28] Ramesh A et al (2004). Bioavailability and Risk Assessment of Orally Ingested Polycyclic Aromatic Hydrocarbons. International Journal of Toxicology, 23:301–333.
[29] DeSimone L. (2009). Quality of water from domestic wells in principal aquifers of the United States, 1991–2004: U.S. Geological Survey Scientific Investigations Report 2008–5227, 139 p., available online at http://pubs.usgs.gov/sir/2008/5227.
[30] National Toxicology Program (2011). 12th Report on Carcinogens. US Department of Health and Human Services.
[31] Federal-Provincial-Territorial Committee on Drinking Water. (2011). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Dichloromethane.
[32] World Health Organization (2011). Drinking Water Guidelines 4th Edition, Available at: http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/index.html

6.0 Food and Beverages

Data Synopsis: Canadian foods are tested for a range of contaminants under two key programs:

- Health Canada - Total Diet Studies[33]. These have been conducted since 1969, with sampling taking place in one or two Canadian cities per year. In each city, typical foods are purchased from local grocery stores, prepared and then analyzed for contaminants or substances of concern. A standard set of substances is not tested for: 1999 is last year data for total (TEQ) dioxin-like substances are available, 2002 is the last year PCBs (total) were measured, and chlorothalonil was measured only in 1995, 1996 and 1998 (one city each year)[34]. Data for lead are available for 1993 to 2007, and arsenic for 2005 to 2007 (but in different cities each year). No other known or suspected carcinogens on the CAREX Canada priority list have been measured in the Total Diet Studies.

- Canadian Food Inspection Agency - National Chemical Residue Monitoring Program[35]. This program is ongoing, but does not test for a standard set of substances in a standard food list every year. Sampling is targeted to specific foods and substances where there is some evidence of elevated risk. For example, dioxins and dioxin-like compounds were recently measured in 2010 in vegetable oils and cheese; in 2009, arsenic species were measured in pears and rice, and pesticide residues were measured in fresh fruits and vegetables.

The most comprehensive and readily accessible data on measured levels of known and suspected carcinogens in a standard food set were from the US Food and Drug Administration's *Total Diet Study* [36] (1991-2004) and the US Environmental Protection Agency's *Dietary Exposure Potential Model* [37]. The *Total Diet Study* is a compilation of 280 common foodstuffs, prepared for consumption and analyzed to measure the levels of over 700 selected contaminants. The *Dietary Exposure Potential Model* integrates several databases comprising of 6,700 food items with over 350 pesticide and environmental contaminants. The CAREX Canada indicators for 2006 are based almost entirely on US data, with the exception of arsenic.

Data on Canadian consumption levels for a wide range of foods and beverages are dated, with the most comprehensive study available being the Nutrition Canada Survey conducted in 1970-1972[38].

[33] More information available at: http://www.hc-sc.gc.ca/fn-an/surveill/total-diet/index-eng.php
[34] Data reports available at: http://www.hc-sc.gc.ca/fn-an/surveill/total-diet/concentration/index-eng.php
[35] More information available at: http://www.inspection.gc.ca/food/chemical-residues-microbiology/chemical-residues/residue-surveillance/eng/1332108703029/1332108819462
[36] More information is available at: http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/TotalDietStudy/ucm186140.htm
[37] More information is available at: http://www.epa.gov/nerlcwww/depm.html
[38] Nutrition Canada. (1973). Nutrition Canada Survey. Ottawa: Information Canada.

Tables 6a, 6b and 6c provide a summary of sources of measured data identified for each substance in foods and beverages, and an assessment of data quality with respect to representing the 'average' Canadian measured level circa 2006.

Table 6a. Summary of Data Quality for Food and Beverages – Known Carcinogens

IARC Group 1 Known Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
1,3-Butadiene	--	Gap	No Canadian or US data were identified.
Chromium (hexavalent)	--	Gap	No Canadian or US data were identified.
TCDD - dioxin	--	Gap	No recent data or studies were identified.
Arsenic and compounds (inorganic)	29 (--)	Very Low	Total arsenic levels from the Canadian Food and Inspection Agency were used for some foods, with additional data from the US.
Benzene	10 (--)	Very Low	No Canadian data on concentrations of benzene in foods and beverages were identified. Data from the US were used for our estimate.
Benzo[a]pyrene	2.3 (--)	Very Low	No Canadian data on concentrations of benzo(a)pyrene in foods and beverages were identified. Data from the US were used for our estimate.
Polychlorinated biphenyls	3.1 (--)	Very Low	No useful Canadian data on concentrations of polychlorinated biphenyls (PCBs) in foods and beverages were identified (Canadian data were reported for meat fats and raw milk). Data from the US were used for this estimate.
Asbestos		n/a	Exposure via Food and Beverages is negligible.
Cadmium		n/a	Not carcinogenic via ingestion.
Diesel engine exhaust		n/a	Not present in Food and Beverages.
Formaldehyde		n/a	Not carcinogenic via ingestion.
Nickel compounds		n/a	Not carcinogenic via ingestion.
Radon		n/a	Exposure via Food and Beverages is negligible.

Table 6b. Summary of Data Quality for Food and Beverages – Probable Carcinogens

IARC Group 2A Probable Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Tetrachloroethylene	0.09 (--)	Very Low	No Canadian data on concentrations of tetrachloroethylene in foods and beverages were identified. Data from the US were used for this estimate.
Lead (Inorg. compounds)	0.5 (--)	Low	Data from the Canadian Food Inspection Agency were used for some foods, with additional data from the US.

Table 6c. Summary of Data Quality for Food and Beverages – Possible Carcinogens

IARC Group 2B Possible Carcinogens	**LECR per million** average (maximum)	**Data Quality**	**Notes**
Benz[a]anthracene	--	Gap	No recent data were identified.
Benzo[k]fluoranthene	--	Gap	No recent data were identified.
Bromodichloromethane	--	Gap	No recent data were identified.
Dichloroacetic acid	--	Gap	No recent data were identified.
Dichloromethane	--	Gap	No Canadian or US data were identified.
MX	--	Gap	No recent data were identified.
N-nitrosomethylethylamine	--	Gap	No recent data were identified.
2,4,6-trichlorophenol	--	Gap	No recent data were identified.
Benzo[b]fluoranthene	0.4 (--)	Very Low	No Canadian data on concentrations of benzo[b]fluoranthene in foods and beverages were identified. Data from the US were used for this estimate.
Chloroform	1.0 (--)	Very Low	No Canadian data on concentrations chloroform in foods and beverages were identified. Data from the US were used for this estimate.
Chrysene	0.004 (--)	Very Low	No Canadian data on concentrations of chrysene in foods and beverages were identified. Data from the US were used for this estimate.
Chlorothalonil	0.01 (--)	Very Low	No Canadian data on concentrations of chlorothalonil in foods and beverages were identified. Data from the US were used for the estimate.
Dichlorvos	0.0003 (--)	Very Low	No Canadian data on concentrations of dichlorvos in foods and beverages were identified. Data from the US were used for the estimate.
Ethylbenzene	0.009 (--)	Very Low	No Canadian data on concentrations of ethylbenzene in foods and beverages were identified. Data from the US were used for this estimate.
Indeno[1,2,3-cd]pyrene	0.1 (--)	Very Low	No Canadian data on concentrations of indeno[1,2,3-cd]pyrene in foods and beverages were identified. Data from the US were used for this estimate.
Lindane	0.3 (--)	Very Low	No Canadian data on concentrations of lindane in foods and beverages were identified. Data from the US were used for the estimate.
Pentachlorophenol	0.0006 (--)	Very Low	No Canadian data on concentrations of pentachlorophenol in foods and beverages were identified. Data from the US were used for the estimate.
Acetaldehyde		n/a	Not carcinogenic via ingestion.

High Priority Data Issues:

- **Lack of standardization in food lists between studies.** In general, while we found that the US conducts a more standardized monitoring program (standard food lists and substances analyzed over time), neither Canada nor the US conducts monitoring programs that directly measure levels of known or suspected carcinogens in conjunction with the amount consumed. Programs focused either on measuring contaminants or substances of concern, OR on documenting types and amounts of foods eaten, but did not use fully comparable food lists, making it difficult in some cases to associate measured levels with consumption levels. The available data support the modelling of potential exposure probability distributions in the Canadian population, but these would be more useful if validated.
    - **An ongoing population-based survey that includes dietary intake AND analysis of foods as eaten would increase our understanding of Canadians' actual exposure via foods and beverages. Survey results could be used to evaluate modelled exposure distributions based on existing data, but should also include known and suspected carcinogens that are not being measured regularly.**

Moderate Priority Data Issues:

- **Arsenic (inorganic) (IARC Group 1 – known carcinogen, very low data quality, average LECR 29 per million)**. Total arsenic levels in a range of foods has been measured as part of the Total Diet Study (2004 – 2007), but only some of the total is made up of inorganic arsenic. The calculated LECR of 29 per million could be lower. The most recent IARC monograph on arsenic reports that organic arsenic is more common in seafood, fruits and vegetables, while inorganic arsenic is more common in meats, poultry, dairy products and cereals[39]. The average LECR based on meats and dairy only (no 2006 data for cereals) is approximately 6 per million.

- **Benzo[a]pyrene (IARC Group 1 – known carcinogen, very low data quality, LECR 2.3 per million)**. Benzo[a]pyrene levels were available for a very limited number of foods (chicken, mutton and lamb, veal, freshwater fish and sea fish, dry beans, milk and orange juice) so the average LECR could be higher.

- **TCDD (IARC Group 1 – known carcinogen, data gap)**. TCDD is persistent and bioaccumulative, with ingestion of contaminated foods being the most important exposure pathway. A new study from the Canadian Food Inspection Agency will provide measured levels in vegetable oils and cheeses circa 2010, but data for other foods containing animal fats were not measured.

- **PCBs (IARC Group 1 – known carcinogens, very low data quality, average LECR 3.1 per million)**. PCBs are persistent and bioaccumulative, and foods containing animal fats tend to have higher

[39] International Agency for Research on Cancer. (2012). A Review of Human Carcinogens: Arsenic, Metals, Fibres, and Dusts, Volume 100C. Available at: http://monographs.iarc.fr/ENG/Monographs/vol100C/index.php

levels of PCBs. The most recent Canadian data are from Health Canada's Total Diet Study program, conducted in Vancouver in 2002 (data for other cities in previous years are also available).

- **Dichloroacetic acid (IARC Group 2B – possible carcinogen, data gap)**. Dichloracetic acid (DCA) is a byproduct of disinfecting drinking water, and has been detected in foods, including vegetables, grains, flours and breads, and beer[40]. DCA was detected in 75 percent of samples from the Ontario Drinking Water Surveillance Program (DWSP) in 2006, and levels measured resulted in an average LECR of 20 per million. There is evidence that levels of DCA are not affected by boiling during food cooking and processing, and may be absorbed by some foods[41].

Low priority Data Issues:

- **Benzene (IARC Group 1 – known carcinogen, very low data quality, average LECR 10 per million)**. Benzene has been identified as a contaminant in some soft drinks in the past, particularly those containing benzoate (as a preservative) and ascorbic acid (Vitamin C)[42]. Our estimate is based on older data, and more recent measured levels are lower. The CAREX Canada indicator will be updated circa 2011.

- **1,3-butadiene (IARC Group 1 – known carcinogen, data gap)**. In the 1980s, foods packaged in rubber-modified plastic containers have been tested for the presence of 1,3-butadiene, but it was infrequently detected in small amounts (less than 5 nanograms per gram)[43]. Because 1,3-butadiene is very unlikely to enter the food chain due to environmental contamination, few Canadians, if any, are potentially exposed via food and beverages.

- **Chromium, hexavalent (IARC Group 1 – known carcinogen, data gap)**. IARC notes that most of the chromium present in foods is of the trivalent form (not carcinogenic)[44]. Exposure to hexavalent chromium is primarily via air and drinking water.

[40] Health Canada. (2008). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document - Haloacetic Acids. Available at: http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/haloaceti/index-eng.php
[41] Raymer J and Michael L. (2010). Uptake of Water Disinfection By-Products Into Food. RTI Press publication No. MR-0016-1008. Research Triangle Park, NC.
[42] More information is available at the Health Canada website "Benzene in Soft Drinks and other Beverage Products:, at: http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/food-aliment/benzene/index-eng.php and the US Food and Drug Administration website for benzene: http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/ChemicalContaminants/Benzene/default.htm
[43] Environment Canada and Health Canada. (2000). Priority Substances List Report – 1,3-butadiene. Available at: http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl2-lsp2/1_3_butadiene/index-eng.php
[44] International Agency for Research on Cancer. (2012). A Review of Human Carcinogens: Arsenic, Metals, Fibres, and Dusts, Volume 100C. Available at: http://monographs.iarc.fr/ENG/Monographs/vol100C/index.php

- **Tetrachloroethylene (IARC Group 2A – probable carcinogen, very low data quality, average LECR 0.09 per million)**. Foods can be contaminated with tetrachloroethylene during processing, and by absorption from air (higher levels have been measured in fatty foods in grocery stores near drycleaners)[45]; however, measured levels in the US suggest the LECR is well below 1 per million, and the use of tetrachloroethylene by Canadian drycleaners is regulated and diminishing[46].

- **Benz[a]anthracene (IARC Group 2B – possible carcinogen, data gap); Benza[b]fluoranthene (IARC Group 2B – possible carcinogen, very low data quality, average LECR 0.4 per million); Benzo[k]fluoranthene (IARC Group 2B – possible carcinogen, data gap); chrysene (IARC Group 2B – possible carcinogen, very low data quality, average LECR 0.004 per million); and indeno[1,2,3-cd]pyrene (IARC Group 2B – possible carcinogen, very low data quality, average LECR 0.1 per million)**. These polycyclic aromatic hydrocarbons may be present in foods due to cooking methods (grilling or smoking) or enter the food chain via deposition from air. Average LECRs are below 1 per million for those PAHs with available data, and cancer potency factors are at least a magnitude lower than for benzo[a]pyrene, a moderate data priority.

- **Bromodichloromethane (IARC Group 2B – possible carcinogen, data gap)**. While no recent data for bromodichloromethane was identified, and it has been detected in a number of foods, exposure via foods and beverages is expected to be uncommon, and at levels below those encountered in drinking water[47].

- **Chloroform (IARC Group 2B – possible carcinogen, very low data quality, average LECR 1.0 per million)**. Chloroform may be present in foods prepared using treated drinking water or that come in contact with disinfectants (chlorine) used on processing equipment and surfaces[48]. While there are not recent Canadian data, US data are likely a good surrogate.

- **Chlorothalonil (IARC Group 2B – possible carcinogen, very low data quality, average LECR 0.01 per million**). Chlorothalonil is used on agricultural crops, but is not persistent or bioaccumulative. Chlorothalonil was detected in 55 of 3,078 samples (detection frequency 1.2 percent) of fruits and leafy greens in 2009-2010 in Canada[49].

[45] Grob K et al (2006). Food Contamination with Organic Materials in Perspective: Packaging Materials as the Largest and Least Controlled Source? A View Focusing on the European Situation. Critical Reviews in Food Science and Nutrition, 46:529–535

[46] More information is available at: http://www.ec.gc.ca/regs-tetra/

[47] National Toxicology Program, US Department of Health and Human Services. (2011). Report on Carcinogens, 12th Edition. Available at: http://ntp.niehs.nih.gov/?objectid=03C9AF75-E1BF-FF40-DBA9EC0928DF8B15

[48] Huang A et al (2009). Formation of trihalomethanes in foods and beverages. Food Additives and Contaminants: Part A 26 (7): pp 947-957.

[49] Canadian Food Inspection Agency. (2010). Food Safety Action Plan 2009-2010 Targeted Surveys- Pesticide Residues in Fresh Fruit and Vegetables. Available at: http://www.inspection.gc.ca/food/chemical-residues-microbiology/chemical-residues/eng/1324258929171/1324264923941#resid

- **Dichloromethane (IARC Group 2B – possible carcinogen, data gap)**. Dichloromethane may be present in foods due to processing and also through environmental contamination, but older studies suggest foods contribute 2 percent of total daily intake at most[50].

- **Dichlorvos (IARC Group 2B – possible carcinogen, very low data quality, average LECR 0.0003 per million)**. Dichlorvos is not persistent or bioaccumulative, and is not frequently detected in foods or beverages. Dichlorvos was not detected in 3,078 samples of fruits and leafy greens in a recent survey conducted by the Canadian Food Inspection Agency[51].

- **Ethylbenzene (IARC Group 2B – possible carcinogen, very low data quality, average LECR 0.009)**. Ethylbenzene is not frequently detected in foods and beverages, but may be present due to migration from plastic packaging or environmental contamination[52]; however, measured levels in US foods are low and the average LECR associated is well below 1 per million.

- **Lindane (IARC Group 2B – possible carcinogen, very low data quality, average LECR 0.3 per million)**. Of the pesticides included on the CAREX Canada priority list, lindane has the highest average LECR; however, given that lindane uses are extremely limited in Canada and the US, increases in exposure are not expected and it is reasonable to assume that few Canadians are currently being exposed. A recent survey of local Canadian fruits and vegetables reported no detections of lindane in 3,078 samples (including apples, assorted berries, leafy greens and tomatoes)[53].

- **MX (IARC Group 2B – possible carcinogen, data gap)**. No data or studies on MX levels in prepared or processed foods and beverages have been identified. The World Health Organization Guidelines for Drinking Water Quality note that MX is detected at levels in drinking water that are well below levels of concern[54], so it is unlikely that MX levels in foods prepared with treated water contain significantly higher levels.

- **N-nitrosomethylethylamine (IARC Group 2B – possible carcinogen, data gap)**. No data or studies on levels of n-nitrosomethylethylamine in prepared or processed foods and beverages have been identified. A recent survey reported that no food assay was available for n-nitrosomethylethylamine, but that n-nitroso compounds in general may also occur in pickled

[50] Federal-Provincial-Territorial Committee on Drinking Water. (2011). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Dichloromethane.
[51] Ibid.
[52] Tang W et al (2000). Estimation of human exposure to styrene and ethylbenzene Toxicology 144: pp 39-50.
[53] Canadian Food Inspection Agency. (2010). Food Safety Action Plan 2009-2010 Targeted Surveys- Pesticide Residues in Fresh Fruit and Vegetables. Available at: http://www.inspection.gc.ca/food/chemical-residues-microbiology/chemical-residues/eng/1324258929171/1324264923941#resid
[54] World Health Organization (2011). Drinking Water Guidelines 4th Edition, Available at: http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/index.html

foods, meats and fish cured with nitrites, and foods dried at high temperatures [55]. It is also likely that some foods might contain n-nitrosomethylethylamine if processed with treated drinking water.

- **Pentachlorophenol (IARC Group 2B – possible carcinogen, very low data quality, average LECR 0.0006 per million)**. While pentachlorophenol is persistent and bioaccumulative, it is not frequently detected in foods. Pentachlorophenol was not tested for in a recent survey of Canadian fruits and vegetables conducted by the Canadian Food Inspection Agency.

- **2,4,6-trichlorophenol (IARC Group 2B – possible carcinogen, data gap)**. 2,4,6-trichlorphenol may be present in foods and beverages processed with treated drinking water; however, levels in drinking water are very low and associated with an LECR of 0.04 per million, suggesting that exposures via foods and beverages would also be very low.

[55] Stuff J et al. (2009). Construction of an N-nitroso database for assessing dietary intake. Journal of Food Composition and Analysis. 22S: ppS42-S47.

7.0 Consumer Products

Data Synopsis: In order to understand the contribution of exposure via consumer products to total exposure, it is necessary to have data on the rate of emissions to air (and subsequent settling as dust), or the concentration of the substance within products applied to the skin, in conjunction with the amount of product typically used or applied. The Canada Consumer Product Safety Act (CCPSA) identifies the sellers (and resellers) of consumer products as those responsible for meeting federal regulations on product safety[56]. The federal government may conduct research or testing of products for regulatory purposes as they deem necessary, or ask the manufacturer/seller to conduct the tests and provide results; however, very few data exist that provide specific concentrations, emission rates, or use levels in Canada. Tables 7a, 7b and 7c list consumer products that may contain the known and suspected carcinogens on the CAREX Canada priority list.

Table 7a. Consumer products containing known carcinogens

IARC Group 1 Known Carcinogens	Cosmetic Hotlist Status[57]	Consumer products (US database)[58]
Arsenic and compounds (inorganic)	Prohibited	Motor oil, concrete powder
Asbestos	Not Listed	Chrysotile asbestos: cements, roof coating and patching
Benzene	Prohibited	Adhesive/ adhesive remover, degreasers, gasoline, motor oil, automotive polish, interior paint, sealant, refinishing product
Benzo[a]pyrene	Not Listed	Not listed
1,3-Butadiene	Prohibited	Cement paste, adhesive
Cadmium and cadmium compounds	Prohibited	Ceramic glazes, motor and gear oils, concrete powder
Chromium (not specifically hexavalent)	Prohibited	Automotive metal repair
Diesel engine exhaust	--	--
Formaldehyde	Restricted	Glues/adhesives, automotive wax, window glazing, insulation, sealants, spackle, wood finishes and cleaners, concrete powder, laminate repair filler, laundry detergents, baby and body washes, hand soaps, hair treatments, flea shampoo, plant fertilizer, fish aquarium supplies
Nickel and nickel compounds	Not Listed	Metal repair, automotive wax, concrete powder, electrical joint compound, nickel metal hydride batteries
Polychlorinated biphenyls	Not listed	Not listed
Radon	--	--
2,3,7,8-Tetrachlorodibenzo-para-dioxin	Prohibited	Not listed

[56] More information is available at: http://www.hc-sc.gc.ca/cps-spc/legislation/acts-lois/ccpsa-lcspc/index-eng.php
[57] Under the Canadian Food and Drug Act, the Cosmetics Hotlist includes all substances that are prohibited or restricted in cosmetic products. More information is available at: http://www.hc-sc.gc.ca/cps-spc/cosmet-person/indust/hot-list-critique/index-eng.php
[58] Available at: http://householdproducts.nlm.nih.gov/

Table 7b. Consumer products containing probable carcinogens

IARC Group 2A Probable Carcinogens	Cosmetic Hotlist Status[59]	Consumer products (US database)[60]
Lead and lead compounds	Prohibited	Ceramic glazes, motor oil, solder, concrete powder
Tetrachloroethylene	Prohibited	Adhesives, automotive cleaners and lubricants, stain remover, spray polish, fabric protector

Table 7c. Consumer products containing possible carcinogens

IARC Group 2B Possible Carcinogens	Cosmetic Hotlist Status[61]	Consumer products (US database)[62]
Acetaldehyde	Not listed	Glues, automotive wax, caulking and fillers, sealants
Benz[a]anthracene	Not listed	Not listed
Benzo[b]fluoranthene	Not listed	Not listed
Benzo[k]fluoranthene	Not listed	Not listed
Bromodichloromethane	--	--
Chloroform	Prohibited	Adhesive remover (discontinued)
Chlorothalonil	Not listed	Exterior acrylic house paint, garden pesticides
Chrysene	Not listed	Not listed
Dichloroacetic acid	--	--
Dichloromethane	Not listed	Not listed
Dichlorvos	Not listed	Indoor pest strips
Ethylbenzene	Not listed	Spray paints, automotive cleaners and lubricants, paints, gas treatments, gasoline, adhesives, sealants, interior oil paints and stains, interior/exterior paints and primers, garden pesticides
Indeno(1,2,3-cd)pyrene	Not listed	Not listed
Lindane	Not listed	Not listed
MX	--	--
N-nitrosomethylethylamine	--	--
Pentachlorophenol	Not listed	Not listed
2,4,6-trichlorophenol	--	--

We found a number of databases related to consumer products, but none provided the information necessary to undertake exposure surveillance:

[59] Under the Canadian Food and Drug Act, the Cosmetics Hotlist includes all substances that are prohibited or restricted in cosmetic products. More information is available at: http://www.hc-sc.gc.ca/cps-spc/cosmet-person/indust/hot-list-critique/index-eng.php

[60] Available at: http://householdproducts.nlm.nih.gov/

[61] Under the Canadian Food and Drug Act, the Cosmetics Hotlist includes all substances that are prohibited or restricted in cosmetic products. More information is available at: http://www.hc-sc.gc.ca/cps-spc/cosmet-person/indust/hot-list-critique/index-eng.php

[62] Available at: http://householdproducts.nlm.nih.gov/

- The online Household Products Database[63] from the US Department of Health and Human Services provides a reasonably comprehensive listing of products and ingredients, but often does not include the concentration of the ingredient in the product, nor are emission rates available. We also found that while some product names were the same in the US and Canada, this was not always the case, and that sometimes product formulations differ by country.

- Nielsen Canada[64] is a commercial enterprise that collects market data for resale to manufacturers and distributors. In general, these data provide purchase frequency information, but not product ingredients. CAREX staff had a number of conversations with representatives of Nielsen Canada to increase our understanding of the data products, how they are collected, strengths and weaknesses, and costs:

    - MarketTrack is a database containing information from cash register receipts of large retailers and grocery stores, including Superstore, Safeway, Sobeys, Walmart, Zellers, Shoppers, some Canadian Tire locations, but does not include department stores (cosmetics), London Drugs, Costco, Home Depot, Rona, or specialty retailers (Capers, Whole Foods, local hardware stores, etc). There are no data for the Yukon, Northwest Territories or Nunavut. Data for Manitoba and Saskatchewan are aggregated together.

    - Total Category plus Brands Reports are customized data reports that provide all buying measures (% households buying, how frequently, demographics for all categories and brands) summarized nationally and by region (province) for one year at a cost of approximately $50,000. A single brand or category report can be purchased for approximately $4,000. Categories are fairly specific, for example, laundry soaps.

    - HomeScan is a household survey including approximately 12,300 Canadians. Households are provided with UPC scanners and scan anything brought into home. This program does not capture purchases without UPC codes (for example, fresh produce or bakery items), and reports only recognized UPC codes (items with UPC codes that are not defined in the Nielsen database are reported in aggregate as 'other'). Statistics include amount spent per buyer, number of units purchased per buyer, but not the volume of product (for example, 500ml or 2 litre size). A customized report for 10 products would cost approximately $5,000, but could be more for less frequently purchased products (for example, garden pesticides) which would require data for two or three years (note: only three years of historical data are available).

- Canadian Home Insulation Program (CHIP) records include information on the insulation purchased to qualify for grants to improve heating efficiency between 1977 and 1986. Asbestos-

[63] Available at: http://householdproducts.nlm.nih.gov/index.htm
[64] http://ca.nielsen.com

contaminated insulation, sold under the brand name Zonolite, was available in Canada during this period. There are approximately 3 million CHIP records in paper form being held by Natural Resources Canada[65]. While these records are useful for individual property searches, converting these to a searchable electronic database would be a significant undertaking. Homes insulated with Zonolite before the grant program would not be included in these records, and not all home that qualified for the grant used Zonolite.

High Priority Data Issue:

- **Lack of concentration and use frequency data for consumer products.** While consumer products are typically thought to be safe in Canada, there is currently no system in place that would allow for ongoing and comprehensive exposure surveillance for a standard set of substances and products.
    - **In order to understand Canadians' exposures to a wide range of known and suspected carcinogens in consumer products, federal and provincial governments could require manufacturers to report concentration levels present in products, and explore ways to work with either retailers or market survey companies to track frequency of use statistics for a variety of products.**

[65] Jacques Brodeur, Natural Resources Canada. August 7, 209. Personal communication.