THIRD REPORT
ON HUMAN
BIOMONITORING
OF ENVIRONMENTAL
CHEMICALS
IN CANADA

Results of the Canadian Health Measures Survey Cycle 3 (2012–2013)

July 2015
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INTRODUCTION

These data tables present national data on concentrations of environmental chemicals in Canadians. These data were collected as part of the Canadian Health Measures Survey (CHMS), an ongoing national direct health measures survey. Statistics Canada, in partnership with Health Canada and the Public Health Agency of Canada, launched the CHMS in 2007 to collect health and wellness data and biological specimens on a nationally representative sample of Canadians. Biological specimens were analyzed for indicators of health status, chronic and infectious diseases, nutritional status, and environmental chemicals.

The CHMS biomonitoring component measures many environmental chemicals and/or their metabolites in blood and urine of survey participants. An environmental chemical can be defined as a chemical substance, either human-made or natural, that is present in the environment and to which humans may be exposed through media such as air, water, food, soil, dust, or consumer products.

The first Report on Human Biomonitoring of Environmental Chemicals in Canada was published in August 2010 and included baseline data for 92 environmental chemicals measured in cycle 1 (Health Canada, 2010). Data for cycle 1 of the CHMS were collected between March 2007 and February 2009 from approximately 5,600 Canadians aged 6 to 79 years at 15 sites across Canada. The Second Report on Human Biomonitoring of Environmental Chemicals in Canada was published in April 2013 (Health Canada, 2013). Data for cycle 2 were collected between August 2009 and November 2011 from approximately 6,400 Canadians aged 3 to 79 years at 18 sites across Canada. Cycle 2 included 91 environmental chemicals, 42 of which were also measured in cycle 1.

The data for cycle 3 were collected between January 2012 and December 2013 from approximately 5,800 Canadians aged 3 to 79 years at 16 sites across Canada. Cycle 3 included 48 environmental chemicals measured in individual samples, 33 of which have been measured in previous cycles.

A summary of the environmental chemicals measured in cycle 1, cycle 2, and cycle 3 of the CHMS is presented in the table below.
### Table 1.1

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organochlorines</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polybrominated flame retardants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polychlorinated biphenyls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorophenols</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perfluoralkyl substances</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phthalate metabolites</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental phenols</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metals and trace elements</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Nicotine metabolite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatile organic compounds: Benzene metabolites</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatile organic compounds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acrylamide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trihalomethanes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Collection for cycle 4 of the CHMS began in January 2014 and will be completed in late 2015. Planning for future cycles is under way.

The general CHMS survey design and implementation are described on the Health Canada website, with emphasis on the biomonitoring component. The website also contains descriptive summaries for each chemical, outlining the chemical’s identity, common uses, occurrence in the environment, potential sources of exposure in the human population, toxicokinetics in the body, health effects, regulatory status, and existing Canadian biomonitoring data.

Data tables specific to each chemical are provided below the relevant text; the tables are broken down by age group and sex, and contain descriptive statistics on the distribution of blood and/or urine concentrations in the sample population. For the 15 new environmental chemicals measured in cycle 3, tables present baseline data for the Canadian population. For chemicals that were also measured in previous cycles, data from all cycles are presented together in tables to allow for ease of comparison. Data for chemicals that were only measured in cycle 1 and/or cycle 2 can be found in the first Report on Human Biomonitoring of Environmental Chemicals in Canada (Health Canada, 2010) or the Second Report on Human Biomonitoring of Environmental Chemicals in Canada (Health Canada, 2013).

**REFERENCES**


The primary purpose of the biomonitoring component of the Canadian Health Measures Survey (CHMS) is to provide human biomonitoring data to scientists and health and environment officials to aid in assessing exposure to environmental chemicals and in developing policies to reduce exposure to toxic chemicals for the protection of the health of Canadians.

Some specific uses of the CHMS biomonitoring data include the following:
- to establish baseline concentrations of chemicals in Canadians that could allow for comparisons with subpopulations in Canada and with other countries
- to establish baseline concentrations of chemicals to track trends in Canadians over time
- to provide information for setting priorities and taking action to protect the health of Canadians and to protect Canadians from exposure to environmental chemicals
- to assess the effectiveness of health and environmental risk management actions intended to reduce exposures and health risks from specific chemicals
- to support future research on the potential links between exposure to certain chemicals and specific health effects
- to contribute to international monitoring programs, such as the Stockholm Convention on Persistent Organic Pollutants
The Canadian Health Measures Survey (CHMS) was designed as a cross-sectional survey to address important data gaps and limitations in existing health information in Canada. Its principal objective is to collect national-level baseline data on important indicators of Canadians’ health status, including those pertaining to exposures to environmental chemicals. This information is important in understanding exposure to risk factors, detecting emerging trends in risk factors and exposures, and advancing health surveillance and research in Canada. Detailed descriptions of the CHMS rationale, survey design, sampling strategy, and mobile examination centre (MEC) operations and logistics for cycle 3 have been published (Labrecque and Quigley, 2014; Statistics Canada, 2015).

3.1 TARGET POPULATION

Cycle 3 of the CHMS targets the population aged 3 to 79 years living at home and residing in the 10 provinces. The following groups are excluded from the survey’s coverage: persons living in the three territories; persons living on reserves and other Aboriginal settlements in the provinces; full-time members of the Canadian Forces; the institutionalized population, and residents of certain remote regions. Altogether, these exclusions represent approximately 4% of the target population.

Although the CHMS is not able to provide representative data for the entire Canadian population, there are a number of surveys and research projects carried out in partnership with Health Canada that directly target some of these population gaps.

The First Nations Biomonitoring Initiative (FNBI) is a survey carried out by the Assembly of First Nations and Health Canada that seeks to establish baseline biomonitoring data for First Nations people living on-reserve south of the 60\textdegree\ parallel (AFN, 2013). Between 2009 and 2011, the FNBI measured the levels of 97 environmental chemicals in blood and urine samples collected from 503 participants living in 13 First Nation communities across Canada. The complete report has been published by the Assembly of First Nations.

In addition, numerous biomonitoring studies have been undertaken in Canada’s North through the Northern Contaminants Program (NCP). The NCP, which is managed by federal government departments, provincial and territorial agencies, and Aboriginal organizations, was established in 1991 to respond to concerns about human exposure to contaminants in traditional diets of Northern Aboriginal peoples. The NCP provides funding for numerous individual studies undertaken in various regions of the North, including the Northwest Territories, Nunavut, and Nunavik (Quebec’s North). More detailed information and results from these studies have been summarized in the Canadian Arctic Contaminants Assessment Reports (CACAR) and numerous scientific articles.
3.2 SAMPLE SIZE AND ALLOCATION

To meet the objective of producing reliable estimates at the national level by age group and sex, cycle 3 of the CHMS required a minimum sample of at least 5,700 participants. The participants were distributed among six age groups (3–5, 6–11, 12–19, 20–39, 40–59, and 60–79 years) and sex (except for 3–5 years), for a total of 11 groups. For the 3– to 5–year age group, the survey was not designed to provide estimates for the individual sexes.

3.3 SAMPLING STRATEGY

To meet the requirements of the CHMS, a multi-stage sampling strategy was used.

3.3.1 Sampling of Collection Sites

The CHMS required participants to report to a MEC and be able to travel to the centre within a reasonable period of time. For cycle 3, the 2011 Census geography was used to create 360 collection sites across the country. A geographic area with a population of at least 10,000 and a maximum participant travel distance of 75 kilometres (50 kilometres in urban areas and 75 kilometres in rural areas) were required for the location of collection sites. Areas not meeting these criteria were excluded.

A larger number of collection sites would have optimized the precision of the estimates. However, the logistical and cost constraints associated with the use of MECs restricted the number of collection sites to 16. The 16 collection sites were selected from within the five standard regional boundaries used by Statistics Canada (Atlantic, Quebec, Ontario, the Prairies, and British Columbia); they were allocated to these regions in proportion to the size of the population. Although not every province in Canada had a collection site, the CHMS sites were chosen to represent the Canadian population in all 10 provinces, east to west, including larger and smaller population densities. The collection sites selected for cycle 3 of the CHMS are listed in the table below.

<table>
<thead>
<tr>
<th>Table 3.3.1.1</th>
<th>Canadian Health Measures Survey cycle 3 collection sites</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Atlantic</strong></td>
<td><strong>Quebec</strong></td>
</tr>
<tr>
<td>• Kent County, N.B.</td>
<td>• South-central Laurentians</td>
</tr>
<tr>
<td>• Halifax, N.S.</td>
<td>• Southwest Montérégie</td>
</tr>
<tr>
<td></td>
<td>• East Montréal</td>
</tr>
<tr>
<td></td>
<td>• West Montréal</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.3.2 Dwelling and Participant Sampling

Within each site, dwellings with known household composition at the time of the 2011 Census, updated with the most recent information from administrative files, were stratified by age of household residents at the time of the survey, with the six age-group strata corresponding to the CHMS cycle 3 age groups (3–5, 6–11, 12–19, 20–39, 40–59, and 60–79 years). Within each site, a simple random sample of dwellings was selected in each stratum. Each selected dwelling was then contacted and asked to provide a list of current household members; this list was used to select the survey participants. One or two people were selected, depending on the household composition.
3.4 SELECTION OF ENVIRONMENTAL CHEMICALS

The process to determine the list of environmental chemicals to be included in cycle 3 of the CHMS built upon the existing consultation process used for cycle 2. The primary mechanism of consultation for cycle 2 was through a questionnaire distributed to key stakeholders with expertise or interest in human biomonitoring of environmental chemicals; the purpose was to define specifically what should be measured in blood and urine samples in the Canadian population. Key participants included various internal Health Canada branches and programs as well as a number of external groups, including other federal departments, provincial/territorial health and environment departments, industry groups, environment and health non-governmental organizations, and academics. Through this consultation, over 310 different chemicals and metabolites were nominated.

Selection was based on health risks; evidence of human exposure; existing data gaps; commitments under national and international treaties, conventions, and agreements; availability of standard laboratory analytical methods; and current and anticipated health policy development and implementations.

The following criteria were used as a general guide for identifying and selecting the environmental chemicals to include in the CHMS:

- seriousness of known or suspected health effects related to the substance
- level of public concern about exposures and possible health effects related to the substance
- evidence of exposure of the Canadian population to the substance
- feasibility of collecting biological specimens in a national survey and associated burden on survey participants
- availability and efficiency of laboratory analytical methods
- costs of performing the test
- parity of selected chemicals with other national and international surveys and studies

Because less than 2 years had passed between the selection processes for cycle 2 and cycle 3, it was determined that an entirely new consultation was unnecessary; rather, the existing priority list from cycle 2 was used as the starting point for cycle 3. Chemicals that were included in the cycle 2 priority list, which could not previously be included for various reasons, were given highest priority for inclusion in cycle 3. In addition, environmental chemicals from cycles 1 and 2 considered to be high priorities were carried forward into cycle 3. Ultimately, the list was narrowed by the volume of biospecimens available from survey participants to conduct the analyses. Blood volume is generally limited; it is also required for analyses of chronic and infectious diseases and nutritional biomarkers. Thus, fewer environmental chemicals were measured in blood than in urine.

A full list of the chemicals measured in individual respondents in CHMS cycle 3 is presented in the table below.
Table 3.4.1
Chemicals measured in individual respondents in the Canadian Health Measures Survey cycle 3 (includes chemicals introduced for cycle 3 and carried forward from cycles 1 and 2).

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metals and trace elements</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury (total)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methylmercury</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inorganic mercury</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluoride</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Arsenic (speciated)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMA (Dimethylarsinic acid)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMA (Monomethylarsonic acid)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenocholine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenobetaine and arsenocholine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Environmental phenols</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bisphenol A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triclosan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nicotine metabolite</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotinine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PAHs (polycyclic aromatic hydrocarbons)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzo[a]pyrene metabolite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-Hydroxybenzo[a]pyrene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chrysene metabolites</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-Hydroxychrysene</td>
<td></td>
<td></td>
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<tr>
<td>3-Hydroxychrysene</td>
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<td></td>
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</tr>
<tr>
<td>4-Hydroxychrysene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-Hydroxychrysene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fluoranthene metabolite</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-Hydroxyfluoranthene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fluorene metabolites</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-Hydroxyfluorene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-Hydroxyfluorene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-Hydroxyfluorene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Naphthalene metabolites</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hydroxynaphthalene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-Hydroxynaphthalene</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Phenanthrene metabolites</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hydroxyphenanthrene</td>
<td></td>
<td></td>
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<tr>
<td>2-Hydroxyphenanthrene</td>
<td></td>
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</tr>
<tr>
<td>3-Hydroxyphenanthrene</td>
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</tr>
<tr>
<td>4-Hydroxyphenanthrene</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>9-Hydroxyphenanthrene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pyrene metabolite</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hydroxypyrene</td>
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<td></td>
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</tbody>
</table>
Owing to the high cost of laboratory analyses, some environmental chemicals were not measured for all CHMS participants. The majority of the environmental chemicals were measured in a subsample of 2,500 participants aged 3 to 79 years, with the following exceptions: lead, cadmium, total mercury, and cotinine were measured in all participants; methylmercury was measured in 1,000 participants aged 20 to 79 years; and trihalomethanes and volatile organic compounds were measured in 2,500 participants aged 12 to 79 years. Further details on the subsampling for environmental chemicals are available in Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015) and in Sampling documentation for cycle 3 of the Canadian Health Measures Survey (Labrecque and Quigley, 2014).

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatile organic compounds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Styrene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toluene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene metabolites</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t,t-MA (trans,trans-Muconic acid)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-PMA (S-Phenylmercapturic acid)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Trihalomethanes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bromodichloromethane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dibromochloromethane</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Tribromomethane</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Trichloromethane</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Xylenes</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>m-Xylene &amp; p-Xylene</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>o-Xylene</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Acrylamide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acrylamide haemoglobin adduct</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glycidamide haemoglobin adduct</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 3.4.2

Environmental chemicals measured by age group

<table>
<thead>
<tr>
<th>Measure</th>
<th>Matrix</th>
<th>Target sample size</th>
<th>Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals and trace elements</td>
<td>Urine, blood</td>
<td>5,700</td>
<td>3–5</td>
</tr>
<tr>
<td>Methylmercury</td>
<td>Blood</td>
<td>1,000</td>
<td>3–5</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Urine</td>
<td>2,500</td>
<td>3–5</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Urine</td>
<td>2,500</td>
<td>3–5</td>
</tr>
<tr>
<td>Acrylamide</td>
<td>Blood</td>
<td>2,500</td>
<td>3–5</td>
</tr>
<tr>
<td>Benzene metabolites</td>
<td>Urine</td>
<td>2,500</td>
<td>3–5</td>
</tr>
<tr>
<td>Environmental phenols</td>
<td>Urine</td>
<td>2,500</td>
<td>3–5</td>
</tr>
<tr>
<td>Nicotine metabolite</td>
<td>Urine</td>
<td>5,700</td>
<td>3–5</td>
</tr>
<tr>
<td>PAH metabolites</td>
<td>Urine</td>
<td>2,500</td>
<td>3–5</td>
</tr>
<tr>
<td>Volatile organic compounds</td>
<td>Blood</td>
<td>2,500</td>
<td>3–5</td>
</tr>
</tbody>
</table>
3.5 ETHICAL CONSIDERATIONS

Personal information collected through the CHMS is protected under the federal Statistics Act (Canada, 1970–71–72). Under the Act, Statistics Canada is obliged to safeguard and to keep in trust the information it obtains from the Canadian public. Consequently, Statistics Canada has established a comprehensive framework of policies, procedures, and practices to protect confidential information against loss, theft, unauthorized access, disclosure, copying, or use; this includes physical, organizational, and technological measures. The steps taken by Statistics Canada to safeguard the information collected in the CHMS have been described previously (Day et al., 2007).

Ethics approval for all components of the CHMS was obtained from the Health Canada and Public Health Agency of Canada Research Ethics Board. Informed written consent for the MEC portion of the CHMS was obtained from participants older than 14 years of age. For younger children, a parent or legal guardian provided written consent, and the child provided assent. Participation in this survey was voluntary, and participants could opt out of any part of the survey at any time.

A strategy was developed to communicate results to survey participants with the advice and expert opinion of the CHMS Laboratory Advisory Committee, the Physician Advisory Committee, l’Institut national de santé publique du Québec (the reference laboratory performing some of the environmental chemical analyses), and Health Canada’s Research Ethics Board (Day et al., 2007). For the environmental chemicals, only results for lead and mercury were actively reported to participants. However, participants could receive all other test results upon request to Statistics Canada. More information on reporting to participants, including the ethical challenges encountered, can be found in Haines et al. (2011).

REFERENCES


Fieldwork for the Canadian Health Measures Survey (CHMS) cycle 3 took place over a period of 2 years from January 2012 to December 2013. Data were collected sequentially at 16 sites across Canada. The sites were ordered to take into account seasonality by region and the temporal effect, subject to operational and logistical constraints.

Statistics Canada mailed an advance letter and brochure to households that were selected as outlined in the Dwelling and Participant Sampling section. The mailing informed potential participants that they would be contacted for the survey’s data collection.

Data were collected from consenting survey participants through a household personal interview, using a computer-assisted method, and a visit to a mobile examination centre (MEC) for physical measures and biospecimen collection. The field team consisted of household interviewers and the CHMS MEC staff, including trained health professionals who performed the physical measures testing (Statistics Canada, 2015).

Participants were first administered a household questionnaire in their home. Using a computer application, the interviewer randomly selected one or two participants and conducted separate 45- to 60-minute health interviews (Statistics Canada, 2015). The interviews collected demographic and socio-economic data and information about lifestyle, medical history, current health status, the environment, and housing conditions. At this time, the collection protocol for the indoor air and tap water component of the survey was also initiated. Within approximately 2 weeks after the home visit, participants visited the MEC. Each MEC consisted of two trailers linked by an enclosed pedestrian walkway. One trailer was for reception and contained an administration area and an examination room; the other trailer contained additional examination rooms and a laboratory. The MEC operated 7 days a week in order to complete approximately 350 visits at each site over 5 to 6 weeks and to accommodate participants’ schedules (Statistics Canada, 2015). MEC appointments averaged about 2.5 hours. A parent or legal guardian accompanied children under 14 years of age. To maximize response rates, participants who were unable or unwilling to go to the MEC were offered the option of a home visit by members of the CHMS MEC staff to perform some of the physical measures and the biospecimen collection portion of the survey (Statistics Canada, 2015).

At the start of the MEC visit, participants signed consent/assent forms prior to any testing and in most cases provided a urine sample immediately thereafter. For logistical purposes, spot samples were collected rather than 24-hour urine samples. The urine samples were collected using the first-catch urine, as opposed to the mid-stream urine collected in cycle 1. Guidelines were provided to participants asking them to abstain from urinating 2 hours prior to their MEC visit. Samples were collected in 120 mL urine specimen containers. Trained health professionals took physical health measurements such as height, weight, blood pressure, lung function, and physical fitness. A series of screening questions were administered to participants to determine their eligibility for the various tests, including phlebotomy (blood collection), based on pre-existing exclusion criteria (Statistics Canada,
Blood specimens were drawn by a certified phlebotomist; the maximum amount depended upon the age of the participant. The approximate volume drawn from participants aged 3–5 years was 22.0 mL; 6–11 years, 28.5 mL; 12–13 years, 48.8 mL; 14–19 years, 52.8 mL; and 20–79 years, 72.8 mL.

All blood and urine specimens collected in the MEC were processed and aliquoted in the MEC. Biospecimens were stored temporarily in temperature-monitored freezers at −30°C until shipping, with the exception of blood samples collected for volatile organic compound analysis; these were refrigerated. Once a week, the specimens were shipped on dry ice or in monitored refrigerated conditions to the reference laboratory for analyses. Standardized operating procedures were developed for the collection of blood and urine specimens, processing and aliquoting procedures, as well as for shipping biospecimens to ensure adequate data quality and to standardize data collection. A priority sequence for laboratory analyses was established in the event that an insufficient volume of biospecimen was collected for complete analyses of the environmental chemicals as well as for analyses of infectious diseases, nutritional status, and chronic diseases. Details on the collection tubes, aliquot volumes, and priority testing are presented in the table below.

### Table 4.1
Urine and blood collection procedure for the environmental chemicals

<table>
<thead>
<tr>
<th>Measure</th>
<th>Collection Tube</th>
<th>Matrix</th>
<th>Collection Tube (size and type)</th>
<th>Optimal Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylamide</td>
<td>Whole Blood</td>
<td>4.0, 6.0 or 10 mL</td>
<td>Lavender EDTA&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.5 mL</td>
</tr>
<tr>
<td>Metals</td>
<td></td>
<td></td>
<td></td>
<td>1.0 mL</td>
</tr>
<tr>
<td>Methylmercury</td>
<td></td>
<td></td>
<td></td>
<td>1.8 mL&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Volatile organic compounds (VOCs)</td>
<td>Whole Blood</td>
<td>10 mL Washed Grey</td>
<td>10 mL</td>
<td></td>
</tr>
<tr>
<td>Creatinine</td>
<td>Urine</td>
<td>120 mL urine specimen container</td>
<td>0.5 mL</td>
<td></td>
</tr>
<tr>
<td>Fluoride</td>
<td></td>
<td></td>
<td></td>
<td>0.8 mL</td>
</tr>
<tr>
<td>Arsenic (speciated)</td>
<td></td>
<td></td>
<td></td>
<td>1.0 mL</td>
</tr>
<tr>
<td>Nicotine metabolite</td>
<td></td>
<td></td>
<td></td>
<td>0.8 mL</td>
</tr>
<tr>
<td>Inorganic mercury</td>
<td></td>
<td></td>
<td></td>
<td>1.5 mL</td>
</tr>
<tr>
<td>Environmental phenols</td>
<td></td>
<td></td>
<td></td>
<td>0.8 mL</td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbon metabolites (PAHs) and benzene metabolites</td>
<td></td>
<td></td>
<td></td>
<td>12 mL</td>
</tr>
<tr>
<td>Specific gravity</td>
<td></td>
<td></td>
<td></td>
<td>0.3 mL</td>
</tr>
</tbody>
</table>

<sup>a</sup> Becton Dickinson Vacutainers were used for the collection of blood; VWR urine specimen containers were used for the collection of urine

<sup>b</sup> Optimum sample volume sent to the reference laboratory

<sup>c</sup> 4.0 mL tubes used for respondents aged 3–5 years; 6.0 mL tubes used for respondents aged 6–11 years; 10 mL tubes used for respondents aged 20–79 years

<sup>d</sup> EDTA: ethylenediaminetetraacetic acid

<sup>e</sup> Methylmercury only collected in respondents aged 20 to 79 years

To maximize the reliability and validity of the data and to reduce systematic bias, the CHMS developed quality assurance and quality control protocols for all aspects of the fieldwork. Quality assurance for the MEC covered staff selection and training, instructions to respondents (pre-testing guidelines), and issues related to data collection. All staff had appropriate education and training for their respective positions. To ensure consistent measurement techniques, procedure manuals and training guides were developed in consultation with, and reviewed by, experts in the field. Quality control samples were done at each site, consisting of three field blanks per site (deionized water for most analytes), blind replicates (three pairs per site except blood VOCs and cotinine), and blind control samples (approximately six per site).

The quality control samples were sent to the laboratory with regular specimen shipments. Results were sent to Statistics Canada’s CHMS headquarters, along with
all other respondent results, where they were assessed to determine the accuracy of the methodology based on the defined analyte concentration. The replicates were used to assess the precision of the analysis in pre-established acceptable ranges. If required, feedback was provided quickly to the reference laboratory for review and remedial action.

Beginning in cycle 2, a subsample of CHMS participants’ households were selected for a component that involved sampling of indoor air over a 7-day period. A tap water sampling protocol was introduced in cycle 3 to complement the indoor air component. By sampling both indoor air and tap water in the home environment, where Canadians spend the majority of their time, two potential sources of exposure to environmental chemicals are captured.

Participants were asked to place the indoor air sampler in their household for 7 days in order to measure a number of VOCs. One indoor air sampler was given per selected household, along with a pencil, a postage-paid envelope, and an information sheet. After the 7-day collection period was over, participants mailed their indoor air sampler in the envelope provided to CASSEN Testing Laboratories where all indoor air analyses were performed.

The tap water sampling was carried out during the household interview by the interviewer and lasted for approximately 10 minutes. The objective of tap water collection was to determine the prevalence of and characterize the distribution of exposure to fluoride and to VOCs from tap water. Two samples were collected at each household and were shipped to the laboratories where the tap water analysis was performed. Fluoride samples were analyzed by the Laboratoire de santé publique du Québec whereas the VOC samples were analyzed by a Health Canada research laboratory.

Indoor air results were not reported back to respondents; however, the tap water test results were reported back to those who participated in both the household and the clinic portion of the survey. Reports included results for those chemicals for which either aesthetic quality or maximum acceptable concentration (MAC) guidelines have been established by the Federal-Provincial-Territorial Committee on Drinking Water. Aesthetic objectives address concentrations that could affect the taste, smell, or colour of water, while still being below the point at which health effects could appear whereas MACs are established on the basis of health considerations. Certain chemicals measured in the tap water sample do not have established guidelines; respondents were able to receive these results only upon request. If one or more of the tap water results was found to exceed a MAC, survey staff contacted the respondents to inform them of their result and to ask for their consent to share the result with provincial authorities.

A complete list of the substances measured in the indoor air and tap water samples is available in the Canadian Health Measures Survey (CHMS) Content summary for cycles 1 to 8 (Statistics Canada, 2013). Further details on the indoor air study and tap water sampling are available in the Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015). Indoor air and tap water data are available upon request by contacting Statistics Canada at info@statcan.gc.ca.

Detailed descriptions of the CHMS MEC operations and logistics have been described previously in Bryan et al. (2007) and are presented in the Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015).

REFERENCES


Statistics Canada (2013). Canadian Health Measures Survey (CHMS) Content summary for cycles 1 to 8. Ottawa, ON. Available upon request (infostats@statcan.gc.ca).

Laboratory analyses of environmental chemicals and creatinine were performed at analytical laboratories within Health Canada, l’Institut national de santé publique du Québec (INSPQ), and the ALS Laboratory Group. Laboratories developed standardized operating procedures for the analytical methods used to measure environmental chemicals or their metabolites in biological samples. Analytical accuracy and precision of measurements were evaluated through rigorous method validation programs at each laboratory.

Internal quality control measures within each laboratory included the analysis of calibration standards, laboratory blanks, method blanks, and in-house quality control samples in each analytical batch. In addition, laboratories conducted periodical analyses of Standard Reference Materials/Certified Reference Materials when available. Quality assurance reviews were conducted on laboratory data on a regular basis to evaluate any issues in the batch processing and to identify inconsistencies in analytical results. Appropriate corrective measures were taken when required. As part of external quality control measures, laboratories participated in external quality control programs and inter-laboratory comparison studies when available. Tables are provided with limits of detection for each method (Appendix A). The methods used in the analyses of the environmental chemicals and creatinine are described below.

### 5.1 Acrylamide

Whole blood was thawed at room temperature and reacted with modified Edman reagent (pentafluorophenyl isothiocyanate) for 2 hours at 55°C. The sample was purified using solid phase extraction on Isolute HM-N sorbent. Analytes were then eluted with diisopropyl ether/ethyl acetate/toluene (50/40/10 v/v/v) and the extract was evaporated under a stream of nitrogen. The sample was reconstituted in methanol/water (40/60 v/v) and analyzed using a Waters Acquity ultraperformance liquid chromatograph (UPLC) system coupled to a Quattro Premier tandem mass spectrometer (Health Canada, 2014).

### 5.2 Environmental Phenols

For the analysis of bisphenol A and triclosan, urine samples were subjected to enzymatic hydrolysis (β-glucuronidase enzyme). The samples were then derivatized with pentafluorobenzyl bromide at 70°C for 2 hours. The derivatized products were extracted with a mixture of dichloromethane-hexane. Evaporated extracts were dissolved in the appropriate solvent and analyzed using an Agilent 6890 or 7890 gas chromatographic system coupled to a Waters Quattro Micro gas chromatograph (GC) tandem mass spectrometer. The mass spectrometer was operated in the negative ion chemical ionization mode.
mode and the analytes were quantified using multiple reaction monitoring (MRM) (INSPQ, 2014a). Free and hydrolyzed forms of bisphenol A were measured together by this procedure.

5.3 METALS AND TRACE ELEMENTS

5.3.1 Arsenic

Urine samples were diluted in ammonium carbonate solution and analyzed for arsenite (As$^{3+}$), arsenate (As$^{5+}$), monomethylarsonic acid, dimethylarsinic acid, and the sum of arsenobetaine and arsenocholine using a Waters Acquity UPLC coupled to a Varian 820-MS inductively coupled plasma-mass spectrometer (ICP-MS) system (INSPQ, 2009a). For arsenocholine, urine was diluted with formic acid and acetonitrile solution and analyzed on Waters Acquity UPLC coupled to a TQ-S tandem mass spectrometer (INSPQ, 2009a).

5.3.2 Cadmium, Lead, and Total Mercury

Blood samples were diluted in a basic solution containing octylphenol ethoxylate and ammonia. They were analyzed for cadmium, lead, and total mercury using a Perkin Elmer Sciex Elan DRC II ICP-MS. Matrix matched calibration was performed using blood from non-exposed individuals (INSPQ, 2010).

5.3.3 Fluoride

Urine samples were diluted with ionic adjustment buffer and analyzed using an Orion pH meter with a fluoride ion selective electrode (Orion Research Inc.) (INSPQ, 2009b).

5.3.4 Inorganic Mercury

Urine was digested in nitric acid at 50°C, diluted, and analyzed for inorganic mercury on a Perkin Elmer FIMS 100 (cold vapour system). Matrix matched calibration was performed using urine from non-exposed individuals (INSPQ, 2009c).

5.3.5 Methylmercury

Methylmercury was extracted by sonication from whole blood using an L-cysteine acid solution. After centrifugation, proteins were precipitated using acetonitrile. The supernatant was extracted using an MCX solid phase extraction cartridge. The extract was evaporated to dryness, reconstituted in the appropriate solvent, and analyzed using a Water Acquity UPLC coupled to a Varian 820-MS ICP-MS (INSPQ, 2011).

5.4 NICOTINE METABOLITE

Free cotinine was recovered from urine samples by solid-phase extraction on an automated Janus workstation. Deuterated cotinine was used as the internal standard. The extract was redissolved in the mobile phase, and analyzed using a Waters Acquity UPLC coupled to a Waters Quattro Premier XE tandem mass spectrometer with an electrospray ionization source operating in positive ion mode. The analytes were quantified using MRM (INSPQ, 2009d).

5.5 POLYCYCLIC AROMATIC HYDROCARBON METABOLITES

For the analysis of polycyclic aromatic hydrocarbon metabolites (3-hydroxybenzo[a]pyrene, 2-hydroxychrysene, 3-hydroxychrysene, 4-hydroxychrysene, 6-hydroxychrysene, 3-hydroxyfluoranthene, 2-hydroxyfluorene, 3-hydroxyfluorene, 9-hydroxyfluorene, 1-hydroxynaphthalene, 2-hydroxynaphthalene, 1-hydroxyphenanthrene, 2-hydroxyphenanthrene, 3-hydroxyphenanthrene, 4-hydroxyphenanthrene, 9-hydroxyphenanthrene, and 1-hydroxypyrene), urine samples were hydrolyzed using β-glucuronidase enzymatic solution and extracted with an organic solvent at neutral pH. The extracts were evaporated and derivatized with N-methyl-N-(trimethylsilyl)-trifluoroacetamide and analyzed using an Agilent 7890 gas chromatograph coupled to an Agilent 7000B triple-quad tandem mass spectrometer operating in electron impact ionization mode. Analytes were quantified using MRM (INSPQ, 2014b).
5.6 VOLATILE ORGANIC COMPOUNDS

Whole blood samples were withdrawn using a previously cleaned air-tight syringe, transferred to a glass vial, and a mixture of isotopically labelled analogs was added. The vial was crimp-sealed and placed in a temperature-controlled autosampler tray. The samples were maintained at 40°C with continuous mixing. The analytes (benzene, toluene, ethylbenzene, m-xylene, o-xylene, p-xylene, chloroform, bromoform, bromodichloromethane, dibromochloromethane, trichloroethane, tetrachloroethene, and styrene) were extracted by inserting a solid phase microextraction fiber into the vial headspace. After extraction, the fiber was transferred to a heated gas chromatograph inlet where the analytes were rapidly desorbed off the fiber. The analytes were focused using a ThermoFisher Scientific Cryotrap (Cryotrap 915) and analyzed using a ThermoFisher Scientific TRACE Ultra gas chromatograph coupled to TSQ Quantum XLS mass spectrometer equipped with electron ionization source. The analytes were quantified in selected reaction monitoring mode (Health Canada, 2012).

5.6.1 Benzene Metabolites

Benzene metabolites (trans,trans-muconic acid and S-phenylmercapturic acid) were extracted from urine using a hydrophilic-lipophilic-balanced solid-phase extraction cartridge on an automated Janus workstation. The extracts were evaporated to dryness, reconstituted in the mobile phase, and analyzed using a Waters Acquity UPLC coupled to a Waters Xevo TQ-S tandem mass spectrometer operated in negative ion mode (INSPQ, 2014c).

5.7 CREATININE

Creatinine was measured in urine using the colorimetric end-point Jaffé method. An alkaline solution of sodium picrate reacts with creatinine in urine to form a red Janovski complex using Microgenics DRI Creatinine-Detect reagents (#917). The absorbance was read at 505 nm on a Hitachi 917 chemistry autoanalyzer (INSPQ, 2008).

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INSPQ (Institut national de santé publique du Québec) (2009a). Analytical method for the determination of arsenic species in urine by ultra performance liquid chromatography coupled to argon plasma induced mass spectrometry (HPLC-ICP-MS) (M-585), condensed version for CHMS. Laboratoire de toxicologie, Québec, QC.

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INSPQ (Institut national de santé publique du Québec) (2011). Analytical method for the determination of methylmercury in blood by Waters Acquity high-pressure liquid chromatography coupled with Varian 820-MS inductively coupled plasma mass spectrometry (HPLC-ICP-MS) (M-595-A), condensed version for CHMS. Laboratoire de toxicologie, Québec, QC.

INSPQ (Institut national de santé publique du Québec) (2014a). Analytical method for the determination of bisphenol A and triclosan in urine by GC-MS-MS (E-475), condensed version for CHMS. Laboratoire de toxicologie, Québec, QC.

INSPQ (Institut national de santé publique du Québec) (2014b). Analytical method for the determination of hydroxy polycyclic aromatic hydrocarbons (PAHs) in urine by GC-MS-MS (E-465-A), condensed version for CHMS. Laboratoire de toxicologie, Québec, QC.

INSPQ (Institut national de santé publique du Québec) (2014c). Analytical method for the determination of benzene metabolites in urine by UPLC-MS-MS (E-477), condensed version for CHMS. Laboratoire de toxicologie, Québec, QC.
Descriptive statistics on the concentrations of environmental chemicals in the blood and urine of Canadians, aged 3 to 79 years, were generated using the Statistical Analysis System software (SAS Institute Inc., version 9.2, 2008) and the SUDAAN® (SUDAAN Release 11.0.1, 2013) statistical software package.

The Canadian Health Measures Survey (CHMS) is a sample survey, meaning that the participants represent many other Canadians not included in the survey. In order for the results of the survey to be representative of the entire population, sample weights were generated by Statistics Canada and incorporated into all estimates presented in the data tables (e.g. geometric means). Survey weights were used to take into account the unequal probability of selection into the survey as well as non-response. Further, to account for the complex survey design of the CHMS, the set of bootstrap weights included with the data set was used to estimate the 95% confidence intervals (CIs) for all means and percentiles (Rao et al., 1992; Rust and Rao, 1996).

For each chemical measured in cycle 3, data tables are presented. Data from cycle 1 and cycle 2 are also provided within the tables for those substances measured in all cycles. In the first Report on Biomonitoring of Environmental Chemicals in Canada, all results were reported to two decimal places. For cycles 2 and 3 of the CHMS, the reporting protocol changed and the results were reported to two significant digits. For consistency, cycle 1 data were adjusted to two significant digits before generating the descriptive statistics and data from all cycles are presented to two significant digits. Therefore, the descriptive statistics presented for cycle 1 may differ from those presented in the first report. The differences are not significant and the values presented in the first report are still considered to be accurate.

The data tables include the sample size (n); percentage of results that fall below the limit of detection (LOD); geometric mean (GM); the 10th, 50th, 90th, and 95th percentiles; and associated 95% CIs. For each chemical, results are presented for the total population as well as by age group and sex. For each chemical that was measured in multiple cycles of the CHMS, a summary table is provided that compares results for the aggregate of all age groups common to all cycles and for that same aggregate population separated by sex. Measurements that fell below the LOD for the laboratory analytical method were assigned a value equal to half the LOD. If the proportion of results below the LOD was greater than 40%, GMs were not calculated. Percentile estimates that are less than the LOD are reported as <LOD. The appendices contain tables of LOD values for each chemical, specific to each cycle, and conversion factors to assist in the comparison of data from other studies that report different units (Appendices A and B).

Chemicals measured in whole blood are presented as weight of chemical per volume of whole blood (e.g. µg chemical/L blood).

For urine measurements, concentrations are presented as weight of chemical per volume of urine (e.g. µg chemical/L urine) and adjusted for urinary creatinine (e.g. µg chemical/g creatinine). Urinary creatinine is a chemical by-product generated from muscle metabolism; it is frequently used to adjust for urine.
concentration (or dilution) in spot urine samples because its production and excretion are relatively constant over 24 hours owing to homeostatic controls (Barr et al., 2005; Boeniger et al., 1993; Pearson et al., 2009). If the chemical measured behaves similarly to creatinine in the kidney, it will be filtered at the same rate, thus expressing the chemical per gram of creatinine helps adjust for the effect of urinary dilution as well as some differences in renal function and lean body mass (Barr et al., 2005; CDC, 2009; Pearson et al., 2009). Creatinine is primarily excreted by glomerular filtration; therefore, creatinine adjustment may not be appropriate for compounds that are excreted primarily by tubular secretion in the kidney (Barr et al., 2005; Teass et al., 2003). In addition, creatinine excretion can vary owing to age, sex, and ethnicity; therefore, it may not be appropriate to compare creatinine-adjusted concentrations among different demographic groups (e.g. children with adults) (Barr et al., 2005). Where urinary creatinine values were missing or <LOD, the estimate of that participant’s creatinine-adjusted chemical was not calculated and was also set to missing.

Descriptive statistics are available for creatinine (mg/dL) (Appendix C). These include n; % <LOD; GM; the 10th, 50th, 90th, and 95th percentiles; and associated 95% CIs for the total population as well as by age group and sex. Measurements that fell below the LOD for the laboratory analytical method were assigned a value equal to half the LOD.

Specific gravity was also measured in all urine samples immediately following sample collection at the mobile examination centre. Urinary specific gravity is the ratio of densities between urine and pure water and can be used to adjust for variations in urine output, similar to urinary creatinine adjustment. Urinary specific gravity adjustment has not been presented for any of the chemicals; however, specific gravity data are available upon request by contacting Statistics Canada at info@statcan.gc.ca should researchers wish to perform this adjustment for their own data analyses.

Under the Statistics Act, Statistics Canada is required to ensure participant confidentiality. Therefore, estimates based on a small number of participants are suppressed. Following suppression rules for the CHMS, any estimate based on fewer than 10 participants is suppressed in the data tables. To avoid suppression, estimates at the 95th percentile require at least 200 participants, estimates at the 10th and 90th percentiles require at least 100 participants, estimates at the 50th percentile require at least 20 participants, and estimates of the geometric mean require at least 10 participants.

Estimates from a sample survey inevitably include sampling errors. Measuring the possible scope of sampling errors is based on the standard error of the estimates drawn from the survey results. To get a better indication of the size of the standard error, it is often more useful to express the standard error in terms of the estimate being measured. The resulting measure, called the coefficient of variation (CV), is obtained by dividing the standard error of the estimate by the estimate itself, and it is expressed as a percentage of the estimate. This report employs the following Statistics Canada guidelines for releasing estimates based on their CV:

• When a CV is between 16.6% and 33.3%, an estimate can be considered for general unrestricted release but is accompanied by a warning cautioning subsequent users of the high sampling variability associated with the estimate. These estimates are identified by the superscript letter E.

• When a CV is greater than 33.3%, Statistics Canada recommends not releasing the estimate because conclusions based on these data will be unreliable and most likely invalid. These estimates will not be published and will instead be replaced by the letter F.

Further details on the sample weights and data analysis are available in the Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015).
REFERENCES


CONSIDERATIONS FOR INTERPRETING THE BIOMONITORING DATA

The Canadian Health Measures Survey (CHMS) was designed to provide estimates of environmental chemical concentrations in blood or urine for the Canadian population as a whole. The first cycle of the survey covered approximately 96% of the Canadian population aged 6 to 79 years. The second and third cycles included children as young as 3 years of age and also covered approximately 96% of the Canadian population up to 79 years of age. The survey was not designed to permit breakdown of data by region, province, or collection site though some analysis is possible if data from more than one cycle are combined (see Instructions for Combining Multiple Cycles of CHMS Data). In addition, the CHMS design did not target specific exposure scenarios; consequently, it did not select or exclude participants on the basis of their potential for low or high exposures to environmental chemicals.

Biomonitoring can estimate how much of a chemical is present in a person, but it cannot say what health effects, if any, may result from that exposure. The ability to measure environmental chemicals at very low concentrations has advanced in recent years. However, the presence alone of a chemical in a person’s body does not necessarily mean that it will cause a health effect. Factors such as the dose, the toxicity of the chemical, and the duration and timing of exposure are important to determine whether potential adverse health effects may occur. For chemicals such as lead or mercury, research studies have provided a good understanding of the health risks associated with different concentrations in blood. However, for many chemicals, further research is needed to understand the potential health effects, if any, from different blood or urine concentrations. Furthermore, small amounts of certain chemicals, such as manganese and zinc, are essential for the maintenance of good health and would be expected to be present in the body. In addition, the way in which a chemical will act in the body will differ among individuals and cannot be predicted with certainty. Certain populations (children, pregnant women, the elderly, or immuno-compromised people) may be more susceptible to the effects of exposure.

The absence of a chemical does not necessarily mean a person has not been exposed. It may be that the technology is not capable of detecting such a small amount, or that the exposure occurred at an earlier point in time allowing for the chemical to be eliminated from the person’s body before measurement took place.

Biomonitoring cannot tell us the source or route of the exposure. The amount of chemical measured indicates the total amount that has entered the body through all routes of exposure (ingestion, inhalation, and skin contact) and from all sources (air, water, soil, food, and consumer products). The detection of the chemical may be the result of exposure to a single source or multiple sources. In addition, in most cases biomonitoring cannot distinguish between natural and anthropogenic sources. Many chemicals (lead, mercury, cadmium, and arsenic) occur naturally in the environment and are also present in human-made products.

While metals are measured in urine as the parent compounds, almost all other chemicals are measured
As metabolites. For many chemicals, parent compounds may be broken down (i.e. metabolized) in the body into one or more metabolites. For example, the polycyclic aromatic hydrocarbon chrysene is broken down into several metabolites. Some metabolites are specific to one parent compound whereas others are common to several parent compounds. Several urinary metabolites are also formed in the environment (e.g. chlorpyrifos metabolites). Their presence in urine does not necessarily mean that an exposure to the parent chemical has occurred; rather, exposure could be to the metabolite itself in media such as food, water, or air.

Factors that contribute to the concentrations of chemicals measured in blood and urine include the quantity entering the body through all routes of exposure, absorption rates, distribution to various tissues in the body, metabolism, and excretion of the chemical and/or its metabolites from the body. These processes, also called toxicokinetics, depend on both the characteristics of the chemical, including its solubility in fat (or lipophilicity), its pH, its particle size, and the characteristics of the individual being exposed, such as age, diet, health status, and race. For these reasons, the way in which a chemical will act in the body will differ among individuals and cannot be predicted with certainty.

The CHMS biomonitoring data currently available include temporal data for substances measured in cycle 1 (2007–2009), cycle 2 (2009–2011), and cycle 3 (2012–2013), as well as baseline data for substances introduced to the survey in cycle 3. Results from future cycles can be compared with the baseline data from the CHMS in order to begin to examine trends in Canadians’ exposures to selected environmental chemicals. It is important to note that there were some sampling and analytical modifications between cycles that may have contributed some variation in results for those substances measured in multiple cycles. The limits of detection (LOD) for certain analytical methods have changed from cycle to cycle. Although the LOD values did not change by a large margin, this difference should be noted when comparing data from multiple cycles. A list of LOD values from cycles 1, 2, and 3 is provided (Appendix A). In addition, the urine collection protocol and guidelines were changed in cycle 2, and this may have resulted in a shift in creatinine levels when cycle 1 data are compared with those from subsequent cycles. This, in turn, could affect creatinine-adjusted levels of some chemicals.

Urinary creatinine concentrations can also be affected by variables such as age, sex, and ethnicity resulting in differences among demographic groups within a single cycle (Mage et al., 2004). In particular, creatinine excretion per unit bodyweight increases substantially with increasing age in children (Aylward et al., 2011; Remer et al., 2002). As a result, it is acceptable to compare creatinine-adjusted concentrations among similar demographic groups (e.g. children with children, adults with adults, males with males) but not among two different demographic groups (e.g. children with adults, males with females) (Barr et al., 2005).

More in-depth statistical analyses of the CHMS biomonitoring data, including time trends, exploring relationships among environmental chemicals, other physical measures, and self-reported information are being published by researchers in the scientific literature. A bibliography of publications using CHMS data is available. CHMS data are available to scientists through Statistics Canada’s Research Data Centres Program and are a resource for additional scientific analyses. Further information about the CHMS can be obtained by contacting Statistics Canada at info@statcan.gc.ca.

REFERENCES


8.1  ACRYLAMIDE

Acrylamide (CASRN 79-06-1) is a chemical used primarily in the production of polymers such as polyacrylamides (ATSDR, 2012). Polyacrylamides are used to clarify drinking water and treat effluent from water treatment plants and industrial processes (ATSDR, 2012). They are also used as binding, thickening, or flocculating agents in grout, cement, pesticide formulations, cosmetics, food manufacturing, and soil erosion prevention (Environment Canada and Health Canada, 2009a). Polymers of acrylamide are also used in ore processing, food packaging, and plastic products (Environment Canada and Health Canada, 2009a). In Canada, polyacrylamide is used as a coagulant and flocculant for the clarification of drinking water, in potting soils, and as a non-medicinal ingredient in natural health products and pharmaceuticals (Environment Canada and Health Canada, 2009b). Acrylamide can also form naturally in certain foods during processing or cooking at high temperatures (Health Canada, 2009a). It is formed mainly in carbohydrate-rich plant-based foods such as potatoes and grains with the highest concentrations detected in potato chips and french fries (Health Canada, 2009a).

Entry into the environment may occur during production and industrial use (ATSDR, 2012). Residual monomers may be released to drinking water during polyacrylamide treatment processes and are the main source of drinking water contamination by acrylamide (ATSDR, 2012). Acrylamide is a component of cigarette smoke and may be released to indoor air as a result of smoking (NTP, 2005; Urban et al., 2006).

Acrylamide exposure in the general population occurs primarily through food and to a lesser degree through air, drinking water, and soil (Environment Canada and Health Canada, 2009a). Inhalation of tobacco smoke, including second-hand smoke, is also a major source of inhalation exposure for the general population (ATSDR, 2012). Once absorbed, acrylamide is widely distributed throughout the body accumulating in red blood cells (ATSDR, 2012). Acrylamide is metabolized to form the epoxide derivative, glycidamide, and both acrylamide and glycidamide react with haemoglobin in red blood cells forming adducts (ATSDR, 2012). Absorbed acrylamide and its metabolites are rapidly eliminated in urine, primarily as mercapturic acid conjugates of acrylamide and glycidamide (ATSDR, 2012). Acrylamide and glycidamide haemoglobin adducts are considered markers of exposure over the previous 120 days, the average life span of red blood cells (ATSDR, 2012).

Exposure to acrylamide is known to cause a number of health effects in humans, including neurotoxicity. Inhalation exposure to acrylamide in occupational settings has been associated with peripheral neuropathy characterized by muscle weakness and numbness in hands and feet (Environment Canada and Health Canada, 2009b). Studies with laboratory animals have observed adverse reproductive and developmental effects and shown that acrylamide is genotoxic and carcinogenic (Environment Canada and Health Canada, 2009b; WHO, 2006). Reviews of existing epidemiological studies have found that
there is inadequate evidence in humans to establish an association between acrylamide exposure and carcinogenicity (Health Canada, 2008; IARC, 1999). However, on the basis of evidence in experimental animals, the International Agency for Research on Cancer (IARC) and the U.S. Environmental Protection Agency (EPA) have classified acrylamide as probably carcinogenic to humans (EPA, 2010; IARC, 1999). Further, on the basis of available evidence from animal studies, the Joint FAO/WHO Expert Committee on Food Additives determined that the estimated intake of acrylamide from certain foods may be a human health concern (FAO/WHO, 2006).

Health Canada and Environment Canada concluded, on the basis of carcinogenic potential, that acrylamide in Canada may constitute a danger to human life or health (Environment Canada and Health Canada, 2009b). Acrylamide is listed on Schedule 1, List of Toxic Substances, under the Canadian Environmental Protection Act, 1999 (CEPA 1999). The Act allows the federal government to control the importation, manufacture, distribution, and use of acrylamide in Canada (Canada, 1999; Canada, 2011). Health Canada’s risk management strategy for acrylamide in food is focused on reducing foodborne exposure to acrylamide (Health Canada, 2009b). To reduce exposure to acrylamide from food sources, Health Canada suggests following the recommendations provided in Canada’s Food Guide, thereby limiting consumption of carbohydrate-rich foods that are high in fat (such as potato chips and french fries), sugar, or salt (Health Canada, 2009a). However, occasional consumption of these products is not likely to be a health concern. Other suggestions for reducing exposure to acrylamide from certain foods include paying careful attention to oil and baking temperatures, following the manufacturer’s cooking instructions, storing potatoes at a temperature above 8°C, washing or soaking cut potatoes in water prior to frying, and toasting bread or baked goods to the lightest colour acceptable (Health Canada, 2009a). Health Canada regularly reviews data on the concentrations of acrylamide in foods sold on the Canadian market; these results may be shared with industry, particularly if elevated levels of acrylamide are identified in certain products. Health Canada continues to encourage the food industry to further pursue reduction efforts for acrylamide in processed foods (Health Canada, 2012a). In order to obtain additional information demonstrating successful acrylamide reduction strategies on the part of food manufacturers, Health Canada initiated a one-year call for data in September 2013 seeking submissions of published and unpublished technical information on the occurrence of acrylamide in foods available for sale in Canada (Health Canada, 2013a). Health Canada has also amended the Food and Drug Regulations to permit the use of asparaginase in certain food products to reduce the formation of acrylamide during cooking (Canada, 2012; Health Canada, 2013b). Acrylamide is included as a prohibited ingredient on the List of Prohibited and Restricted Cosmetic Ingredients (more commonly referred to as the Cosmetic Ingredient Hotlist or simply the Hotlist). The Hotlist is an administrative tool that Health Canada uses to communicate to manufacturers and others that certain substances, when present in a cosmetic, may contravene the general prohibition found in section 16 of the Food and Drugs Act or a provision of the Cosmetic Regulations (Health Canada, 2014).

Because acrylamide-containing polymers are used in drinking water treatment, most Canadian jurisdictions have requirements to meet health-based standards for additives that limit the amount of acrylamide present in the treated drinking water (NSF International, 2013; NSF International, 2014). Health Canada has also set a maximum level for acrylamide in polyacrylamide-containing formulations used in natural health products in Canada (Environment Canada and Health Canada, 2009a; Health Canada, 2012b).

In a study carried out on Montreal Island to assess the levels of acrylamide in 195 non-smoking teenagers aged 10 to 17 years, the geometric mean concentrations of haemoglobin adducts of acrylamide and glycidamide were 45.4 pmol/g globin and 45.6 pmol/g globin, respectively (Brisson et al., 2014). Acrylamide and its metabolite glycidamide were analyzed as adducts in whole blood of CHMS participants aged 3 to 79 years in cycle 3 (2012–2013). Data are presented in blood as pmol/g haemoglobin (Hb). Finding a measurable amount of acrylamide or glycidamide haemoglobin adducts in blood is an indicator of exposure to acrylamide and does not necessarily mean that an adverse health effect will occur. These data provide baseline levels for acrylamide and glycidamide haemoglobin adducts in the Canadian population.
### Table 8.1.1
Acrylamide haemoglobin adduct — Geometric means and selected percentiles of whole blood concentrations (pmol/g Hb) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2492</td>
<td>0</td>
<td>73 (65–82)</td>
<td>35 (30–40)</td>
<td>64 (57–70)</td>
<td>190 (160–230)</td>
<td>240 (190–290)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>471</td>
<td>0</td>
<td>59 (55–64)</td>
<td>39 (35–43)</td>
<td>59 (55–63)</td>
<td>87 (73–100)</td>
<td>100 (82–120)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>0</td>
<td>61 (57–65)</td>
<td>37 (34–41)</td>
<td>62 (58–67)</td>
<td>100 (86–110)</td>
<td>110 (98–120)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

### Table 8.1.2
Glycidamide haemoglobin adduct — Geometric means and selected percentiles of whole blood concentrations (pmol/g Hb) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2492</td>
<td>0.76</td>
<td>68 (62–75)</td>
<td>36 (34–38)</td>
<td>65 (59–70)</td>
<td>150 (120–180)</td>
<td>190 (150–220)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1267</td>
<td>0.39</td>
<td>67 (60–74)</td>
<td>36 (32–40)</td>
<td>64 (57–71)</td>
<td>130 (100–160)</td>
<td>160 (130–200)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>471</td>
<td>0</td>
<td>80 (75–85)</td>
<td>51 (43–59)</td>
<td>78 (74–81)</td>
<td>120 (110–130)</td>
<td>140 (120–150)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>0</td>
<td>73 (70–77)</td>
<td>47 (45–48)</td>
<td>74 (66–81)</td>
<td>110 (97–120)</td>
<td>130 (110–150)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>1.71</td>
<td>60 (53–67)</td>
<td>34 (29–39)</td>
<td>60 (50–70)</td>
<td>100 (90–110)</td>
<td>120 (110–130)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
REFERENCES


Health Canada (2013b). Food and nutrition: Notice of modification to the list of permitted food enzymes to enable the use of the enzyme asparaginase, obtained from Aspergillus oryzae (pCaHj621/BEC2#10), in green coffee. Minister of Health, Ottawa, ON. Retrieved April 21, 2015.


SUMMARIES AND RESULTS FOR ENVIRONMENTAL PHENOLS

9.1 BISPHENOL A

Bisphenol A (BPA; CASRN 80-05-7) is a synthetic chemical used as a monomer in the production of some polycarbonate plastics and as a precursor for monomers of certain epoxy-phenolic resins (EFSA, 2007). Polycarbonate is used in the manufacture of food and beverage containers such as repeat-use water bottles and storage containers; it was also used in infant bottles in Canada prior to 2010. Epoxy resins are used as an interior protective lining for food and beverage cans. Additional end-use products containing polycarbonate plastics and resins include medical devices, some dental fillings and sealants, sporting and safety equipment, electronics, and automotive parts (EFSA, 2007; NTP, 2007). BPA is also used in the paper industry to produce thermal paper used for various products including receipts, prescription labels, airline tickets, and lottery tickets (Geens et al., 2011).

BPA does not occur naturally in the environment (Environment Canada and Health Canada, 2008a). Entry into the environment may occur from industrial sources or from product leaching, disposal, and use (CDC, 2009).

The primary route of exposure to BPA for the general public is through dietary intake as a result of various sources, including migration from food packaging and repeat-use polycarbonate containers (Health Canada, 2008). Health Canada has recently updated its dietary exposure estimates for BPA following the completion of a number of specific food surveys, including canned foods and beverages, liquid infant formula, and Total Diet samples (Health Canada, 2012). Exposure can also occur from contact with environmental media, including ambient and indoor air, drinking water, soil, and dust, and from the use of consumer products (Environment Canada and Health Canada, 2008a). BPA exposure from dental fillings and sealants is short term and considered unlikely to contribute substantially to chronic exposure (WHO, 2011). However, further clinical research would help to answer questions about the potential harms caused by the exposure to BPA from dental composite materials (CADTH, 2012).

In humans, BPA is readily absorbed and undergoes extensive metabolism in the gut wall and the liver (WHO, 2011). Recent studies have also suggested that it may be absorbed and metabolized by the skin following dermal exposure to free BPA in products such as those made from thermal printing papers (Mielke et al., 2011; Zalko et al., 2011). Glucuronidation has been recognized as a major metabolic pathway for BPA, resulting in the BPA-glucuronide conjugate metabolite (EFSA, 2008; FDA, 2008). Conjugation of BPA to BPA-sulphate has been shown to be a minor metabolic pathway (Dekant and Völkel, 2008). The BPA-glucuronide metabolite is rapidly excreted in urine with a half-life of less than 2 hours (WHO, 2011). Urinary levels of total BPA, including both conjugated and free unconjugated forms, are commonly used as biomarkers to assess recent exposures (Ye et al., 2005).

Characterization of the potential risk to human health from exposure to BPA includes key effects on the liver and on reproduction, including fertility and developmental effects (Environment Canada and Health Canada, 2008a; EU, 2010). Developmental
neurotoxicity studies in laboratory animals have suggested that, at low levels of exposure in fetuses and newborns, BPA can affect neural development and behaviour (Environment Canada and Health Canada, 2008a; WHO, 2011). An American prospective birth cohort study demonstrated affected behavioural and emotional regulation domains in 3-year-olds following gestational BPA exposure (Braun et al., 2011). The potential role of BPA and other environmental estrogens in the prevalence of obesity and related metabolic diseases, as well as certain types of cancer, is under intensive debate and investigation among scientific communities (Ben-Jonathan et al., 2009; Carwile and Michels, 2011; Newbold et al., 2009; Song et al., 2014; Soto et al., 2008).

The Government of Canada has conducted a scientific screening assessment of the impact of human and environmental exposure to BPA and determined that it is toxic to human health and the environment as per the criteria set out under the Canadian Environmental Protection Act, 1999 (CEPA 1999) (Canada, 1999; Canada, 2010a). Because of the uncertainty raised in some laboratory animal studies relating to the potential effects of low levels of BPA, a precautionary approach was applied when characterizing risk. Combining the highest potential exposure and subpopulations with potential vulnerability due to potential differences in the toxicokinetics and metabolism of BPA, the risk management strategy for health focused on decreasing exposure to newborns and infants (Environment Canada and Health Canada, 2008b). As of March 2010, under the Canada Consumer Product Safety Act, Health Canada has prohibited the manufacturing, advertisement, sale, or import of polycarbonate baby bottles that contain BPA (Canada, 2010b).

Health Canada has concluded that current dietary exposure to BPA through food packaging uses is not expected to pose a health risk to the general population, including newborns and young children (Health Canada, 2012). However, the general principle of as low as reasonably achievable (ALARA) was applied to continue efforts on limiting BPA exposure from food packaging applications to infants and newborns, specifically from pre-packaged infant formula products as a sole source food. As part of this ALARA approach, Health Canada committed to supporting industry to reduce levels of BPA in infant-formula can linings (Health Canada, 2010). In addition, Health Canada has assessed a number of proposed industry alternatives to BPA and deemed them acceptable for packaging of liquid infant-formula. Infant-formula manufacturers are now phasing out the use of BPA-containing packaging materials, and the can-coating industry has developed various BPA-free alternatives for can coatings currently available on the market. Health Canada will continue to review pre-market submissions for infant-formula packaging to ensure the lowest levels of BPA achievable (Health Canada, 2010). BPA is also included as a prohibited ingredient on the List of Prohibited and Restricted Cosmetic Ingredients (more commonly referred to as the Cosmetic Ingredient Hotlist or simply the Hotlist). The Hotlist is an administrative tool that Health Canada uses to communicate to manufacturers and others that certain substances, when present in a cosmetic, may contravene the general prohibition found in section 16 of the Food and Drugs Act or a provision of the Cosmetic Regulations (Health Canada, 2014). Risk management actions have also been developed under CEPA 1999 with the objective of minimizing releases of BPA in industrial effluents (Canada, 2012).

The Maternal-Infant Research on Environmental Chemicals (MIREC) Study is a national-level prospective biomonitoring study carried out in pregnant women aged 18 years and older from 10 sites across Canada (Arbuckle et al., 2013). In the MIREC Study of 1,936 participants in their first trimester of pregnancy, the geometric mean and 95th percentile for total BPA in urine were 0.80 µg/L and 5.40 µg/L, respectively (Arbuckle et al., 2014). The First Nations Biomonitoring Initiative (FNBI) is a nationally representative biomonitoring study of adult First Nations peoples living on reserves south of the 60° parallel (AFN, 2013). It comprises 13 randomly selected First Nation communities in Canada with 503 First Nations participants aged 20 years and older. The geometric mean and 95th percentile for total bisphenol A in urine were 1.55 µg/L and 11.27 µg/L, respectively.

Urinary total BPA (including both free and conjugated forms) was analyzed in the urine of Canadian Health Measures Survey participants aged 6 to 79 years in cycle 1 (2007–2009), and 3 to 79 years in cycle 2 (2009–2011) and cycle 3 (2012–2013). Data from these cycles are presented as both µg/L and µg/g creatinine. Finding a measurable amount of BPA in urine is an indicator of exposure to BPA and does not necessarily mean that an adverse health effect will occur.
### Table 9.1.1

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>5476</td>
<td>9.26</td>
<td>1.2 (1.1–1.2)</td>
<td>F</td>
<td>1.3 (1.1–1.4)</td>
<td>4.6 (4.1–5.1)</td>
<td>6.9 (5.6–8.2)</td>
</tr>
<tr>
<td>Total</td>
<td>6–79</td>
<td>2 (2009–2011)</td>
<td>2036</td>
<td>5.26</td>
<td>1.2 (1.1–1.3)</td>
<td>0.27 (0.22–0.31)</td>
<td>1.2 (1.1–1.3)</td>
<td>4.5 (3.9–5.0)</td>
<td>6.7 (4.8–8.5)</td>
</tr>
<tr>
<td>Total</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>5149</td>
<td>8.00</td>
<td>1.1 (1.0–1.2)</td>
<td>0.29 (0.26–0.32)</td>
<td>1.1 (0.95–1.2)</td>
<td>4.2 (3.5–4.8)</td>
<td>6.6 (5.7–7.5)</td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2659</td>
<td>7.67</td>
<td>1.3 (1.2–1.4)</td>
<td>0.23 (0.19–0.34)</td>
<td>1.4 (1.2–1.6)</td>
<td>4.4 (3.9–5.0)</td>
<td>6.7 (5.3–8.1)</td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>2 (2009–2011)</td>
<td>1021</td>
<td>4.90</td>
<td>1.3 (1.2–1.4)</td>
<td>0.27 (0.21–0.37)</td>
<td>1.3 (1.3–1.5)</td>
<td>4.6 (4.1–5.2)</td>
<td>7.3 (4.0–11)</td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2817</td>
<td>10.76</td>
<td>1.2 (1.1–1.3)</td>
<td>0.35 (0.26–0.46)</td>
<td>1.2 (0.98–1.4)</td>
<td>4.4 (3.7–5.0)</td>
<td>6.5 (4.5–7.5)</td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>2 (2009–2011)</td>
<td>1015</td>
<td>5.62</td>
<td>1.2 (1.0–1.3)</td>
<td>0.26 (0.21–0.32)</td>
<td>1.1 (0.98–1.3)</td>
<td>4.0 (2.9–5.2)</td>
<td>6.6 (4.8–8.4)</td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>2583</td>
<td>8.79</td>
<td>1.0 (0.88–1.2)</td>
<td>0.29 (&lt;LOD–0.36)</td>
<td>1.0 (0.90–1.1)</td>
<td>4.1 (3.2–4.9)</td>
<td>6.9 (5.3–8.5)</td>
</tr>
</tbody>
</table>

a For the purpose of total population comparisons, only values from participants aged 6–79 years were included as participants under the age of 6 years were not included in cycle 1 (2007–2009).

b If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.

F Data is too unreliable to be published.

### Table 9.1.2

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
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</thead>
<tbody>
<tr>
<td>Total</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>5462</td>
<td>9.26</td>
<td>1.4 (1.3–1.5)</td>
<td>0.39 (0.30–0.48)</td>
<td>1.3 (1.2–1.5)</td>
<td>4.7 (4.0–5.4)</td>
<td>7.2 (6.4–8.0)</td>
</tr>
<tr>
<td>Total</td>
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</table>

a For the purpose of total population comparisons, only values from participants aged 6–79 years were included as participants under the age of 6 years were not included in cycle 1 (2007–2009).

b If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.
<table>
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<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
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<th>95th (95% CI)</th>
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</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
b Data not available as participants under the age of 6 years were not included in cycle 1 (2007–2009).
E Use data with caution.
F Data is too unreliable to be published.
### Table 9.1.4


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<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
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<td>1 (2007–2009)</td>
<td>124</td>
<td>12.06</td>
<td>1.3 (1.2–1.5)</td>
<td>0.36E (0.22–0.51)</td>
<td>1.2 (1.0–1.4)</td>
<td>4.7 (3.8–5.7)</td>
<td>7.5 (6.1–8.8)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>358</td>
<td>6.11</td>
<td>1.0 (0.99–1.4)</td>
<td>0.39 (0.27–0.50)</td>
<td>1.1 (0.88–1.3)</td>
<td>4.2E (3.2–6.2)</td>
<td>6.9E (3.4–10)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>1074</td>
<td>9.86</td>
<td>0.9 (&lt;LOD–0.45)</td>
<td>0.39 (0.27–0.50)</td>
<td>1.1 (0.88–1.3)</td>
<td>4.2E (3.2–6.2)</td>
<td>6.9E (3.4–10)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>1 (2007–2009)</td>
<td>1081</td>
<td>11.66</td>
<td>1.1 (1.1–1.4)</td>
<td>0.39 (0.27–0.50)</td>
<td>1.1 (0.88–1.3)</td>
<td>4.3 (3.0–5.9)</td>
<td>7.6 (5.4–8.8)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>290</td>
<td>7.22</td>
<td>1.2 (0.99–1.4)</td>
<td>0.29E (&lt;LOD–0.45)</td>
<td>1.0 (0.80–1.1)</td>
<td>4.7 (3.3–6.8)</td>
<td>6.8E (2.9–11)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>1038</td>
<td>10.31</td>
<td>1.0 (0.97–1.1)</td>
<td>0.35 (0.30–0.41)</td>
<td>0.99 (0.94–1.0)</td>
<td>3.0 (2.7–3.4)</td>
<td>4.7E (2.7–6.7)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

b Data not available as participants under the age of 6 years were not included in cycle 1 (2007–2009).

E Use data with caution.

F Data is too unreliable to be published.
REFERENCES


EFSA (European Food Safety Authority) (2007). Opinion of the scientific panel on food additives, flavourings, processing aids and materials in contact with food on a request from the Commission related to 2,2-bis(4-hydroxyphenyl)propane (bisphenol A), question number EFSA-Q-2005-100. European Food Safety Authority Journal, 428, 1–75.

EFSA (European Food Safety Authority) (2008). Toxicokinetics of bisphenol A. Scientific opinion of the panel on food additives, flavourings, processing aids and materials in contact with food (AFC) on a request from the commission on the toxicokinetics of bisphenol A. European Food Safety Authority Journal, 759, 1–10.


9.2 TRICLOSAN

Triclosan (CASRN 3380-34-5) is a synthetic chemical with wide application since 1972 as an antimicrobial agent and as a preservative (Jones et al., 2000). It is used as a medicinal ingredient in non-prescription drug products and as a non-medicinal ingredient in cosmetics, natural health products, and drug products. Cosmetic products containing triclosan have been notified to Health Canada, including skin moisturizers (body, face, and hands), face and eye makeup, deodorant sticks/sprays, fragrances, tanning products, skin cleansers, shaving preparations, and shampoos (Environment Canada and Health Canada, 2012a). In addition, a number of products containing triclosan as an active medicinal ingredient are regulated as non-prescription drug products in Canada, including toothpastes, skin cleansers, and moisturizers (Health Canada, 2013). Triclosan is also used to control the
Triclosan does not occur naturally in the environment (Environment Canada and Health Canada, 2012a). The use of triclosan-containing products results in its release to waste-water systems and subsequently surface water (Environment Canada and Health Canada, 2012a). The potential routes of exposure for the general public are oral and dermal contact with products such as toothpastes and cosmetics that contain triclosan, ingestion of triclosan-contaminated drinking water, breast milk, or ingestion of household dust (Environment Canada and Health Canada, 2012b).

Following oral exposures, triclosan is rapidly absorbed and distributed in humans, with plasma levels increasing rapidly within 1 to 4 hours (Environment Canada and Health Canada, 2012b). Absorption following dermal exposure to triclosan-containing products ranges from 11% to 17% in humans (Maibach, 1969; Queckenberg et al., 2010; Stierlin, 1972). Only limited absorption (approximately 5% to 10%) occurs under normal conditions of toothpaste use (SCCP, 2009). Following all routes of administration, absorbed triclosan is nearly totally converted to glucuronic and sulfuric acid conjugates (Fang et al., 2010). Triclosan is rapidly eliminated after metabolism with an observed half-life in humans ranging from 13 to 29 hours following oral administration (SCCP, 2009). About 24% to 83% of absorbed triclosan is excreted in urine, mostly as the glucuronide conjugate (Fang et al., 2010; Sandborgh-Englund et al., 2006). Excretion of triclosan in feces is as the free unchanged compound and represents a smaller portion of the administered dose (10% to 30%) (Environment Canada and Health Canada, 2012b). Currently, there is no evidence of bioaccumulation potential in humans (SCCP, 2009). The concentration of total triclosan in urine (conjugated and free) can be used as a biomarker of exposure to triclosan (Calafat et al., 2007).

Triclosan is not acutely toxic to mammals, but it can interact with cellular enzymes and receptors (Calafat et al., 2007). The potential effects of these interactions remain unknown. In rodents, there have been observations of adverse effects of triclosan on thyroid hormone homeostasis resulting from liver toxicity; however, the overall weight of evidence does not currently support effects of triclosan on thyroid function as a critical effect for risk characterization in humans (Environment Canada and Health Canada, 2012b). To date, triclosan has not been assessed for carcinogenic potential by the International Agency for Research on Cancer; the United States Environmental Protection Agency has classified triclosan as not likely to be carcinogenic to humans (EPA, 2008).

Health Canada and Environment Canada have jointly reviewed triclosan in a preliminary risk assessment and have proposed to conclude that it is not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger in Canada to human life or health (Environment Canada and Health Canada, 2012b). In the same preliminary assessment, Health Canada’s Pest Management Regulatory Agency has proposed to conclude that the use of pest control products containing triclosan in Canada does not pose an unacceptable risk to human health (Environment Canada and Health Canada, 2012b). However, at current environmental levels, it is proposed to conclude that triclosan is an ecological concern and therefore it meets the definition of toxic under the Canadian Environmental Protection Act, 1999 (Canada, 1999).

Triclosan is included as a restricted ingredient on the List of Prohibited and Restricted Cosmetic Ingredients (more commonly referred to as the Cosmetic Ingredient Hotlist or simply the Hotlist). The Hotlist is an administrative tool that Health Canada uses to communicate to manufacturers and others that certain substances, when present in a cosmetic, may contravene the general prohibition found in section 16 of the Food and Drugs Act or a provision of the Cosmetic Regulations (Health Canada, 2014b). The Hotlist indicates concentration limits of triclosan in mouthwash and other cosmetic products (Health Canada, 2014b). In addition, the Hotlist indicates that oral cosmetics containing triclosan shall include a label statement...
indicating that the product is not to be used by children under 12 years of age (Health Canada, 2014b). The Hotlist also indicates that mouthwashes include a label statement to the effect of “avoid swallowing” (Health Canada, 2014b).

Total triclosan (including both free and conjugated forms) was analyzed in the urine of Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years and is presented as both µg/L and µg/g creatinine. Finding a measurable amount of triclosan in urine is an indicator of exposure to triclosan and does not necessarily mean that an adverse health effect will occur.

### Table 9.2.1

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>5645</td>
<td>34.47</td>
<td>17 (15–18)</td>
<td>&lt;LOD</td>
<td>350 (270–430)</td>
<td>720 (460–980)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2815</td>
<td>34.03</td>
<td>17 (14–21)</td>
<td>&lt;LOD</td>
<td>330 (180–480)</td>
<td>760 (380–1100)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2830</td>
<td>34.91</td>
<td>17 (13–22)</td>
<td>&lt;LOD</td>
<td>9.6 (7.8–12)</td>
<td>390 (220–550)</td>
<td>700 (380–1100)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>523</td>
<td>29.45</td>
<td>8.9 (7.3–11)</td>
<td>&lt;LOD</td>
<td>7.3 (4.9–9.6)</td>
<td>50 (40–81)</td>
<td>120 (68–160)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>518</td>
<td>36.29</td>
<td>9.5 (7.4–13)</td>
<td>&lt;LOD</td>
<td>7.7 (4.3–11)</td>
<td>78 (43–110)</td>
<td>110 (47–170)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>515</td>
<td>33.98</td>
<td>8.5 (6.7–11)</td>
<td>&lt;LOD</td>
<td>3.8 (2.5–5.9)</td>
<td>130 (54–210)</td>
<td>250 (82–410)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>1072</td>
<td>37.22</td>
<td>16 (12–22)</td>
<td>&lt;LOD</td>
<td>8.9 (6.6–11)</td>
<td>360 (140–620)</td>
<td>910 (280–1600)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>290</td>
<td>41.72</td>
<td>–</td>
<td>&lt;LOD</td>
<td>4.8 (2.5–8.8)</td>
<td>360 (150–560)</td>
<td>590 (400–750)</td>
</tr>
</tbody>
</table>

a If ≥40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.
### Table 9.2.2

Triclosan (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>513</td>
<td>33.98</td>
<td>8.5 (6.2–12)</td>
<td>&lt;LOD</td>
<td>5.0F (4.0–7.3)</td>
<td>150F (65–250)</td>
<td>270F</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>289</td>
<td>41.72</td>
<td>–</td>
<td>&lt;LOD</td>
<td>7.1 (5.0–9.2)</td>
<td>370F (200–550)</td>
<td>600F</td>
</tr>
</tbody>
</table>

---

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.

F Data is too unreliable to be published.
REFERENCES


10.1 ARSENIC

Arsenic (CASRN 7440-38-2) is a naturally occurring element making up a small fraction (0.00015%) of the Earth’s crust (ATSDR, 2007; Emsley, 2001). It is classified as a metalloid, exhibiting properties of both a metal and a non-metal. Arsenic is commonly found as an inorganic sulphide complexed with other metals (CCME, 1997). Arsenic also forms stable organic compounds in its trivalent (+3) and pentavalent (+5) states. Common organic arsenic compounds include monomethylarsonic acid (MMA), dimethylarsinic acid (DMA), arsenobetaine, and arsenocholine (WHO, 2001).

Arsenic may enter lakes, rivers, or groundwater naturally through erosion and weathering of soils, minerals, and ores (Health Canada, 2006). The primary anthropogenic sources of arsenic are the smelting of metal ores, the use of arsenical pesticides, and the burning of fossil fuels (WHO, 2001).

Arsenic is used in the manufacture of transistors, lasers, and semi-conductors, and in the processing of glass, pigments, textiles, paper, metal adhesives, ceramics, wood preservatives, ammunition, and explosives. Historical uses of arsenic include application of lead arsenate as a pesticide in apple orchards and vineyards and arsenic trioxide as a herbicide (ATSDR, 2007; Health Canada, 2006). Chromated copper arsenate was formerly used as a wood preservative in residential construction projects, such as playground structures and decks; however, it is now used only for industrial purposes and for domestic wood foundations (Health Canada, 2005). Organic arsenical herbicides, such as MMA and DMA, are no longer registered for use in Canada (Environment Canada, 2008; Health Canada, 2014a).

The public can be exposed to arsenic through food, drinking water, soil, and ambient air (Environment Canada and Health Canada, 1993). Food is the major source of exposure with total arsenic concentrations being highest in seafood (IARC, 2012). Organic forms of arsenic, including arsenobetaine and arsenocholine, make up the majority of arsenic in seafood (Ackley et al., 1999; Leufroy et al., 2011; Rutten et al., 2012). In other foods, there is growing evidence to suggest that inorganic arsenic may represent the predominant form of arsenic (Batista et al., 2011; CFIA, 2013; Conklin and Chen, 2012; Huang et al., 2012). Exposure to arsenic may also arise from indoor house dust; levels in dust can exceed levels in soil (Rasmussen et al., 2001). Further, exposure to arsenic may be elevated in populations residing in areas where industrial or natural sources occur.

Inorganic arsenic and organic arsenic are readily absorbed via the oral and inhalation routes of exposure; arsenic in all its forms is not readily absorbed via the dermal route. Absorption of arsenic is much lower for highly insoluble forms of arsenic such as arsenic sulfide, arsenic triselenide, and lead arsenate (ATSDR, 2007). Following absorption, arsenic appears rapidly in blood circulation where it binds primarily to haemoglobin. Within 24 hours, it is found in the liver, kidney, lung, spleen, and skin. Skin, bone, and muscle represent the major storage organs. In cases of chronic exposure, arsenic will preferentially accumulate in tissues rich
in keratin or sulfhydryl functional groups, such as hair, nails, skin, and other protein-containing tissues (HBM Commission, 2003). Metabolism of inorganic arsenic involves an initial reduction of pentavalent to trivalent arsenic followed by oxidative methylation to monomethylated, dimethylated, and trimethylated products, including MMA and DMA (WHO, 2011). Methylation facilitates the excretion of inorganic arsenic from the body because the end-products MMA and DMA are water soluble and readily excreted in urine (WHO, 2001). Organic arsenic species do not undergo significant metabolism and are predominantly and rapidly eliminated in urine (WHO, 2001).

Biomarkers of arsenic exposure include the levels of arsenic or its metabolites in blood, hair, nails, and urine (WHO, 2001). Measurements of speciated metabolites in urine expressed either as inorganic arsenic or as the sum of metabolites (inorganic arsenic + MMA + DMA) are generally accepted as the most reliable indicator of recent arsenic exposure (ATSDR, 2007; WHO, 2001). Measurements of arsenic in urine have been used to identify recent arsenic ingestion or above-average exposures in populations living near industrial point sources of arsenic (ATSDR, 2007).

Acute oral arsenic exposure may cause gastrointestinal effects in humans as well as pain to the extremities and muscles (Health Canada, 2006). These symptoms are often followed by numbness and tingling of the extremities and muscular cramping and may progress into burning paraesthesias of the extremities, palmar-plantar hyperkeratosis, and deterioration in motor and sensory responses (Health Canada, 2006).

Chronic exposure to inorganic arsenic has been associated with decreased lung function, non-cancer skin effects, and cardiovascular effects including increased incidence of high blood pressure and circulatory problems (ATSDR, 2007; Environment Canada and Health Canada, 1993). In addition, increased incidences of skin cancer and various cancers of the internal organs have been associated with chronic ingestion of inorganic arsenic-contaminated drinking water (Health Canada, 2006). Much of the evidence comes from an epidemiological study conducted in southwestern Taiwan (Chen et al., 1985; Health Canada, 2006; Tseng, 1977; Wu et al., 1989). Arsenic and inorganic arsenic compounds are classified as carcinogenic to humans by Health Canada and other international agencies (EPA, 1998; Health Canada, 2006; IARC, 2012). Although the majority of assessments on the toxicity of arsenic have concentrated on the inorganic forms, recent studies have highlighted the potential for organic arsenic compounds, in particular the pentavalent DMA, to exert carcinogenic effects (Cohen et al., 2006; IARC, 2012; Schwerdtle et al., 2003). The International Agency for Research on Cancer (IARC) has classified the methylated arsenic metabolites MMA and DMA as Group 2B, possibly carcinogenic to humans, based on evidence from experimental animals (IARC, 2012). IARC has also evaluated arsenobetaine and other organic arsenic compounds and found them to be not classifiable as to their carcinogenicity to humans (Group 3) (IARC, 2012).

Health Canada and Environment Canada concluded that arsenic and its inorganic compounds in Canada may be harmful to the environment and may constitute a danger to human life or health (Environment Canada and Health Canada, 1993). Inorganic arsenic compounds are listed on Schedule 1, List of Toxic Substances, under the Canadian Environmental Protection Act, 1999 (CEPA 1999). The Act allows the federal government to control the importation, manufacture, distribution, and use of inorganic arsenic compounds in Canada (Canada, 1999; Canada, 2000). Risk management actions under CEPA 1999 have been developed to control releases of arsenic from thermal electric power generation, base-metal smelting, wood preservation, and steel manufacturing processes (Environment Canada, 2010). Arsenic and its compounds are included as prohibited ingredients on the List of Prohibited and Restricted Cosmetic Ingredients (more commonly referred to as the Cosmetic Ingredient Hotlist or simply the Hotlist). The Hotlist is an administrative tool that Health Canada uses to communicate to manufacturers and others that certain substances, when present in a cosmetic, may contravene the general prohibition found in section 16 of the Food and Drugs Act or a provision of the Cosmetic Regulations (Canada, 1985; Health Canada, 2014b). The Food and Drug Regulations prohibit the sale in Canada of drugs for human use containing arsenic or any of its salts or derivatives (Canada, 2012). Further, the leachable arsenic content in a variety of consumer products is regulated under the Canada Consumer Product Safety Act (Canada, 2010a). These regulated consumer products include paints and other surface coatings on cribs, toys, and other products for use by a child in learning or play situations (Canada, 2010b; Canada, 2011).
The Federal-Provincial-Territorial Committee on Drinking Water has developed a guideline for Canadian drinking water quality that establishes a maximum acceptable concentration for arsenic in drinking water (Health Canada, 2006). The guideline was developed based on the incidence of internal (lung, bladder, and liver) cancers in humans and the ability of currently available treatment technologies to remove arsenic from drinking water at or below the guideline level (Health Canada, 2006). Arsenic is also included in the list of various chemicals analyzed as part of Health Canada’s ongoing Total Diet Study surveys (Health Canada, 2013). The food items analyzed represent those that are most typical of the Canadian diet, and the surveys are used to provide dietary exposure estimates for chemicals that Canadians in different age-sex groups are exposed to through the food supply. The concentration of arsenic in some foods is regulated by Health Canada under the Food and Drug Regulations; current food tolerances, specifically those for arsenic in a variety of beverages including apple juice and bottled water, are in the process of being updated (Canada, 2012; Health Canada, 2014c).

In a study carried out in British Columbia to assess the levels of trace elements in 61 non-smoking adults aged 30 to 65 years, the geometric mean concentration and 95th percentile of total arsenic in urine were 27.8 µg/g creatinine and 175.5 µg/g creatinine, respectively (Clark et al., 2007). In a biomonitoring study carried out in the region of the city of Quebec with 500 participants aged 18 to 65 years, the geometric mean of total arsenic in urine was 12.73 µg/L and in whole blood was 0.95 µg/L (INSPQ, 2004).

Arsenite (+3), arsenate (+5), and methylated metabolites of arsenic (MMA and DMA) were analyzed individually in the urine of Canadian Health Measures Survey (CHMS) cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years. The data from these cycles are presented as both µg As/L and µg As/g creatinine. The organoarsenic compounds, arsenobetaine and arsenocholine, were analyzed together in the urine of CHMS cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years and arsenocholine was also analyzed alone in cycle 3. The data are presented as both µg As/L and µg As/g creatinine. Finding a measurable amount of arsenic in urine is an indicator of exposure to arsenic and does not necessarily mean that an adverse health effect will occur. These data provide baseline levels for the urinary arsenocholine in the Canadian population.
Table 10.1.1
Arsenate — Geometric means and selected percentiles of urine concentrations (μg As/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011)* and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2538</td>
<td>99.49</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2536</td>
<td>99.25</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1285</td>
<td>99.46</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>516</td>
<td>98.84</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>500</td>
<td>98.60</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>511</td>
<td>99.61</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>507</td>
<td>99.61</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>510</td>
<td>99.41</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>510</td>
<td>98.82</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>357</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>99.04</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>289</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>352</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

*a In the Second Report on Human Biomonitoring of Environmental Chemicals in Canada, all speciated arsenic was reported as μg of arsenic species per litre (e.g., μg arsenate/L). For this reason, the values presented in this report may differ from those in the Second Report.

b If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
### Table 10.1.2
Arsenate (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg As/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011)\(^a\) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>515</td>
<td>98.84</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>499</td>
<td>98.60</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>99.61</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>507</td>
<td>99.61</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>510</td>
<td>98.82</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>288</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>352</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

\(^a\) In the Second Report on Human Biomonitoring of Environmental Chemicals in Canada, all speciated arsenic was reported as μg of arsenic species per litre (e.g., μg arsenate/L). For this reason, the values presented in this report may differ from those in the Second Report.

\(^b\) If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
**Table 10.1.3**

Arsenite — Geometric means and selected percentiles of urine concentrations (μg As/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011)* and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD&lt;sup&gt;a&lt;/sup&gt;</th>
<th>GM (95% CI)</th>
<th>10&lt;sup&gt;b&lt;/sup&gt; (95% CI)</th>
<th>50&lt;sup&gt;b&lt;/sup&gt; (95% CI)</th>
<th>90&lt;sup&gt;b&lt;/sup&gt; (95% CI)</th>
<th>95&lt;sup&gt;b&lt;/sup&gt; (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2537</td>
<td>75.60</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.7 (1–2.3)</td>
<td>2.7&lt;sup&gt;E&lt;/sup&gt;</td>
<td>(1.3–4.9)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2535</td>
<td>73.96</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.7&lt;sup&gt;E&lt;/sup&gt;</td>
<td></td>
<td>(0.92–2.5)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1271</td>
<td>72.54</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.7 (1–2.3)</td>
<td>2.8&lt;sup&gt;E&lt;/sup&gt;</td>
<td>(0.82–4.7)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1250</td>
<td>71.20</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.4 (1–1.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1266</td>
<td>78.67</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.5&lt;sup&gt;F&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;E&lt;/sup&gt;</td>
<td>(0.72–2.3)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1285</td>
<td>76.65</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td></td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>516</td>
<td>84.50</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.79&lt;sup&gt;E&lt;/sup&gt;</td>
<td>1.3&lt;sup&gt;E&lt;/sup&gt;</td>
<td>(0.74–1.9)</td>
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<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>500</td>
<td>81.80</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.94 (LOD–1.2)</td>
<td>1.9&lt;sup&gt;E&lt;/sup&gt;</td>
<td>(0.75–3.0)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>511</td>
<td>78.86</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.0&lt;sup&gt;E&lt;/sup&gt;</td>
<td>1.8&lt;sup&gt;E&lt;/sup&gt;</td>
<td>(1.1–2.4)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>506</td>
<td>76.09</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.1 (0.81–1.4)</td>
<td>1.6&lt;sup&gt;E&lt;/sup&gt;</td>
<td>(0.92–2.5)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>510</td>
<td>72.35</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.9&lt;sup&gt;E&lt;/sup&gt;</td>
<td></td>
<td>(1.2–2.7)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>510</td>
<td>68.43</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.5&lt;sup&gt;E&lt;/sup&gt;</td>
<td>2.6&lt;sup&gt;E&lt;/sup&gt;</td>
<td>(1.1–4.0)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>69.86</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.9&lt;sup&gt;F&lt;/sup&gt;</td>
<td></td>
<td>(1.0–3.3)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>355</td>
<td>70.70</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td></td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>356</td>
<td>70.51</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.3&lt;sup&gt;E&lt;/sup&gt;</td>
<td>2.0&lt;sup&gt;E&lt;/sup&gt;</td>
<td>(0.71–1.8)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>70.19</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td></td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>289</td>
<td>73.01</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.9&lt;sup&gt;F&lt;/sup&gt;</td>
<td></td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>352</td>
<td>74.43</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.8 (1.1–2.4)</td>
<td>3.2&lt;sup&gt;E&lt;/sup&gt;</td>
<td>(1.3–3.2)</td>
</tr>
</tbody>
</table>

* In the Second Report on Human Biomonitoring of Environmental Chemicals in Canada, all speciated arsenic was reported as μg of arsenic species per litre (e.g., μg arsenate/L). For this reason, the values presented in this report may differ from those in the Second Report.

<sup>a</sup> If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

<sup>b</sup> Use data with caution.

<sup>E</sup> Data is too unreliable to be published.
### Table 10.1.4

Arsenite (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg As/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011)\(^a\) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2527</td>
<td>75.60</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>2.0 (1.5–2.3)</td>
<td>2.9 (1.9–3.9)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2534</td>
<td>73.96</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.9F (1.2–2.7)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1267</td>
<td>72.54</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.4F (0.85–1.9)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1250</td>
<td>71.20</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.2 (0.94–1.5)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1260</td>
<td>78.67</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>2.2 (1.6–2.8)</td>
<td>3.0 (2.1–3.9)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1284</td>
<td>76.65</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>2.4F (0.86–3.9)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>515</td>
<td>84.50</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.9 (1.7–2.2)</td>
<td>2.9 (1.9–3.9)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>499</td>
<td>81.80</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>2.5F (1.3–3.7)</td>
<td>4.3F (2.6–6.1)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>78.86</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.6F (1.0–2.2)</td>
<td>2.2F (1.2–3.1)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>506</td>
<td>76.09</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.7 (1.1–2.2)</td>
<td>2.5F (1.3–3.6)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>508</td>
<td>72.35</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.4F (0.85–1.9)</td>
<td>2.9F (1.4–4.5)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>510</td>
<td>68.43</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.4F (LOD–2.0)</td>
<td>1.9F (1.0–2.8)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>353</td>
<td>69.86</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.9F (0.89–3.0)</td>
<td>2.6F (0.86–4.3)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>355</td>
<td>70.70</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.9 (1.3–2.8)</td>
<td>2.0F (1.2–4.8)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>354</td>
<td>70.51</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.9 (1.3–2.6)</td>
<td>2.0F (1.2–4.8)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>70.19</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>2.3F (1.2–3.3)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>288</td>
<td>73.01</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>2.3F (1.2–3.3)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>352</td>
<td>74.43</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>2.3F (0.78–3.8)</td>
<td>3.7F (1.7–5.6)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) In the Second Report on Human Biomonitoring of Environmental Chemicals in Canada, all speciated arsenic was reported as μg of arsenic species per litre (e.g., μg arsenate/L). For this reason, the values presented in this report may differ from those in the Second Report.

\(^b\) If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.

F Data is too unreliable to be published.
Table 10.1.5
Arsenocholine — Geometric means and selected percentiles of urine concentrations (μg As/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD&lt;sup&gt;a&lt;/sup&gt;</th>
<th>GM (95% CI)</th>
<th>10&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
<th>50&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
<th>90&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
<th>95&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2536</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1251</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1285</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>500</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>507</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>510</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>355</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>352</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

<sup>a</sup> If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

Table 10.1.6
Arsenocholine (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg As/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD&lt;sup&gt;a&lt;/sup&gt;</th>
<th>GM (95% CI)</th>
<th>10&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
<th>50&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
<th>90&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
<th>95&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2535</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1251</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1284</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>499</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>507</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>510</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>355</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>352</td>
<td>100</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

<sup>a</sup> If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
## Table 10.1.7

arsenocholine and arsenobetaine — Geometric means and selected percentiles of urine concentrations (μg As/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD&lt;sup&gt;a&lt;/sup&gt;</th>
<th>GM (95% CI)</th>
<th>10&lt;sup&gt;b&lt;/sup&gt; (95% CI)</th>
<th>50&lt;sup&gt;b&lt;/sup&gt; (95% CI)</th>
<th>90&lt;sup&gt;b&lt;/sup&gt; (95% CI)</th>
<th>95&lt;sup&gt;b&lt;/sup&gt; (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2538</td>
<td>48.50</td>
<td>&lt;LOD</td>
<td>1.4&lt;sup&gt;e&lt;/sup&gt; (1.0–2.2)</td>
<td>28&lt;sup&gt;e&lt;/sup&gt; (16–39)</td>
<td>48&lt;sup&gt;e&lt;/sup&gt; (30–67)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2536</td>
<td>48.15</td>
<td>&lt;LOD</td>
<td>1.4&lt;sup&gt;e&lt;/sup&gt; (1.0–2.1)</td>
<td>24&lt;sup&gt;e&lt;/sup&gt; (11–38)</td>
<td>56&lt;sup&gt;e&lt;/sup&gt; (37–75)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1271</td>
<td>46.34</td>
<td>&lt;LOD</td>
<td>1.5&lt;sup&gt;e&lt;/sup&gt; (1.0–2.5)</td>
<td>29&lt;sup&gt;e&lt;/sup&gt; (14–43)</td>
<td></td>
<td>F</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1251</td>
<td>47.40</td>
<td>&lt;LOD</td>
<td>1.4&lt;sup&gt;e&lt;/sup&gt; (1.0–2.0)</td>
<td>21&lt;sup&gt;e&lt;/sup&gt; (13–29)</td>
<td>38&lt;sup&gt;e&lt;/sup&gt; (25–51)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1267</td>
<td>50.67</td>
<td>&lt;LOD</td>
<td>1.4&lt;sup&gt;e&lt;/sup&gt; (1.0–2.0)</td>
<td>29&lt;sup&gt;e&lt;/sup&gt; (15–41)</td>
<td>49&lt;sup&gt;e&lt;/sup&gt; (29–69)</td>
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<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1285</td>
<td>48.87</td>
<td>&lt;LOD</td>
<td>1.5&lt;sup&gt;e&lt;/sup&gt; (1.0–2.5)</td>
<td>28&lt;sup&gt;e&lt;/sup&gt; (11–36)</td>
<td>58&lt;sup&gt;e&lt;/sup&gt; (33–83)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>516</td>
<td>59.69</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td></td>
<td>34&lt;sup&gt;e&lt;/sup&gt; (19–49)</td>
</tr>
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<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>500</td>
<td>57.40</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td></td>
<td>27&lt;sup&gt;e&lt;/sup&gt; (14–39)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>511</td>
<td>58.12</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>507</td>
<td>59.57</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>510</td>
<td>57.65</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>12&lt;sup&gt;e&lt;/sup&gt; (6.3–17)</td>
<td></td>
<td>38&lt;sup&gt;e&lt;/sup&gt; (16–59)</td>
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<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>510</td>
<td>51.18</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>16&lt;sup&gt;e&lt;/sup&gt; (7.2–24)</td>
<td></td>
<td>37&lt;sup&gt;e&lt;/sup&gt; (17–56)</td>
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<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>38.59</td>
<td>&lt;LOD</td>
<td>2.3&lt;sup&gt;e&lt;/sup&gt; (1.3–3.6)</td>
<td>F</td>
<td>33&lt;sup&gt;e&lt;/sup&gt; (15–52)</td>
<td>68&lt;sup&gt;e&lt;/sup&gt; (20–110)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>355</td>
<td>44.51</td>
<td>&lt;LOD</td>
<td>F</td>
<td>19&lt;sup&gt;e&lt;/sup&gt; (11–28)</td>
<td></td>
<td>35&lt;sup&gt;e&lt;/sup&gt; (12–58)</td>
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<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>357</td>
<td>30.81</td>
<td>&lt;LOD</td>
<td>1.8&lt;sup&gt;e&lt;/sup&gt; (1.4–2.4)</td>
<td>F</td>
<td>35&lt;sup&gt;e&lt;/sup&gt; (19–52)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>34.29</td>
<td>&lt;LOD</td>
<td>2.6&lt;sup&gt;e&lt;/sup&gt; (1.3–3.8)</td>
<td>F</td>
<td></td>
<td>57&lt;sup&gt;e&lt;/sup&gt; (30–84)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>289</td>
<td>29.41</td>
<td>&lt;LOD</td>
<td>3.6&lt;sup&gt;e&lt;/sup&gt; (2.2–5.9)</td>
<td>F</td>
<td>30&lt;sup&gt;e&lt;/sup&gt; (16–55)</td>
<td>74&lt;sup&gt;e&lt;/sup&gt; (33–120)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>352</td>
<td>30.11</td>
<td>&lt;LOD</td>
<td>2.6&lt;sup&gt;e&lt;/sup&gt; (1.8–3.8)</td>
<td>F</td>
<td>21&lt;sup&gt;e&lt;/sup&gt; (13–34)</td>
<td>67&lt;sup&gt;e&lt;/sup&gt; (29–100)</td>
</tr>
</tbody>
</table>

<sup>a</sup> In the Second Report on Human Biomonitoring of Environmental Chemicals in Canada, all speciated arsenic was reported as μg of arsenic species per litre (e.g., μg arsenate/L). For this reason, the values presented in this report may differ from those in the Second Report.

<sup>b</sup> If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

<sup>E</sup> Use data with caution.

<sup>F</sup> Data is too unreliable to be published.
### Table 10.1.8
Arsenocholine and arsenobetaine (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg As/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2528</td>
<td>48.50</td>
<td>&lt;LOD</td>
<td>1.3 (&lt;=LOD–2.5)</td>
<td>22 (16–28)</td>
<td>44 (19–71)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2535</td>
<td>48.15</td>
<td>&lt;LOD</td>
<td>1.6 (1.1–2.1)</td>
<td>25 (12–39)</td>
<td>44 (24–63)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1267</td>
<td>46.34</td>
<td>&lt;LOD</td>
<td>F</td>
<td>18 (9.4–27)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1251</td>
<td>47.40</td>
<td>&lt;LOD</td>
<td>1.2 (0.77–1.6)</td>
<td>16 (7.3–24)</td>
<td>34 (25–43)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1284</td>
<td>48.87</td>
<td>&lt;LOD</td>
<td>2.1 (0.84–3.3)</td>
<td>33 (9.5–56)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>515</td>
<td>59.69</td>
<td>&lt;LOD</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>499</td>
<td>57.40</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>21 (11–31)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>58.12</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>507</td>
<td>59.57</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td>40 (12–69)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>508</td>
<td>57.65</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>9.3 (4.0–15)</td>
<td>24 (10–38)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>510</td>
<td>51.18</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>10 (3.8–17)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>353</td>
<td>38.59</td>
<td>1.9 (1.2–2.8)</td>
<td>&lt;LOD</td>
<td>F</td>
<td>22 (7.8–37)</td>
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<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>355</td>
<td>44.51</td>
<td>&lt;LOD</td>
<td>1.4 (0.89–1.9)</td>
<td>12 (5.5–19)</td>
<td>21 (9.8–32)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>30.81</td>
<td>1.8 (1.3–2.5)</td>
<td>&lt;LOD</td>
<td>1.9 (&lt;LOD–3.1)</td>
<td>17 (10–24)</td>
<td>24 (9.8–39)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>34.29</td>
<td>2.6 (1.6–4.4)</td>
<td>&lt;LOD</td>
<td>F</td>
<td>33 (14–52)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>288</td>
<td>29.41</td>
<td>4.2 (2.6–6.8)</td>
<td>&lt;LOD</td>
<td>4.6 (1.7–7.5)</td>
<td>47 (13–80)</td>
<td>84 (43–120)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>352</td>
<td>30.11</td>
<td>2.9 (1.9–4.6)</td>
<td>&lt;LOD</td>
<td>F</td>
<td>35 (13–57)</td>
<td>F</td>
</tr>
</tbody>
</table>

a In the Second Report on Human Biomonitoring of Environmental Chemicals in Canada, all speciated arsenic was reported as μg of arsenic species per litre (e.g., μg arsenate/L). For this reason, the values presented in this report may differ from those in the Second Report.

b If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.

F Data is too unreliable to be published.
### Table 10.1.9

Dimethylarsinic acid (DMA) — Geometric means and selected percentiles of urine concentrations (μg As/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2538</td>
<td>3.78</td>
<td>3.5 (3.0–4.0)</td>
<td>0.93 (0.89–0.97)</td>
<td>3.6 (3.1–4.1)</td>
<td>11 (8.3–13)</td>
<td>16 (6.8–25)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2536</td>
<td>3.86</td>
<td>3.6 (3.2–4.0)</td>
<td>1.1 (0.89–1.4)</td>
<td>3.4 (3.0–3.8)</td>
<td>11 (7.8–13)</td>
<td>16 (7.4–25)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1271</td>
<td>3.15</td>
<td>3.6 (3.1–4.3)</td>
<td>0.95 (&lt;LOD–1.3)</td>
<td>3.7 (2.8–4.5)</td>
<td>11 (7.9–14)</td>
<td>16 (7.7–24)</td>
</tr>
<tr>
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<td>3 (2012–2013)</td>
<td>1251</td>
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<td>3.8 (3.3–4.4)</td>
<td>1.3E (0.75–1.8)</td>
<td>3.8 (3.3–4.3)</td>
<td>9.8 (7.6–12)</td>
<td>14E (4.8–23)</td>
</tr>
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<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1267</td>
<td>4.42</td>
<td>3.3 (2.8–3.9)</td>
<td>0.92 (0.75–1.1)</td>
<td>3.5 (3.0–3.9)</td>
<td>11 (7.5–14)</td>
<td>18E (7.3–29)</td>
</tr>
<tr>
<td>Females</td>
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<td>3 (2012–2013)</td>
<td>1285</td>
<td>4.75</td>
<td>3.4 (2.9–4.1)</td>
<td>1.0 (0.85–1.2)</td>
<td>3.1 (2.7–3.5)</td>
<td>12 (8.4–16)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>516</td>
<td>3.68</td>
<td>3.6 (3.1–4.3)</td>
<td>1.4E (0.89–1.9)</td>
<td>3.5 (3.0–4.0)</td>
<td>9.4 (6.9–12)</td>
<td>13E (9.5–18)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>500</td>
<td>3.00</td>
<td>3.3 (3.0–3.8)</td>
<td>1.1 (0.93–1.4)</td>
<td>3.4 (3.2–3.8)</td>
<td>10 (7.8–12)</td>
<td>16E (9.9–21)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>511</td>
<td>2.74</td>
<td>3.9 (3.5–4.6)</td>
<td>1.5 (1.0–1.9)</td>
<td>4.1 (3.5–4.7)</td>
<td>9.8 (8.4–11)</td>
<td>14E (7.7–20)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>507</td>
<td>2.76</td>
<td>3.6 (3.1–4.3)</td>
<td>1.1E (&lt;LOD–1.6)</td>
<td>3.7 (3.0–4.4)</td>
<td>9.1 (6.6–12)</td>
<td>14E (6.9–22)</td>
</tr>
<tr>
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<td>12–19</td>
<td>2 (2009–2011)</td>
<td>510</td>
<td>2.75</td>
<td>3.6 (2.4–4.0)</td>
<td>0.94E (&lt;LOD–1.9)</td>
<td>3.5 (3.0–4.4)</td>
<td>11 (7.5–14)</td>
<td>17E (9.3–25)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>510</td>
<td>3.53</td>
<td>3.6 (3.0–3.9)</td>
<td>1.3 (0.98–1.7)</td>
<td>3.4 (2.6–4.2)</td>
<td>9.9 (6.6–13)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>5.63</td>
<td>3.6 (2.9–4.5)</td>
<td>0.92 (0.72–1.1)</td>
<td>3.9 (3.0–4.3)</td>
<td>22E (11–33)</td>
<td>22E (11–33)</td>
</tr>
<tr>
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<td>3 (2012–2013)</td>
<td>355</td>
<td>4.79</td>
<td>3.8 (3.3–4.5)</td>
<td>1.2E (&lt;LOD–1.9)</td>
<td>3.5 (2.9–4.1)</td>
<td>12E (4.4–20)</td>
<td>24E (8.5–40)</td>
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<tr>
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<td>357</td>
<td>5.32</td>
<td>3.2 (2.8–3.8)</td>
<td>0.91E (&lt;LOD–1.2)</td>
<td>3.1 (2.5–3.8)</td>
<td>9.0 (7.4–11)</td>
<td>12E (8.8–15)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>6.09</td>
<td>3.5 (2.8–4.4)</td>
<td>1.1 (0.77–1.5)</td>
<td>3.4 (2.6–4.1)</td>
<td>12E (6.0–17)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
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<td>2 (2009–2011)</td>
<td>289</td>
<td>3.46</td>
<td>3.6 (2.8–4.5)</td>
<td>0.92 (0.82–1.0)</td>
<td>3.6 (2.9–4.3)</td>
<td>13E (5.8–20)</td>
<td>21E (6.5–35)</td>
</tr>
<tr>
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<td>60–79</td>
<td>3 (2012–2013)</td>
<td>352</td>
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<td>3.5 (3.0–4.2)</td>
<td>1.0 (0.86–1.2)</td>
<td>3.4 (2.6–4.2)</td>
<td>10 (7.4–13)</td>
<td>18E (10–28)</td>
</tr>
</tbody>
</table>

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**Notes:**

- **a** In the *Second Report on Human Biomonitoring of Environmental Chemicals in Canada*, all speciated arsenic was reported as μg of arsenic species per litre (e.g., μg arsenate/L). For this reason, the values presented in this report may differ from those in the *Second Report*.
- **b** If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
- **E** Use data with caution.
- **F** Data is too unreliable to be published.
Table 10.1.10  
Dimethylarsinic acid (DMA) (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg As/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011)\(^a\) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10(^{th}) (95% CI)</th>
<th>50(^{th}) (95% CI)</th>
<th>90(^{th}) (95% CI)</th>
<th>95(^{th}) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2528</td>
<td>3.78</td>
<td>3.5 (3.0–4.0)</td>
<td>1.4 (1.2–1.8)</td>
<td>3.0 (2.6–3.4)</td>
<td>9.5 (7.1–12)</td>
<td>15(^{E}) (9.1–21)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2535</td>
<td>3.86</td>
<td>3.7 (3.2–4.3)</td>
<td>1.4 (1.3–1.5)</td>
<td>3.4 (3.0–3.8)</td>
<td>11(^{E}) (5.8–16)</td>
<td>20(^{E}) (11–30)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1267</td>
<td>3.15</td>
<td>3.1 (2.7–3.6)</td>
<td>1.3 (1.0–1.5)</td>
<td>2.9 (2.5–3.3)</td>
<td>7.7 (5.3–10)</td>
<td>10(^{E}) (4.4–16)</td>
</tr>
<tr>
<td>Males</td>
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<td>3 (2012–2013)</td>
<td>1251</td>
<td>2.96</td>
<td>3.1 (2.8–3.6)</td>
<td>1.3 (1.1–1.4)</td>
<td>3.0 (2.4–3.5)</td>
<td>7.2 (5.4–9.1)</td>
<td>13(^{E}) (7.1–19)</td>
</tr>
<tr>
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<td>2 (2009–2011)</td>
<td>1261</td>
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<td>1.6 (1.3–1.8)</td>
<td>3.3 (2.8–3.9)</td>
<td>11(^{E}) (5.9–16)</td>
<td>18(^{E}) (11–24)</td>
</tr>
<tr>
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<td>4.3 (3.6–5.3)</td>
<td>1.5 (1.3–1.7)</td>
<td>3.8 (3.1–4.4)</td>
<td>15(^{E}) (5.2–25)</td>
<td>24(^{E}) (15–33)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>515</td>
<td>3.68</td>
<td>6.4 (5.6–7.3)</td>
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<td>5.6 (4.7–6.5)</td>
<td>16 (11–20)</td>
<td>23(^{E}) (10–38)</td>
</tr>
<tr>
<td>Total</td>
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<td>3 (2012–2013)</td>
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<td>3.00</td>
<td>6.5 (5.9–7.1)</td>
<td>2.8 (2.1–3.4)</td>
<td>6.1 (5.5–6.8)</td>
<td>14 (11–17)</td>
<td>24(^{E}) (13–38)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>2.74</td>
<td>4.5 (4.1–5.0)</td>
<td>2.1 (1.9–2.3)</td>
<td>4.2 (3.8–4.7)</td>
<td>11 (7.9–13)</td>
<td>17(^{E}) (10–24)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>507</td>
<td>2.76</td>
<td>4.5 (3.9–5.2)</td>
<td>2.2 (1.9–2.4)</td>
<td>4.1 (3.7–4.4)</td>
<td>9.9 (5.7–13)</td>
<td>14(^{E}) (7.2–21)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>508</td>
<td>2.75</td>
<td>2.8 (2.3–3.5)</td>
<td>1.1 (0.76–1.4)</td>
<td>2.4 (1.9–3.0)</td>
<td>8.5(^{E}) (4.5–13)</td>
<td>13(^{E}) (7.8–19)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>510</td>
<td>3.53</td>
<td>3.1 (2.5–3.9)</td>
<td>1.2 (1.1–1.4)</td>
<td>2.3 (1.7–2.9)</td>
<td>7.4(^{E}) (2.8–12)</td>
<td>12(^{E}) (5.9–17)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>353</td>
<td>5.63</td>
<td>3.1 (2.5–3.9)</td>
<td>1.3 (0.97–1.6)</td>
<td>2.6 (1.9–3.3)</td>
<td>9.1(^{E}) (5.8–12)</td>
<td>14(^{E}) (7.2–21)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>355</td>
<td>4.79</td>
<td>2.9 (2.6–3.3)</td>
<td>1.1(^{E}) (&lt;LOD–1.6)</td>
<td>2.7 (2.3–3.0)</td>
<td>F</td>
<td>17(^{E}) (4.7–29)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>5.32</td>
<td>3.3 (2.9–3.7)</td>
<td>1.6 (1.3–1.8)</td>
<td>3.0 (2.7–3.2)</td>
<td>7.7 (5.5–9.9)</td>
<td>11(^{E}) (6.1–15)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>6.09</td>
<td>4.1 (3.3–5.2)</td>
<td>1.5 (1.2–1.7)</td>
<td>3.8 (3.1–4.5)</td>
<td>F</td>
<td>24(^{E}) (7.1–40)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>288</td>
<td>3.46</td>
<td>4.2 (3.4–5.3)</td>
<td>1.5(^{E}) (&lt;LOD–2.1)</td>
<td>4.1 (3.1–5.0)</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>352</td>
<td>4.26</td>
<td>4.0 (3.3–4.9)</td>
<td>1.5 (1.2–1.9)</td>
<td>3.6 (2.9–4.3)</td>
<td>11(^{E}) (4.6–18)</td>
<td>20(^{E}) (10–30)</td>
</tr>
</tbody>
</table>

\(a\) In the Second Report on Human Biomonitoring of Environmental Chemicals in Canada, all speciated arsenic was reported as μg of arsenic species per litre (e.g., μg arsenate/L). For this reason, the values presented in this report may differ from those in the Second Report.

\(b\) If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

\(E\) Use data with caution.

\(F\) Data is too unreliable to be published.
## Table 10.1.11
Monomethylarsonic acid (MMA) — Geometric means and selected percentiles of urine concentrations (μg As/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011)a and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
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<td>2 (2009–2011)</td>
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<td>73.01</td>
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<td>&lt;LOD</td>
<td>0.97 (0.94–0.99)</td>
<td>1.1E (1.0–1.5)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
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<td>2536</td>
<td>71.53</td>
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<td>&lt;LOD</td>
<td>1.2 (1.1–1.4)</td>
<td>1.5 (1.3–1.7)</td>
<td></td>
</tr>
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<td>69.63</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.98 (0.84–1.3)</td>
<td>1.5E (0.88–2.1)</td>
<td></td>
</tr>
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<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1251</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.2 (1.0–1.4)</td>
<td>1.5 (1.3–1.7)</td>
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</tr>
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<td>&lt;LOD</td>
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<td>0.99 (0.88–1.1)</td>
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<td>3 (2012–2013)</td>
<td>1285</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.2 (0.88–1.5)</td>
<td>1.5 (1.3–1.8)</td>
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</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>516</td>
<td>77.91</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.92 (0.84–1.0)</td>
<td>0.98 (0.96–1.0)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>500</td>
<td>79.20</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.91 (&lt;LOD–1.2)</td>
<td>1.5 (1.1–1.9)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>511</td>
<td>76.52</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.93 (0.83–1.0)</td>
<td>1.2 (0.77–1.6)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>507</td>
<td>72.58</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.0 (0.84–1.2)</td>
<td>1.3 (1.1–1.4)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>510</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.99 (0.80–1.2)</td>
<td>1.5E (0.93–2.1)</td>
<td></td>
</tr>
<tr>
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<td>&lt;LOD</td>
<td>1.3 (1.1–1.6)</td>
<td>1.6 (1.3–1.8)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
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<td>2 (2009–2011)</td>
<td>355</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.98 (0.86–1.1)</td>
<td>1.3E (&lt;LOD–2.0)</td>
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</tr>
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<td>20–39</td>
<td>3 (2012–2013)</td>
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<td>&lt;LOD</td>
<td>1.3 (1.0–1.5)</td>
<td>1.5 (1.3–1.7)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>357</td>
<td>71.43</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.96 (0.92–1.0)</td>
<td>1.0E (&lt;LOD–1.8)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>72.76</td>
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<td>&lt;LOD</td>
<td>1.1 (0.84–1.4)</td>
<td>1.6 (1.1–2.2)</td>
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</tr>
<tr>
<td>Total</td>
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<td>2 (2009–2011)</td>
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<td>81.31</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.93 (0.61–1.0)</td>
<td>0.99E (&lt;LOD–1.4)</td>
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<tr>
<td>Total</td>
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<td>3 (2012–2013)</td>
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<td>76.70</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.1 (0.79–1.5)</td>
<td>1.4 (1.2–1.6)</td>
<td></td>
</tr>
</tbody>
</table>

a In the Second Report on Human Biomonitoring of Environmental Chemicals in Canada, all speciated arsenic was reported as μg of arsenic species per litre (e.g., μg arsenate/L). For this reason, the values presented in this report may differ from those in the Second Report.

b If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.
### Table 10.1.12
Monomethylarsonic acid (MMA) (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (µg As/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle 1</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2528</td>
<td>73.01</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.0 (0.79–1.2)</td>
<td>1.6 (1.3–1.9)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2535</td>
<td>71.53</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.2 (1.1–1.4)</td>
<td>1.7 (1.5–1.9)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1267</td>
<td>69.63</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.96 (0.92–0.99)</td>
<td>1.2E (0.70–1.7)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1251</td>
<td>68.35</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.0 (0.87–1.1)</td>
<td>1.3 (1.0–1.6)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1261</td>
<td>76.40</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.3 (0.85–1.7)</td>
<td>1.8 (1.3–2.3)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1284</td>
<td>74.63</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.6 (1.3–1.9)</td>
<td>2.1 (1.8–2.5)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>515</td>
<td>77.91</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.5 (1.2–1.8)</td>
<td>2.2 (1.6–2.8)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>499</td>
<td>79.20</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>2.0 (1.5–2.5)</td>
<td>3.0 (2.0–4.0)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>76.52</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.99 (0.87–1.1)</td>
<td>1.5 (1.2–1.9)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>507</td>
<td>72.58</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.3 (1.1–1.5)</td>
<td>1.8 (1.5–2.0)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>508</td>
<td>62.94</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.93 (0.83–1.0)</td>
<td>0.99&lt;sup&gt;F&lt;/sup&gt; (0.87–1.0)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>510</td>
<td>62.16</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.99 (0.75–1.2)</td>
<td>1.5 (1.0–2.0)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>353</td>
<td>70.14</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.98&lt;sup&gt;E&lt;/sup&gt; (&lt;LOD–1.5)</td>
<td>1.6E (&lt;LOD–2.5)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>355</td>
<td>66.48</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.97 (&lt;LOD–1.2)</td>
<td>1.3 (0.87–1.8)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>71.43</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.99 (0.76–1.2)</td>
<td>1.5 (1.0–2.0)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>72.76</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.3 (0.92–1.6)</td>
<td>1.7 (1.3–2.0)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>288</td>
<td>81.31</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.4 (0.95–1.9)</td>
<td>1.8 (1.5–2.1)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>352</td>
<td>76.70</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.4&lt;sup&gt;F&lt;/sup&gt; (0.87–1.9)</td>
<td>2.1F (1.3–2.9)</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> In the Second Report on Human Biomonitoring of Environmental Chemicals in Canada, all speciated arsenic was reported as µg of arsenic species per litre (e.g., µg arsenate/L). For this reason, the values presented in this report may differ from those in the Second Report.

<sup>b</sup> If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

<sup>E</sup> Use data with caution.
REFERENCES


10.2 CADMIUM

Cadmium (CASRN 7440-43-9) is among the least abundant metals in the Earth’s crust at an average concentration of approximately 0.00001% (Emsley, 2001). It is a naturally occurring soft, silvery white, blue-tinged metal. Cadmium often occurs in zinc ores (Health Canada, 1986). Common forms include soluble and insoluble species that may also be found as particulate matter in the atmosphere (ATSDR, 2012; CCME, 1999).

Cadmium is released to the environment as a result of natural processes, including forest fires, volcanic emissions, and weathering of soil and bedrock (Morrow, 2000). The main anthropogenic sources of atmospheric cadmium are industrial base-metal smelting and refining processes, and combustion processes such as coal-fired electrical plants and waste incineration where cadmium is released as a by-product (CCME, 1999).

Cadmium is primarily used in the manufacture of nickel-cadmium batteries (USGS, 2012). It is also used in industrial coatings and electroplating, in pigments, and as a stabilizer in polyvinyl chloride plastics. Cadmium is present in metal alloy sheets, wires, rods, solders, and shields for various industrial applications (Environment Canada and Health Canada, 1994). It is also sometimes used in costume jewellery and as a pigment in ceramic glazes. Cadmium may also be present in fertilizers as the result of recycling of by-products and waste materials for land application. It is frequently an impurity in galvanized pipes and can leach into drinking water (Health Canada, 1986).

In smokers, inhalation of cigarette smoke is a major source of cadmium exposure (Environment Canada and Health Canada, 1994; IARC, 2012). For non-smoking adults and children, the largest source of cadmium exposure is through the ingestion of food (Environment Canada and Health Canada, 1994; IARC, 2012). Ambient air is a minor source of exposure with intakes estimated to be two to three orders of magnitude lower than food, although cadmium compounds are more readily absorbed following inhalation than ingestion (Friberg, 1985). Other potential sources of exposure include ingestion of drinking water, soil, or dust (ATSDR, 2012; Environment Canada and Health Canada, 1994; Rasmussen et al., 2013).

Absorption of dietary cadmium into the bloodstream depends on one’s nutritional status and the levels of other components of the diet such as iron, calcium, and protein. The average gastrointestinal absorption of dietary cadmium is estimated at 5% in adult men and 10% or higher in women (CDC, 2009). About 25% to 60% of inhaled cadmium is absorbed through the lungs (ATSDR, 2012). Absorbed cadmium accumulates mainly in the kidney and liver, with approximately one-third to one-half of the total body burden accumulating in the kidney (CDC, 2009). The biological half-life of cadmium in the kidney has been estimated to be approximately 10 to 12 years (Amzal et al., 2009; Lauwerys et al., 1994). Only a small proportion of absorbed cadmium is eliminated, mainly in the urine and feces with small amounts also eliminated through hair, nails, and sweat.

Cadmium can be measured in blood, urine, feces, liver, kidney, and hair among other tissues. Cadmium concentrations in urine best reflect cumulative exposure and the concentration of cadmium in the kidney, although slight fluctuations occur with recent exposures (Adams and Newcomb, 2014). Concentrations in blood reflect more recent exposures (Adams and Newcomb, 2014). Blood cadmium concentrations are about twice as high in smokers compared with non-smokers; concentrations can also be elevated following occupational exposures (ATSDR, 2012).

Oral exposure to high doses of cadmium may cause severe gastrointestinal irritation and kidney effects (ATSDR, 2012). Chronic exposure via inhalation has been associated with effects in the lungs, including emphysema, and in the kidneys (ATSDR, 2012). The kidney is the critical organ that exhibits the first adverse effects following both oral and inhalation exposure (Lauwerys et al., 1994).

Cadmium and its compounds have been classified as probably carcinogenic to humans by inhalation by Environment Canada and Health Canada (Environment Canada and Health Canada, 1994). More recently, the International Agency for Research on Cancer has classified cadmium and its compounds as carcinogenic to humans (Group 1) based on various data, including associations between occupational inhalation exposure and lung cancer (IARC, 2012). There is insufficient evidence to determine whether or not cadmium is carcinogenic following oral exposure (ATSDR, 2012).
Health Canada and Environment Canada concluded that inorganic cadmium compounds are a concern for human health based on a potential for carcinogenesis and effects on the kidneys (Environment Canada and Health Canada, 1994). Inorganic cadmium compounds are listed on Schedule 1, List of Toxic Substances, under the *Canadian Environmental Protection Act, 1999* (CEPA 1999). The Act allows the federal government to control the importation, manufacture, distribution, and use of inorganic cadmium compounds in Canada (Canada, 1999; Canada, 2000). Risk management actions under CEPA 1999 have been developed to control releases of cadmium from thermal electric power generation, base-metal smelting, and steel manufacturing processes (Environment Canada, 2013).

In Canada, the leachable cadmium content in a variety of consumer products is regulated under the *Canada Consumer Product Safety Act* (Canada, 2010a). Consumer products regulated for leachable cadmium content include glazed ceramics and glassware, as well as paints and other surface coatings on cribs, toys, and other products for use by a child in learning or play situations (Canada, 1998; Canada, 2010b; Canada, 2011; Health Canada, 2009). In addition, since children’s jewellery items containing high levels of cadmium have been found on the Canadian marketplace, a guideline limit for total cadmium in children’s jewellery was proposed by Health Canada in 2011 (Health Canada, 2011). Cadmium and its compounds are included as prohibited ingredients on the List of Prohibited and Restricted Cosmetic Ingredients (more commonly referred to as the Cosmetic Ingredient Hotlist or simply the Hotlist) (Health Canada, 2014). The Hotlist is an administrative tool that Health Canada uses to communicate to manufacturers and others that certain substances, when present in a cosmetic, may contravene the general prohibition found in section 16 of the *Food and Drugs Act* or a provision of the *Cosmetic Regulations*. On the basis of health considerations, Health Canada, in collaboration with the Federal-Provincial-Territorial Committee on Drinking Water, has developed a guideline for Canadian drinking water quality that sets out the maximum acceptable concentration for cadmium in drinking water (Health Canada, 1986; Health Canada, 2012). Cadmium is also included in the list of various chemicals analyzed as part of Health Canada’s ongoing Total Diet Study surveys (Health Canada, 2013). The food items analyzed represent those that are most typical of the Canadian diet, and the surveys are used to provide dietary exposure estimates for chemicals that Canadians in different age-sex groups are exposed to through the food supply.

In a biomonitoring study carried out in the region of the city of Quebec with 500 participants aged 18 to 65 years, the geometric means for cadmium in whole blood was 0.69 µg/L (INSPQ, 2004). The First Nations Biomonitoring Initiative (FNBI) is a nationally representative biomonitoring study of adult First Nations peoples living on reserves south of the 60° parallel (AFN, 2013). It comprises 13 randomly selected First Nation communities in Canada with 503 First Nations participants aged 20 years and older. In 2011, the geometric mean and 95th percentile for cadmium in blood were 0.96 µg/L and 4.65 µg/L, respectively. In northern Canada, the contaminant component of the Inuit Health Survey (2007–2008) has measured the body burden of cadmium for 2,172 Inuit participants from 36 communities in Nunavut, Nunatsiavut, and the Inuvialuit Settlement Region (Laird et al., 2013). The geometric mean blood concentration of cadmium for all participants (18 years and older) was 1.6 µg/L.

Cadmium was analyzed in the whole blood of all Canadian Health Measures Survey participants aged 6 to 79 years in cycle 1 (2007–2009), and 3 to 79 years in cycle 2 (2009–2011) and cycle 3 (2012–2013). Data from these cycles are presented in blood as µg/L. Finding a measurable amount of cadmium in blood is an indicator of exposure to cadmium and does not necessarily mean that an adverse health effect will occur.
### Table 10.2.1

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>5319</td>
<td>2.91</td>
<td>0.34 (0.31–0.37)</td>
<td>0.091 (0.087–0.094)</td>
<td>0.27 (0.25–0.29)</td>
<td>2.4 (2.0–2.8)</td>
<td>3.6 (3.1–4.1)</td>
</tr>
<tr>
<td>Total</td>
<td>6–79</td>
<td>2 (2009–2011)</td>
<td>5575</td>
<td>4.27</td>
<td>0.30 (0.27–0.33)</td>
<td>0.089 (0.080–0.097)</td>
<td>0.27 (0.25–0.30)</td>
<td>2.6 (2.2–3.1)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>5067</td>
<td>8.51</td>
<td>0.34 (0.31–0.37)</td>
<td>0.10 (0.098–0.10)</td>
<td>0.28 (0.26–0.30)</td>
<td>3.4 (2.5–4.3)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2576</td>
<td>3.34</td>
<td>0.30 (0.27–0.34)</td>
<td>0.084 (0.073–0.095)</td>
<td>0.22 (0.20–0.25)</td>
<td>3.4 (2.8–4.0)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>2 (2009–2011)</td>
<td>2687</td>
<td>4.84</td>
<td>0.27 (0.25–0.30)</td>
<td>0.084 (0.074–0.093)</td>
<td>0.24 (0.21–0.27)</td>
<td>3.5 (2.5–4.0)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>2540</td>
<td>9.53</td>
<td>0.31 (0.28–0.34)</td>
<td>0.099 (0.085–0.11)</td>
<td>0.23 (0.20–0.26)</td>
<td>3.7 (2.6–4.3)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2743</td>
<td>2.52</td>
<td>0.38 (0.35–0.41)</td>
<td>0.093 (0.091–0.095)</td>
<td>0.32 (0.29–0.38)</td>
<td>2.1 (1.5–2.7)</td>
<td>3.7 (3.1–4.3)</td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>2 (2009–2011)</td>
<td>2888</td>
<td>3.74</td>
<td>0.33 (0.29–0.38)</td>
<td>0.091 (0.086–0.095)</td>
<td>0.31 (0.27–0.34)</td>
<td>2.7 (2.1–3.4)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>2527</td>
<td>7.48</td>
<td>0.39 (0.34–0.44)</td>
<td>0.10 (0.10–0.11)</td>
<td>0.33 (0.29–0.38)</td>
<td>3.4 (2.7–4.1)</td>
<td></td>
</tr>
</tbody>
</table>

a For the purpose of total population comparisons, only values from participants aged 6–79 years were included as participants under the age of 6 years were not included in cycle 1 (2007–2009).
b If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
### Table 10.2.2

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD a</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>0.29 (0.26–0.32)</td>
<td>0.083 (0.074–0.093)</td>
<td>0.26 (0.24–0.29)</td>
<td>1.7 (1.3–2.0)</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>6070</td>
<td>5.16</td>
<td>0.29 (0.24–0.32)</td>
<td>0.079 (0.070–0.089)</td>
<td>0.23 (0.20–0.26)</td>
<td>1.7 (1.5–2.0)</td>
<td>2.4 (2.0–2.9)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>5538</td>
<td>11.48</td>
<td>0.33 (0.30–0.36)</td>
<td>0.099 (0.092–0.11)</td>
<td>0.27 (0.25–0.29)</td>
<td>2.0 (1.4–2.6)</td>
<td>3.4 (2.5–4.3)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>0.26 (0.24–0.29)</td>
<td>0.079 (0.070–0.089)</td>
<td>0.23 (0.20–0.26)</td>
<td>1.7 (1.5–2.0)</td>
<td>–</td>
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<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2940</td>
<td>5.78</td>
<td>0.29 (0.27–0.32)</td>
<td>0.089 (&lt;LOD–0.10)</td>
<td>0.22 (0.19–0.25)</td>
<td>2.1 (1.5–2.7)</td>
<td>3.3 (2.5–4.2)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2769</td>
<td>12.35</td>
<td>0.37 (0.33–0.41)</td>
<td>0.10 (0.099–0.10)</td>
<td>0.32 (0.28–0.37)</td>
<td>1.7 (0.62–2.8)</td>
<td>3.4 (1.8–5.0)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5 b</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>495</td>
<td>15.15</td>
<td>0.073 (0.065–0.081)</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>471</td>
<td>43.52</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.091 (0.082–0.10)</td>
<td>0.16 (0.11–0.20)</td>
<td>0.18 (1.0–0.29)</td>
</tr>
<tr>
<td>Total</td>
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<td>1 (2007–2009)</td>
<td>910</td>
<td>9.12</td>
<td>0.081 (0.076–0.090)</td>
<td>&lt;LOD</td>
<td>0.092 (&lt;LOD–0.094)</td>
<td>0.20 (0.18–0.21)</td>
<td>0.22 (0.19–0.26)</td>
</tr>
<tr>
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<td>0.083 (0.076–0.090)</td>
<td>&lt;LOD</td>
<td>0.090 (0.087–0.094)</td>
<td>0.17 (0.088–0.25)</td>
<td>0.20 (0.08–0.23)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>944</td>
<td>27.44</td>
<td>0.095 (&lt;LOD–0.11)</td>
<td>&lt;LOD</td>
<td>0.10 (&lt;LOD–0.10)</td>
<td>0.18 (0.16–0.20)</td>
<td>0.21 (0.16–0.24)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>1 (2007–2009)</td>
<td>945</td>
<td>3.92</td>
<td>0.16 (0.13–0.20)</td>
<td>0.066 (0.045–0.066)</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>997</td>
<td>5.72</td>
<td>0.17 (0.12–0.15)</td>
<td>0.062 (0.040–0.064)</td>
<td>0.096 (0.095–0.097)</td>
<td>0.48 (0.27–0.70)</td>
<td>0.82 (0.45–1.2)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>977</td>
<td>12.49</td>
<td>0.34 (0.30–0.38)</td>
<td>0.091 (0.084–0.098)</td>
<td>0.24 (0.21–0.27)</td>
<td>1.0 (1.0–2.0)</td>
<td>2.1 (1.0–2.3)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>1 (2007–2009)</td>
<td>1165</td>
<td>1.55</td>
<td>0.28 (0.24–0.34)</td>
<td>0.10 (0.086–0.11)</td>
<td>0.24 (0.20–0.29)</td>
<td>1.7 (0.62–2.8)</td>
<td>3.4 (1.8–5.0)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>1313</td>
<td>2.21</td>
<td>0.31 (0.24–0.34)</td>
<td>0.10 (0.084–0.12)</td>
<td>0.25 (0.20–0.29)</td>
<td>2.0 (0.71–3.3)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>1032</td>
<td>3.68</td>
<td>0.45 (0.43–0.54)</td>
<td>0.095 (0.097–0.10)</td>
<td>0.34 (0.31–0.37)</td>
<td>2.2 (1.5–2.8)</td>
<td>3.1 (1.8–5.0)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>1 (2007–2009)</td>
<td>1220</td>
<td>0.90</td>
<td>0.45 (0.37–0.47)</td>
<td>0.19 (0.18–0.20)</td>
<td>0.19 (0.18–0.20)</td>
<td>1.5 (1.3–1.8)</td>
<td>2.6 (1.9–3.3)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
b Data not available as participants under the age of 6 years were not included in cycle 1 (2007–2009).
E Use data with caution.
F Data is too unreliable to be published.
REFERENCES


Health Canada (2009). Notice regarding Canada’s legislated safety requirements related to heavy metal content in surface coating materials applied to children’s toys. Minister of Health, Ottawa, ON.


**10.3 FLUORIDE**

Fluorine (CASRN 16984-48-8) is the 13th most abundant element, occurring naturally in the Earth’s crust at an average concentration of about 0.09% (ATSDR, 2003). It is widely distributed and naturally occurring, but it is rarely found in nature because it reacts readily with most organic and inorganic substances. Fluorides are formed when fluorine reacts with metals. Four inorganic fluorides of environmental importance are calcium fluoride (fluorspar and fluorite), sodium fluoride, sulphur hexafluoride, and hydrogen fluoride (Cotton and Wilkinson, 1988; Mackay and Mackay, 1989).

Fluorides are found in rocks, coal, clay, and soil. Gases and particles produced from volcanic eruptions and minerals leached from bedrock release inorganic fluorides into the environment (ATSDR, 2003; CCME, 2002). In addition to these natural sources, inorganic fluorides are released through human activities such as phosphate fertilizer production, chemical production, and aluminum smelting (Environment Canada and Health Canada, 1993).

Hydrogen fluoride is one of the most commonly used fluoride compounds; it is a component in the production of refrigerants, herbicides, pharmaceuticals, aluminum, plastics, high-octane gasoline, electrical components, and fluorescent light bulbs (ATSDR, 2003). In water, hydrogen fluoride becomes hydrofluoric acid, which is used in the metal and glass manufacturing industries (ATSDR, 2003). Calcium fluoride is used in the production of steel, aluminum, glass, and enamel, and as the raw material for the production of hydrofluoric acid and hydrogen fluoride (CCME, 2002). Fluoride-containing compounds are often added to drinking water and dental products to prevent dental cavities. Toothpastes are the most commonly used dental product that contain fluoride (Health Canada, 2010a). Other fluoride-containing dental products available to consumers include fluoride supplements, fluoride mouth rinses, and dental floss. Fluoride is also used by professionals in some dental filling material, sealants, and fluoride varnishes. Sodium fluoride is also used as a preservative in wood and glues and in the production of glass, enamel, steel, and aluminum (CCME, 2002). Sulphur hexafluoride is used extensively in electrical switch gear such as power circuit breakers, compressed gas transmission lines, and various components in electrical substations.

Fluoride compounds are ubiquitous in the environment; however, the major sources of exposure to the general population are water, food, beverages, and dental products (Health Canada, 2010a). Following ingestion of soluble fluoride salts and inhalation of gaseous hydrogen fluoride, fluoride is rapidly and efficiently absorbed (ATSDR, 2003). Once absorbed, fluoride is rapidly distributed throughout the body via the bloodstream (ATSDR, 2003). In infants, about 80% to
90% of the total absorbed fluoride is retained in bones and teeth with the level dropping to about 60% in adults (Fawell et al., 2006). The remaining fluoride in adults and infants is excreted through urine (ATSDR, 2003). The biological half-life of fluoride is on the order of several hours (ATSDR, 2003; NRC, 2006). Urine and blood analyses are the most common tests for fluoride exposure (ATSDR, 2003).

The primary adverse effects associated with chronic excess fluoride intake are dental and skeletal fluorosis (IOM, 1997). Exposure to excessive levels of fluoride over a very long period of time can lead to skeletal fluorosis characterized by dense bones, joint pain, and limited range of joint movement (ATSDR, 2003). Dense bones are often more brittle or fragile than normal bones and there is an increased risk of bone fractures in older adults. Dental fluorosis is a dose-response effect caused by fluoride ingestion during tooth formation that becomes apparent upon eruption of the teeth. The effects of dental fluorosis can range from mild discolouration of the tooth surface to severe staining, enamel loss, and pitting (NRC, 2006).

Health Canada found that the weight of evidence from existing scientific data does not support an association between fluoride and increased risks of cancer, and has classified fluoride in Group VI, unclassifiable with respect to carcinogenicity in humans (Health Canada, 2010a). Similarly, the International Agency for Research on Cancer has classified fluorides (inorganic, used in drinking water) as Group 3, not classifiable as to its carcinogenicity to humans (IARC, 1987).

Health Canada and Environment Canada have reviewed and assessed inorganic fluorides under the Canadian Environmental Protection Act, 1999 (CEPA 1999) (Canada, 1999). The screening assessment concluded that levels of inorganic fluorides normally found in the Canadian environment are not considered harmful to human health but are a concern for the environment (Environment Canada and Health Canada, 1993). Inorganic fluorides are listed on Schedule 1, List of Toxic Substances, under CEPA 1999. The Act allows the federal government to control the importation, manufacture, distribution, and use of inorganic fluorides in Canada (Canada, 1999; Canada, 2000).

Health Canada recommends that fluoride requirements be based on the beneficial effect on dental caries (Health Canada, 2010a). Young children tend to swallow toothpaste during brushing, so guidelines have been established that strive to balance the health risks with the health benefits of fluoride use. In general, toothpaste use is not recommended for children under the age of 3, unless recommended by a health professional. For children 3 to 6 years old, Health Canada recommends supervision during brushing and use of only a small amount of fluoridated toothpaste (Health Canada, 2010b). Fluoride-containing substances are included as restricted ingredients on the List of Prohibited and Restricted Cosmetic Ingredients (more commonly referred to as the Cosmetic Ingredient Hotlist or simply the Hotlist) and are not permitted in oral products (Health Canada, 2014). The Hotlist is an administrative tool that Health Canada uses to communicate to manufacturers and others that certain substances, when present in a cosmetic, may contravene the general prohibition found in section 16 of the Food and Drugs Act or a provision of the Cosmetic Regulations.

Health Canada completed a review of the health risks associated with fluoride in drinking water in which moderate dental fluorosis was chosen as the endpoint of concern for fluoride (Health Canada, 2010a). Although moderate dental fluorosis is not a health concern and is not considered to be a toxicological endpoint, Health Canada considers it to be an adverse effect based on its potential aesthetic concern. The current guideline for Canadian drinking water quality established by the Federal-Provincial-Territorial Committee on Drinking Water sets out the maximum acceptable concentration for fluoride in drinking water (Health Canada, 2010a). This guideline is considered to be protective against all potential adverse health effects, including those related to cancer, immunotoxicity, reproductive/developmental toxicity, genotoxicity, and/or neurotoxicity (Health Canada, 2010a). For communities wishing to fluoridate their water supply, Health Canada has determined an optimal concentration of fluoride in drinking water to promote dental health while protecting against adverse effects (Health Canada, 2010b). Tolerable upper intake levels for fluoride that account for its potential toxicity have been developed by the Institute of Medicine and adopted by Health Canada (Health Canada, 2010c; IOM, 1997).

The concentration of fluoride in some foods and prepackaged water and ice is regulated by Health Canada under the Food and Drug Regulations (Canada, 2012). Food tolerances, or maximum levels, for fluoride currently exist for edible bone meal and fish protein...
12% had one or more teeth with fluorosis classified as very mild, and 4% had fluorosis classified as mild. The prevalence of moderate or severe fluorosis was too low to allow reporting (less than 0.3%).

Fluoride was analyzed in the urine of CHMS cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years and is presented as both mg/L and mg/g creatinine. Finding a measurable amount of fluoride in urine is an indicator of exposure to fluoride and does not necessarily mean that an adverse health effect will occur.

### Table 10.3.1
Fluoride — Geometric means and selected percentiles of urine concentrations (mg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2530</td>
<td>0</td>
<td>0.50 (0.46–0.55)</td>
<td>0.19 (0.17–0.22)</td>
<td>0.48 (0.44–0.53)</td>
<td>1.2 (1.0–1.3)</td>
<td>1.5 (1.2–1.7)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2671</td>
<td>0</td>
<td>0.43 (0.39–0.48)</td>
<td>0.15 (0.14–0.17)</td>
<td>0.44 (0.39–0.49)</td>
<td>1.1 (0.97–1.3)</td>
<td>1.4 (0.99–1.7)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1267</td>
<td>0</td>
<td>0.53 (0.47–0.60)</td>
<td>0.23 (0.20–0.25)</td>
<td>0.51 (0.42–0.60)</td>
<td>1.3 (1.0–1.5)</td>
<td>1.6 (1.4–1.9)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1320</td>
<td>0</td>
<td>0.44 (0.39–0.49)</td>
<td>0.16 (0.13–0.19)</td>
<td>0.44 (0.39–0.49)</td>
<td>1.1 (0.92–1.3)</td>
<td>1.3 (0.81–1.8)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1263</td>
<td>0</td>
<td>0.47 (0.43–0.52)</td>
<td>0.17 (0.15–0.20)</td>
<td>0.47 (0.41–0.53)</td>
<td>1.1 (0.92–1.3)</td>
<td>1.3 (1.0–1.6)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1351</td>
<td>0</td>
<td>0.43 (0.38–0.48)</td>
<td>0.14 (0.11–0.16)</td>
<td>0.45 (0.37–0.53)</td>
<td>1.1 (0.92–1.4)</td>
<td>1.4 (1.0–1.8)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>510</td>
<td>0</td>
<td>0.47 (0.42–0.52)</td>
<td>0.18 (0.13–0.23)</td>
<td>0.51 (0.44–0.58)</td>
<td>0.99 (0.88–1.1)</td>
<td>1.3 (0.92–1.7)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>493</td>
<td>0</td>
<td>0.39 (0.32–0.48)</td>
<td>0.13 (0.098–0.17)</td>
<td>0.37 (0.25–0.50)</td>
<td>0.99 (0.77–1.2)</td>
<td>1.2 (0.97–1.5)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>514</td>
<td>0</td>
<td>0.50 (0.44–0.57)</td>
<td>0.20 (0.17–0.24)</td>
<td>0.49 (0.42–0.55)</td>
<td>1.1 (0.99–1.3)</td>
<td>1.5 (1.1–1.8)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>549</td>
<td>0</td>
<td>0.40 (0.36–0.45)</td>
<td>0.18 (0.15–0.20)</td>
<td>0.38 (0.35–0.41)</td>
<td>0.85 (0.61–1.1)</td>
<td>1.1 (0.88–1.4)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>507</td>
<td>0</td>
<td>0.41 (0.37–0.46)</td>
<td>0.17 (0.15–0.19)</td>
<td>0.44 (0.36–0.52)</td>
<td>0.94 (0.82–1.1)</td>
<td>1.2 (0.98–1.3)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>549</td>
<td>0</td>
<td>0.39 (0.35–0.44)</td>
<td>0.16 (0.13–0.20)</td>
<td>0.37 (0.33–0.41)</td>
<td>0.93 (0.71–1.2)</td>
<td>1.1 (0.85–1.3)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>354</td>
<td>0</td>
<td>0.53 (0.47–0.59)</td>
<td>0.23 (0.19–0.27)</td>
<td>0.50 (0.38–0.62)</td>
<td>1.2 (0.96–1.5)</td>
<td>1.4 (1.1–1.8)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>371</td>
<td>0</td>
<td>0.43 (0.38–0.53)</td>
<td>0.15 (0.11–0.19)</td>
<td>0.47 (0.37–0.57)</td>
<td>1.1 (0.77–1.4)</td>
<td>1.3 (0.58–2.1)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>357</td>
<td>0</td>
<td>0.51 (0.44–0.58)</td>
<td>0.19 (0.13–0.25)</td>
<td>0.51 (0.46–0.56)</td>
<td>1.2 (0.93–1.6)</td>
<td>1.7 (1.3–2.2)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>359</td>
<td>0</td>
<td>0.46 (0.42–0.50)</td>
<td>0.16 (0.13–0.20)</td>
<td>0.46 (0.41–0.50)</td>
<td>1.2 (1.0–1.3)</td>
<td>1.4 (0.88–1.9)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>288</td>
<td>0</td>
<td>0.50 (0.44–0.56)</td>
<td>0.19 (0.11–0.27)</td>
<td>0.48 (0.42–0.54)</td>
<td>1.2 (0.99–1.5)</td>
<td>1.6 (1.3–2.0)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>0</td>
<td>0.43 (0.36–0.51)</td>
<td>0.13 (0.086–0.18)</td>
<td>0.45 (0.34–0.56)</td>
<td>1.3 (0.85–1.7)</td>
<td>1.7 (1.3–2.0)</td>
</tr>
</tbody>
</table>

---

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.
## Table 10.3.2
Fluoride (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (mg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2520</td>
<td>0</td>
<td>0.50 (0.45–0.55)</td>
<td>0.20 (0.18–0.22)</td>
<td>0.48 (0.45–0.54)</td>
<td>1.2 (0.99–1.4)</td>
<td>1.6 (1.3–2.0)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2669</td>
<td>0</td>
<td>0.46 (0.41–0.51)</td>
<td>0.18 (0.16–0.21)</td>
<td>0.45 (0.37–0.53)</td>
<td>1.0 (0.86–1.1)</td>
<td>1.4 (1.1–1.7)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1263</td>
<td>0</td>
<td>0.46 (0.40–0.52)</td>
<td>0.20 (0.16–0.24)</td>
<td>0.43 (0.36–0.50)</td>
<td>1.0 (0.86–1.2)</td>
<td>1.2 (0.88–1.6)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1320</td>
<td>0</td>
<td>0.40 (0.35–0.45)</td>
<td>0.16 (0.12–0.20)</td>
<td>0.41 (0.33–0.48)</td>
<td>0.87 (0.75–0.98)</td>
<td>1.1 (0.90–1.2)</td>
</tr>
<tr>
<td>Females</td>
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<td>2 (2009–2011)</td>
<td>1257</td>
<td>0</td>
<td>0.54 (0.49–0.60)</td>
<td>0.21 (0.18–0.24)</td>
<td>0.52 (0.45–0.60)</td>
<td>1.4 (1.2–1.6)</td>
<td>1.9 (1.5–2.3)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1349</td>
<td>0</td>
<td>0.53 (0.47–0.59)</td>
<td>0.22 (0.19–0.25)</td>
<td>0.53 (0.43–0.63)</td>
<td>1.2 (0.93–1.4)</td>
<td>1.6 (1.3–2.0)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>0</td>
<td>0.81 (0.73–0.90)</td>
<td>0.40 (0.34–0.46)</td>
<td>0.78 (0.72–0.85)</td>
<td>1.7 (1.3–2.0)</td>
<td>2.6E (1.7–4.0)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>492</td>
<td>0</td>
<td>0.76 (0.68–0.86)</td>
<td>0.37 (0.30–0.44)</td>
<td>0.73 (0.55–0.90)</td>
<td>1.5 (1.3–1.6)</td>
<td>1.7 (1.4–1.9)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>512</td>
<td>0</td>
<td>0.58 (0.53–0.63)</td>
<td>0.30 (0.28–0.32)</td>
<td>0.57 (0.50–0.63)</td>
<td>1.2 (0.96–1.4)</td>
<td>1.5 (1.0–2.0)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>549</td>
<td>0</td>
<td>0.50 (0.43–0.57)</td>
<td>0.24 (0.19–0.28)</td>
<td>0.45 (0.39–0.50)</td>
<td>1.0 (0.91–1.1)</td>
<td>1.2 (0.88–1.5)</td>
</tr>
<tr>
<td>Total</td>
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<td>2 (2009–2011)</td>
<td>505</td>
<td>0</td>
<td>0.32 (0.28–0.35)</td>
<td>0.15 (0.13–0.16)</td>
<td>0.32 (0.28–0.37)</td>
<td>0.62 (0.52–0.72)</td>
<td>0.75 (0.54–0.97)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>548</td>
<td>0</td>
<td>0.29 (0.25–0.33)</td>
<td>0.14 (0.12–0.16)</td>
<td>0.27 (0.23–0.31)</td>
<td>0.61 (0.45–0.76)</td>
<td>0.76 (0.63–0.89)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>352</td>
<td>0</td>
<td>0.46 (0.39–0.55)</td>
<td>0.20 (0.17–0.24)</td>
<td>0.42 (0.33–0.51)</td>
<td>1.1 (0.74–1.4)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>371</td>
<td>0</td>
<td>0.40 (0.35–0.46)</td>
<td>0.16 (0.12–0.19)</td>
<td>0.39 (0.30–0.49)</td>
<td>0.87 (0.71–1.0)</td>
<td>1.0 (0.76–1.2)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>0</td>
<td>0.53 (0.46–0.60)</td>
<td>0.22 (0.18–0.26)</td>
<td>0.54 (0.43–0.66)</td>
<td>1.2 (0.94–1.4)</td>
<td>1.6 (1.2–2.0)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>359</td>
<td>0</td>
<td>0.52 (0.46–0.59)</td>
<td>0.22 (0.20–0.24)</td>
<td>0.55 (0.44–0.66)</td>
<td>1.0 (0.87–1.2)</td>
<td>1.2 (0.77–1.7)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>287</td>
<td>0</td>
<td>0.58 (0.50–0.66)</td>
<td>0.22 (0.16–0.27)</td>
<td>0.55 (0.44–0.67)</td>
<td>1.6 (1.3–1.9)</td>
<td>1.9 (1.4–2.5)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>0</td>
<td>0.52 (0.43–0.62)</td>
<td>0.20 (0.16–0.24)</td>
<td>0.52 (0.45–0.59)</td>
<td>1.4* (0.89–1.9)</td>
<td>2.1* (1.1–3.0)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.
REFERENCES


10.4 LEAD

Lead (CASRN 7439-92-1) is a naturally occurring element present at a median background concentration of 0.008% in Canada (Rencz et al., 2006). It is a base metal and can exist in various oxidation states and in both inorganic and organic forms (ATSDR, 2007). Inorganic forms include substances such as elemental lead, lead sulphate, lead carbonate and hydroxyl carbonate, lead oxides, lead chromate, and lead citrate (Rasmussen et al., 2014). Organic lead compounds include tetra-alkyl, trialkyl, and dialkyl lead compounds.

Lead is found in bedrock, soils, sediments, surface water, groundwater, and sea water (Health Canada, 2013a). It enters the environment from a variety of natural and anthropogenic sources. Natural processes include soil weathering, erosion, and volcanic activity (ATSDR, 2007; IARC, 2006). Lead released from industrial emissions can be a major source of environmental contamination, especially near point sources such as smelters or refineries (ATSDR, 2007). Historical use of leaded motor fuels has contributed to the ubiquitous distribution of lead throughout the globe (WHO, 2000).

In North America, tetraethyl and tetramethyl lead were added to motor vehicle fuels as an anti-knock agent up until the 1990s. Presently in Canada, the addition of lead to gasoline is prohibited, with the exception of fuels for piston engine aircraft and racing fuels for competition vehicles (Health Canada, 2013a). Lead is currently used in the refining and manufacturing of products such as lead acid automotive batteries, lead shot and fishing weights, sheet lead, lead solder, some brass and bronze products, and some ceramic glazes (ATSDR, 2007; WHO, 2000). Other uses of lead include dyes in paints and pigments. It is also used in scientific equipment, as a stabilizer in plastics, in military equipment and ammunition, and in radiation detection and medical equipment for radiation shielding (ATSDR, 2007; WHO, 2000). Lead is also used in the manufacturing of cable sheathing, circuit boards, chemical baths and storage vessel linings, chemical transmission pipes, electrical components, and polyvinyl chloride (Health Canada, 2013a).

Everyone is exposed to trace amounts of lead through food, drinking water, soil, household dust, air, and some consumer products. Over the past 30 years, lead exposure has declined by approximately 75% in Canadians (Statistics Canada, 2013). The substantial decrease in exposure to lead is attributed mainly to the phase out of leaded gasoline, reduction of lead content in paint and surface coatings, and the elimination of lead solder in food cans (Health Canada, 2013b). Today, the main route of exposure for the general adult population is from ingestion of food and drinking water (ATSDR, 2007; Health Canada, 2013a). For infants and children, the primary sources of exposure are food, drinking water, and the ingestion of non-food items containing lead such as house dust, paint, soil, and products (Health Canada, 2013a). Lead can enter the water supply from lead service lines in older homes, brass plumbing fittings that contain lead, or lead solder in the plumbing in homes. Other potential sources of exposure include costume jewellery, art supplies, leaded crystal, and glazes on ceramics and pottery; having a hobby, or living with someone who has, that uses lead or lead solder, such as making stained glass, ceramic glazing, lead shot or lead fishing weights, and furniture refinishing; living near airports with piston aircraft activity; and behaviours such as smoking (Health Canada, 2013b). The Canadian House Dust Study reported that lead is enriched in house dust compared with the natural geochemical background, as a result of the use of lead in consumer products, paints and building materials, and infiltration from outdoor sources (Rasmussen et al., 2011; Rasmussen et al., 2013).

Approximately 3% to 10% of ingested lead is absorbed into blood in adults; the amount absorbed can increase up to 40% to 50% in children (Health Canada, 2013a). Nutritional calcium and iron deficiencies in children appear to increase lead absorption and decrease lead excretion (Health Canada, 2013a). Once absorbed by the human body, lead circulates in the bloodstream where it accumulates in tissues, particularly bone, and is excreted from the body. Some lead may also be absorbed into soft tissues such as the liver, kidneys, pancreas, and lungs. Bones account for approximately 70% of the total body burden of lead in children and more than 90% of the total body burden in adults (EPA, 2006). Lead stored in bone can be remobilized and released back into circulating blood. Pregnancy, lactation, menopause, andropause, post-menopause, extended bed rest, hyperparathyroidism, and osteoporosis are all conditions that can increase remobilization of lead from bone, increasing blood lead levels (Health Canada, 2013a).
During pregnancy, lead stored in maternal bone becomes a source of exposure to both fetus and mother (Rothenberg et al., 2000). Lead can also be present in breast milk and is transferred from lactating mothers to infants (ATSDR, 2007; EPA, 2006). The half-life for lead in blood is approximately 30 days whereas the half-life for lead accumulated in the body, such as in bone, is around 10 to 30 years (ATSDR, 2007; Health Canada, 2009a; Health Canada, 2013a). Excretion of absorbed lead, independent of the route of exposure, occurs primarily in urine and feces (ATSDR, 2007). Blood lead is the preferred indicator of human exposure to lead, although other matrices such as urine, bone, and teeth have also been used (ATSDR, 2007; CDC, 2009).

Lead is considered a cumulative general poison, with developing fetuses, infants, toddlers, and children being most susceptible to adverse health effects (WHO, 2011). Following acute exposure, a variety of metabolic processes may be affected. Very high exposure may result in vomiting, diarrhea, convulsions, coma, and death. Cases of lead poisoning are rare in Canada (Health Canada, 2009a). Symptoms of chronic exposure to relatively low levels of lead are often not apparent (ATSDR, 2007). Chronic low-level exposure may affect both the central and peripheral nervous systems (Health Canada, 2013a). Chronic low-level exposure to lead has also been associated with developmental neurotoxicity, increases in blood pressure, decreases in renal functioning, and reproductive problems as well as other health endpoints (ATSDR, 2007; Bushnik et al., 2014; Health Canada, 2013a). Cognitive and neurobehavioural effects have been recognized as major concerns for children exposed to lead. In infants and children, neurodevelopmental effects are most strongly associated with lead exposure, specifically the reduction of intelligence quotient (Lanphear et al., 2005) and an increased risk of attention-related behaviours (Health Canada, 2013a). Based on available data, no threshold has yet been identified for the effects of lead exposure on cognitive function and neurobehavioural development. Developmental neurotoxicity has been associated with the lowest levels of lead exposure measured to date (Health Canada, 2013a). The International Agency for Research on Cancer classifies inorganic lead compounds as Group 2A, probably carcinogenic to humans (IARC, 2006).

Lead is listed on Schedule 1, List of Toxic Substances, under the Canadian Environmental Protection Act, 1999 (CEPA 1999). The Act allows the federal government to control the importation, manufacture, distribution, and use of lead and lead compounds in Canada (Canada, 1999; Health Canada, 2009a). CEPA 1999 prohibits the addition of lead in gasoline and controls its release from secondary lead smelters, steel manufacturing, and mining effluents (Environment Canada, 2010). The use of lead in toys, children’s jewellery and other products intended for children, glazed ceramics and glass foodware, and other consumer products representing a potential risk of lead exposure is limited under the Canada Consumer Product Safety Act and its associated regulations (Canada, 2010a; Canada, 2010b; Health Canada, 2013a). Lead and its compounds are included as prohibited ingredients on the List of Prohibited and Restricted Cosmetic Ingredients (more commonly referred to as the Cosmetic Ingredient Hotlist or simply the Hotlist) (Health Canada, 2014a). The Hotlist is an administrative tool that Health Canada uses to communicate to manufacturers and others that certain substances, when present in a cosmetic, may contravene the general prohibition found in section 16 of the Food and Drugs Act or a provision of the Cosmetic Regulations.

On the basis of health considerations, Health Canada developed a guideline for Canadian drinking water quality that established the maximum acceptable concentration for lead (Health Canada, 1992). This guideline is currently under review by Health Canada in collaboration with the Federal-Provincial-Territorial Committee on Drinking Water (Health Canada, 2013c). Health Canada has also published guidance on controlling corrosion in drinking water distribution systems to help control the leaching of metals, including lead, from the corrosion of distribution system materials and components (Health Canada, 2009b). The concentration of lead in some foods is managed by Health Canada under the Food and Drug Regulations; the existing food tolerances are in the process of being updated, with focus first being placed on a variety of beverages, including bottled water and fruit juices (Canada, 2012; Health Canada, 2011; Health Canada, 2014b). These regulatory updates are one of several Health Canada activities that are under way to ensure that dietary exposure to lead is as low as reasonably achievable (Health Canada, 2011). Lead is also included in the list of various chemicals analyzed as part of Health Canada’s ongoing Total Diet Study surveys (Health Canada, 2013d). The food items analyzed represent those that are most typical of the Canadian diet, and the surveys are used to provide dietary exposure estimates for chemicals that Canadians in
different age-sex groups are exposed to through the food supply. From 1981 to 2000, the average dietary exposure to lead in Canadians decreased by approximately eightfold (Health Canada, 2011).

In 1994, the Federal-Provincial-Territorial Committee on Environmental and Occupational Health recommended a blood lead intervention level of 10 µg/dL as guidance for low-level exposure to lead (CEOH, 1994). Recent scientific assessments indicate that chronic health effects are occurring in children at blood lead levels below 10 µg/dL and that there is sufficient evidence that blood lead levels below 5 µg/dL are associated with adverse health effects (Health Canada, 2013a). The current guidance for lead in blood (CEOH, 1994) is under review by the federal, provincial, and territorial Council of Chief Medical Officers of Health.

A number of biomonitoring studies measuring blood lead levels have been conducted in various locations in Canada over the years. The reported geometric mean blood lead levels ranged from 0.7 to 5.6 µg/dL for various age groups within the Canadian population (Health Canada, 2013a). The highest concentrations were reported for communities with point sources of environmental lead such as smelting (Trail Health and Environment Committee, 2011). In northern Canada, the contaminant component of the Inuit Health Survey (2007–2008) has measured the body burden of lead for 2,172 Inuit participants from 36 communities in Nunavut, Nunatsiavut, and the Inuvialuit Settlement Region (Laird et al., 2013). The geometric mean blood lead level for all participants (18 years and older) was 3.52 µg/dL. In 2008, a study conducted in Hamilton on 643 children aged 0 to 6 years reported a geometric mean blood lead level of 2.21 µg/dL (Richardson et al., 2011). The First Nations Biomonitoring Initiative (FNBI) is a nationally representative biomonitoring study of adult First Nations peoples living on reserves south of the 60° parallel (AFN, 2013). It comprises 13 randomly selected First Nation communities in Canada with 503 First Nations participants aged 20 years and older. In 2011, the geometric mean and 95th percentile for lead in blood were 1.17 µg/dL and 3.27 µg/dL, respectively.

Lead was analyzed in the whole blood of all Canadian Health Measures Survey participants aged 6 to 79 years in cycle 1 (2007–2009), and 3 to 79 years in cycle 2 (2009–2011) and cycle 3 (2012–2013). Data from these cycles are presented in blood as µg/dL.

### Table 10.4.1

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>5319</td>
<td>0.02</td>
<td>1.3 (1.2–1.4)</td>
<td>0.60 (0.56–0.64)</td>
<td>1.2 (1.2–1.3)</td>
<td>3.0 (2.7–3.3)</td>
<td>3.8 (3.3–4.2)</td>
</tr>
<tr>
<td>Total</td>
<td>6–79</td>
<td>2 (2009–2011)</td>
<td>5575</td>
<td>0</td>
<td>1.2 (1.1–1.3)</td>
<td>0.54 (0.50–0.59)</td>
<td>1.1 (1.1–1.2)</td>
<td>2.5 (2.3–2.8)</td>
<td>3.2 (3.0–3.5)</td>
</tr>
<tr>
<td>Total</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>5067</td>
<td>0.10</td>
<td>1.1 (1.0–1.2)</td>
<td>0.49 (0.46–0.52)</td>
<td>1.0 (0.96–1.1)</td>
<td>2.4 (2.3–2.5)</td>
<td>3.2 (2.9–3.4)</td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2576</td>
<td>0</td>
<td>1.5 (1.4–1.6)</td>
<td>0.71 (0.65–0.76)</td>
<td>1.4 (1.3–1.5)</td>
<td>3.2 (2.8–3.6)</td>
<td>4.2 (3.6–4.7)</td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>2 (2009–2011)</td>
<td>2687</td>
<td>0</td>
<td>1.3 (1.3–1.4)</td>
<td>0.62 (0.56–0.68)</td>
<td>1.2 (1.2–1.3)</td>
<td>2.8 (2.5–3.2)</td>
<td>3.4 (3.1–3.7)</td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>2540</td>
<td>0.08</td>
<td>1.2 (1.2–1.3)</td>
<td>0.57 (0.53–0.59)</td>
<td>1.2 (1.1–1.2)</td>
<td>2.7 (2.4–2.9)</td>
<td>3.6 (3.1–4.1)</td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2743</td>
<td>0.04</td>
<td>1.2 (1.1–1.3)</td>
<td>0.55 (0.50–0.59)</td>
<td>1.1 (0.99–1.2)</td>
<td>2.7 (2.3–3.1)</td>
<td>3.5 (3.0–3.9)</td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>2 (2009–2011)</td>
<td>2888</td>
<td>0</td>
<td>1.1 (1.0–1.1)</td>
<td>0.50 (0.46–0.54)</td>
<td>1.0 (0.96–1.1)</td>
<td>2.3 (2.1–2.5)</td>
<td>2.8 (2.6–3.0)</td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>2527</td>
<td>0.12</td>
<td>0.97 (0.91–1.0)</td>
<td>0.42 (0.37–0.47)</td>
<td>0.94 (0.88–1.0)</td>
<td>2.2 (2.1–2.3)</td>
<td>2.7 (2.2–3.1)</td>
</tr>
</tbody>
</table>

a For the purpose of total population comparisons, only values from participants aged 6–79 years were included as participants under the age of 6 years were not included in cycle 1 (2007–2009).

b If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
### Table 10.4.2


<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD&lt;sup&gt;a&lt;/sup&gt;</th>
<th>GM (95% CI)</th>
<th>10&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
<th>50&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
<th>90&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
<th>95&lt;sup&gt;th&lt;/sup&gt; (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>1 (2007–2009)</td>
<td>6070</td>
<td>0</td>
<td>1.2 (1.3–1.2)</td>
<td>0.54 (0.50–0.59)</td>
<td>1.1 (1.1–1.2)</td>
<td>2.5 (2.3–2.7)</td>
<td>3.2 (2.9–3.4)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>5538</td>
<td>0.09</td>
<td>1.1 (1.0–1.1)</td>
<td>0.49 (0.46–0.52)</td>
<td>1.0 (0.95–1.1)</td>
<td>2.4 (2.3–2.5)</td>
<td>3.2 (2.9–3.4)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2940</td>
<td>0</td>
<td>1.3 (1.3–1.4)</td>
<td>0.62 (0.56–0.67)</td>
<td>1.2 (1.2–1.3)</td>
<td>2.8 (2.5–3.1)</td>
<td>3.4 (3.1–3.7)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>4 (2014–2016)</td>
<td>2769</td>
<td>0.07</td>
<td>1.2 (1.2–1.3)</td>
<td>0.56 (0.55–0.56)</td>
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<td>2.6 (2.4–2.9)</td>
<td>3.6 (3.1–4.0)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>1 (2007–2009)</td>
<td>3 (2012–2013)</td>
<td>2769</td>
<td>0.11</td>
<td>0.96 (0.90–1.0)</td>
<td>0.42 (0.37–0.47)</td>
<td>0.93 (0.87–1.0)</td>
<td>2.2 (2.1–2.3)</td>
</tr>
<tr>
<td>Females</td>
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<td>2 (2009–2011)</td>
<td>910</td>
<td>0</td>
<td>0.90 (0.81–0.99)</td>
<td>0.53 (0.49–0.56)</td>
<td>0.87 (0.77–0.97)</td>
<td>1.6 (1.5–1.8)</td>
<td>2.1 (1.8–2.4)</td>
</tr>
<tr>
<td>Females</td>
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<td>3 (2012–2013)</td>
<td>961</td>
<td>0</td>
<td>0.79 (0.74–0.84)</td>
<td>0.44 (0.38–0.50)</td>
<td>0.74 (0.68–0.81)</td>
<td>1.4 (1.3–1.6)</td>
<td>1.9 (1.6–2.2)</td>
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<tr>
<td>Total</td>
<td>3–5</td>
<td>1 (2007–2009)</td>
<td>495</td>
<td>0</td>
<td>0.93 (0.87–1.0)</td>
<td>0.51 (0.44–0.58)</td>
<td>0.93 (0.86–1.0)</td>
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<td>2.1 (1.8–2.4)</td>
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<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
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<td>0</td>
<td>0.77 (0.73–0.82)</td>
<td>0.40 (0.33–0.47)</td>
<td>0.72 (0.68–0.77)</td>
<td>1.4 (1.3–1.6)</td>
<td>2.2 (1.9–2.5)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>1 (2007–2009)</td>
<td>944</td>
<td>0</td>
<td>0.71 (0.67–0.76)</td>
<td>0.39 (0.36–0.42)</td>
<td>0.67 (0.64–0.71)</td>
<td>1.3 (1.1–1.5)</td>
<td>1.6 (1.3–1.9)</td>
</tr>
<tr>
<td>Total</td>
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<td>0</td>
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<td>0.47 (0.44–0.50)</td>
<td>0.76 (0.70–0.82)</td>
<td>1.3 (1.1–1.5)</td>
<td>1.6 (1.4–1.8)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>997</td>
<td>0</td>
<td>0.71 (0.68–0.75)</td>
<td>0.39 (0.35–0.43)</td>
<td>0.68 (0.63–0.72)</td>
<td>1.2 (1.1–1.3)</td>
<td>1.6 (1.3–1.8)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>1 (2007–2009)</td>
<td>977</td>
<td>0.10</td>
<td>0.64 (0.60–0.69)</td>
<td>0.34 (0.32–0.36)</td>
<td>0.60 (0.56–0.64)</td>
<td>1.2 (1.1–1.4)</td>
<td>1.5 (1.3–1.6)</td>
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<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>1165</td>
<td>0.09</td>
<td>1.1 (1.0–1.2)</td>
<td>0.57 (0.52–0.61)</td>
<td>1.0 (0.95–1.1)</td>
<td>2.3 (2.0–2.6)</td>
<td>3.1 (2.7–3.4)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>1313</td>
<td>0</td>
<td>0.98 (0.93–1.0)</td>
<td>0.50 (0.43–0.57)</td>
<td>0.94 (0.87–1.0)</td>
<td>1.6 (1.5–2.1)</td>
<td>2.2 (1.9–2.9)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>1 (2007–2009)</td>
<td>1032</td>
<td>0.19</td>
<td>0.90 (0.79–1.0)</td>
<td>0.44 (0.36–0.53)</td>
<td>0.88 (0.79–0.97)</td>
<td>1.7 (1.5–2.0)</td>
<td>2.1 (1.8–2.4)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>1220</td>
<td>0</td>
<td>1.6 (1.5–1.8)</td>
<td>0.82 (0.69–0.94)</td>
<td>1.5 (1.4–1.6)</td>
<td>3.1 (2.6–3.8)</td>
<td>3.8 (3.1–4.5)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>1222</td>
<td>0</td>
<td>1.4 (1.3–1.5)</td>
<td>0.70 (0.61–0.79)</td>
<td>1.4 (1.3–1.4)</td>
<td>2.7 (2.4–3.0)</td>
<td>3.2 (2.9–3.5)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>1 (2007–2009)</td>
<td>1079</td>
<td>0</td>
<td>2.1 (1.8–2.3)</td>
<td>1.0 (0.92–1.1)</td>
<td>2.0 (1.8–2.2)</td>
<td>4.1 (3.3–4.8)</td>
<td>5.2 (4.2–6.2)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>1082</td>
<td>0</td>
<td>1.9 (1.8–1.9)</td>
<td>1.0 (0.94–1.1)</td>
<td>1.7 (1.7–1.8)</td>
<td>3.5 (3.2–3.8)</td>
<td>4.2 (3.8–4.8)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>1043</td>
<td>0.10</td>
<td>1.6 (1.6–1.7)</td>
<td>0.81 (0.78–0.85)</td>
<td>1.6 (1.4–1.7)</td>
<td>3.3 (3.0–3.5)</td>
<td>4.0 (3.6–4.4)</td>
</tr>
</tbody>
</table>

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<sup>a</sup> If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

<sup>b</sup> Data not available as participants under the age of 6 years were not included in cycle 1 (2007–2009).
REFERENCES


CEOH (Federal-Provincial Committee on Environmental and Occupational Health) (1994). Update of evidence for low-level effects of lead and blood-lead intervention levels and strategies—final report of the working group. Minister of Health, Ottawa, ON.


10.5 MERCURY

Mercury (CASRN 7439-97-6) is a naturally occurring soft, silvery white metal present in the Earth’s crust at an average concentration of approximately 0.000005% (Emsley, 2001). It is the only metal that is a liquid at room temperature. Mercury exists in elemental, inorganic, and organic forms (CCME, 1999). Elemental and certain organic forms of mercury have sufficiently high vapour pressures to be present as vapour in air (ATSDR, 1999). The most common organic mercury compounds in nature are methylmercury (monomethylmercury) and dimethylmercury. Mercury can be converted among its elemental, inorganic, and organic forms by a variety of processes, including biological transformation (Environment Canada, 2010).

Mercury is found throughout the environment, including remote Arctic regions because of its persistence, mobility, and tendency to accumulate in colder climates. Natural sources include volcanic activity and natural erosion of mercury-containing deposits (Environment Canada and Health Canada, 2010). Metabolism of inorganic mercury by microorganisms in the environment creates organic mercury (methylmercury) that often bioaccumulates in terrestrial and aquatic food chains (ATSDR, 1999). Anthropogenic sources of inorganic mercury include metal mining and smelting; combustion of fossil fuels, particularly coal; incineration of municipal wastes; cement production; and sewage sludge and waste water (UNEP, 2002). Inorganic mercury may also be released to the environment following disposal of products containing mercury.

Mercury has unique properties that have made it useful in certain products such as wiring devices, switches, and scientific measuring devices, including vacuum gauges and thermometers (ATSDR, 1999). Today it has been phased out of most products manufactured in Canada; however, many products that contain mercury are still imported into the Canadian marketplace (Canada, 2011a). Inorganic mercury is still found in some medical devices, such as thermostats and X-ray tubes, and in button-cell batteries used in small electronics and hearing aids. Mercury vapour is also present in many lamps and lights, including all fluorescent lamps, mercury vapour lamps, metal halide lamps, and sodium vapour lamps (Environment Canada, 2010). Use of mercury-containing light bulbs is increasing because of widespread replacement of incandescent bulbs with compact fluorescent bulbs. Mercury is also used as an industrial catalyst and in laboratory reagents, disinfectants, embalming solutions, and some pharmaceuticals. A significant use of inorganic mercury is in dental amalgam, which is composed of approximately 50% mercury (IMERC, 2010). Of the total Canadian population in 2007–2009, 63.95% had one or more amalgam-restored tooth surfaces (Richardson, 2014).

Mercury exposure in the general population is primarily through the consumption of fish and seafood in which methylmercury is the predominant form (Health Canada, 2007). To a much lesser extent, the general population is exposed to inorganic mercury from such sources as dental amalgams (Health Canada, 2007). The general population may also be exposed to elemental mercury via inhalation of vapours in ambient air, ingestion, or through dental and medical treatments (ATSDR, 1999).

Approximately 95% of organic mercury is absorbed from the gastrointestinal tract following oral ingestion (ATSDR, 1999). Following absorption, organic mercury is distributed to all tissues, including hair, with highest accumulation in the kidneys (ATSDR, 1999). It readily passes the blood-brain barrier and enters the brain, and in pregnant women can easily cross the placental barrier into the fetus (Health Canada, 2004). Absorbed organic mercury is demethylated in the body to inorganic mercury that accumulates primarily in the liver and kidneys. The biological half-life of methylmercury is approximately 50 days. The majority of mercury in the body is excreted via feces, with a small amount excreted as inorganic mercury in urine (ATSDR, 1999).

Generally less than 10% of inorganic mercury is absorbed through the intestinal tract (Health Canada, 2004). Absorbed inorganic mercury accumulates readily in the kidneys (IPCS, 2003). It also accumulates in placental tissues but does not cross placental or blood-brain barriers as easily as elemental or methylmercury (Health Canada, 2004). Excretion of elemental and inorganic mercury compounds occurs mainly in urine and feces with an absorbed dose half-life of approximately 1 to 2 months (IPCS, 2003).

Elemental mercury is absorbed across the lungs and gastrointestinal tract with absorption rates of about 80% and 0.01%, respectively (Health Canada, 2004). Once absorbed, elemental mercury enters the
bloodstream and is rapidly transported to other parts of the body, including the brain and kidneys. As with organic mercury, it readily crosses the blood-brain and placental barriers (Health Canada, 2004). Once in the body, elemental mercury is oxidized in the tissues to inorganic forms and can remain for weeks or months with an estimated half-life of approximately 60 days (Sandborgh-Englund et al., 1998).

Long-term exposure to elemental and inorganic mercury is commonly evaluated using mercury concentrations in blood (IPCS, 2003). Hair also may be used as a biomarker of chronic exposure, although inorganic forms of mercury are not excreted to any significant amount in scalp hair, making it an inappropriate biomarker of inorganic mercury exposure (ATSDR, 1999; IPCS, 2003). Total blood mercury concentrations primarily reflect recent dietary exposure to organic forms of mercury, particularly methylmercury (ATSDR, 1999; IPCS, 2003). The concentration of total mercury in blood is accepted as a reasonable measure of methylmercury exposure, however methylmercury itself may also be measured directly in blood. Based on a review of existing data from other countries, the World Health Organization has estimated that the average total blood mercury concentration for the general population is approximately 8 µg/L (WHO, 1990). In individuals who consume fish daily, methylmercury concentrations in blood can be as high as 200 µg/L (WHO, 1990).

Mercury is known to be toxic to humans, with the effects depending on the mercury form, the route of exposure, the timing of exposure, and the absorbed concentration. Chronic oral exposure to low levels of methylmercury may not result in any observable symptoms (Health Canada, 2007). The primary effects associated with oral exposure to organic mercury compounds are neurological effects and developmental neurotoxicity (UNEP, 2002). Symptoms of organic mercury toxicity include a tingling sensation in the extremities; impaired peripheral vision, hearing, taste, and smell; slurred speech; muscle weakness and an unsteady gait; irritability; memory loss; depression; and sleeping difficulties (UNEP, 2002). Exposure of a fetus or young child to organic mercury can result in effects on the development of the nervous system, affecting fine-motor function, attention, verbal learning, and memory (ATSDR, 1999; Health Canada, 2007). Exposure to elemental mercury may be hazardous, depending upon the levels of exposure, because the vapour that can be released from this form is readily absorbed into the body through inhalation. Inhalation of mercury vapour may cause respiratory, cardiovascular, kidney, and neurological effects. Exposure to inorganic mercury from dental amalgams has not been associated with neurologic effects in children or adults (Bates et al., 2004; Bellinger et al., 2007; DeRouen et al., 2006; Factor-Litvak et al., 2003). Health Canada concluded that mercury exposure from dental amalgams does not pose a health impact for the general population (Health Canada, 1996).

The International Agency for Research on Cancer (IARC) determined that methylmercury compounds are possibly carcinogenic to humans (Group 2B), based on animal data showing a link to certain cancers, particularly renal cancer (IARC, 1993). Elemental mercury and inorganic mercury compounds were classified by IARC as Group 3, not classifiable as to their carcinogenicity to humans (IARC, 1993).

The United Nations Environment Programme (UNEP) Global Risk Assessment for Mercury concluded that there was sufficient evidence of adverse impacts from mercury to warrant further international action to reduce the risks to human health and the environment (UNEP, 2002). International negotiations under UNEP resulted in the signing of the Minamata Convention on Mercury, a global legally binding agreement to prevent mercury emissions and releases (UNEP, 2013). The Minamata Convention is intended to reduce global atmospheric emissions, supply, trade, and demand for mercury, and to find environmentally sound solutions for storage of mercury and mercury-containing wastes.

In Canada, mercury and its compounds are listed as toxic substances on Schedule 1 of the Canadian Environmental Protection Act, 1999 (CEPA 1999) (Canada, 1999; Canada, 2012a). Existing and planned actions to manage the risks from mercury are summarized in the Government of Canada’s Risk Management Strategy for Mercury (Environment Canada and Health Canada, 2010). These risk management actions include several Canada-wide standards that have been established to reduce the releases of mercury to the environment (CCME, 2000; CCME, 2005; CCME, 2006; CCME, 2007). The Surface Coating Materials Regulations, in effect under the Canada Consumer Product Safety Act, restrict the level of mercury in all surface coating materials advertised, sold, or imported into Canada (Canada, 2005). In addition, the Toys
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*Regulations* prohibit any compound of mercury in the surface coating material that is applied to a product that is used by a child in learning or play situations (Canada, 2011b). In 2011, a regulation was proposed under CEPA 1999 with prohibitions on the import, manufacture, sale, and offer for sale of mercury-containing products that are not currently regulated under other legislation (Canada, 2011a). Mercury and its compounds are also included as prohibited ingredients on the List of Prohibited and Restricted Cosmetic Ingredients (more commonly referred to as the Cosmetic Ingredient Hotlist or simply the Hotlist). The Hotlist is an administrative tool that Health Canada uses to communicate to manufacturers and others that certain substances, when present in a cosmetic, may contravene the general prohibition found in section 16 of the *Food and Drugs Act* or a provision of the *Cosmetic Regulations* (Canada, 1985; Health Canada, 2014). The *Food and Drug Regulations* prohibit sale in Canada of drugs for human use containing mercury or any of its salts or derivatives except in some specific instances, including those where it is present as a preservative (Canada, 2012b).

Health Canada has established a total mercury blood guidance value of 20 µg/L for the general adult population (Health Canada, 2004). For children (less than 18 years of age), pregnant women, and women of childbearing age (less than 50 years of age), a provisional methylmercury blood guidance value of 8 µg/L has been proposed for the protection of the developing nervous system (Legrand et al., 2010). On the basis of health considerations, Health Canada, in collaboration with the Federal-Provincial-Territorial Committee on Drinking Water, has developed a guideline for Canadian drinking water quality that establishes the maximum acceptable concentration for mercury in drinking water (Health Canada, 1986; Health Canada, 2012a). Health Canada has also established maximum levels for mercury in retail fish (Health Canada, 2012b), and provides consumption advice for consumers of certain types of fish (Health Canada, 2008). *Eating Well with Canada’s Food Guide* recommends eating at least two food guide servings each week of fish that are low in mercury and high in omega-3 fatty acids (Health Canada, 2011). Mercury is also included in the list of various chemicals analyzed as part of Health Canada’s ongoing Total Diet Study surveys (Health Canada, 2013). The food items analyzed represent those that are most typical of the Canadian diet, and the surveys are used to provide dietary exposure estimates for chemicals that Canadians in different age-sex groups are exposed to through the food supply.

During cycle 1 (2007–2009) of the CHMS, the geometric mean blood total mercury level of the Canadian population aged 6 to 79 years was 0.69 µg/L (Lye et al., 2013). The majority (97.8%) of Canadian women aged 16 to 49 years, including pregnant women, had blood mercury values below the provisional Health Canada blood guidance value of 8 µg/L (Lye et al., 2013). The mean urinary inorganic mercury concentration in dental amalgam-free participants from cycle 1 of the CHMS was 0.10 µg/L compared with the overall population mean concentration of 0.22 µg/L (Nicolae et al., 2013). In general, mean urinary inorganic mercury concentrations tended to increase with the number of amalgam surfaces and appeared to be influenced by age and sex (Nicolae et al., 2013). The population coverage of the CHMS excludes persons living on reserves and other Aboriginal settlements in the provinces of Canada. However, this subpopulation has been surveyed as part of the First Nations Biomonitoring Initiative (FNBI), a nationally representative biomonitoring study of adult First Nations peoples living on reserves south of the 60° parallel (AFN, 2013). It comprises 13 randomly selected First Nation communities in Canada with 503 First Nations participants aged 20 years and older. In 2011, the geometric mean and 95th percentile for total mercury in blood were 0.95 µg/L and 9.28 µg/L, respectively. For inorganic mercury in urine, the geometric mean and 95th percentile were 0.26 µg/L and 1.98 µg/L, respectively.

Total mercury was analyzed in the whole blood of all Canadian Health Measures Survey (CHMS) participants aged 6 to 79 years in cycle 1 (2007–2009), and 3 to 79 years in cycle 2 (2009–2011) and cycle 3 (2012–2013). Methylmercury was analyzed in the whole blood of CHMS participants aged 20 to 79 years in cycle 3 (2012–2013). Inorganic mercury was analyzed in the urine of all CHMS participants aged 6 to 79 years in cycle 1 (2007–2009) and 3 to 79 years in cycle 3 (2012–2013). Data from these cycles are presented in blood as µg/L (µg Hg/L for methylmercury) and in urine as both µg/L and µg/g creatinine. Finding a measurable amount of mercury in blood or urine is an indicator of exposure to mercury and does not necessarily mean that an adverse health effect will occur.
### Table 10.5.1
Mercury (inorganic) — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 6–79 years\(^a\), Canadian Health Measures Survey cycle 1 (2007–2009) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD(^b)</th>
<th>GM (95% CI)</th>
<th>10(^{th}) (95% CI)</th>
<th>50(^{th}) (95% CI)</th>
<th>90(^{th}) (95% CI)</th>
<th>95(^{th}) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>5444</td>
<td>49.63</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.8 (1.6–2.0)</td>
<td>2.9 (2.5–3.3)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>5176</td>
<td>47.97</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.3 (1.1–1.5)</td>
<td>2.0 (1.7–2.3)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2636</td>
<td>48.33</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.7 (1.6–1.9)</td>
<td>2.7 (2.3–3.0)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>2582</td>
<td>46.90</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.2 (0.94–1.5)</td>
<td>1.9 (1.3–2.4)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2808</td>
<td>50.85</td>
<td>–</td>
<td>&lt;LOD</td>
<td>2.0 (1.7–2.3)</td>
<td>3.1 (2.7–3.6)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>2594</td>
<td>49.04</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.4 (0.99–1.8)</td>
<td>2.2 (1.5–2.8)</td>
<td></td>
</tr>
</tbody>
</table>

\(a\) For the purpose of total population comparisons, only values from participants aged 6–79 years were included as participants under the age of 6 years were not included in cycle 1 (2007–2009).

\(b\) If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

\(E\) Use data with caution.

### Table 10.5.2
Mercury (inorganic) (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 6–79 years\(^a\), Canadian Health Measures Survey cycle 1 (2007–2009) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD(^b)</th>
<th>GM (95% CI)</th>
<th>10(^{th}) (95% CI)</th>
<th>50(^{th}) (95% CI)</th>
<th>90(^{th}) (95% CI)</th>
<th>95(^{th}) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>5432</td>
<td>49.63</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.6 (1.3–1.9)</td>
<td>2.5 (2.1–2.9)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>5175</td>
<td>47.97</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.0 (0.94–1.1)</td>
<td>1.6 (1.3–1.7)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2628</td>
<td>48.33</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.2 (1.1–1.3)</td>
<td>1.8 (1.5–2.1)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>2582</td>
<td>46.90</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.87 (0.63–1.1)</td>
<td>1.2 (1.0–1.4)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2804</td>
<td>50.85</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.0 (0.92–1.1)</td>
<td>1.4 (1.2–1.5)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>2593</td>
<td>49.04</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.3 (0.88–1.6)</td>
<td>1.9 (1.5–2.4)</td>
<td></td>
</tr>
</tbody>
</table>

\(a\) For the purpose of total population comparisons, only values from participants aged 6–79 years were included as participants under the age of 6 years were not included in cycle 1 (2007–2009).

\(b\) If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total 3–79</td>
<td>3–79</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Total 3–79</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>5696</td>
<td>50.42</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.19 (1.00–0.24)</td>
<td>1.3 (1.1–1.5)</td>
<td>2.0 (1.7–2.3)</td>
</tr>
<tr>
<td>Males 3–79</td>
<td>3–79</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Males 3–79</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2842</td>
<td>49.37</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.20 (1.22–0.27)</td>
<td>1.2 (0.92–1.5)</td>
<td>1.9 (1.3–2.4)</td>
</tr>
<tr>
<td>Females 3–79</td>
<td>3–79</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Females 3–79</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2854</td>
<td>51.47</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.19 (1.00–0.25)</td>
<td>1.4 (0.97–1.8)</td>
<td>2.1 (1.5–2.8)</td>
</tr>
<tr>
<td>Total 3–5</td>
<td>3–5</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Total 3–5</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>520</td>
<td>74.81</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.28 (0.00–0.48)</td>
<td>0.59 (0.35–0.84)</td>
<td></td>
</tr>
<tr>
<td>Total 6–11</td>
<td>6–11</td>
<td>1 (2007–2009)</td>
<td>1028</td>
<td>66.05</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.99 (0.56–1.4)</td>
<td>1.8 (0.99–2.7)</td>
<td></td>
</tr>
<tr>
<td>Total 6–11</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>1010</td>
<td>61.29</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.93 (0.50–1.4)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Total 12–19</td>
<td>12–19</td>
<td>1 (2007–2009)</td>
<td>975</td>
<td>57.54</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.2 (0.76–1.6)</td>
<td>2.2 (1.5–3.0)</td>
<td></td>
</tr>
<tr>
<td>Total 12–19</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>997</td>
<td>59.58</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.55 (0.33–0.78)</td>
<td>1.1 (0.53–1.6)</td>
<td></td>
</tr>
<tr>
<td>Total 20–39</td>
<td>20–39</td>
<td>1 (2007–2009)</td>
<td>1166</td>
<td>46.23</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.22 (0.16–0.28)</td>
<td>1.4 (1.0–1.7)</td>
<td>2.3 (1.8–2.7)</td>
</tr>
<tr>
<td>Total 20–39</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>1048</td>
<td>45.13</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.20 (0.12–0.28)</td>
<td>1.1 (0.87–1.3)</td>
<td>1.9 (0.89–3.0)</td>
</tr>
<tr>
<td>Total 40–59</td>
<td>40–59</td>
<td>1 (2007–2009)</td>
<td>1207</td>
<td>36.04</td>
<td>0.31 (0.25–0.37)</td>
<td>&lt;LOD</td>
<td>0.37 (0.28–0.47)</td>
<td>2.5 (1.8–3.2)</td>
<td>3.5 (2.3–4.7)</td>
</tr>
<tr>
<td>Total 40–59</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>1080</td>
<td>36.20</td>
<td>0.31 (0.26–0.39)</td>
<td>&lt;LOD</td>
<td>0.30 (0.20–0.40)</td>
<td>2.0 (1.2–2.2)</td>
<td>2.2 (1.7–2.6)</td>
</tr>
<tr>
<td>Total 60–79</td>
<td>60–79</td>
<td>1 (2007–2009)</td>
<td>1068</td>
<td>45.69</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.25 (0.15–0.35)</td>
<td>3.0 (2.5–3.5)</td>
<td></td>
</tr>
<tr>
<td>Total 60–79</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>1041</td>
<td>39.00</td>
<td>0.26 (0.23–0.30)</td>
<td>&lt;LOD</td>
<td>0.24 (0.18–0.30)</td>
<td>1.4 (0.98–1.8)</td>
<td>2.3 (1.6–2.9)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
b Data not available as participants under the age of 6 years were not included in cycle 1 (2007–2009).
E Use data with caution.
F Data is too unreliable to be published.
### Table 10.5.4
Mercury (inorganic) (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 1 (2007–2009) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79b</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>5694</td>
<td>50.42</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.0 (0.94–1.1)</td>
<td>1.6 (1.3–1.9)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3–79a</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2842</td>
<td>49.37</td>
<td>&lt;LOD</td>
<td>0.21 (0.17–0.24)</td>
<td>0.86 (0.63–1.1)</td>
<td>1.2 (1.1–1.4)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>3–79a</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2852</td>
<td>51.47</td>
<td>&lt;LOD</td>
<td>1.2 (0.87–1.5)</td>
<td>1.9 (1.5–2.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
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<td>1 (2007–2009)</td>
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<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>519</td>
<td>74.81</td>
<td>&lt;LOD</td>
<td>0.73f (0.45–1.0)</td>
<td>1.0 (0.72–1.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>1 (2007–2009)</td>
<td>1025</td>
<td>66.95</td>
<td>&lt;LOD</td>
<td>1.3f (0.62–1.9)</td>
<td>2.0 (1.3–2.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>1010</td>
<td>61.29</td>
<td>&lt;LOD</td>
<td>0.99f (0.55–1.4)</td>
<td>1.9f (0.84–3.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>1 (2007–2009)</td>
<td>975</td>
<td>57.54</td>
<td>&lt;LOD</td>
<td>0.79 (0.55–1.0)</td>
<td>1.3f (0.79–1.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>997</td>
<td>59.58</td>
<td>&lt;LOD</td>
<td>0.42f (0.27–0.58)</td>
<td>0.73f (0.42–1.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>1 (2007–2009)</td>
<td>1162</td>
<td>46.23</td>
<td>&lt;LOD</td>
<td>0.21 (0.18–0.24)</td>
<td>1.1 (0.89–1.4)</td>
<td>1.9 (1.5–2.2)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>1048</td>
<td>45.13</td>
<td>&lt;LOD</td>
<td>0.22 (0.18–0.26)</td>
<td>0.85 (0.58–1.3)</td>
<td>1.2 (0.97–1.3)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>1 (2007–2009)</td>
<td>1202</td>
<td>36.04</td>
<td>0.39 (0.33–0.48)</td>
<td>&lt;LOD</td>
<td>0.43 (0.33–0.52)</td>
<td>2.1 (1.5–2.7)</td>
<td>3.0 (2.3–3.7)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>1079</td>
<td>36.20</td>
<td>0.33 (0.29–0.38)</td>
<td>&lt;LOD</td>
<td>0.33 (0.27–0.40)</td>
<td>1.3 (0.91–1.7)</td>
<td>1.7 (1.5–2.0)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>1 (2007–2009)</td>
<td>1068</td>
<td>45.69</td>
<td>&lt;LOD</td>
<td>0.29f (0.17–0.42)</td>
<td>2.0 (1.7–2.3)</td>
<td>2.7 (2.1–3.4)</td>
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</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>1041</td>
<td>39.00</td>
<td>0.32 (0.28–0.36)</td>
<td>&lt;LOD</td>
<td>0.32 (0.27–0.37)</td>
<td>1.3 (0.95–1.6)</td>
<td>2.2 (1.6–2.8)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

b Data not available as participants under the age of 6 years were not included in cycle 1 (2007–2009).

e Use data with caution.
### Table 10.5.5


<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD(^b)</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>5319</td>
<td>11.64</td>
<td>0.69 (0.59–0.86)</td>
<td>&lt;LOD</td>
<td>0.81 (0.64–0.97)</td>
<td>3.0 (2.2–3.9)</td>
<td>4.6E (2.5–6.7)</td>
</tr>
<tr>
<td>Total</td>
<td>6–79</td>
<td>2 (2009–2011)</td>
<td>5575</td>
<td>14.28</td>
<td>0.71 (0.57–0.89)</td>
<td>&lt;LOD</td>
<td>0.76 (0.57–0.96)</td>
<td>3.5 (2.4–4.6)</td>
<td>5.6E (3.3–7.8)</td>
</tr>
<tr>
<td>Total</td>
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<td>3 (2012–2013)</td>
<td>5067</td>
<td>34.93</td>
<td>0.81 (0.65–1.0)</td>
<td>&lt;LOD</td>
<td>0.81 (0.63–0.99)</td>
<td>3.2E (1.5–5.0)</td>
<td>5.4E (3.1–7.6)</td>
</tr>
<tr>
<td>Males</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2576</td>
<td>12.11</td>
<td>0.68 (0.55–0.84)</td>
<td>&lt;LOD</td>
<td>0.79 (0.64–0.94)</td>
<td>3.1 (2.1–4.1)</td>
<td>5.1E (2.7–7.5)</td>
</tr>
<tr>
<td>Males</td>
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<td>2 (2009–2011)</td>
<td>2687</td>
<td>14.77</td>
<td>0.74 (0.58–0.94)</td>
<td>&lt;LOD</td>
<td>0.80 (0.68–1.0)</td>
<td>3.9 (2.7–5.2)</td>
<td>6.3E (2.9–9.7)</td>
</tr>
<tr>
<td>Males</td>
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<td>3 (2012–2013)</td>
<td>2540</td>
<td>35.67</td>
<td>0.78 (0.61–1.0)</td>
<td>&lt;LOD</td>
<td>0.77 (0.60–0.98)</td>
<td>3.6E (1.4–5.1)</td>
<td>5.7E (3.4–7.9)</td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>1 (2007–2009)</td>
<td>2743</td>
<td>11.19</td>
<td>0.70 (0.56–0.88)</td>
<td>&lt;LOD</td>
<td>0.82 (0.63–1.0)</td>
<td>3.0 (2.1–3.8)</td>
<td>4.5E (2.6–6.4)</td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>2 (2009–2011)</td>
<td>2888</td>
<td>13.82</td>
<td>0.69 (0.55–0.86)</td>
<td>&lt;LOD</td>
<td>0.74 (0.56–0.92)</td>
<td>3.0 (2.0–4.0)</td>
<td>5.1E (3.0–7.2)</td>
</tr>
<tr>
<td>Females</td>
<td>6–79</td>
<td>3 (2012–2013)</td>
<td>2527</td>
<td>34.19</td>
<td>0.83 (0.68–1.0)</td>
<td>&lt;LOD</td>
<td>0.84 (0.68–0.99)</td>
<td>3.2E (1.4–5.0)</td>
<td>5.1E (2.4–7.9)</td>
</tr>
</tbody>
</table>

\(^a\) For the purpose of total population comparisons, only values from participants aged 6–79 years were included as participants under the age of 6 years were not included in cycle 1 (2007–2009).

\(^b\) If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

\(^E\) Use data with caution.
### Table 10.5.6


<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD(^a)</th>
<th>GM (95% CI)</th>
<th>10(^{th}) (95% CI)</th>
<th>50(^{th}) (95% CI)</th>
<th>90(^{th}) (95% CI)</th>
<th>95(^{th}) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79(^a)</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>0.69 (0.56–0.87)</td>
<td>&lt;LOD</td>
<td>0.74 (0.55–0.93)</td>
<td>3.4 (2.4–4.5)</td>
<td>5.5E (3.3–7.6)</td>
</tr>
<tr>
<td>Total</td>
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<td>2 (2009–2011)</td>
<td>6070</td>
<td>15.55</td>
<td>0.79 (0.64–0.97)</td>
<td>&lt;LOD</td>
<td>0.79 (0.62–0.96)</td>
<td>3.2E (1.5–4.9)</td>
<td>5.2E (3.0–7.5)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79(^a)</td>
<td>3 (2012–2013)</td>
<td>5538</td>
<td>37.02</td>
<td>0.76 (0.60–0.97)</td>
<td>&lt;LOD</td>
<td>0.76 (0.53–0.99)</td>
<td>3.9 (2.7–5.1)</td>
<td>6.1E (2.7–9.5)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2940</td>
<td>16.16</td>
<td>0.72 (0.59–0.91)</td>
<td>&lt;LOD</td>
<td>0.76 (0.53–0.99)</td>
<td>3.4E (2.4–4.5)</td>
<td>5.1E (3.0–7.1)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2769</td>
<td>37.63</td>
<td>0.76 (0.60–0.97)</td>
<td>&lt;LOD</td>
<td>0.74 (0.54–0.94)</td>
<td>3.2E (1.3–5.0)</td>
<td>5.6E (3.4–7.8)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79(^a)</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>3130</td>
<td>14.98</td>
<td>0.67 (0.54–0.83)</td>
<td>&lt;LOD</td>
<td>0.71 (0.53–0.88)</td>
<td>3.0 (2.0–4.0)</td>
<td>5.1E (3.0–7.1)</td>
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<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2769</td>
<td>36.40</td>
<td>0.81 (0.61–0.99)</td>
<td>&lt;LOD</td>
<td>0.82 (0.67–0.97)</td>
<td>3.2E (1.4–4.8)</td>
<td>5.1E (1.4–7.8)</td>
</tr>
<tr>
<td>Total</td>
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<td>Total</td>
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<td>2 (2009–2011)</td>
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<td>0.27 (0.20–0.36)</td>
<td>&lt;LOD</td>
<td>0.19E (&lt;LOD–0.29)</td>
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<td>3.0E (1.7–4.3)</td>
</tr>
<tr>
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<td>1 (2007–2009)</td>
<td>910</td>
<td>24.84</td>
<td>0.26 (0.22–0.32)</td>
<td>&lt;LOD</td>
<td>0.24 (0.18–0.29)</td>
<td>1.3 (1.0–1.6)</td>
<td>2.1E (1.3–2.9)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>961</td>
<td>29.03</td>
<td>0.28 (0.22–0.34)</td>
<td>&lt;LOD</td>
<td>0.21E (0.11–0.30)</td>
<td>1.2 (0.84–1.5)</td>
<td>2.0 (1.3–2.6)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>944</td>
<td>54.77</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.2 (0.76–1.7)</td>
<td>1.9E (0.91–2.9)</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>1 (2007–2009)</td>
<td>945</td>
<td>20.85</td>
<td>0.30 (0.23–0.40)</td>
<td>&lt;LOD</td>
<td>0.28 (0.23–0.37)</td>
<td>1.3E (0.47–2.2)</td>
<td>2.2E (0.88–3.5)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>997</td>
<td>26.58</td>
<td>0.27 (0.21–0.35)</td>
<td>&lt;LOD</td>
<td>0.19E (&lt;LOD–0.30)</td>
<td>1.3 (0.84–1.7)</td>
<td>2.4E (1.3–2.5)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>977</td>
<td>52.61</td>
<td>–</td>
<td>&lt;LOD</td>
<td>1.6E (0.62–2.6)</td>
<td>2.8E (1.3–4.4)</td>
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</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>1 (2007–2009)</td>
<td>1165</td>
<td>8.76</td>
<td>0.65 (0.52–0.81)</td>
<td>&lt;LOD</td>
<td>0.76 (0.61–0.91)</td>
<td>3.0E (1.9–4.1)</td>
<td>4.9E (2.4–7.4)</td>
</tr>
<tr>
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<td>2 (2009–2011)</td>
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<td>10.05</td>
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<td>5.2E (2.8–7.8)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>1032</td>
<td>30.91</td>
<td>0.82 (0.65–1.0)</td>
<td>&lt;LOD</td>
<td>0.77 (0.57–0.96)</td>
<td>4.1E (1.5–6.6)</td>
<td>6.0E (3.6–4.3)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>1 (2007–2009)</td>
<td>1220</td>
<td>3.52</td>
<td>1.0 (0.80–1.3)</td>
<td>0.21E (0.12–0.30)</td>
<td>1.1 (0.83–1.3)</td>
<td>3.6 (2.3–4.9)</td>
<td>6.4E (3.0–4.8)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>1222</td>
<td>5.16</td>
<td>1.0 (0.79–1.3)</td>
<td>0.15 (0.11–0.20)</td>
<td>1.0 (0.84–1.2)</td>
<td>4.1E (2.4–5.8)</td>
<td>7.3E (2.5–12)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>1071</td>
<td>20.54</td>
<td>0.96 (0.74–1.2)</td>
<td>&lt;LOD</td>
<td>0.99 (0.78–1.2)</td>
<td>3.4E (1.5–5.4)</td>
<td>5.2E (2.8–7.6)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>1 (2007–2009)</td>
<td>1079</td>
<td>4.73</td>
<td>0.87 (0.64–1.2)</td>
<td>F</td>
<td>0.96 (0.75–1.2)</td>
<td>3.4 (2.4–4.4)</td>
<td>4.8E (2.7–6.9)</td>
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<tr>
<td>Total</td>
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<td>1082</td>
<td>5.27</td>
<td>1.1 (0.86–1.5)</td>
<td>0.17E (&lt;LOD–0.28)</td>
<td>1.2 (0.89–1.5)</td>
<td>4.3 (3.1–5.5)</td>
<td>6.5E (3.9–9.1)</td>
</tr>
<tr>
<td>Total</td>
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<td>3 (2012–2013)</td>
<td>1043</td>
<td>19.18</td>
<td>1.0 (0.82–1.3)</td>
<td>&lt;LOD</td>
<td>0.99 (0.71–1.3)</td>
<td>3.8E (2.2–5.3)</td>
<td>6.7E (1.9–11)</td>
</tr>
</tbody>
</table>

\(^a\) If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

\(^b\) Data not available as participants under the age of 6 years were not included in cycle 1 (2007–2009).

\(^E\) Use data with caution.

\(^F\) Data is too unreliable to be published.
### Table 10.5.7

Methylmercury — Geometric means and selected percentiles of whole blood concentrations (μg Hg/L) for the Canadian population aged 20–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>20–79</td>
<td>3 (2012-2013)</td>
<td>1032</td>
<td>18.70</td>
<td>0.64 (0.48 - 0.84)</td>
<td>&lt;LOD</td>
<td>0.72 (0.50 - 0.95)</td>
<td>3.1E (1.2 - 5.0)</td>
<td>5.2E (2.7 - 7.8)</td>
</tr>
<tr>
<td>Males</td>
<td>20–79</td>
<td>3 (2012-2013)</td>
<td>502</td>
<td>18.33</td>
<td>0.63E (0.38 - 1.0)</td>
<td>&lt;LOD</td>
<td>0.63E (0.23 - 1.0)</td>
<td>4.3E (1.2 - 7.3)</td>
<td>7.5E (3.9 - 11)</td>
</tr>
<tr>
<td>Females</td>
<td>20–79</td>
<td>3 (2012-2013)</td>
<td>530</td>
<td>19.06</td>
<td>0.65 (0.53 - 0.79)</td>
<td>&lt;LOD</td>
<td>0.83 (0.68 - 0.97)</td>
<td>2.6E (1.3 - 3.9)</td>
<td>4.4E (2.8 - 6.1)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012-2013)</td>
<td>359</td>
<td>24.51</td>
<td>0.56 (0.42 - 0.76)</td>
<td>&lt;LOD</td>
<td>0.60E (0.38 - 0.81)</td>
<td>3.0E (1.7 - 5.1)</td>
<td>5.4E (2.1 - 8.7)</td>
</tr>
<tr>
<td>Total</td>
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<td>3 (2012-2013)</td>
<td>313</td>
<td>19.17</td>
<td>0.60E (0.41 - 0.89)</td>
<td>&lt;LOD</td>
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<td>3.0E (0.85 - 5.1)</td>
<td>5.4E (2.1 - 8.7)</td>
</tr>
<tr>
<td>Total</td>
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<td>3 (2012-2013)</td>
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<td>0.87 (0.62 - 1.2)</td>
<td>&lt;LOD</td>
<td>0.99 (0.65 - 1.3)</td>
<td>3.1E (1.8 - 4.5)</td>
<td>F</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.

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### REFERENCES


11.1 COTININE

Cotinine (CASRN 486-56-6) is the major primary metabolite of nicotine, a chemical found naturally in the tobacco plant and present in tobacco products such as cigarettes, cigars, and smokeless tobacco products (e.g. chewing tobacco and snuff) (Benowitz and Jacob, 1994). Nicotine is also incorporated into nicotine replacement therapies such as the nicotine gum, patch, lozenge, inhaler, e-cigarettes, and buccal spray.

Human exposure to nicotine occurs primarily through the use of tobacco products, exposure to environmental tobacco smoke, and the use of nicotine replacement therapies (HSDB, 2009). In addition, infants breast fed by women who smoke may be exposed to nicotine in breast milk (HSDB, 2009).

Inhalation is the most effective intake route with an average 60% to 80% of nicotine absorbed through the lungs (Iwase et al., 1991). Nicotine can also be absorbed through the skin and gastrointestinal tract, but at a much lower efficiency (Karaconji, 2005). Once inside the body, approximately 70% to 80% of nicotine is metabolized into cotinine. It has a half-life of 10 to 20 hours and can remain in the body at detectable levels for up to 4 days (Benowitz and Jacob, 1994; Curvall et al., 1990). Cotinine is considered to be the most relevant biomarker for exposure to tobacco products and tobacco smoke (Brown et al., 2005; CDC, 2009; Seaton and Vesell, 1993).

Tobacco smoke is a combination of gases, liquids, and breathable particles, some of which are harmful to human health. It contains over 4,000 chemicals, including at least 70 that cause, initiate, or promote cancer, and has been classified by the International Agency for Research on Cancer (IARC) as Group 1, carcinogenic to humans (Health Canada, 2011; IARC, 2004). Exposure to these chemicals also contributes directly to other diseases, such as emphysema and heart disease, and an increased risk of asthma (CDC, 2004). During pregnancy, smoking may lead to miscarriages, low-birth-weight infants and less breast milk (WHO, 2010). Most of these chemicals are formed during the combustion of tobacco; others are found naturally in tobacco and are released as the tobacco burns (CDC, 2004). Smokeless tobaccos, including chewing tobacco and snuff, contain 28 known cancer-causing chemicals and, similar to the tobaccos used in cigarettes, pipes, and cigars, can lead to nicotine dependence and addiction (Health Canada, 2010; IARC, 2007). Smokeless tobacco use causes oral and pancreatic cancer and has been classified by IARC as Group 1, carcinogenic to humans (IARC, 2007). It can also cause serious dental health problems, including recession of the gums, tooth loss, and discolouration of the teeth and gums (Walsh and Epstein, 2000). Levels of cotinine in the blood and urine of non-smokers have been correlated with some adverse health effects related to tobacco smoke exposure, and cotinine itself may contribute to the neuropharmacological effects of tobacco smoking (Benowitz, 1996; Crooks and Dwoskin, 1997).

As a result of the adverse health effects associated with tobacco use, the Government of Canada, along with provincial and territorial governments and various
municipalities, has taken several steps to reduce the prevalence of tobacco use as well as exposure to tobacco smoke. These steps include prohibitions on the sale of tobacco to youth, requirements to apply health warnings on tobacco packaging, and restrictions on the promotion of tobacco products, including the display of tobacco products at retail outlets (Health Canada, 2006). Additional steps include the offer of cessation help along with initiatives to eliminate smoking in workplaces and enclosed public locations (Health Canada, 2006).

The First Nations Biomonitoring Initiative (FNBI) is a nationally representative biomonitoring study of adult First Nations peoples living on reserves south of the 60° parallel (AFN, 2013). It comprises 13 randomly selected First Nation communities in Canada with 503 First Nations participants aged 20 years and older. In 2011, the 50th percentile concentrations of cotinine in urine from smokers and non-smokers were 315.79 µg/L and <1.1 µg/L, respectively. Data from cycle 1 (2007–2009) of the Canadian Health Measures Survey (CHMS) demonstrated that a substantial proportion of the Canadian population is exposed to secondhand smoke. The study found that certain non-smoking subpopulations, including children, adolescents, and those exposed to secondhand smoke in the home, had higher percentages with detectable cotinine concentrations (≥1.1 µg/L), indicating secondhand smoke exposure (Wong et al., 2013). A study of occupationally exposed non-smoking bar workers in the Toronto area examined the effects of a 2004 smoke-free workplace bylaw; the study showed a 1-month post-ban decline in the geometric mean of urinary cotinine from 10.3 µg/L to 3.10 µg/L (Repace et al., 2013). A concentration of 50 µg/L urine for cotinine is recommended for determining smoking status; levels greater than this concentration are attributed to smokers (SRNT Subcommittee on Biochemical Verification, 2002). Using this concentration, a study assessed the validity of self-reported cigarette smoking status among Canadians using urinary cotinine data from cycle 1 (2007–2009) of the CHMS (Wong et al., 2012). Compared with estimates based on urinary cotinine concentration, smoking prevalence based on self-reporting was only 0.3 percentage points lower, indicating that accurate estimates of the prevalence of cigarette smoking among Canadians can be derived from self-reported smoking status data.

Cotinine was analyzed in the urine of all CHMS participants aged 6 to 79 years in cycle 1 (2007–2009), and 3 to 79 years in cycle 2 (2009–2011) and cycle 3 (2012–2013). Data from these cycles are presented as both µg/L and µg/g creatinine for non-smokers and smokers. Survey participants aged 3 to 11 years were assumed to be non-smokers. In this survey, a smoker is defined as someone who is a current daily or occasional smoker and a non-smoker is defined as someone who does not currently smoke and has either never smoked or who was previously a daily or occasional smoker. Finding a measurable amount of cotinine in urine is an indicator of exposure to nicotine and does not necessarily mean that an adverse health effect will occur.

In addition to free cotinine, nicotine and several other metabolites (cotinine-N-glucuronide, nicotine-N-glucuronide, trans-3-hydroxycotinine, trans-3-hydroxycotinine-O-glucuronide, and anabasine) were analyzed in cycle 3 (2012–2013) of the CHMS. Free and total 4-(methylnitrosoamino)-1-(3-pyridyl)-1-butanol (NNAL), a metabolite of a tobacco-specific N-nitrosamine found only in tobacco and products derived from tobacco, were also analyzed in cycle 3 (2012–2013) of the CHMS. Data on these tobacco chemicals and their metabolites are available from Statistics Canada through the Research Data Centres Program.
## Table 11.1.1

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
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<td>F</td>
</tr>
<tr>
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<td>&lt;LOD</td>
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<td>F</td>
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<tr>
<td>Total</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
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<tr>
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<td>1 (2007–2009)</td>
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<td>82.95</td>
<td>–</td>
<td>&lt;LOD</td>
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<tr>
<td>Males</td>
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<td>84.55</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Males</td>
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<td>3 (2012–2013)</td>
<td>2183</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
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<td>F</td>
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<td>88.96</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.4E (&lt;LOD–2.3)</td>
<td>F</td>
</tr>
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<td>6–79</td>
<td>3 (2012–2013)</td>
<td>2273</td>
<td>89.97</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

a For the purpose of total population comparisons, only values from participants aged 6–79 years were included as participants under the age of 6 years were not included in cycle 1 (2007–2009).
b If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.

## Table 11.1.2

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODb</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
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<tbody>
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<td>1 (2007–2009)</td>
<td>4694</td>
<td>85.84</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>4.6 (3.3–5.8)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
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<td>2 (2009–2011)</td>
<td>4883</td>
<td>86.88</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>3.1 (2.1–4.1)</td>
<td>F</td>
</tr>
<tr>
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<td>3 (2012–2013)</td>
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<td>88.64</td>
<td>–</td>
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<td>&lt;LOD</td>
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<td>F</td>
</tr>
<tr>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>4.8E (2.7–6.9)</td>
<td>F</td>
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<td>2 (2009–2011)</td>
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<td>84.55</td>
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<td>&lt;LOD</td>
<td>3.8E (1.7–5.9)</td>
<td>F</td>
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<tr>
<td>Males</td>
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<td>3 (2012–2013)</td>
<td>2183</td>
<td>87.27</td>
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<td>&lt;LOD</td>
<td>2.3E (1.4–3.3)</td>
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<td>&lt;LOD</td>
<td>3.0 (2.2–3.7)</td>
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<tr>
<td>Females</td>
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<td>&lt;LOD</td>
<td>2.7 (2.1–3.2)</td>
<td>4.4E (1.7–7.0)</td>
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</tbody>
</table>

a For the purpose of total population comparisons, only values from participants aged 6–79 years were included as participants under the age of 6 years were not included in cycle 1 (2007–2009).
b If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.
### Table 11.1.3

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD*</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
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<tbody>
<tr>
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<td>3–79</td>
<td>1 (2007–2009)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
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</tr>
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<tr>
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<td>1 (2007–2009)</td>
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<td>–</td>
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<td>F</td>
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</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
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<td>82.56</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td>F</td>
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</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
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<td>&lt;LOD</td>
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<tr>
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<td>20–39</td>
<td>3 (2012–2013)</td>
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<td>&lt;LOD</td>
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</tr>
<tr>
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<td>1 (2007–2009)</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
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<td></td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
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</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>917</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td></td>
</tr>
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</table>

* If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

b Data not available as participants under the age of 6 years were not included in cycle 1 (2007–2009).

e Use data with caution.

f Data is too unreliable to be published.
### Table 11.1.4


<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD*</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
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<tr>
<td>Total</td>
<td>3–79</td>
<td>1 (2007–2009)</td>
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<td>–</td>
<td>–</td>
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<td>Total</td>
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<td>&lt;LOD</td>
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<td>(2.2–4.4)</td>
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</tr>
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<td>&lt;LOD</td>
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</tr>
<tr>
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<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Males</td>
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<td>2588</td>
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</tr>
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<td>–</td>
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<td>&lt;LOD</td>
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<td>(2.0–3.9)</td>
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<td>(2.3–3.5)</td>
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<td>–</td>
<td>–</td>
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<td>Total</td>
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<td>2 (2009–2011)</td>
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<td>&lt;LOD</td>
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</tr>
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<td>1042</td>
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<td>&lt;LOD</td>
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<td>(1.9–10)</td>
<td>F</td>
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<tr>
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<td>&lt;LOD</td>
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<td>(1.9–8.5)</td>
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</tr>
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<td>3 (2012–2013)</td>
<td>1007</td>
<td>86.79</td>
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<td>&lt;LOD</td>
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<td>(1.1–5.8)</td>
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<td>&lt;LOD</td>
<td>7.9†</td>
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<td>&lt;LOD</td>
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<td>F</td>
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</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>889</td>
<td>82.56</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>3.2†</td>
<td>(1.0–5.5)</td>
<td>F</td>
</tr>
<tr>
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<td>1 (2007–2009)</td>
<td>871</td>
<td>85.35</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>4.5†</td>
<td>(1.7–7.4)</td>
<td>F</td>
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<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>1007</td>
<td>86.22</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Total</td>
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<td>3 (2012–2013)</td>
<td>792</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>2.2</td>
<td>(1.5–2.9)</td>
<td>3.3†</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>1 (2007–2009)</td>
<td>944</td>
<td>88.81</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>4.6†</td>
<td>(2.9–6.4)</td>
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</tr>
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<td>Total</td>
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<td>91.56</td>
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<td>&lt;LOD</td>
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<td>&lt;LOD</td>
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<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>1 (2007–2009)</td>
<td>956</td>
<td>90.69</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>3.0</td>
<td>(1.9–4.0)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
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<td>921</td>
<td>93.08</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>2.7</td>
<td>(1.9–3.6)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
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<td>3 (2012–2013)</td>
<td>917</td>
<td>92.58</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>2.6</td>
<td>(1.9–3.2)</td>
<td>4.1†</td>
</tr>
</tbody>
</table>

---

* If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

* Data not available as participants under the age of 6 years were not included in cycle 1 (2007–2009).

* Use data with caution.

* Data is too unreliable to be published.
Table 11.1.5

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.

F Data is too unreliable to be published.

X Suppressed to meet the confidentiality requirements of the Statistics Act.
### Table 11.1.6

**Cotinine (smokers) (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 1 (2007–2009), cycle 2 (2009–2011) and cycle 3 (2012–2013).**

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD*</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
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</thead>
<tbody>
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<td>2 (2009–2011)</td>
<td>102</td>
<td>11.76</td>
<td>F &lt;LOD F</td>
<td>F</td>
<td>1300 (990–1500)</td>
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<td>228</td>
<td>2.63</td>
<td>840 (520–1300)</td>
<td>F</td>
<td>940 (570–1300)</td>
<td>3500 (1500–5500)</td>
<td>5200 (2500–7800)</td>
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<td>2 (2009–2011)</td>
<td>152</td>
<td>1.96</td>
<td>F</td>
<td>F</td>
<td>1000 (700–1600)</td>
<td>3000 (1700–4500)</td>
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</table>

*If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.*

*E Use data with caution.*

*F Data is too unreliable to be published.*

*X Suppressed to meet the confidentiality requirements of the Statistics Act.*
REFERENCES


12.1 OVERVIEW

Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds characterized by the presence of two or more fused aromatic rings. The United States Environmental Protection Agency has prioritized 16 PAHs because of their potential human health and/or ecological toxicity (EPA, 2013). The table below lists seven of these priority PAHs and their metabolites measured in cycle 3 of the Canadian Health Measures Survey (CHMS).

Table 12.1.1
Hydroxylated polycyclic aromatic hydrocarbon (PAH) metabolites measured in the Canadian Health Measures Survey cycle 3 (2012–2013) and their parent PAH compounds

<table>
<thead>
<tr>
<th>PAH</th>
<th>CASRN</th>
<th>Hydroxylated PAH metabolites</th>
<th>CASRN</th>
</tr>
</thead>
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<td>Benzo[a]pyrene</td>
<td>50-32-8</td>
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<td>Chrysene</td>
<td>218-01-9</td>
<td>2-Hydroxychrysene</td>
<td>65945-06-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-Hydroxychrysene</td>
<td>63019-39-6</td>
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<td>4-Hydroxychrysene</td>
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<td></td>
<td>6-Hydroxychrysene</td>
<td>37515-51-8</td>
</tr>
<tr>
<td>Chrysene</td>
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<td>65945-06-4</td>
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<td>Chrysene</td>
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<td>3-Hydroxychrysene</td>
<td>63019-39-6</td>
</tr>
<tr>
<td>Chrysene</td>
<td>218-01-9</td>
<td>4-Hydroxychrysene</td>
<td>63019-40-9</td>
</tr>
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<td>Chrysene</td>
<td>218-01-9</td>
<td>6-Hydroxychrysene</td>
<td>37515-51-8</td>
</tr>
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<td>2-Hydroxyfluorene</td>
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<td>1-Hydroxypyrene</td>
<td>5315-79-7</td>
</tr>
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</table>
PAHs are released to the environment from both natural and anthropogenic sources; the contribution from anthropogenic sources is substantially higher than from natural sources (ATSDR, 1995). In Canada, forest fires are the largest natural source of PAHs in the environment (Environment Canada, 2010). Other natural sources include crude oil, coal, and volcanic eruptions. Anthropogenic PAH emissions are predominantly due to the incomplete combustion of organic substances from waste incineration, tobacco smoke, cooking, vehicle exhaust, mining and refining operations, oil spills, and the use of creosote-treated products (ATSDR, 1995; ATSDR, 2005; Environment Canada and Health Canada, 1994).

For the general population, the major routes of exposure to PAHs are ingestion and inhalation from sources including diet, smoking, and ambient and indoor air (IARC, 2010; WHO, 2011). Levels in food depend on the source of the food and the method of cooking (ATSDR, 1995). PAHs can be formed when food is charbroiled, grilled, roasted, fried, or baked. Drinking water is considered to be a negligible source of exposure in Canada (Environment Canada and Health Canada, 1994). Vehicle exhaust, tobacco smoke, emissions from wood and charcoal-fired stoves, house dust, and ambient air all contribute to inhalation exposure. Human exposure to PAHs may also occur through skin contact with soot and tars (ATSDR, 1995).

PAHs can be absorbed following inhalation, oral, and dermal exposure. They undergo multi-step metabolism leading to several types of metabolites, including hydroxylated PAHs (Strickland et al., 1996). Elimination occurs through urine and feces, with urinary hydroxylated PAH metabolites observed within a few days of exposure (Viau et al., 1995). These metabolites are excreted both in the free form and as glucuronic acid and sulphate conjugates (Castaño-Vinyals et al., 2004).

Several approaches exist to assess human exposure to PAHs. The analysis of urinary hydroxylated PAH metabolites is the most common approach and has been used in several biomonitoring studies (Becker et al., 2003; CDC, 2009).

Evaluating health effects of exposure to individual PAH species in humans is difficult because exposure is generally to PAH mixtures. Studies in laboratory animals have shown that several PAHs are carcinogenic, mutagenic, and/or teratogenic (IARC, 2010; IARC, 2012). The carcinogenic potency of PAHs differs among PAH species, and can differ across routes of exposure (ATSDR, 1995). For some PAHs, formation of epoxides through metabolic activation is considered a key step in eliciting carcinogenic effects (Guillén and Sopelana, 2003). Benzo[a]pyrene, PAH-containing mixtures such as soot and coal tar, as well as occupational PAH exposures during selected industrial activities (i.e. coal-tar distillation, coal gasification, coke production, aluminium production) have recently been classified as carcinogenic to humans (Group 1) by the International Agency for Research on Cancer (IARC) (IARC, 2012). However, IARC has also classified some PAHs, such as chrysene and naphthalene, as possibly carcinogenic to humans (Group 2B) and others, such as fluoranthene, fluorene, phenanthrene, and pyrene, as not classifiable as to their carcinogenicity to humans (Group 3) (IARC, 2010). PAHs also elicit adverse immunologic effects, developmental and reproductive effects, as well as hepatic and renal effects in laboratory animals, but generally at doses higher than those that elicit a carcinogenic response (ATSDR, 1995).

In Canada, PAHs are listed as toxic substances on Schedule 1 of the Canadian Environmental Protection Act, 1999, based on an evaluation of the environmental and health effects of several PAHs, including benzo[a]pyrene (Canada, 1999; Canada, 2000; Environment Canada and Health Canada, 1994). Several environmental performance agreements, codes of practice, and recommendations have been established to reduce releases of PAHs to the environment from the aluminum production, metal refining and founding, and wood preservation sectors (Environment Canada, 2010). Health Canada has established a maximum level for PAHs in a specific food product called olive-pomace oil (Health Canada, 2012).

In the following sections, some priority PAHs are discussed, and data on the levels of urinary hydroxylated PAH metabolites in the Canadian population are presented.


REFERENCES


12.2 BENZO[a]PYRENE

Benzo[a]pyrene is a polycyclic aromatic hydrocarbon (PAH) composed of five fused benzene rings. It is not manufactured in Canada and no industrial uses are known (Health Canada, 1986).

In laboratory rats, 40% to 60% of benzo[a]pyrene was shown to be absorbed following exposure through gavage or diet (Faust, 1994). Based on laboratory studies, approximately 3% of benzo[a]pyrene is expected to be absorbed through skin after 24 hours (Kao et al., 1985), although an optimized absorption study using rats showed 46% absorption over 5 days (Yang et al., 1986). Benzo[a]pyrene absorption through skin may be facilitated by metabolism in the cellular epidermis and the formation of stable adducts of benzo[a]pyrene metabolites and cellular structures. Evidence for absorption of benzo[a]pyrene following inhalation comes from the presence of urinary metabolites in workers exposed to PAHs in air (ATSDR, 1995). Inhalation absorption of benzo[a]pyrene is highly dependent on the type of particles onto which it is adsorbed. After absorption, benzo[a]pyrene distributes to several organs, including lungs, liver, and intestines (Faust, 1994). Like other PAHs, benzo[a]pyrene can be metabolized by many tissues forming various arene epoxides that after rearrangement produce hydroxylated PAHs and dihydrodiols (Bouchard and Viau, 1996). The metabolite 3-hydroxybenzo[a]pyrene has been used as a human urine biomarker for exposure to benzo[a]pyrene (Chien and Yeh, 2012).

Adverse health effects have been observed in laboratory animals following benzo[a]pyrene exposure via inhalation, oral, and dermal routes. Non-carcinogenic effects have been observed, but generally at dose levels at least an order of magnitude higher than that of carcinogenic effects (ATSDR, 1995; Health Canada, 1986; Jules et al., 2012). The diolepoxides formed during metabolism of benzo[a]pyrene are considered to be the primary carcinogenic agents (IARC, 2012). Occupational exposures to benzo[a]pyrene-containing mixtures have been associated with a series of cancers (IARC, 2012). Based on the strong evidence for the carcinogenicity of benzo[a]pyrene in many animal species, and supported by evidence from laboratory and human studies, the International Agency for Research on Cancer has classified benzo[a]pyrene as Group 1, a known human carcinogen (IARC, 2012). Prior to this, Environment Canada and Health Canada had classified benzo[a]pyrene as probably carcinogenic to humans (Group II) based primarily on results from studies with laboratory animals (Environment Canada and Health Canada, 1994).

The Federal-Provincial-Territorial Committee on Drinking Water has developed a guideline for Canadian drinking water quality that establishes a maximum acceptable concentration for benzo[a]pyrene in drinking water (Health Canada, 1986). This guideline, which was reaffirmed in 2005 (Health Canada, 2012), is currently under review and is expected to be published for public consultation in early 2015.

The benzo[a]pyrene metabolite, 3-hydroxybenzo[a]pyrene, was analyzed in the urine of Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years and is presented as both µg/L and µg/g creatinine. Finding a measurable amount of 3-hydroxybenzo[a]pyrene in urine is an indicator of exposure to benzo[a]pyrene and does not necessarily mean that an adverse health effect will occur.
### Table 12.2.1
3-Hydroxybenzo[a]pyrene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1163</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1188</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>453</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>466</td>
<td>99.79</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>468</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
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<tr>
<td>Total</td>
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<td>2 (2009–2011)</td>
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<td>100</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
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<td>3 (2012–2013)</td>
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<td>&lt;LOD</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
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<td>2 (2009–2011)</td>
<td>328</td>
<td>100</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
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<tr>
<td>Total</td>
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<td>3 (2012–2013)</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
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<td>267</td>
<td>100</td>
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<td>&lt;LOD</td>
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<tr>
<td>Total</td>
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<td>331</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
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</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

### Table 12.2.2
3-Hydroxybenzo[a]pyrene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1163</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1188</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>453</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>466</td>
<td>99.79</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
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<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>468</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>473</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
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<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>486</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
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<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
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<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>300</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
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<tr>
<td>Total</td>
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<td>2 (2009–2011)</td>
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<tr>
<td>Total</td>
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<td>3 (2012–2013)</td>
<td>331</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
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<td>&lt;LOD</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
**REFERENCES**


**12.3 CHRYSENE**

Chrysene is a polycyclic aromatic hydrocarbon (PAH) composed of four fused benzene rings. There are no known uses of chrysene other than its use as a research chemical (ATSDR, 1995).

Chrysene is highly lipophilic. In animal pharmacokinetic studies, approximately 75% of chrysene was absorbed when administered through oral, inhalation, and dermal routes of exposure; after absorption, it preferentially distributed to adipose tissues (Borges, 1994). Chrysene is metabolized into several mono- and dihydroxychrysene metabolites (CDC, 2009). Chrysene metabolites are excreted predominantly in the feces. However, PAH biomonitoring studies in humans have attempted to measure urinary levels of 1-, 2-, 3-, 4, and 6-hydroxychrysene, and have been able to detect urinary 3- and 6-hydroxychrysene in a small proportion of samples (Nethery et al., 2012).

Data on the systemic toxicity of chrysene in animals and humans are limited (Borges, 1994). In mice, chrysene exposure resulted in an increased incidence of skin papillomas and hepatic and lung tumours (Chang et al., 1983; Wislocki et al., 1986). Based on a limited amount of available carcinogenicity data, the International Agency for Research on Cancer has classified chrysene as Group 2B, possibly carcinogenic to humans (IARC, 2010).

The urinary chrysene metabolites 3- and 6-hydroxychrysene were measured for 73 non-smoking, non-occupationally exposed individuals (aged 16 to 64 years) living approximately 1 km from an aluminum plant in Baie-Comeau, Quebec. These chrysene metabolites were measured as part of a spectrum of PAH metabolites. Although the levels of some other
urinary PAH metabolites were higher compared with a control group of 71 individuals living at least 11 km from the plant, the urinary concentrations of these chrysene metabolites were below the limit of detection (0.032 µg/L for 3-hydroxychrysene and 0.019 µg/L for 6-hydroxychrysene) for most samples (Bouchard et al., 2009). Similarly, 2-, 3-, 4-, and 6-hydroxychrysene concentrations were below the limit of detection when measured in urine of pregnant women living in Hamilton, Ontario (Nethery et al., 2012).

The chrysene metabolites, 2-, 3-, 4-, and 6-hydroxychrysene, were analyzed in the urine of Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years and are presented as both µg/L and µg/g creatinine. Given that chrysene metabolites are predominantly excreted in the feces, their urinary absence alone does not indicate that exposure to chrysene did not occur. Finding a measurable amount of chrysene metabolites in urine is an indicator of exposure to chrysene and does not necessarily mean that an adverse health effect will occur.

## Table 12.3.1
2-Hydroxychrysene — Geometric means and selected percentiles of urine concentrations (µg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
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</tr>
<tr>
<td>Males</td>
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<td>3 (2012–2013)</td>
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</tr>
<tr>
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<td>3 (2012–2013)</td>
<td>492</td>
<td>100</td>
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<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
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<tr>
<td>Total</td>
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<td>Total</td>
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<tr>
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<tr>
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</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
### Table 12.3.2
2-Hydroxychrysene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
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<td>2 (2009–2011)</td>
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</tr>
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<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1237</td>
<td>100</td>
<td>–</td>
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<td>2 (2009–2011)</td>
<td>506</td>
<td>99.80</td>
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<tr>
<td>Total</td>
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</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

### Table 12.3.3
3-Hydroxychrysene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
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<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>492</td>
<td>99.80</td>
<td>–</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
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<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>496</td>
<td>99.80</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
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<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>346</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>358</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
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<td>2 (2009–2011)</td>
<td>283</td>
<td>100</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
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</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
### Table 12.3.4

3-Hydroxychrysene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>491</td>
<td>99.80</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>504</td>
<td>99.41</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>496</td>
<td>99.80</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>496</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
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<td>100</td>
<td>–</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>282</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

*If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.*

### Table 12.3.5

4-Hydroxychrysene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2498</td>
<td>99.84</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1237</td>
<td>99.84</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>508</td>
<td>99.61</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>496</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>346</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>358</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>99.68</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

*If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.*
### Table 12.3.6
4-Hydroxychrysene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>3–79</td>
<td>2 (2009–2011)</td>
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<td>99.76</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
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<td>99.84</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1237</td>
<td>99.84</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1260</td>
<td>99.84</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>497</td>
<td>99.80</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>491</td>
<td>99.39</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
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<td>2 (2009–2011)</td>
<td>506</td>
<td>99.61</td>
<td>−</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>496</td>
<td>100</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>497</td>
<td>99.80</td>
<td>−</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>100</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>346</td>
<td>100</td>
<td>−</td>
<td>&lt;LOD</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>356</td>
<td>100</td>
<td>−</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>99.68</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>282</td>
<td>99.65</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>100</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

### Table 12.3.7
6-Hydroxychrysene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
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<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2459</td>
<td>96.87</td>
<td>−</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
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<td>3 (2012–2013)</td>
<td>2494</td>
<td>99.84</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
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<td>2 (2009–2011)</td>
<td>1239</td>
<td>96.37</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
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<td>3 (2012–2013)</td>
<td>1234</td>
<td>99.84</td>
<td>−</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
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</tr>
<tr>
<td>Females</td>
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<td>2 (2009–2011)</td>
<td>1220</td>
<td>97.38</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1260</td>
<td>99.84</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>494</td>
<td>97.37</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>492</td>
<td>100</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>499</td>
<td>95.79</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>494</td>
<td>100</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>489</td>
<td>97.55</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>504</td>
<td>99.80</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>344</td>
<td>96.80</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>354</td>
<td>96.33</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>310</td>
<td>100</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
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<td>2 (2009–2011)</td>
<td>279</td>
<td>97.49</td>
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<td>&lt;LOD</td>
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<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>99.71</td>
<td>−</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
Table 12.3.8
6-Hydroxychrysene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
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<td>Total</td>
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<td>2449</td>
<td>96.87</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
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<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2493</td>
<td>99.84</td>
<td>–</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
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<td>3 (2012–2013)</td>
<td>1234</td>
<td>99.84</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>491</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>497</td>
<td>95.79</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>494</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>487</td>
<td>97.55</td>
<td>–</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>504</td>
<td>99.80</td>
<td>–</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>342</td>
<td>96.80</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>310</td>
<td>100</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>278</td>
<td>97.49</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

REFERENCES


12.4 **FLUORANTHENE**

Fluoranthene, also known as benzo[j,k]fluorene, is a polycyclic aromatic hydrocarbon (PAH) with five fused aromatic rings. It is found naturally in the environment in some bacteria, algae, and plants, and as a result of anthropogenic releases from incomplete combustion of organic substances (EPA, 1980). Fluoranthene is used in the synthesis of dyes and in biomedical research (Wu et al., 2010).

Limited pharmacokinetic data for fluoranthene are available. Similar to other structurally related PAHs, fluoranthene may be absorbed following oral, inhalation, or dermal exposure (Faust, 1993a; Storer et al., 1984). Because of its high lipophilicity, fluoranthene distributes to adipose tissue (EPA, 1980). Metabolism of fluoranthene produces hydroxylated metabolites, and urinary 3-hydroxyfluoranthene is considered an indicator of recent exposures.

Kidney and liver effects were observed in rats orally administered fluoranthene (Faust, 1993). Fluoranthene exposure in mice has resulted in lung tumours (Busby Jr. et al., 1989; IARC, 2010). Dermal exposure in mice to a combination of benz[a]pyrene and fluoranthene significantly increased the incidence of skin tumours (IARC, 2010). Based on the limited data on fluoranthene carcinogenicity, the International Agency for Research on Cancer has classified fluoranthene as Group 3, not classifiable as to its carcinogenicity to humans (IARC, 2010).

The urinary fluoranthene metabolite, 3-hydroxyfluoranthene, was measured for 73 non-smoking, non-occupationally exposed individuals (aged 16 to 64 years) living approximately 1 km from an aluminum plant in Baie-Comeau, Quebec. The fluoranthene metabolite was measured as part of a spectrum of PAH metabolites. Although the levels of some other urinary PAH metabolites were higher compared with a control group of 71 individuals living at least 11 km from the plant, the concentration of 3-hydroxyfluoranthene was below the limit of detection (0.030 µg/L) for most samples (Bouchard et al., 2009).

The fluoranthene metabolite, 3-hydroxyfluoranthene, was analyzed in the urine of Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years and is presented as both µg/L and µg/g creatinine. Finding a measurable amount of 3-hydroxyfluoranthene in urine is an indicator of exposure to fluoranthene and does not necessarily mean that an adverse health effect will occur.
### Table 12.4.1
3-Hydroxyfluoranthene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2265</td>
<td>98.23</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2263</td>
<td>98.37</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1145</td>
<td>98.25</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1133</td>
<td>98.41</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1120</td>
<td>98.21</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1130</td>
<td>98.32</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>428</td>
<td>97.20</td>
<td>–</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
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<td>3 (2012–2013)</td>
<td>435</td>
<td>97.93</td>
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<td>&lt;LOD</td>
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</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>463</td>
<td>97.41</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
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<td>98.67</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>469</td>
<td>98.08</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>98.72</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>288</td>
<td>98.26</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>266</td>
<td>97.74</td>
<td>–</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
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<td>3 (2012–2013)</td>
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<td>98.71</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

### Table 12.4.2
3-Hydroxyfluoranthene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2257</td>
<td>98.23</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2262</td>
<td>98.37</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
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<td>2 (2009–2011)</td>
<td>1142</td>
<td>98.25</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1133</td>
<td>98.41</td>
<td>–</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1120</td>
<td>98.21</td>
<td>–</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1130</td>
<td>98.32</td>
<td>–</td>
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<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>428</td>
<td>97.20</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>435</td>
<td>97.93</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>463</td>
<td>97.41</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>450</td>
<td>98.67</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>469</td>
<td>98.08</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>98.72</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
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<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>288</td>
<td>98.26</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>266</td>
<td>97.74</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>309</td>
<td>98.71</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
REFERENCES


12.5 FLUORENE

Fluorene is a polycyclic aromatic hydrocarbon (PAH) with three fused aromatic rings. Fluorene and its derivatives are used in the manufacture of dyes, pharmaceuticals, polymer materials, photonics, and basic research (Belfield et al., 1999; Bernius et al., 2000; Mondal et al., 2009).

Animal studies indicate that fluorene is absorbed following oral, inhalation, and dermal exposure (ATSDR, 1995). Metabolism of fluorene produces several hydroxylated metabolites that are further conjugated with glucuronic or sulphonic acids and rapidly eliminated in the urine (ATSDR, 1995). Several urinary monohydroxy fluorene metabolites, including 2-, 3-, and 9-hydroxyfluorene, have been identified in humans and are considered indicators of recent PAH exposure (Becker et al., 2003; CDC, 2009; Nethery et al., 2012). Urinary 3-hydroxyfluorene may be a good predictive biomarker for specifically assessing inhalation exposure to fluorene (Nethery et al., 2012).

Hematological and liver effects were observed in laboratory animals exposed orally to fluorene (ATSDR, 1995). Data on the carcinogenicity of fluorene in humans have not been identified and the International Agency for Research on Cancer has classified fluorene as Group 3, not classifiable as to its carcinogenicity in humans (IARC, 2010).

In a pilot biomonitoring study carried out in Hamilton, Ontario, with 19 pregnant women aged 19 to 42 years, the geometric means for 2-, 3-, and 9-hydroxyfluorene in urine were 0.2157 µg/g creatinine, 0.04827 µg/g creatinine, and 0.3908 µg/g creatinine, respectively (Nethery et al., 2012).

The fluorene metabolites, 2-, 3-, and 9-hydroxyfluorene, were analyzed in the urine of Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years and are presented as both µg/L and µg/g creatinine. Finding a measurable amount of fluorene metabolites in urine is an indicator of exposure to fluorene and does not necessarily mean that an adverse health effect will occur.
Table 12.5.1
2-Hydroxyfluorene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
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<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2524</td>
<td>0</td>
<td>0.27 (0.24–0.29)</td>
<td>0.069 (0.058–0.080)</td>
<td>0.24 (0.22–0.27)</td>
<td>1.2 (0.95–1.5)</td>
<td>2.3 (1.7–2.8)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2514</td>
<td>0</td>
<td>0.26 (0.24–0.29)</td>
<td>0.063 (0.051–0.075)</td>
<td>0.22 (0.20–0.24)</td>
<td>1.6 (1.4–1.8)</td>
<td>2.2 (1.8–2.7)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1268</td>
<td>0</td>
<td>0.32 (0.27–0.38)</td>
<td>0.087 (0.071–0.10)</td>
<td>0.27 (0.23–0.32)</td>
<td>1.6 (0.95–2.3)</td>
<td>3.0 (2.1–4.0)</td>
</tr>
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<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1243</td>
<td>0</td>
<td>0.32 (0.29–0.35)</td>
<td>0.079 (0.058–0.10)</td>
<td>0.26 (0.23–0.29)</td>
<td>1.8 (1.5–2.0)</td>
<td>2.5 (1.7–3.2)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1256</td>
<td>0</td>
<td>0.22 (0.21–0.25)</td>
<td>0.064 (0.051–0.078)</td>
<td>0.21 (0.17–0.26)</td>
<td>0.88E (0.54–1.2)</td>
<td>1.8 (1.3–2.3)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1271</td>
<td>0</td>
<td>0.21 (0.17–0.27)</td>
<td>0.050 (0.035–0.065)</td>
<td>0.18 (0.14–0.21)</td>
<td>1.4F (0.84–2.9)</td>
<td>2.0 (1.4–2.6)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>506</td>
<td>0</td>
<td>0.17 (0.16–0.19)</td>
<td>0.069 (0.061–0.077)</td>
<td>0.18 (0.16–0.20)</td>
<td>0.37 (0.29–0.45)</td>
<td>0.47 (0.32–0.62)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>496</td>
<td>0</td>
<td>0.16 (0.13–0.18)</td>
<td>0.045 (0.029–0.060)</td>
<td>0.17 (0.13–0.21)</td>
<td>0.41 (0.32–0.51)</td>
<td>0.61 (0.41–0.81)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>511</td>
<td>0</td>
<td>0.22 (0.18–0.25)</td>
<td>0.088 (0.077–0.10)</td>
<td>0.24 (0.19–0.29)</td>
<td>0.48 (0.40–0.56)</td>
<td>0.57 (0.38–0.76)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>502</td>
<td>0</td>
<td>0.19 (0.17–0.21)</td>
<td>0.062 (0.045–0.078)</td>
<td>0.18 (0.16–0.21)</td>
<td>0.49 (0.38–0.60)</td>
<td>0.66 (0.53–0.78)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>506</td>
<td>0</td>
<td>0.26 (0.24–0.29)</td>
<td>0.098 (0.073–0.12)</td>
<td>0.26 (0.22–0.30)</td>
<td>0.73 (0.55–0.90)</td>
<td>1.1 (0.87–1.3)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>506</td>
<td>0</td>
<td>0.28 (0.23–0.33)</td>
<td>0.079 (0.063–0.095)</td>
<td>0.25 (0.19–0.31)</td>
<td>1.0F (0.52–1.5)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>0</td>
<td>0.30 (0.25–0.35)</td>
<td>0.085 (0.061–0.11)</td>
<td>0.28 (0.22–0.33)</td>
<td>1.3 (0.86–1.7)</td>
<td>2.2 (1.5–3.0)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>351</td>
<td>0</td>
<td>0.36 (0.29–0.46)</td>
<td>0.087 (0.066–0.11)</td>
<td>0.33 (0.27–0.39)</td>
<td>1.8 (1.3–2.4)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>359</td>
<td>0</td>
<td>0.30 (0.25–0.37)</td>
<td>0.066F (0.037–0.095)</td>
<td>0.25 (0.18–0.31)</td>
<td>1.9 (1.2–2.6)</td>
<td>3.3 (2.4–4.2)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>0</td>
<td>0.27 (0.21–0.34)</td>
<td>0.062 (0.044–0.081)</td>
<td>0.21 (0.16–0.27)</td>
<td>1.6 (1.2–2.0)</td>
<td>2.0F (1.3–2.8)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>287</td>
<td>0</td>
<td>0.21 (0.16–0.25)</td>
<td>0.054 (0.043–0.064)</td>
<td>0.18 (0.13–0.20)</td>
<td>1.1F (0.83–1.5)</td>
<td>2.3F (1.2–3.3)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>347</td>
<td>0</td>
<td>0.21 (0.16–0.27)</td>
<td>0.041F (0.020–0.062)</td>
<td>0.17 (0.14–0.20)</td>
<td>1.7i (0.82–2.7)</td>
<td>3.0F (1.3–4.8)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.
### Table 12.5.2

2-Hydroxyfluorene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2514</td>
<td>0</td>
<td>0.27 (0.24–0.29)</td>
<td>0.10 (0.091–0.11)</td>
<td>0.21 (0.18–0.23)</td>
<td>1.1 (0.82–1.4)</td>
<td>1.9 (1.4–2.4)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2513</td>
<td>0</td>
<td>0.27 (0.23–0.32)</td>
<td>0.096 (0.089–0.10)</td>
<td>0.21 (0.18–0.23)</td>
<td>1.4 (1.1–1.7)</td>
<td>2.0 (1.6–2.3)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1264</td>
<td>0</td>
<td>0.27 (0.23–0.32)</td>
<td>0.083 (0.071–0.096)</td>
<td>0.20 (0.16–0.23)</td>
<td>1.4 (0.81–1.9)</td>
<td>2.4 (1.3–3.5)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1243</td>
<td>0</td>
<td>0.27 (0.23–0.31)</td>
<td>0.12 (0.10–0.13)</td>
<td>0.21 (0.19–0.22)</td>
<td>0.87 (0.46–1.3)</td>
<td>1.7 (1.3–2.1)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1250</td>
<td>0</td>
<td>0.26 (0.24–0.28)</td>
<td>0.10 (0.097–0.11)</td>
<td>0.21 (0.18–0.24)</td>
<td>1.4 (0.87–1.9)</td>
<td>2.0 (1.5–2.5)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1270</td>
<td>0</td>
<td>0.27 (0.23–0.32)</td>
<td>0.16 (0.14–0.18)</td>
<td>0.30 (0.26–0.33)</td>
<td>0.62 (0.46–0.78)</td>
<td>0.75 (0.63–0.88)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>505</td>
<td>0</td>
<td>0.31 (0.28–0.34)</td>
<td>0.16 (0.15–0.18)</td>
<td>0.28 (0.26–0.31)</td>
<td>0.57 (0.50–0.65)</td>
<td>0.77 (0.58–0.95)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>495</td>
<td>0</td>
<td>0.30 (0.28–0.33)</td>
<td>0.14 (0.12–0.16)</td>
<td>0.23 (0.19–0.26)</td>
<td>0.46 (0.37–0.55)</td>
<td>0.59 (0.41–0.78)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>0</td>
<td>0.25 (0.22–0.28)</td>
<td>0.12 (0.11–0.13)</td>
<td>0.22 (0.18–0.26)</td>
<td>0.55 (0.44–0.66)</td>
<td>0.67 (0.58–0.75)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>502</td>
<td>0</td>
<td>0.24 (0.21–0.27)</td>
<td>0.10 (0.092–0.11)</td>
<td>0.17 (0.15–0.18)</td>
<td>0.44 (0.33–0.55)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>504</td>
<td>0</td>
<td>0.20 (0.18–0.22)</td>
<td>0.099 (0.091–0.11)</td>
<td>0.17 (0.15–0.20)</td>
<td>0.58 (0.33–0.83)</td>
<td>1.1E (0.37–1.8)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>506</td>
<td>0</td>
<td>0.21 (0.18–0.24)</td>
<td>0.10 (0.091–0.11)</td>
<td>0.17 (0.15–0.20)</td>
<td>0.58 (0.33–0.83)</td>
<td>1.1E (0.37–1.8)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>353</td>
<td>0</td>
<td>0.27 (0.22–0.33)</td>
<td>0.10 (0.080–0.12)</td>
<td>0.20 (0.17–0.24)</td>
<td>1.1E (0.56–1.6)</td>
<td>2.2E (1.0–3.3)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>351</td>
<td>0</td>
<td>0.28 (0.23–0.35)</td>
<td>0.096 (0.080–0.11)</td>
<td>0.22 (0.18–0.29)</td>
<td>1.3E (0.50–2.1)</td>
<td>1.7 (1.1–2.2)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>357</td>
<td>0</td>
<td>0.30 (0.26–0.36)</td>
<td>0.10 (0.081–0.12)</td>
<td>0.22 (0.18–0.25)</td>
<td>1.6 (1.1–2.1)</td>
<td>2.5 (1.6–3.3)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>312</td>
<td>0</td>
<td>0.31 (0.25–0.38)</td>
<td>0.090 (0.074–0.11)</td>
<td>0.23 (0.17–0.29)</td>
<td>1.7 (1.1–2.2)</td>
<td>2.2 (1.6–2.9)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>286</td>
<td>0</td>
<td>0.25 (0.22–0.28)</td>
<td>0.089 (0.092–0.10)</td>
<td>0.18 (0.16–0.20)</td>
<td>1.2E (0.76–1.6)</td>
<td>1.8 (1.3–2.2)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>347</td>
<td>0</td>
<td>0.24 (0.19–0.30)</td>
<td>0.084 (0.089–0.099)</td>
<td>0.16 (0.12–0.20)</td>
<td>1.0E (0.92–2.2)</td>
<td>2.2E (1.2–3.1)</td>
</tr>
</tbody>
</table>

* a  If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
  E  Use data with caution.
  F  Data is too unreliable to be published.
### Table 12.5.3
3-Hydroxyfluorene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2523</td>
<td>0.04</td>
<td>0.096 (0.087–0.11)</td>
<td>0.022 (0.020–0.025)</td>
<td>0.081 (0.072–0.091)</td>
<td>0.64 (0.46–0.81)</td>
<td>1.3 (0.96–1.7)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2513</td>
<td>0</td>
<td>0.10 (0.090–0.11)</td>
<td>0.019 (0.016–0.022)</td>
<td>0.082 (0.072–0.091)</td>
<td>0.95 (0.70–1.2)</td>
<td>1.3 (1.0–1.7)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1266</td>
<td>0</td>
<td>0.12 (0.099–0.14)</td>
<td>0.028 (0.024–0.032)</td>
<td>0.096 (0.089–0.11)</td>
<td>0.79F (0.34–1.2)</td>
<td>1.7F (1.1–2.3)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1242</td>
<td>0</td>
<td>0.13 (0.11–0.15)</td>
<td>0.024 (0.016–0.031)</td>
<td>0.099 (0.093–0.11)</td>
<td>1.1 (0.75–1.4)</td>
<td>1.5 (1.1–1.9)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1257</td>
<td>0.08</td>
<td>0.078 (0.070–0.086)</td>
<td>0.019 (0.015–0.023)</td>
<td>0.071 (0.058–0.083)</td>
<td>0.38F (0.15–0.60)</td>
<td>0.99F (0.59–1.4)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1271</td>
<td>0</td>
<td>0.078 (0.061–0.10)</td>
<td>0.016 (0.012–0.020)</td>
<td>0.063 (0.043–0.083)</td>
<td>0.68F (0.39–0.98)</td>
<td>1.2 (0.84–1.6)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>507</td>
<td>0</td>
<td>0.069 (0.063–0.077)</td>
<td>0.025 (0.020–0.030)</td>
<td>0.071 (0.061–0.080)</td>
<td>0.16 (0.10–0.22)</td>
<td>0.23F (0.099–0.37)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>496</td>
<td>0</td>
<td>0.064 (0.054–0.075)</td>
<td>0.0216F (0.0076–0.024)</td>
<td>0.068 (0.052–0.083)</td>
<td>0.18 (0.13–0.23)</td>
<td>0.26 (0.18–0.34)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>511</td>
<td>0</td>
<td>0.084 (0.069–0.10)</td>
<td>0.023 (0.016–0.031)</td>
<td>0.080 (0.073–0.087)</td>
<td>0.25F (0.16–0.35)</td>
<td>0.36F (0.21–0.52)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>501</td>
<td>0</td>
<td>0.077 (0.067–0.089)</td>
<td>0.029 (0.022–0.036)</td>
<td>0.093 (0.081–0.11)</td>
<td>0.31F (0.19–0.42)</td>
<td>0.53F (0.33–0.73)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>506</td>
<td>0.20</td>
<td>0.093 (0.082–0.11)</td>
<td>0.028 (0.019–0.037)</td>
<td>0.088 (0.074–0.10)</td>
<td>0.59F (0.24–0.93)</td>
<td>0.94F (0.31–1.6)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>506</td>
<td>0</td>
<td>0.10 (0.088–0.12)</td>
<td>0.028 (0.019–0.037)</td>
<td>0.088 (0.074–0.10)</td>
<td>0.59F (0.24–0.93)</td>
<td>0.94F (0.31–1.6)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>354</td>
<td>0</td>
<td>0.11 (0.092–0.13)</td>
<td>0.025 (0.018–0.032)</td>
<td>0.10 (0.079–0.12)</td>
<td>0.75F (0.39–1.1)</td>
<td>1.1F (0.70–1.5)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>351</td>
<td>0</td>
<td>0.14 (0.11–0.18)</td>
<td>0.026F (0.014–0.038)</td>
<td>0.10 (0.089–0.11)</td>
<td>1.1 (0.77–1.4)</td>
<td>1.4F (0.72–2.0)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>358</td>
<td>0</td>
<td>0.11 (0.090–0.14)</td>
<td>0.020F (0.011–0.030)</td>
<td>0.080 (0.062–0.099)</td>
<td>1.2F (0.86–1.8)</td>
<td>2.2 (1.5–3.0)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>0</td>
<td>0.11 (0.079–0.14)</td>
<td>0.018F (0.011–0.025)</td>
<td>0.078 (0.052–0.10)</td>
<td>0.99F (0.54–1.4)</td>
<td>1.3F (0.76–1.8)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>287</td>
<td>0</td>
<td>0.067 (0.056–0.079)</td>
<td>0.018 (0.014–0.022)</td>
<td>0.050 (0.043–0.057)</td>
<td>0.44F (0.24–0.64)</td>
<td>1.1F (0.58–1.7)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>0</td>
<td>0.074 (0.051–0.095)</td>
<td>0.012F (0.005–0.018)</td>
<td>0.052 (0.037–0.068)</td>
<td>0.95F (0.28–1.6)</td>
<td>1.8F (0.83–2.8)</td>
</tr>
</tbody>
</table>

*a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.
### Table 12.5.4

3-Hydroxyfluorene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM  (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2513</td>
<td>0.04</td>
<td>0.096       (0.087–0.11)</td>
<td>0.032         (0.031–0.034)</td>
<td>0.070         (0.065–0.077)</td>
<td>0.68E         (0.41–0.95)</td>
<td>1.1           (0.84–1.3)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2512</td>
<td>0</td>
<td>0.10        (0.096–0.11)</td>
<td>0.029         (0.025–0.032)</td>
<td>0.072         (0.063–0.081)</td>
<td>0.83           (0.64–1.0)</td>
<td>1.2           (0.94–1.4)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1262</td>
<td>0</td>
<td>0.10        (0.096–0.12)</td>
<td>0.031         (0.029–0.033)</td>
<td>0.074         (0.060–0.088)</td>
<td>0.81E         (0.47–1.1)</td>
<td>1.4E          (0.88–1.9)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1242</td>
<td>0</td>
<td>0.11        (0.090–0.13)</td>
<td>0.026         (0.021–0.030)</td>
<td>0.077         (0.062–0.091)</td>
<td>0.84           (0.64–1.0)</td>
<td>1.0           (0.82–1.3)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1251</td>
<td>0.08</td>
<td>0.089       (0.081–0.098)</td>
<td>0.035         (0.031–0.038)</td>
<td>0.069         (0.063–0.074)</td>
<td>F</td>
<td>0.99           (0.73–1.3)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1270</td>
<td>0</td>
<td>0.10        (0.084–0.12)</td>
<td>0.032         (0.028–0.036)</td>
<td>0.071         (0.061–0.082)</td>
<td>0.79E         (0.38–1.2)</td>
<td>1.2           (0.92–1.6)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>506</td>
<td>0</td>
<td>0.12        (0.11–0.14)</td>
<td>0.061         (0.057–0.066)</td>
<td>0.11           (0.089–0.13)</td>
<td>0.25           (0.19–0.30)</td>
<td>0.32E         (0.16–0.49)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>495</td>
<td>0</td>
<td>0.12        (0.11–0.14)</td>
<td>0.062         (0.053–0.072)</td>
<td>0.11           (0.10–0.13)</td>
<td>0.27           (0.23–0.30)</td>
<td>0.40           (0.27–0.53)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>0</td>
<td>0.098       (0.085–0.11)</td>
<td>0.050         (0.042–0.057)</td>
<td>0.094         (0.089–0.11)</td>
<td>0.20           (0.15–0.25)</td>
<td>0.26           (0.20–0.33)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>501</td>
<td>0</td>
<td>0.099       (0.083–0.12)</td>
<td>0.044         (0.039–0.050)</td>
<td>0.085         (0.070–0.10)</td>
<td>0.25F         (0.11–0.38)</td>
<td>0.43F         (0.23–0.62)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>504</td>
<td>0.20</td>
<td>0.071       (0.062–0.082)</td>
<td>0.031         (0.027–0.035)</td>
<td>0.063         (0.055–0.070)</td>
<td>0.22F         (0.11–0.33)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>506</td>
<td>0</td>
<td>0.079       (0.069–0.090)</td>
<td>0.033         (0.028–0.038)</td>
<td>0.065         (0.056–0.074)</td>
<td>F</td>
<td>0.61E         (0.25–0.96)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>352</td>
<td>0</td>
<td>0.099       (0.081–0.12)</td>
<td>0.033         (0.027–0.038)</td>
<td>0.070         (0.056–0.083)</td>
<td>0.66F         (0.26–1.0)</td>
<td>1.1E          (0.47–1.7)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>351</td>
<td>0</td>
<td>0.11        (0.083–0.14)</td>
<td>0.032         (0.026–0.037)</td>
<td>0.079         (0.060–0.089)</td>
<td>0.78F         (0.36–1.2)</td>
<td>0.99           (0.69–1.3)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>356</td>
<td>0</td>
<td>0.11        (0.092–0.14)</td>
<td>0.033         (0.028–0.038)</td>
<td>0.072         (0.052–0.093)</td>
<td>1.0           (0.72–1.4)</td>
<td>1.6           (1.2–2.0)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>0</td>
<td>0.12        (0.095–0.16)</td>
<td>0.027         (0.019–0.035)</td>
<td>0.078         (0.058–0.099)</td>
<td>1.1           (0.80–1.4)</td>
<td>1.5           (1.0–1.9)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>286</td>
<td>0</td>
<td>0.078       (0.067–0.090)</td>
<td>0.028         (0.025–0.031)</td>
<td>0.055         (0.047–0.063)</td>
<td>0.58F         (0.23–0.92)</td>
<td>0.96           (0.81–1.1)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>0</td>
<td>0.085       (0.067–0.11)</td>
<td>0.025         (0.022–0.028)</td>
<td>0.053         (0.041–0.064)</td>
<td>0.82          (0.40–1.2)</td>
<td>1.4           (1.0–1.8)</td>
</tr>
</tbody>
</table>

a  If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E  Use data with caution.
F  Data is too unreliable to be published.
Table 12.5.5
9-Hydroxyfluorene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2514</td>
<td>0</td>
<td>0.16 (0.10–0.17)</td>
<td>0.051 (0.045–0.058)</td>
<td>0.16 (0.14–0.17)</td>
<td>0.46 (0.37–0.55)</td>
<td>0.66 (0.57–0.76)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012-2013)</td>
<td>2499</td>
<td>0</td>
<td>0.15 (0.13–0.17)</td>
<td>0.045 (0.037–0.053)</td>
<td>0.14 (0.13–0.16)</td>
<td>0.53 (0.44–0.61)</td>
<td>0.71 (0.60–0.82)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1260</td>
<td>0</td>
<td>0.17 (0.15–0.20)</td>
<td>0.057 (0.048–0.068)</td>
<td>0.17 (0.13–0.20)</td>
<td>0.58 (0.46–0.70)</td>
<td>0.73 (0.61–0.85)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012-2013)</td>
<td>1238</td>
<td>0</td>
<td>0.17 (0.15–0.18)</td>
<td>0.051 (0.037–0.065)</td>
<td>0.16 (0.15–0.17)</td>
<td>0.58 (0.46–0.71)</td>
<td>0.73 (0.62–0.85)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1254</td>
<td>0</td>
<td>0.15 (0.13–0.16)</td>
<td>0.048 (0.040–0.055)</td>
<td>0.14 (0.13–0.16)</td>
<td>0.39 (0.33–0.48)</td>
<td>0.49 (0.32–0.66)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012-2013)</td>
<td>1261</td>
<td>0</td>
<td>0.13 (0.11–0.16)</td>
<td>0.041 (0.031–0.050)</td>
<td>0.13 (0.10–0.16)</td>
<td>0.49 (0.36–0.63)</td>
<td>0.65 (0.43–0.86)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>505</td>
<td>0</td>
<td>0.098 (0.086–0.11)</td>
<td>0.040 (0.032–0.048)</td>
<td>0.098 (0.086–0.11)</td>
<td>0.24 (0.18–0.29)</td>
<td>0.30 (0.25–0.34)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012-2013)</td>
<td>490</td>
<td>0</td>
<td>0.084 (0.070–0.099)</td>
<td>0.029 (0.022–0.036)</td>
<td>0.085 (0.065–0.10)</td>
<td>0.22 (0.15–0.28)</td>
<td>0.29 (0.21–0.37)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>0</td>
<td>0.11 (0.091–0.13)</td>
<td>0.042 (0.032–0.051)</td>
<td>0.11 (0.096–0.13)</td>
<td>0.29 (0.21–0.37)</td>
<td>0.38 (0.28–0.47)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012-2013)</td>
<td>498</td>
<td>0</td>
<td>0.091 (0.082–0.10)</td>
<td>0.038 (0.030–0.045)</td>
<td>0.081 (0.072–0.090)</td>
<td>0.24 (0.19–0.30)</td>
<td>0.34 (0.25–0.42)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>501</td>
<td>0</td>
<td>0.15 (0.13–0.17)</td>
<td>0.060 (0.047–0.073)</td>
<td>0.14 (0.13–0.17)</td>
<td>0.38 (0.32–0.45)</td>
<td>0.49 (0.35–0.62)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012-2013)</td>
<td>505</td>
<td>0</td>
<td>0.13 (0.12–0.15)</td>
<td>0.047 (0.039–0.055)</td>
<td>0.13 (0.11–0.15)</td>
<td>0.38 (0.23–0.54)</td>
<td>0.58 (0.40–0.77)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>0</td>
<td>0.17 (0.15–0.20)</td>
<td>0.058 (0.041–0.076)</td>
<td>0.18 (0.15–0.21)</td>
<td>0.52 (0.34–0.70)</td>
<td>0.66 (0.53–0.79)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012-2013)</td>
<td>351</td>
<td>0</td>
<td>0.20 (0.17–0.22)</td>
<td>0.065 (0.041–0.089)</td>
<td>0.19 (0.13–0.25)</td>
<td>0.54 (0.34–0.74)</td>
<td>0.77 (0.60–0.93)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>358</td>
<td>0</td>
<td>0.17 (0.15–0.20)</td>
<td>0.048 (0.029–0.068)</td>
<td>0.17 (0.13–0.20)</td>
<td>0.51 (0.34–0.68)</td>
<td>0.80 (0.55–1.1)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012-2013)</td>
<td>310</td>
<td>0</td>
<td>0.17 (0.13–0.20)</td>
<td>0.045 (0.035–0.056)</td>
<td>0.15 (0.11–0.19)</td>
<td>0.58 (0.49–0.68)</td>
<td>0.76 (0.56–0.95)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>286</td>
<td>0</td>
<td>0.16 (0.14–0.18)</td>
<td>0.052 (0.046–0.058)</td>
<td>0.15 (0.13–0.17)</td>
<td>0.48 (0.31–0.66)</td>
<td>0.73 (0.46–1.0)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012-2013)</td>
<td>345</td>
<td>0</td>
<td>0.13 (0.11–0.16)</td>
<td>0.037 (0.018–0.056)</td>
<td>0.12 (0.10–0.15)</td>
<td>0.49 (0.28–0.71)</td>
<td>0.71 (0.48–0.94)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
Table 12.5.6
9-Hydroxyfluorene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
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<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2504</td>
<td>0</td>
<td>0.16 (0.15–0.17)</td>
<td>0.059 (0.053–0.066)</td>
<td>0.14 (0.13–0.16)</td>
<td>0.43 (0.35–0.52)</td>
<td>0.62 (0.51–0.72)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2498</td>
<td>0</td>
<td>0.16 (0.14–0.17)</td>
<td>0.055 (0.048–0.062)</td>
<td>0.14 (0.13–0.16)</td>
<td>0.48 (0.43–0.52)</td>
<td>0.72 (0.64–0.81)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1256</td>
<td>0</td>
<td>0.15 (0.13–0.17)</td>
<td>0.055 (0.047–0.064)</td>
<td>0.13 (0.11–0.15)</td>
<td>0.50 (0.35–0.64)</td>
<td>0.62 (0.50–0.73)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1238</td>
<td>0</td>
<td>0.14 (0.12–0.16)</td>
<td>0.049 (0.041–0.058)</td>
<td>0.13 (0.10–0.15)</td>
<td>0.46 (0.35–0.56)</td>
<td>0.62 (0.48–0.76)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1248</td>
<td>0</td>
<td>0.17 (0.15–0.19)</td>
<td>0.065 (0.058–0.071)</td>
<td>0.15 (0.13–0.18)</td>
<td>0.42 (0.34–0.50)</td>
<td>0.62 (0.44–0.80)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1260</td>
<td>0</td>
<td>0.17 (0.15–0.20)</td>
<td>0.061 (0.050–0.071)</td>
<td>0.15 (0.14–0.17)</td>
<td>0.57 (0.35–0.80)</td>
<td>0.83 (0.63–1.0)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>504</td>
<td>0</td>
<td>0.17 (0.15–0.19)</td>
<td>0.068 (0.053–0.083)</td>
<td>0.17 (0.15–0.20)</td>
<td>0.41 (0.31–0.50)</td>
<td>0.62 (0.42–0.81)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>489</td>
<td>0</td>
<td>0.16 (0.14–0.18)</td>
<td>0.065 (0.058–0.072)</td>
<td>0.15 (0.12–0.18)</td>
<td>0.44 (0.36–0.52)</td>
<td>0.54 (0.45–0.64)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>507</td>
<td>0</td>
<td>0.13 (0.11–0.15)</td>
<td>0.056 (0.049–0.064)</td>
<td>0.11 (0.090–0.13)</td>
<td>0.31 (0.22–0.40)</td>
<td>0.42 (0.20–0.64)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>498</td>
<td>0</td>
<td>0.12 (0.10–0.13)</td>
<td>0.046 (0.029–0.063)</td>
<td>0.11 (0.096–0.13)</td>
<td>0.27 (0.22–0.31)</td>
<td>0.43 (0.30–0.56)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>499</td>
<td>0</td>
<td>0.11 (0.097–0.13)</td>
<td>0.048 (0.039–0.056)</td>
<td>0.10 (0.083–0.12)</td>
<td>0.27 (0.19–0.35)</td>
<td>0.43 (0.18–0.57)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>0</td>
<td>0.10 (0.087–0.12)</td>
<td>0.042 (0.033–0.048)</td>
<td>0.088 (0.077–0.098)</td>
<td>0.25 (0.17–0.34)</td>
<td>0.47 (0.22–0.51)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>353</td>
<td>0</td>
<td>0.15 (0.13–0.18)</td>
<td>0.060 (0.049–0.070)</td>
<td>0.14 (0.11–0.16)</td>
<td>0.35 (0.15–0.54)</td>
<td>0.56 (0.39–0.73)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>351</td>
<td>0</td>
<td>0.15 (0.13–0.18)</td>
<td>0.055 (0.038–0.072)</td>
<td>0.13 (0.092–0.16)</td>
<td>0.51 (0.33–0.69)</td>
<td>0.69 (0.52–0.84)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>356</td>
<td>0</td>
<td>0.17 (0.16–0.19)</td>
<td>0.064 (0.055–0.073)</td>
<td>0.16 (0.14–0.18)</td>
<td>0.52 (0.40–0.63)</td>
<td>0.64 (0.40–0.88)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>310</td>
<td>0</td>
<td>0.19 (0.16–0.23)</td>
<td>0.063 (0.043–0.084)</td>
<td>0.20 (0.15–0.24)</td>
<td>0.62 (0.38–0.86)</td>
<td>0.81 (0.52–1.1)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>285</td>
<td>0</td>
<td>0.19 (0.16–0.22)</td>
<td>0.065 (0.044–0.086)</td>
<td>0.16 (0.13–0.19)</td>
<td>0.52 (0.34–0.70)</td>
<td>0.77 (0.56–0.98)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>345</td>
<td>0</td>
<td>0.15 (0.13–0.18)</td>
<td>0.056 (0.038–0.073)</td>
<td>0.15 (0.13–0.17)</td>
<td>0.45 (0.31–0.60)</td>
<td>0.64 (0.52–0.76)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.
Naphthalene is a polycyclic aromatic hydrocarbon (PAH) with two fused benzene rings. Naphthalene is manufactured and imported into Canada for a wide variety of industrial uses (Environment Canada and Health Canada, 2008). The major consumer products made from naphthalene are moth repellents, in the form of mothballs or crystals. Other commercial uses of naphthalene include components of polyvinyl chloride phthalate plasticizers, dyes, resins, and leather-tanning agents (EPA, 2008; IARC, 2002).

Naphthalene evaporates easily and is often found in the gaseous phase in ambient air (WHO, 2010). Although diet and smoking are the most important sources of intake for most PAHs, inhalation of ambient and indoor air is the main source of naphthalene exposure for the general population. In Canada, indoor air exposure accounts for more than 95% of the total daily exposure across age groups (Environment Canada and Health Canada, 2008). A recent study identified mothballs and some building materials and furnishings (vinyl and wooden furniture, and painted walls and ceilings) as significant contributors to indoor naphthalene concentrations in Canadian homes (Kang et al., 2012). Other sources of naphthalene in indoor and ambient air include migration of volatile organic compounds from attached garages, during cooking, and from kerosene space heaters and wood stoves (Batterman et al., 2007; Environment Canada and Health Canada, 2008). Food and drinking water are considered minor sources of exposure to naphthalene (NTP, 2002).

Naphthalene is rapidly absorbed and metabolized following oral and inhalation exposures in laboratory animals (Bagchi et al., 2002; NTP, 2002). Naphthalene is also absorbed following dermal application in humans and laboratory animals (Storer et al., 1984; Turkall et al., 1994). Like other PAHs, naphthalene undergoes multi-step metabolism, the result of which includes the production of the hydroxynaphthalene metabolites.
Summary and Results for Polycyclic Aromatic Hydrocarbon Metabolites

In humans, the most serious effects of acute exposure to naphthalene are reported in individuals with glucose 6-phosphate dehydrogenase deficiency, where hemolytic anemia is the primary adverse effect (Health Canada, 2013; WHO, 2010). Reports from occupational exposure and animal studies suggest chronic exposure to naphthalene may lead to the development of lens opacities such as cataracts (Health Canada, 2013; WHO, 2010). Respiratory tract lesions have also been observed in laboratory animals following acute and chronic exposures (WHO, 2010). Naphthalene has been observed to induce airway tumours in laboratory animals (NTP, 2002). Increased cell proliferation due to cytotoxicity (cell damage) is considered a key element in the development of airway tumours (WHO, 2010). The International Agency for Research on Cancer has classified naphthalene as Group 2B, possibly carcinogenic to humans (IARC, 2002). The carcinogenicity of naphthalene has been proposed to involve non-genotoxic mechanisms (IARC, 2002). Based upon an assessment of acute and chronic effects, Health Canada has established a long-term residential maximum exposure limit for naphthalene (Health Canada, 2013). The guideline is considered to protect against the carcinogenic and non-carcinogenic effects to the respiratory tract resulting from naphthalene exposure.

On the basis of its potential cancer risk, and the margin between levels to which Canadians might be exposed and the critical effect level for non-cancer effects, Health Canada and Environment Canada have concluded that naphthalene is a concern for human health (Environment Canada and Health Canada, 2008). As a result, naphthalene is listed as a toxic substance on Schedule 1 of the Canadian Environmental Protection Act, 1999 (Canada, 1999; Canada, 2010a). In an effort to reduce exposure to naphthalene, several risk management approaches have been taken (Canada, 2010b). In 2010, the Pest Management Regulatory Agency (PMRA) re-evaluated the insecticidal uses of naphthalene. PMRA concluded that pest control products containing naphthalene do not present unacceptable risks to human health when used according to label directions and has granted continued registration (Health Canada, 2010). As a condition of the continued registration of naphthalene uses, Health Canada has introduced new packaging and labelling requirements for naphthalene-containing consumer products (mothballs and moth flakes) in order to minimize exposure (Health Canada, 2012). Naphthalene and 2-hydroxynaphthalene are included as prohibited ingredients and 1-hydroxynaphthalene and its salts as restricted ingredients on the List of Prohibited and Restricted Cosmetic Ingredients (more commonly referred to as the Cosmetic Ingredient Hotlist or simply the Hotlist) (Health Canada 2014). The Hotlist is an administrative tool that Health Canada uses to communicate to manufacturers and others that certain substances, when present in a cosmetic, may contravene the general prohibition found in section 16 of the Food and Drugs Act or a provision of the Cosmetic Regulations (Canada, 1985; Health Canada, 2014).

1-Hydroxynaphthalene and 2-hydroxynaphthalene have been measured in urine as biomarkers of exposure to naphthalene in several studies. For various adult populations in Quebec living near industrial facilities, the reported geometric means ranged from 0.80 to 3.17 µg/g creatinine for 1-hydroxynaphthalene and 1.38 to 3.26 µg/g creatinine for 2-hydroxynaphthalene (Bouchard et al., 2001; Bouchard et al., 2009). These naphthalene metabolites were also measured in a pilot biomonitoring study carried out in Hamilton, Ontario, with 19 pregnant women aged 19 to 42 years. The geometric mean urinary concentrations were 1.411 µg/g creatinine for 1-hydroxynaphthalene and 2.605 µg/g creatinine for 2-hydroxynaphthalene (Nethery et al., 2012). A study aiming to assess naphthalene exposure in pregnant Canadian women residing in Ottawa, Ontario, reported geometric mean concentrations in urine ranging from 1.04–1.32 µg/L and 2.72–2.92 µg/L for 1-hydroxynaphthalene and 2-hydroxynaphthalene, respectively (Wheeler et al., 2014).

Naphthalene metabolites, 1-hydroxynaphthalene and 2-hydroxynaphthalene, were analyzed in the urine of Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years and are presented as both µg/L and µg/g creatinine. Finding a measurable amount of naphthalene
metabolites in urine can be an indicator of exposure to naphthalene or carbaryl (for 1-hydroxynaphthalene) and does not necessarily mean that an adverse health effect will occur.

Naphthalene was also analyzed in indoor air from households of CHMS participants in cycle 2 (2009–2011) (Zhu et al., 2013) and cycle 3 (2012–2013). Further details on the indoor air studies are available in the Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015). Indoor air data are available through Statistics Canada’s Research Data Centres or upon request by contacting Statistics Canada at info@statcan.gc.ca.

Table 12.6.1  
1-Hydroxynaphthalene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2522</td>
<td>0.79</td>
<td>1.5 (1.3–1.7)</td>
<td>0.27 (0.18–0.37)</td>
<td>1.3 (1.1–1.5)</td>
<td>9.9 (7.7–12)</td>
<td>15 (12–19)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2511</td>
<td>2.27</td>
<td>1.0 (0.89–1.2)</td>
<td>0.19 (0.16–0.23)</td>
<td>0.85 (0.68–1.0)</td>
<td>7.8 (6.6–9.0)</td>
<td>11 (8.2–14)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1267</td>
<td>0.39</td>
<td>1.6 (1.3–2.0)</td>
<td>0.29 (0.16–0.42)</td>
<td>1.3 (1.0–1.7)</td>
<td>11 (9.5–14)</td>
<td>17 (13–21)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1241</td>
<td>1.69</td>
<td>1.3 (1.1–1.6)</td>
<td>0.24 (0.18–0.30)</td>
<td>1.1 (0.75–1.4)</td>
<td>8.3 (6.4–10)</td>
<td>12E (7.2–16)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1255</td>
<td>1.20</td>
<td>1.4 (1.2–1.6)</td>
<td>0.26 (0.14–0.37)</td>
<td>1.2 (1.1–1.4)</td>
<td>6.2 (3.7–9.4)</td>
<td>9.9 (6.8–13)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1241</td>
<td>1.69</td>
<td>1.3 (1.1–1.6)</td>
<td>0.26 (0.14–0.37)</td>
<td>1.2 (1.1–1.4)</td>
<td>6.2 (3.7–9.4)</td>
<td>9.9 (6.8–13)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>506</td>
<td>0.40</td>
<td>1.4 (1.2–1.6)</td>
<td>0.43 (0.33–0.59)</td>
<td>1.2 (1.0–1.4)</td>
<td>5.4 (3.3–7.5)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>495</td>
<td>1.82</td>
<td>0.69 (0.54–0.88)</td>
<td>0.19 (0.12–0.26)</td>
<td>0.68 (0.53–0.82)</td>
<td>2.9 (2.1–3.8)</td>
<td>4.2 (2.7–5.7)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>511</td>
<td>0.39</td>
<td>0.95 (0.79–1.1)</td>
<td>0.25 (&lt;LOD–0.40)</td>
<td>0.92 (0.73–1.1)</td>
<td>2.8 (2.1–3.5)</td>
<td>4.0 (2.9–5.2)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>502</td>
<td>2.19</td>
<td>0.75 (0.63–0.90)</td>
<td>0.23 (0.16–0.30)</td>
<td>0.68 (0.55–0.82)</td>
<td>3.0E (1.8–4.2)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>505</td>
<td>1.39</td>
<td>1.2 (0.98–1.4)</td>
<td>0.26 (0.14–0.41)</td>
<td>1.0 (0.83–1.2)</td>
<td>4.1E (2.1–6.1)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>2.57</td>
<td>0.95 (0.70–1.3)</td>
<td>0.19 (0.12–0.26)</td>
<td>0.74 (0.50–0.98)</td>
<td>7.2 (4.8–9.6)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>354</td>
<td>1.13</td>
<td>1.4 (1.0–1.7)</td>
<td>0.29 (0.14–0.43)</td>
<td>1.4 (1.0–1.7)</td>
<td>7.1E (4.5–9.7)</td>
<td>13 (9.9–15)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>2.29</td>
<td>1.2 (0.85–1.6)</td>
<td>0.26 (0.12–0.29)</td>
<td>0.9E (0.56–1.3)</td>
<td>8.4E (5.2–12)</td>
<td>12E (6.4–18)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>359</td>
<td>1.11</td>
<td>1.7 (1.3–2.3)</td>
<td>0.26 (0.11–0.44)</td>
<td>1.3 (0.97–1.7)</td>
<td>13 (9.7–15)</td>
<td>19E (11–27)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>3.22</td>
<td>1.1E (0.74–1.6)</td>
<td>0.18 (0.10–0.25)</td>
<td>0.97E (0.57–1.7)</td>
<td>8.1 (5.2–11)</td>
<td>11 (7.1–15)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>287</td>
<td>0.35</td>
<td>1.7 (1.3–2.3)</td>
<td>0.25 (0.12–0.39)</td>
<td>1.6 (1.2–1.9)</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>1.72</td>
<td>0.99 (0.77–1.3)</td>
<td>0.21E (0.13–0.28)</td>
<td>0.86 (0.68–1.0)</td>
<td>7.0 (4.5–9.4)</td>
<td>13E (7.5–19)</td>
</tr>
</tbody>
</table>

a  If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E  Use data with caution.
F  Data is too unreliable to be published.
Table 12.6.2
1-Hydroxynaphthalene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2512</td>
<td>0.79</td>
<td>1.5 (1.3–1.7)</td>
<td>0.32 (0.23–0.41)</td>
<td>1.2 (1.0–1.4)</td>
<td>9.5 (7.9–12)</td>
<td>15 (12–18)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2510</td>
<td>2.27</td>
<td>1.1 (0.91–1.2)</td>
<td>0.20 (0.16–0.25)</td>
<td>0.99 (0.81–1.2)</td>
<td>6.9 (5.4–8.4)</td>
<td>10 (7.7–12)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1263</td>
<td>0.39</td>
<td>1.4 (1.1–1.7)</td>
<td>0.27 (0.18–0.36)</td>
<td>1.1 (0.84–1.3)</td>
<td>9.8 (6.9–14)</td>
<td>16 (12–20)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1241</td>
<td>1.69</td>
<td>1.1 (0.85–1.4)</td>
<td>0.20 (0.15–0.25)</td>
<td>1.0 (0.66–1.3)</td>
<td>7.6 (5.0–10)</td>
<td>9.2 (6.8–12)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1249</td>
<td>1.20</td>
<td>1.6 (1.4–1.8)</td>
<td>0.41 (0.31–0.50)</td>
<td>1.4 (1.2–1.5)</td>
<td>8.7 (5.6–12)</td>
<td>F</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1269</td>
<td>2.83</td>
<td>1.0 (0.77–1.4)</td>
<td>0.23F (0.14–0.31)</td>
<td>0.97 (0.66–1.3)</td>
<td>6.5F (3.1–9.9)</td>
<td>12 (8.3–15)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>505</td>
<td>0.40</td>
<td>2.5 (2.2–2.9)</td>
<td>0.74 (0.53–0.94)</td>
<td>2.2 (1.9–2.6)</td>
<td>8.4F (3.5–13)</td>
<td>16F (5.7–25)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>494</td>
<td>1.82</td>
<td>1.3 (1.3–1.6)</td>
<td>0.46 (0.34–0.57)</td>
<td>1.2 (1.1–1.4)</td>
<td>4.9 (3.6–8.2)</td>
<td>6.7 (4.8–8.6)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>0.39</td>
<td>1.1 (0.92–1.3)</td>
<td>0.35F (0.22–0.48)</td>
<td>1.0 (0.85–1.1)</td>
<td>3.4 (2.5–4.2)</td>
<td>4.9 (3.4–6.5)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>502</td>
<td>2.19</td>
<td>0.96 (0.76–1.2)</td>
<td>0.30 (0.26–0.34)</td>
<td>0.79 (0.61–0.98)</td>
<td>4.1F (2.5–5.9)</td>
<td>5.8F (3.2–8.5)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>503</td>
<td>1.39</td>
<td>0.90 (0.75–1.1)</td>
<td>0.26 (0.18–0.33)</td>
<td>0.83 (0.72–0.94)</td>
<td>3.5F (1.9–5.0)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>2.57</td>
<td>0.72 (0.56–0.92)</td>
<td>0.15F (0.089–0.22)</td>
<td>0.67 (0.46–0.88)</td>
<td>4.7F (1.3–8.2)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>352</td>
<td>1.13</td>
<td>1.3 (0.97–1.7)</td>
<td>0.24F (0.15–0.33)</td>
<td>1.2 (0.79–1.7)</td>
<td>8.2F (3.8–13)</td>
<td>13F (7.2–18)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>2.29</td>
<td>0.89 (0.62–1.3)</td>
<td>0.17F (0.074–0.26)</td>
<td>0.78F (0.40–1.2)</td>
<td>5.9F (2.1–9.6)</td>
<td>9.1F (5.7–13)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>357</td>
<td>1.11</td>
<td>1.7 (1.2–2.1)</td>
<td>0.37F (0.19–0.54)</td>
<td>1.3F (0.74–1.9)</td>
<td>13F (8.3–18)</td>
<td>18F (10–27)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>3.22</td>
<td>1.3 (0.88–1.8)</td>
<td>0.23F (0.11–0.36)</td>
<td>1.3F (0.80–1.8)</td>
<td>9.8 (6.3–13)</td>
<td>13 (8.6–17)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>286</td>
<td>0.35</td>
<td>2.0 (1.6–2.5)</td>
<td>0.50 (0.36–0.65)</td>
<td>1.5 (1.2–1.8)</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>1.72</td>
<td>1.1 (0.93–1.4)</td>
<td>0.24F (0.13–0.36)</td>
<td>1.0 (0.70–1.3)</td>
<td>6.5F (4.1–8.9)</td>
<td>11 (8.0–14)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.
### Table 12.6.3

2-Hydroxynaphthalene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM  (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2503</td>
<td>0</td>
<td>3.8 (3.4–4.4)</td>
<td>0.84 (0.68–1.0)</td>
<td>3.8 (3.2–4.4)</td>
<td>17 (14–20)</td>
<td>24 (18–30)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2506</td>
<td>0</td>
<td>4.1 (3.6–4.6)</td>
<td>0.93 (0.79–1.1)</td>
<td>4.0 (3.4–4.6)</td>
<td>18 (14–22)</td>
<td>26 (22–30)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1251</td>
<td>0</td>
<td>4.0 (3.3–4.9)</td>
<td>0.99 (0.81–1.2)</td>
<td>3.9 (3.1–4.8)</td>
<td>19 (13–26)</td>
<td>26 (19–32)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1239</td>
<td>0</td>
<td>4.6 (4.0–5.3)</td>
<td>0.96 (0.80–1.1)</td>
<td>4.4 (3.7–5.2)</td>
<td>20 (13–27)</td>
<td>30 (22–38)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1252</td>
<td>0</td>
<td>3.7 (3.2–4.2)</td>
<td>0.63 (0.40–0.87)</td>
<td>3.5 (3.0–4.1)</td>
<td>17 (13–20)</td>
<td>23 (13–32)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1267</td>
<td>0</td>
<td>3.7 (2.9–4.7)</td>
<td>0.88 (0.65–1.1)</td>
<td>3.7 (2.8–4.6)</td>
<td>16 (12–20)</td>
<td>23 (18–28)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>499</td>
<td>0</td>
<td>3.3 (2.8–3.8)</td>
<td>1.1 (0.91–1.3)</td>
<td>3.0 (2.4–3.6)</td>
<td>11E (5.8–15)</td>
<td>17E (8.9–24)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>494</td>
<td>0</td>
<td>3.2 (2.6–4.0)</td>
<td>0.72 (0.50–0.93)</td>
<td>3.4 (2.7–4.1)</td>
<td>12E (6.7–16)</td>
<td>19E (12–26)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>0</td>
<td>3.2 (2.6–4.0)</td>
<td>1.1 (0.82–1.3)</td>
<td>3.0 (2.3–3.8)</td>
<td>8.8E (4.7–13)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>498</td>
<td>0</td>
<td>3.2 (2.5–3.7)</td>
<td>0.84 (0.60–1.1)</td>
<td>3.2 (2.6–3.8)</td>
<td>10E (6.3–14)</td>
<td>14 (9.8–18)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>503</td>
<td>0</td>
<td>4.4 (3.9–5.0)</td>
<td>1.2 (0.93–1.3)</td>
<td>4.4 (3.5–5.3)</td>
<td>15 (9.8–20)</td>
<td>24 (19–29)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>0</td>
<td>5.3 (4.8–6.2)</td>
<td>1.3 (0.77–1.7)</td>
<td>5.0 (3.8–6.2)</td>
<td>17 (13–21)</td>
<td>23 (15–32)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>352</td>
<td>0</td>
<td>4.4 (3.9–5.5)</td>
<td>0.88E (0.53–1.2)</td>
<td>4.8 (3.5–9.9)</td>
<td>17 (13–21)</td>
<td>22 (18–27)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>0</td>
<td>5.2 (4.6–6.3)</td>
<td>1.2 (0.91–1.6)</td>
<td>5.6 (3.8–7.6)</td>
<td>18E (9.7–26)</td>
<td>26E (15–37)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>354</td>
<td>0</td>
<td>4.1 (3.1–5.4)</td>
<td>0.75E (0.27–1.2)</td>
<td>3.7E (2.1–5.2)</td>
<td>21E (13–30)</td>
<td>31 (20–42)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>0</td>
<td>4.2 (3.3–5.2)</td>
<td>0.97 (0.77–1.2)</td>
<td>4.1 (2.7–5.5)</td>
<td>18E (9.6–26)</td>
<td>28 (21–35)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>286</td>
<td>0</td>
<td>2.8 (2.4–3.3)</td>
<td>0.58E (0.31–0.86)</td>
<td>2.5 (1.9–3.2)</td>
<td>12E (7.5–16)</td>
<td>22 (19–26)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>0</td>
<td>3.0 (2.5–3.5)</td>
<td>0.73 (0.48–0.97)</td>
<td>2.9 (2.4–3.4)</td>
<td>14E (6.4–22)</td>
<td>24 (15–33)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.

F Data is too unreliable to be published.
Table 12.6.4
2-Hydroxynaphthalene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2493</td>
<td>0</td>
<td>3.8 (3.0–4.3)</td>
<td>1.2 (1.0–1.3)</td>
<td>3.4 (2.9–4.0)</td>
<td>15 (13–17)</td>
<td>20 (17–22)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2505</td>
<td>0</td>
<td>4.3 (3.3–4.7)</td>
<td>1.3 (1.1–1.5)</td>
<td>4.1 (3.4–4.7)</td>
<td>14 (12–17)</td>
<td>19 (16–21)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1247</td>
<td>0</td>
<td>3.5 (2.9–4.1)</td>
<td>1.0 (0.94–1.2)</td>
<td>2.9 (2.3–3.5)</td>
<td>14 (10–19)</td>
<td>20 (14–25)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1239</td>
<td>0</td>
<td>3.9 (3.3–4.5)</td>
<td>1.1 (0.91–1.4)</td>
<td>3.5 (2.6–4.4)</td>
<td>13 (9.7–17)</td>
<td>18 (15–21)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1246</td>
<td>0</td>
<td>4.3 (3.9–4.6)</td>
<td>1.4 (1.1–1.7)</td>
<td>3.8 (3.3–4.2)</td>
<td>15 (12–18)</td>
<td>20 (16–23)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1266</td>
<td>0</td>
<td>4.7 (4.0–5.5)</td>
<td>1.6 (1.3–1.8)</td>
<td>4.4 (3.4–5.3)</td>
<td>15 (13–17)</td>
<td>19 (16–23)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>498</td>
<td>0</td>
<td>5.9 (5.1–6.8)</td>
<td>2.1 (1.9–2.2)</td>
<td>5.0 (4.2–5.9)</td>
<td>16 (11–21)</td>
<td>23 (13–33)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>493</td>
<td>0</td>
<td>6.3 (5.4–7.3)</td>
<td>2.2 (1.7–2.7)</td>
<td>5.8 (4.8–6.8)</td>
<td>19 (13–25)</td>
<td>27 (17–37)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>507</td>
<td>0</td>
<td>3.8 (3.2–4.5)</td>
<td>1.5 (1.3–1.8)</td>
<td>3.6 (2.6–4.6)</td>
<td>9.4 (6.8–12)</td>
<td>12 (5.1–19)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>498</td>
<td>0</td>
<td>4.1 (3.4–5.0)</td>
<td>1.5 (1.1–1.9)</td>
<td>3.9 (3.3–4.5)</td>
<td>11 (8.3–14)</td>
<td>13 (5.1–22)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>501</td>
<td>0</td>
<td>3.4 (3.0–3.9)</td>
<td>1.1 (1.0–1.3)</td>
<td>3.1 (2.6–3.6)</td>
<td>9.9 (7.6–12)</td>
<td>15 (10–16)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>0</td>
<td>4.1 (3.7–4.4)</td>
<td>1.4 (1.1–1.7)</td>
<td>3.6 (2.4–4.0)</td>
<td>12 (9.6–15)</td>
<td>15 (11–20)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>350</td>
<td>0</td>
<td>3.9 (3.3–4.7)</td>
<td>1.2 (0.93–1.4)</td>
<td>3.4 (2.5–4.4)</td>
<td>15 (10–19)</td>
<td>19 (15–23)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>0</td>
<td>4.0 (3.4–4.8)</td>
<td>1.3E (0.80–1.8)</td>
<td>4.0 (3.1–4.9)</td>
<td>11 (8.7–13)</td>
<td>14 (11–18)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>352</td>
<td>0</td>
<td>4.1 (3.3–5.2)</td>
<td>1.0E (0.64–1.4)</td>
<td>3.7 (2.8–4.7)</td>
<td>19 (14–25)</td>
<td>25 (20–30)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>0</td>
<td>5.0 (4.1–6.0)</td>
<td>1.4 (1.1–1.8)</td>
<td>5.1 (3.4–6.7)</td>
<td>18 (14–21)</td>
<td>21 (17–25)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>285</td>
<td>0</td>
<td>3.3 (2.8–3.7)</td>
<td>1.1 (1.0–1.3)</td>
<td>2.6 (2.1–3.1)</td>
<td>14 (9.7–18)</td>
<td>18 (15–20)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>0</td>
<td>3.4 (3.0–3.9)</td>
<td>1.0 (0.77–1.2)</td>
<td>3.2 (2.7–3.6)</td>
<td>12 (8.1–16)</td>
<td>17 (13–21)</td>
</tr>
</tbody>
</table>

a  If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E  Use data with caution.
REFERENCES


12.7 PHENANTHRENE

Phenanthrene is a polycyclic aromatic hydrocarbon (PAH) with three fused benzene rings. It is used in the manufacture of dyes, polymer materials, and biomedical research (Mondal et al., 2009).

After oral administration in rats, phenanthrene was found to be absorbed from the gastrointestinal tract (Faust, 1993). It is also absorbed through the skin in humans following dermal exposure (Storer et al., 1984). Metabolism of phenanthrene proceeds through the formation of epoxides that rearrange to form hydroxy and dihydrodiol metabolites (Jacob and Seidel, 2002). Phenanthrene metabolites are primarily excreted in the urine (Faust, 1993).

Urinary hydroxylated phenanthrene metabolites (1-, 2-, 3-, 4-, and 9-hydroxyphenanthrene) have been assessed in several biomonitoring studies and are indicators of recent PAH exposure (Becker et al., 2003; CDC, 2009; Jacob and Seidel, 2002; Nethery et al., 2012). Their relatively high abundance in the urine and the availability of validated analytical methods for their detection and quantification make them good biomarkers for assessing exposure. Additionally, urinary concentrations of monohydroxyphenanthrene metabolites are less sensitive to smoking status than other PAH metabolites; they are therefore better suited for assessing exposures where the study population comprises both smokers and non-smokers (Jacob et al., 1999; Rihs et al., 2005). Urinary 3-hydroxyphenanthrene may be a predictive biomarker for specifically assessing inhalation exposure to phenanthrene (Nethery et al., 2012).

In animal studies, phenanthrene did not elicit systemic or carcinogenic effects (ATSDR, 1995). The International Agency for Research on Cancer has classified phenanthrene as Group 3, not classifiable as to its carcinogenicity in humans (IARC, 2010).

In a pilot biomonitoring study carried out in Hamilton, Ontario, with 19 pregnant women aged 19 to 42 years, the geometric means for 1-, 2-, 3-, and 4-hydroxyphenanthrene in urine were 0.2439 µg/g creatinine, 0.0824 µg/g creatinine, 0.06989 µg/g creatinine, and 0.040 µg/g creatinine, respectively (Nethery et al., 2012).
Phenanthrene metabolites, 1-, 2-, 3-, 4-, and 9-hydroxyphenanthrene, were analyzed in the urine of Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years and are presented as both µg/L and µg/g creatinine. Finding a measurable amount of phenanthrene metabolites in urine is an indicator of exposure to phenanthrene and does not necessarily mean that an adverse health effect will occur.

**Table 12.7.1**
1-Hydroxyphenanthrene — Geometric means and selected percentiles of urine concentrations (µg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD*</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total 3–79</td>
<td>2 (2009–2011)</td>
<td>2522</td>
<td>0.04</td>
<td>0.15 (0.14–0.17)</td>
<td>0.049 (0.042–0.056)</td>
<td>0.15 (0.14–0.17)</td>
<td>0.47 (0.38–0.57)</td>
<td>0.69 (0.53–0.84)</td>
<td></td>
</tr>
<tr>
<td>Total 3–79</td>
<td>3 (2012–2013)</td>
<td>2505</td>
<td>0.04</td>
<td>0.15 (0.13–0.16)</td>
<td>0.040 (0.029–0.051)</td>
<td>0.13 (0.12–0.15)</td>
<td>0.50 (0.38–0.62)</td>
<td>0.73 (0.58–0.89)</td>
<td></td>
</tr>
<tr>
<td>Males 3–79</td>
<td>2 (2009–2011)</td>
<td>1268</td>
<td>0</td>
<td>0.16 (0.14–0.19)</td>
<td>0.054 (0.046–0.062)</td>
<td>0.16 (0.14–0.19)</td>
<td>0.50 (0.38–0.62)</td>
<td>0.73 (0.57–0.90)</td>
<td></td>
</tr>
<tr>
<td>Males 3–79</td>
<td>3 (2012–2013)</td>
<td>1241</td>
<td>0.08</td>
<td>0.16 (0.14–0.18)</td>
<td>0.051 (0.038–0.064)</td>
<td>0.15 (0.13–0.17)</td>
<td>0.48 (0.37–0.59)</td>
<td>0.78 (0.54–1.0)</td>
<td></td>
</tr>
<tr>
<td>Females 3–79</td>
<td>2 (2009–2011)</td>
<td>1254</td>
<td>0.08</td>
<td>0.14 (0.13–0.16)</td>
<td>0.041 (0.032–0.049)</td>
<td>0.14 (0.12–0.16)</td>
<td>0.42 (0.30–0.54)</td>
<td>0.66 (0.40–0.92)</td>
<td></td>
</tr>
<tr>
<td>Females 3–79</td>
<td>3 (2012–2013)</td>
<td>1264</td>
<td>0</td>
<td>0.13 (0.11–0.16)</td>
<td>0.035 (0.026–0.044)</td>
<td>0.13 (0.096–0.15)</td>
<td>0.51 (0.35–0.66)</td>
<td>0.67 (0.56–0.79)</td>
<td></td>
</tr>
<tr>
<td>Total 3–5</td>
<td>2 (2009–2011)</td>
<td>505</td>
<td>0</td>
<td>0.11 (0.097–0.13)</td>
<td>0.044 (0.037–0.051)</td>
<td>0.10 (0.094–0.12)</td>
<td>0.29 (0.23–0.36)</td>
<td>0.34 (0.26–0.42)</td>
<td></td>
</tr>
<tr>
<td>Total 3–5</td>
<td>3 (2012–2013)</td>
<td>490</td>
<td>0</td>
<td>0.092 (0.079–0.11)</td>
<td>0.031 (0.021–0.042)</td>
<td>0.097 (0.088–0.11)</td>
<td>0.27 (0.22–0.31)</td>
<td>0.36 (0.30–0.42)</td>
<td></td>
</tr>
<tr>
<td>Total 6–11</td>
<td>2 (2009–2011)</td>
<td>510</td>
<td>0</td>
<td>0.12 (0.11–0.14)</td>
<td>0.046 (0.039–0.054)</td>
<td>0.12 (0.097–0.14)</td>
<td>0.30 (0.21–0.39)</td>
<td>0.42 (0.32–0.51)</td>
<td></td>
</tr>
<tr>
<td>Total 6–11</td>
<td>3 (2012–2013)</td>
<td>501</td>
<td>0.20</td>
<td>0.11 (0.094–0.12)</td>
<td>0.031 (0.015–0.047)</td>
<td>0.11 (0.092–0.12)</td>
<td>0.26 (0.21–0.30)</td>
<td>0.36 (0.30–0.43)</td>
<td></td>
</tr>
<tr>
<td>Total 12–19</td>
<td>2 (2009–2011)</td>
<td>506</td>
<td>0</td>
<td>0.15 (0.14–0.17)</td>
<td>0.058 (0.044–0.073)</td>
<td>0.15 (0.13–0.18)</td>
<td>0.44 (0.29–0.58)</td>
<td>0.55 (0.43–0.67)</td>
<td></td>
</tr>
<tr>
<td>Total 12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>0</td>
<td>0.15 (0.13–0.18)</td>
<td>0.050 (0.035–0.066)</td>
<td>0.14 (0.11–0.17)</td>
<td>0.53 (0.40–0.65)</td>
<td>0.76 (0.61–1.1)</td>
<td></td>
</tr>
<tr>
<td>Total 20–39</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>0</td>
<td>0.16 (0.14–0.18)</td>
<td>0.049 (0.033–0.066)</td>
<td>0.17 (0.15–0.19)</td>
<td>0.49 (0.35–0.63)</td>
<td>0.64 (0.41–0.87)</td>
<td></td>
</tr>
<tr>
<td>Total 20–39</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>0</td>
<td>0.18 (0.16–0.21)</td>
<td>0.052 (0.036–0.068)</td>
<td>0.20 (0.14–0.26)</td>
<td>0.46 (0.27–0.65)</td>
<td>0.70 (0.48–1.1)</td>
<td></td>
</tr>
<tr>
<td>Total 40–59</td>
<td>2 (2009–2011)</td>
<td>359</td>
<td>0</td>
<td>0.16 (0.14–0.19)</td>
<td>0.052 (0.031–0.073)</td>
<td>0.16 (0.12–0.19)</td>
<td>0.51 (0.32–0.71)</td>
<td>0.77 (0.58–0.97)</td>
<td></td>
</tr>
<tr>
<td>Total 40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>0</td>
<td>0.14 (0.12–0.17)</td>
<td>0.036 (0.018–0.055)</td>
<td>0.13 (0.095–0.16)</td>
<td>0.51 (0.30–0.73)</td>
<td>0.69 (0.43–0.94)</td>
<td></td>
</tr>
<tr>
<td>Total 60–79</td>
<td>2 (2009–2011)</td>
<td>287</td>
<td>0.35</td>
<td>0.15 (0.13–0.17)</td>
<td>0.038 (0.026–0.050)</td>
<td>0.16 (0.13–0.18)</td>
<td>0.50 (0.37–0.64)</td>
<td>0.81 (0.53–1.1)</td>
<td></td>
</tr>
<tr>
<td>Total 60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>0</td>
<td>0.14 (0.11–0.17)</td>
<td>0.032 (0.0094–0.054)</td>
<td>0.12 (0.085–0.15)</td>
<td>0.68 (0.53–0.82)</td>
<td>0.85 (0.37–1.3)</td>
<td></td>
</tr>
</tbody>
</table>

* a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
### Table 12.7.2

1-Hydroxyphenanthrene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2512</td>
<td>0.04</td>
<td>0.15 (0.14–0.16)</td>
<td>0.069 (0.064–0.075)</td>
<td>0.14 (0.12–0.15)</td>
<td>0.37 (0.31–0.44)</td>
<td>0.52 (0.41–0.63)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2504</td>
<td>0.04</td>
<td>0.15 (0.14–0.16)</td>
<td>0.059 (0.055–0.068)</td>
<td>0.14 (0.13–0.15)</td>
<td>0.39 (0.31–0.46)</td>
<td>0.59 (0.47–0.72)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1264</td>
<td>0</td>
<td>0.14 (0.13–0.16)</td>
<td>0.060 (0.051–0.069)</td>
<td>0.13 (0.11–0.15)</td>
<td>0.35 (0.27–0.43)</td>
<td>0.51 (0.39–0.64)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1241</td>
<td>0.08</td>
<td>0.13 (0.12–0.15)</td>
<td>0.052 (0.042–0.061)</td>
<td>0.13 (0.11–0.14)</td>
<td>0.34 (0.29–0.39)</td>
<td>0.53 (0.32–0.75)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1248</td>
<td>0.08</td>
<td>0.17 (0.15–0.18)</td>
<td>0.078 (0.066–0.090)</td>
<td>0.15 (0.13–0.16)</td>
<td>0.39 (0.31–0.46)</td>
<td>0.55 (0.40–0.71)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1263</td>
<td>0</td>
<td>0.17 (0.15–0.19)</td>
<td>0.070 (0.058–0.081)</td>
<td>0.15 (0.13–0.17)</td>
<td>0.47 (0.36–0.57)</td>
<td>0.63 (0.52–0.74)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>504</td>
<td>0</td>
<td>0.20 (0.17–0.22)</td>
<td>0.094 (0.077–0.11)</td>
<td>0.18 (0.16–0.21)</td>
<td>0.40 (0.32–0.47)</td>
<td>0.57 (0.39–0.75)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>489</td>
<td>0</td>
<td>0.18 (0.17–0.19)</td>
<td>0.088 (0.073–0.10)</td>
<td>0.16 (0.14–0.18)</td>
<td>0.38 (0.33–0.43)</td>
<td>0.53 (0.42–0.63)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>508</td>
<td>0</td>
<td>0.14 (0.13–0.16)</td>
<td>0.079 (0.071–0.087)</td>
<td>0.12 (0.11–0.14)</td>
<td>0.31 (0.26–0.37)</td>
<td>0.44 (0.26–0.63)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>501</td>
<td>0.20</td>
<td>0.13 (0.12–0.15)</td>
<td>0.068 (0.060–0.077)</td>
<td>0.12 (0.10–0.14)</td>
<td>0.29 (0.20–0.38)</td>
<td>0.37 (0.29–0.45)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>504</td>
<td>0</td>
<td>0.12 (0.11–0.13)</td>
<td>0.059 (0.053–0.063)</td>
<td>0.11 (0.095–0.12)</td>
<td>0.25 (0.18–0.32)</td>
<td>0.32 (0.25–0.40)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>0</td>
<td>0.11 (0.097–0.13)</td>
<td>0.052 (0.040–0.064)</td>
<td>0.099 (0.089–0.11)</td>
<td>0.29 (0.22–0.35)</td>
<td>0.37 (0.29–0.45)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>353</td>
<td>0</td>
<td>0.14 (0.12–0.16)</td>
<td>0.057 (0.043–0.071)</td>
<td>0.12 (0.099–0.16)</td>
<td>0.35 (0.23–0.47)</td>
<td>0.49 (0.36–0.62)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>0</td>
<td>0.14 (0.12–0.16)</td>
<td>0.060 (0.041–0.079)</td>
<td>0.13 (0.12–0.14)</td>
<td>0.34 (0.27–0.41)</td>
<td>0.50 (0.39–0.61)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>357</td>
<td>0</td>
<td>0.17 (0.15–0.18)</td>
<td>0.078 (0.067–0.088)</td>
<td>0.15 (0.12–0.17)</td>
<td>0.42 (0.36–0.47)</td>
<td>0.58 (0.45–0.70)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>0</td>
<td>0.17 (0.15–0.19)</td>
<td>0.062E (0.038–0.085)</td>
<td>0.16 (0.13–0.19)</td>
<td>0.48E (0.30–0.67)</td>
<td>0.63 (0.44–0.82)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>286</td>
<td>0.35</td>
<td>0.18 (0.16–0.19)</td>
<td>0.075 (0.066–0.089)</td>
<td>0.16 (0.14–0.18)</td>
<td>0.36E (0.24–0.53)</td>
<td>0.62 (0.47–0.78)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>0</td>
<td>0.16 (0.13–0.19)</td>
<td>0.059 (0.048–0.069)</td>
<td>0.13 (0.11–0.15)</td>
<td>0.46 (0.36–0.57)</td>
<td>0.81E (0.24–1.4)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.
Table 12.7.3
2-Hydroxyphenanthrene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2520</td>
<td>0</td>
<td>0.067 (0.062–0.071)</td>
<td>0.027 (0.024–0.031)</td>
<td>0.065 (0.060–0.069)</td>
<td>0.17 (0.14–0.20)</td>
<td>0.23 (0.19–0.29)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2503</td>
<td>0</td>
<td>0.061 (0.054–0.068)</td>
<td>0.021 (0.018–0.025)</td>
<td>0.056 (0.048–0.064)</td>
<td>0.18 (0.16–0.20)</td>
<td>0.28 (0.24–0.33)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1265</td>
<td>0</td>
<td>0.074 (0.066–0.083)</td>
<td>0.029 (0.025–0.033)</td>
<td>0.070 (0.062–0.078)</td>
<td>0.18 (0.13–0.23)</td>
<td>0.26 (0.19–0.33)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1238</td>
<td>0</td>
<td>0.071 (0.065–0.078)</td>
<td>0.027 (0.023–0.031)</td>
<td>0.065 (0.058–0.071)</td>
<td>0.19 (0.15–0.23)</td>
<td>0.31 (0.21–0.41)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1255</td>
<td>0</td>
<td>0.060 (0.056–0.065)</td>
<td>0.024 (0.020–0.029)</td>
<td>0.058 (0.052–0.064)</td>
<td>0.14 (0.11–0.16)</td>
<td>0.19 (0.12–0.26)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1265</td>
<td>0</td>
<td>0.052 (0.044–0.063)</td>
<td>0.017 (0.013–0.021)</td>
<td>0.047 (0.035–0.059)</td>
<td>0.15 (0.11–0.18)</td>
<td>0.22 (0.10–0.33)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>506</td>
<td>0</td>
<td>0.043 (0.038–0.049)</td>
<td>0.023 (0.019–0.027)</td>
<td>0.040 (0.033–0.046)</td>
<td>0.086 (0.066–0.11)</td>
<td>0.11 (0.077–0.15)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>490</td>
<td>0</td>
<td>0.033 (0.028–0.038)</td>
<td>0.014 (0.010–0.018)</td>
<td>0.031 (0.028–0.035)</td>
<td>0.074 (0.067–0.081)</td>
<td>0.090 (0.076–0.10)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>510</td>
<td>0</td>
<td>0.052 (0.046–0.059)</td>
<td>0.025 (0.021–0.030)</td>
<td>0.050 (0.045–0.056)</td>
<td>0.10 (0.076–0.13)</td>
<td>0.14 (0.11–0.17)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>500</td>
<td>0</td>
<td>0.041 (0.036–0.045)</td>
<td>0.018 (0.014–0.022)</td>
<td>0.040 (0.034–0.047)</td>
<td>0.090 (0.073–0.11)</td>
<td>0.12 (0.085–0.17)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>506</td>
<td>0</td>
<td>0.067 (0.061–0.074)</td>
<td>0.024 (0.020–0.027)</td>
<td>0.064 (0.058–0.069)</td>
<td>0.16 (0.11–0.20)</td>
<td>0.19 (0.15–0.24)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>0</td>
<td>0.064 (0.059–0.075)</td>
<td>0.024 (0.020–0.027)</td>
<td>0.061 (0.051–0.071)</td>
<td>0.16 (0.12–0.20)</td>
<td>0.16 (0.13–0.38)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>354</td>
<td>0</td>
<td>0.069 (0.060–0.078)</td>
<td>0.028 (0.023–0.033)</td>
<td>0.067 (0.059–0.074)</td>
<td>0.17 (0.13–0.21)</td>
<td>0.26 (0.13–0.32)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>0</td>
<td>0.083 (0.072–0.095)</td>
<td>0.031 (0.026–0.036)</td>
<td>0.087 (0.078–0.097)</td>
<td>0.19 (0.12–0.26)</td>
<td>0.33 (0.17–0.49)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>359</td>
<td>0</td>
<td>0.073 (0.064–0.083)</td>
<td>0.027 (0.022–0.033)</td>
<td>0.071 (0.062–0.081)</td>
<td>0.20 (0.14–0.26)</td>
<td>0.27 (0.20–0.33)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>0</td>
<td>0.057 (0.048–0.068)</td>
<td>0.019 (0.011–0.028)</td>
<td>0.050 (0.037–0.062)</td>
<td>0.16 (0.098–0.23)</td>
<td>0.27 (0.17–0.37)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>285</td>
<td>0</td>
<td>0.064 (0.058–0.071)</td>
<td>0.026 (0.018–0.034)</td>
<td>0.062 (0.055–0.070)</td>
<td>0.15 (0.11–0.19)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>347</td>
<td>0</td>
<td>0.059 (0.049–0.073)</td>
<td>0.019 (0.012–0.027)</td>
<td>0.054 (0.043–0.064)</td>
<td>0.24 (0.12–0.36)</td>
<td>F</td>
</tr>
</tbody>
</table>

a  If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E  Use data with caution.
F  Data is too unreliable to be published.
### Table 12.7.4
2-Hydroxyphenanthrene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2510</td>
<td>0</td>
<td>0.067 (0.062–0.072)</td>
<td>0.030 (0.021–0.039)</td>
<td>0.062 (0.051–0.067)</td>
<td>0.14 (0.12–0.16)</td>
<td>0.18 (0.16–0.20)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2502</td>
<td>0</td>
<td>0.063 (0.058–0.068)</td>
<td>0.028 (0.025–0.031)</td>
<td>0.056 (0.052–0.060)</td>
<td>0.16 (0.14–0.18)</td>
<td>0.21 (0.17–0.26)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1261</td>
<td>0</td>
<td>0.063 (0.058–0.070)</td>
<td>0.029 (0.027–0.031)</td>
<td>0.059 (0.052–0.066)</td>
<td>0.15 (0.12–0.18)</td>
<td>0.19 (0.15–0.23)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1238</td>
<td>0</td>
<td>0.059 (0.053–0.066)</td>
<td>0.028 (0.024–0.031)</td>
<td>0.054 (0.049–0.059)</td>
<td>0.17 (0.14–0.19)</td>
<td>0.20 (0.16–0.24)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1249</td>
<td>0</td>
<td>0.070 (0.062–0.078)</td>
<td>0.033 (0.028–0.039)</td>
<td>0.066 (0.060–0.072)</td>
<td>0.14 (0.11–0.17)</td>
<td>0.18 (0.12–0.23)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1264</td>
<td>0</td>
<td>0.067 (0.060–0.075)</td>
<td>0.031 (0.025–0.036)</td>
<td>0.061 (0.050–0.073)</td>
<td>0.16 (0.12–0.19)</td>
<td>0.22 (0.17–0.28)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>505</td>
<td>0</td>
<td>0.071 (0.066–0.080)</td>
<td>0.040 (0.032–0.047)</td>
<td>0.076 (0.064–0.088)</td>
<td>0.15 (0.12–0.19)</td>
<td>0.18 (0.089–0.27)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>489</td>
<td>0</td>
<td>0.063 (0.058–0.071)</td>
<td>0.034 (0.027–0.040)</td>
<td>0.058 (0.051–0.064)</td>
<td>0.13 (0.11–0.15)</td>
<td>0.17 (0.14–0.19)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>508</td>
<td>0</td>
<td>0.061 (0.055–0.067)</td>
<td>0.034 (0.029–0.039)</td>
<td>0.057 (0.052–0.061)</td>
<td>0.11 (0.089–0.15)</td>
<td>0.17 (0.12–0.22)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>500</td>
<td>0</td>
<td>0.052 (0.046–0.060)</td>
<td>0.027 (0.020–0.034)</td>
<td>0.048 (0.039–0.058)</td>
<td>0.10 (0.085–0.12)</td>
<td>0.13 (0.10–0.16)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>504</td>
<td>0</td>
<td>0.051 (0.046–0.057)</td>
<td>0.027 (0.020–0.029)</td>
<td>0.047 (0.042–0.052)</td>
<td>0.10 (0.073–0.13)</td>
<td>0.13 (0.078–0.18)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>0</td>
<td>0.048 (0.040–0.058)</td>
<td>0.024 (0.020–0.028)</td>
<td>0.045 (0.036–0.053)</td>
<td>0.099 (0.072–0.13)</td>
<td>0.13 (0.060–0.21)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>352</td>
<td>0</td>
<td>0.061 (0.053–0.071)</td>
<td>0.029 (0.026–0.032)</td>
<td>0.057 (0.048–0.066)</td>
<td>0.15 (0.10–0.19)</td>
<td>0.18 (0.14–0.22)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>0</td>
<td>0.064 (0.055–0.073)</td>
<td>0.029 (0.024–0.033)</td>
<td>0.055 (0.049–0.062)</td>
<td>0.17 (0.14–0.20)</td>
<td>0.20 (0.14–0.26)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>357</td>
<td>0</td>
<td>0.074 (0.067–0.081)</td>
<td>0.033 (0.028–0.038)</td>
<td>0.071 (0.063–0.078)</td>
<td>0.17 (0.13–0.20)</td>
<td>0.18 (0.14–0.22)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>0</td>
<td>0.067 (0.059–0.077)</td>
<td>0.029 (0.024–0.035)</td>
<td>0.066 (0.057–0.075)</td>
<td>0.17 (0.12–0.21)</td>
<td>0.22 (0.16–0.29)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>284</td>
<td>0</td>
<td>0.075 (0.067–0.084)</td>
<td>0.036 (0.029–0.043)</td>
<td>0.066 (0.051–0.072)</td>
<td>0.14 (0.085–0.19)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>347</td>
<td>0</td>
<td>0.068 (0.051–0.082)</td>
<td>0.029 (0.022–0.037)</td>
<td>0.057 (0.048–0.066)</td>
<td>0.19 (0.13–0.24)</td>
<td>F</td>
</tr>
</tbody>
</table>

---

*a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

*E Use data with caution.

*F Data is too unreliable to be published.
### Table 12.7.5

3-Hydroxyphenanthrene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total 3–79</td>
<td>2 (2009–2011)</td>
<td>2515</td>
<td>0</td>
<td>0.087 (0.080–0.095)</td>
<td>0.026 (0.023–0.029)</td>
<td>0.089 (0.080–0.098)</td>
<td>0.28 (0.23–0.35)</td>
<td>0.39 (0.31–0.48)</td>
<td></td>
</tr>
<tr>
<td>Total 3–79</td>
<td>3 (2012–2013)</td>
<td>2505</td>
<td>0</td>
<td>0.083 (0.077–0.090)</td>
<td>0.021 (0.018–0.026)</td>
<td>0.081 (0.075–0.087)</td>
<td>0.29 (0.24–0.34)</td>
<td>0.48 (0.40–0.57)</td>
<td></td>
</tr>
<tr>
<td>Males 3–79</td>
<td>2 (2009–2011)</td>
<td>1265</td>
<td>0</td>
<td>0.10 (0.087–0.12)</td>
<td>0.030 (0.028–0.035)</td>
<td>0.099 (0.085–0.11)</td>
<td>0.33 (0.25–0.42)</td>
<td>0.45 (0.30–0.60)</td>
<td></td>
</tr>
<tr>
<td>Males 3–79</td>
<td>3 (2012–2013)</td>
<td>1241</td>
<td>0</td>
<td>0.099 (0.092–0.11)</td>
<td>0.029 (0.020–0.039)</td>
<td>0.098 (0.084–0.11)</td>
<td>0.33 (0.25–0.40)</td>
<td>0.54 (0.44–0.64)</td>
<td></td>
</tr>
<tr>
<td>Females 3–79</td>
<td>2 (2009–2011)</td>
<td>1250</td>
<td>0</td>
<td>0.075 (0.069–0.082)</td>
<td>0.022 (0.018–0.026)</td>
<td>0.078 (0.066–0.090)</td>
<td>0.22 (0.14–0.29)</td>
<td>0.35 (0.26–0.44)</td>
<td></td>
</tr>
<tr>
<td>Females 3–79</td>
<td>3 (2012–2013)</td>
<td>1264</td>
<td>0</td>
<td>0.070 (0.066–0.082)</td>
<td>0.017 (0.013–0.021)</td>
<td>0.065 (0.051–0.079)</td>
<td>0.28 (0.22–0.34)</td>
<td>0.40 (0.27–0.52)</td>
<td></td>
</tr>
<tr>
<td>Total 3–5</td>
<td>2 (2009–2011)</td>
<td>501</td>
<td>0</td>
<td>0.077 (0.068–0.086)</td>
<td>0.030 (0.026–0.034)</td>
<td>0.076 (0.064–0.088)</td>
<td>0.18 (0.10–0.25)</td>
<td>0.28 (0.20–0.33)</td>
<td></td>
</tr>
<tr>
<td>Total 3–5</td>
<td>3 (2012–2013)</td>
<td>490</td>
<td>0</td>
<td>0.065 (0.058–0.074)</td>
<td>0.020 (0.015–0.024)</td>
<td>0.067 (0.059–0.075)</td>
<td>0.19 (0.16–0.22)</td>
<td>0.28 (0.22–0.34)</td>
<td></td>
</tr>
<tr>
<td>Total 6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>0</td>
<td>0.084 (0.071–0.099)</td>
<td>0.029 (0.023–0.035)</td>
<td>0.092 (0.072–0.11)</td>
<td>0.21 (0.16–0.27)</td>
<td>0.28 (0.21–0.34)</td>
<td></td>
</tr>
<tr>
<td>Total 6–11</td>
<td>3 (2012–2013)</td>
<td>501</td>
<td>0</td>
<td>0.069 (0.059–0.081)</td>
<td>0.021 (0.014–0.029)</td>
<td>0.073 (0.059–0.087)</td>
<td>0.17 (0.13–0.21)</td>
<td>0.22 (0.16–0.28)</td>
<td></td>
</tr>
<tr>
<td>Total 12–19</td>
<td>2 (2009–2011)</td>
<td>506</td>
<td>0</td>
<td>0.094 (0.084–0.11)</td>
<td>0.033 (0.025–0.042)</td>
<td>0.091 (0.077–0.10)</td>
<td>0.26 (0.18–0.33)</td>
<td>0.35 (0.20–0.50)</td>
<td></td>
</tr>
<tr>
<td>Total 12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>0</td>
<td>0.091 (0.081–0.10)</td>
<td>0.028 (0.015–0.040)</td>
<td>0.089 (0.075–0.10)</td>
<td>0.28 (0.19–0.38)</td>
<td>0.42 (0.30–0.55)</td>
<td></td>
</tr>
<tr>
<td>Total 20–39</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>0</td>
<td>0.091 (0.076–0.11)</td>
<td>0.027 (0.020–0.034)</td>
<td>0.099 (0.070–0.13)</td>
<td>0.30 (0.21–0.39)</td>
<td>0.38 (0.27–0.49)</td>
<td></td>
</tr>
<tr>
<td>Total 20–39</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>0</td>
<td>0.11 (0.093–0.13)</td>
<td>0.035 (0.026–0.044)</td>
<td>0.10 (0.077–0.13)</td>
<td>0.30 (0.19–0.40)</td>
<td>0.58 (0.25–0.91)</td>
<td></td>
</tr>
<tr>
<td>Total 40–59</td>
<td>2 (2009–2011)</td>
<td>358</td>
<td>0</td>
<td>0.091 (0.076–0.11)</td>
<td>0.023 (0.014–0.032)</td>
<td>0.093 (0.082–0.10)</td>
<td>0.34 (0.27–0.41)</td>
<td>0.44 (0.27–0.60)</td>
<td></td>
</tr>
<tr>
<td>Total 40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>0</td>
<td>0.078 (0.066–0.092)</td>
<td>0.021 (0.015–0.027)</td>
<td>0.074 (0.060–0.088)</td>
<td>0.29 (0.22–0.35)</td>
<td>0.38 (0.26–0.50)</td>
<td></td>
</tr>
<tr>
<td>Total 60–79</td>
<td>2 (2009–2011)</td>
<td>286</td>
<td>0</td>
<td>0.073 (0.063–0.085)</td>
<td>0.020 (0.016–0.025)</td>
<td>0.073 (0.059–0.086)</td>
<td>0.24 (0.18–0.29)</td>
<td>0.33 (0.12–0.54)</td>
<td></td>
</tr>
<tr>
<td>Total 60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>0</td>
<td>0.072 (0.058–0.089)</td>
<td>0.015 (0.008–0.024)</td>
<td>0.066 (0.050–0.083)</td>
<td>0.48 (0.32–0.65)</td>
<td>0.58 (0.39–0.76)</td>
<td></td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.
### Table 12.7.6

3-Hydroxyphenanthrene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (µg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2505</td>
<td>0</td>
<td>0.087 (0.088–0.094)</td>
<td>0.038 (0.035–0.041)</td>
<td>0.079 (0.073–0.085)</td>
<td>0.23 (0.18–0.27)</td>
<td>0.37 (0.29–0.48)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2504</td>
<td>0</td>
<td>0.086 (0.088–0.092)</td>
<td>0.032 (0.029–0.035)</td>
<td>0.082 (0.072–0.091)</td>
<td>0.26 (0.23–0.28)</td>
<td>0.35 (0.29–0.42)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1261</td>
<td>0</td>
<td>0.086 (0.078–0.098)</td>
<td>0.035 (0.031–0.039)</td>
<td>0.079 (0.069–0.090)</td>
<td>0.26 (0.18–0.35)</td>
<td>0.42 (0.29–0.55)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1241</td>
<td>0</td>
<td>0.083 (0.074–0.093)</td>
<td>0.031 (0.027–0.036)</td>
<td>0.078 (0.063–0.093)</td>
<td>0.26 (0.24–0.27)</td>
<td>0.35 (0.25–0.44)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1244</td>
<td>0</td>
<td>0.087 (0.079–0.095)</td>
<td>0.042 (0.037–0.046)</td>
<td>0.079 (0.072–0.086)</td>
<td>0.19 (0.15–0.23)</td>
<td>0.31E (0.15–0.47)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1263</td>
<td>0</td>
<td>0.090 (0.081–0.099)</td>
<td>0.036 (0.033–0.039)</td>
<td>0.084 (0.073–0.095)</td>
<td>0.26 (0.20–0.32)</td>
<td>0.35 (0.26–0.45)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>500</td>
<td>0</td>
<td>0.14 (0.12–0.15)</td>
<td>0.067 (0.059–0.076)</td>
<td>0.13 (0.11–0.15)</td>
<td>0.29 (0.25–0.33)</td>
<td>0.36 (0.27–0.44)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>489</td>
<td>0</td>
<td>0.13 (0.12–0.14)</td>
<td>0.065 (0.056–0.074)</td>
<td>0.11 (0.097–0.12)</td>
<td>0.28 (0.24–0.31)</td>
<td>0.41 (0.31–0.51)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>507</td>
<td>0</td>
<td>0.098 (0.087–0.11)</td>
<td>0.049 (0.039–0.058)</td>
<td>0.087 (0.075–0.10)</td>
<td>0.20 (0.14–0.25)</td>
<td>0.27E (0.098–0.44)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>501</td>
<td>0</td>
<td>0.088 (0.076–0.10)</td>
<td>0.043 (0.038–0.048)</td>
<td>0.082 (0.074–0.10)</td>
<td>0.18 (0.13–0.24)</td>
<td>0.24 (0.17–0.38)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>504</td>
<td>0</td>
<td>0.072 (0.064–0.081)</td>
<td>0.037 (0.034–0.039)</td>
<td>0.068 (0.061–0.074)</td>
<td>0.14F (0.095–0.22)</td>
<td>0.23F (0.13–0.32)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>505</td>
<td>0</td>
<td>0.069 (0.062–0.077)</td>
<td>0.034 (0.034–0.039)</td>
<td>0.060 (0.051–0.068)</td>
<td>0.15 (0.11–0.19)</td>
<td>0.24F (0.13–0.36)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>353</td>
<td>0</td>
<td>0.081 (0.071–0.093)</td>
<td>0.038 (0.033–0.042)</td>
<td>0.069 (0.055–0.082)</td>
<td>0.23F (0.12–0.33)</td>
<td>0.38F (0.23–0.52)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>350</td>
<td>0</td>
<td>0.084 (0.070–0.10)</td>
<td>0.031 (0.025–0.038)</td>
<td>0.081 (0.065–0.098)</td>
<td>0.25 (0.20–0.31)</td>
<td>0.34 (0.22–0.47)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>356</td>
<td>0</td>
<td>0.092 (0.083–0.10)</td>
<td>0.037 (0.032–0.043)</td>
<td>0.086 (0.073–0.099)</td>
<td>0.27 (0.18–0.35)</td>
<td>0.45 (0.32–0.58)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>311</td>
<td>0</td>
<td>0.092 (0.081–0.10)</td>
<td>0.033 (0.026–0.040)</td>
<td>0.069 (0.057–0.081)</td>
<td>0.28 (0.20–0.35)</td>
<td>0.34 (0.22–0.45)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>285</td>
<td>0</td>
<td>0.085 (0.075–0.096)</td>
<td>0.039 (0.032–0.045)</td>
<td>0.077 (0.071–0.083)</td>
<td>0.18F (0.11–0.24)</td>
<td>0.30F (0.13–0.47)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>348</td>
<td>0</td>
<td>0.083 (0.069–0.10)</td>
<td>0.030 (0.022–0.038)</td>
<td>0.069 (0.059–0.079)</td>
<td>0.33 (0.24–0.41)</td>
<td>0.43F (0.18–0.68)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.
### Table 12.7.7
4-Hydroxyphenanthrene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2519</td>
<td>0.08</td>
<td>0.024 (0.022–0.027)</td>
<td>0.0065 (0.0055–0.0075)</td>
<td>0.019 (0.016–0.022)</td>
<td>0.091 (0.074–0.11)</td>
<td>0.13 (0.11–0.15)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2495</td>
<td>4.33</td>
<td>0.021 (0.019–0.023)</td>
<td>0.0055 (0.0044–0.0065)</td>
<td>0.020 (0.016–0.023)</td>
<td>0.086 (0.068–0.10)</td>
<td>0.14 (0.11–0.18)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1266</td>
<td>0</td>
<td>0.027 (0.023–0.031)</td>
<td>0.0071 (0.0053–0.0088)</td>
<td>0.022 (0.017–0.027)</td>
<td>0.10 (0.074–0.13)</td>
<td>0.15 (0.10–0.20)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1236</td>
<td>3.32</td>
<td>0.024 (0.021–0.027)</td>
<td>0.0067 (0.0047–0.0087)</td>
<td>0.023 (0.020–0.026)</td>
<td>0.097 (0.074–0.12)</td>
<td>0.15 (0.11–0.19)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1253</td>
<td>0.16</td>
<td>0.022 (0.020–0.024)</td>
<td>0.0058 (0.0047–0.0070)</td>
<td>0.017 (0.014–0.020)</td>
<td>0.085 (0.065–0.10)</td>
<td>0.13 (0.095–0.16)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1259</td>
<td>5.32</td>
<td>0.018 (0.015–0.023)</td>
<td>0.0044 (0.0031–0.0058)</td>
<td>0.017 (0.011–0.022)</td>
<td>0.076 (0.052–0.10)</td>
<td>0.13 (0.079–0.18)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>505</td>
<td>0</td>
<td>0.017 (0.015–0.020)</td>
<td>0.0056 (0.0045–0.0068)</td>
<td>0.014 (0.012–0.016)</td>
<td>0.051 (0.042–0.061)</td>
<td>0.063 (0.032–0.093)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>488</td>
<td>4.30</td>
<td>0.014 (0.012–0.016)</td>
<td>0.0045 (0.0031–0.0059)</td>
<td>0.013 (0.011–0.016)</td>
<td>0.047 (0.036–0.056)</td>
<td>0.062 (0.051–0.073)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>510</td>
<td>0</td>
<td>0.020 (0.018–0.023)</td>
<td>0.0063 (0.0054–0.0073)</td>
<td>0.016 (0.012–0.020)</td>
<td>0.057 (0.040–0.075)</td>
<td>0.074 (0.049–0.099)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>500</td>
<td>4.40</td>
<td>0.014 (0.013–0.017)</td>
<td>0.0046 (0.0033–0.0059)</td>
<td>0.015 (0.012–0.018)</td>
<td>0.041 (0.032–0.050)</td>
<td>0.062 (0.050–0.073)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>505</td>
<td>0.20</td>
<td>0.023 (0.020–0.025)</td>
<td>0.0075 (0.0055–0.0096)</td>
<td>0.018 (0.016–0.021)</td>
<td>0.067 (0.053–0.081)</td>
<td>0.094 (0.063–0.12)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>504</td>
<td>4.56</td>
<td>0.021 (0.018–0.024)</td>
<td>0.0068 (0.0053–0.0083)</td>
<td>0.018 (0.015–0.021)</td>
<td>0.077 (0.052–0.10)</td>
<td>0.11 (0.070–0.16)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>0</td>
<td>0.026 (0.022–0.031)</td>
<td>0.0064 (0.0045–0.0083)</td>
<td>0.025 (0.014–0.036)</td>
<td>0.088 (0.057–0.12)</td>
<td>0.13 (0.086–0.18)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>349</td>
<td>2.87</td>
<td>0.027 (0.022–0.034)</td>
<td>0.0072 (0.0054–0.0090)</td>
<td>0.028 (0.020–0.036)</td>
<td>0.095 (0.057–0.13)</td>
<td>0.16 (0.088–0.24)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>357</td>
<td>0</td>
<td>0.027 (0.023–0.032)</td>
<td>0.0075 (0.0053–0.0098)</td>
<td>0.020 (0.015–0.024)</td>
<td>0.11 (0.085–0.14)</td>
<td>0.15 (0.097–0.21)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>308</td>
<td>4.55</td>
<td>0.021 (0.017–0.025)</td>
<td>0.0045 (LOD–0.0067)</td>
<td>0.019 (0.014–0.025)</td>
<td>0.090 (0.050–0.13)</td>
<td>0.12 (0.075–0.17)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>287</td>
<td>0.35</td>
<td>0.022 (0.019–0.026)</td>
<td>0.0057 (0.0044–0.0070)</td>
<td>0.018 (0.013–0.022)</td>
<td>0.086 (0.054–0.12)</td>
<td>0.14 (0.075–0.21)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>346</td>
<td>5.20</td>
<td>0.020 (0.016–0.024)</td>
<td>0.0047 (LOD–0.0071)</td>
<td>0.018 (0.013–0.022)</td>
<td>F</td>
<td>0.25 (0.12–0.39)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.

F Data is too unreliable to be published.
**Table 12.7.8**

4-Hydroxyphenanthrene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2</td>
<td>2509</td>
<td>0.08</td>
<td>0.024 (0.022–0.026)</td>
<td>0.0089 (0.0084–0.0094)</td>
<td>0.020 (0.016–0.024)</td>
<td>0.077 (0.060–0.094)</td>
<td>0.11 (0.082–0.14)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3</td>
<td>2494</td>
<td>4.33</td>
<td>0.022 (0.020–0.024)</td>
<td>0.0077 (0.0066–0.0088)</td>
<td>0.019 (0.016–0.021)</td>
<td>0.076 (0.067–0.085)</td>
<td>0.10 (0.083–0.12)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2</td>
<td>1262</td>
<td>0</td>
<td>0.022 (0.019–0.026)</td>
<td>0.0078 (0.0070–0.0087)</td>
<td>0.020 (0.019–0.020)</td>
<td>0.088 (0.061–0.11)</td>
<td>0.13 (0.085–0.17)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3</td>
<td>1236</td>
<td>3.32</td>
<td>0.020 (0.017–0.023)</td>
<td>0.0071 (0.0056–0.0087)</td>
<td>0.017 (0.014–0.019)</td>
<td>0.077 (0.063–0.091)</td>
<td>0.099 (0.081–0.12)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2</td>
<td>1247</td>
<td>0.16</td>
<td>0.026 (0.023–0.029)</td>
<td>0.0092 (0.0089–0.0095)</td>
<td>0.027 (0.018–0.035)</td>
<td>0.068 (0.051–0.086)</td>
<td>0.10 (0.070–0.13)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3</td>
<td>1258</td>
<td>5.32</td>
<td>0.023 (0.021–0.026)</td>
<td>0.0081 (0.0069–0.0094)</td>
<td>0.022 (0.019–0.025)</td>
<td>0.076 (0.061–0.090)</td>
<td>0.11 (0.079–0.14)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2</td>
<td>504</td>
<td>0</td>
<td>0.030 (0.026–0.035)</td>
<td>0.0095 (0.0089–0.010)</td>
<td>0.024 (0.021–0.028)</td>
<td>0.085 (0.068–0.10)</td>
<td>0.097 (0.076–0.12)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3</td>
<td>487</td>
<td>4.30</td>
<td>0.026 (0.024–0.029)</td>
<td>0.011 (0.010–0.012)</td>
<td>0.023 (0.019–0.027)</td>
<td>0.066 (0.062–0.074)</td>
<td>0.095 (0.075–0.12)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2</td>
<td>508</td>
<td>0</td>
<td>0.022 (0.018–0.026)</td>
<td>0.0091 (0.0088–0.0094)</td>
<td>0.016 (0.012–0.020)</td>
<td>0.060 (0.042–0.078)</td>
<td>0.080 (0.069–0.10)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3</td>
<td>500</td>
<td>4.40</td>
<td>0.018 (0.016–0.021)</td>
<td>0.0078 (0.0066–0.0089)</td>
<td>0.017 (0.014–0.020)</td>
<td>0.045 (0.040–0.050)</td>
<td>0.052 (0.043–0.061)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2</td>
<td>503</td>
<td>0.20</td>
<td>0.017 (0.015–0.019)</td>
<td>0.0077 (0.0068–0.0086)</td>
<td>0.019 (0.011–0.027)</td>
<td>0.042 (0.030–0.054)</td>
<td>0.059 (0.039–0.078)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3</td>
<td>504</td>
<td>4.56</td>
<td>0.016 (0.014–0.018)</td>
<td>0.0070 (0.0060–0.0080)</td>
<td>0.013 (0.011–0.016)</td>
<td>0.036 (0.025–0.047)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2</td>
<td>353</td>
<td>0</td>
<td>0.023 (0.019–0.027)</td>
<td>0.0078 (0.0065–0.0091)</td>
<td>0.020 (0.018–0.02)</td>
<td>0.076 (0.041–0.098)</td>
<td>0.11 (0.067–0.16)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3</td>
<td>349</td>
<td>2.87</td>
<td>0.021 (0.017–0.026)</td>
<td>0.0080 (0.0064–0.0096)</td>
<td>0.017 (0.012–0.022)</td>
<td>0.077 (0.059–0.095)</td>
<td>0.093 (0.071–0.11)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2</td>
<td>355</td>
<td>0</td>
<td>0.027 (0.024–0.030)</td>
<td>0.0091 (0.0077–0.0095)</td>
<td>0.027 (0.018–0.036)</td>
<td>0.091 (0.074–0.11)</td>
<td>0.14 (0.088–0.19)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3</td>
<td>308</td>
<td>4.55</td>
<td>0.024 (0.020–0.029)</td>
<td>0.0080 (0.0054–0.011)</td>
<td>0.024 (0.018–0.030)</td>
<td>0.083 (0.066–0.11)</td>
<td>0.11 (0.070–0.15)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2</td>
<td>286</td>
<td>0.35</td>
<td>0.026 (0.023–0.031)</td>
<td>0.0090 (0.0062–0.0098)</td>
<td>0.029 (0.018–0.040)</td>
<td>0.081 (0.048–0.11)</td>
<td>0.13 (0.070–0.19)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3</td>
<td>346</td>
<td>5.20</td>
<td>0.023 (0.019–0.027)</td>
<td>0.0074 (0.0058–0.0090)</td>
<td>0.020 (0.015–0.024)</td>
<td>0.096 (0.058–0.13)</td>
<td>0.14 (0.075–0.21)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.

F Data is too unreliable to be published.
**Table 12.7.9**

9-Hydroxyphenanthrene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2474</td>
<td>5.86</td>
<td>0.039 (0.034–0.044)</td>
<td>0.0075 (0.0069–0.0084)</td>
<td>0.036 (0.029–0.043)</td>
<td>0.24 (0.18–0.31)</td>
<td>0.41 (0.33–0.48)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2295</td>
<td>3.66</td>
<td>0.036 (0.033–0.040)</td>
<td>0.0080 (0.0059–0.010)</td>
<td>0.034 (0.029–0.039)</td>
<td>0.19 (0.14–0.23)</td>
<td>0.32 (0.21–0.43)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1249</td>
<td>5.44</td>
<td>0.043 (0.035–0.052)</td>
<td>0.0080 (0.0065–0.0094)</td>
<td>0.043 (0.033–0.053)</td>
<td>0.25 (0.15–0.35)</td>
<td>0.49 (0.32–0.65)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1155</td>
<td>2.60</td>
<td>0.040 (0.036–0.045)</td>
<td>0.0099 (0.0088–0.011)</td>
<td>0.037 (0.023–0.041)</td>
<td>0.19 (0.15–0.22)</td>
<td>0.26 (0.12–0.40)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1225</td>
<td>6.29</td>
<td>0.035 (0.031–0.040)</td>
<td>0.0070 (0.0053–0.0086)</td>
<td>0.032 (0.028–0.038)</td>
<td>0.23 (0.11–0.34)</td>
<td>0.38 (0.26–0.50)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1140</td>
<td>4.74</td>
<td>0.032 (0.026–0.039)</td>
<td>0.0070 (0.0045–0.0095)</td>
<td>0.032 (0.026–0.037)</td>
<td>0.19 (0.083–0.29)</td>
<td>0.39 (0.25–0.53)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>490</td>
<td>11.43</td>
<td>0.018 (0.015–0.022)</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>426</td>
<td>4.46</td>
<td>0.019 (0.017–0.022)</td>
<td>0.0069 (0.0030–0.0099)</td>
<td>0.019 (0.015–0.023)</td>
<td>0.057 (0.042–0.072)</td>
<td>0.27 (0.051–0.093)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>502</td>
<td>5.78</td>
<td>0.019 (0.017–0.023)</td>
<td>0.0044 (0.0015–0.0075)</td>
<td>0.022 (0.019–0.028)</td>
<td>0.056 (0.043–0.069)</td>
<td>0.076 (0.055–0.097)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>447</td>
<td>4.92</td>
<td>0.019 (0.017–0.022)</td>
<td>0.0058 (0.0030–0.0091)</td>
<td>0.021 (0.019–0.028)</td>
<td>0.048 (0.041–0.054)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>499</td>
<td>5.41</td>
<td>0.027 (0.023–0.032)</td>
<td>0.0073 (0.0058–0.0089)</td>
<td>0.029 (0.023–0.035)</td>
<td>0.099 (0.076–0.12)</td>
<td>0.15 (0.095–0.20)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>480</td>
<td>3.75</td>
<td>0.026 (0.021–0.031)</td>
<td>0.0070 (0.0040–0.0099)</td>
<td>0.022 (0.019–0.026)</td>
<td>0.10 (0.084–0.13)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>348</td>
<td>3.45</td>
<td>0.041 (0.034–0.050)</td>
<td>0.0088 (0.0055–0.012)</td>
<td>0.040 (0.030–0.050)</td>
<td>0.23 (0.088–0.38)</td>
<td>0.38 (0.20–0.58)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>331</td>
<td>2.11</td>
<td>0.040 (0.031–0.051)</td>
<td>0.0094 (0.0072–0.012)</td>
<td>0.036 (0.030–0.043)</td>
<td>0.19 (0.13–0.25)</td>
<td>0.23 (0.088–0.38)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>350</td>
<td>3.14</td>
<td>0.049 (0.040–0.059)</td>
<td>0.0089 (0.0071–0.011)</td>
<td>0.045 (0.034–0.056)</td>
<td>0.31 (0.23–0.38)</td>
<td>0.48 (0.40–0.56)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>287</td>
<td>4.18</td>
<td>0.041 (0.031–0.054)</td>
<td>0.0080 (0.0052–0.011)</td>
<td>0.043 (0.031–0.055)</td>
<td>0.22 (0.086–0.35)</td>
<td>0.38 (0.22–0.53)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>285</td>
<td>3.51</td>
<td>0.043 (0.033–0.056)</td>
<td>0.0065 (0.0030–0.0092)</td>
<td>0.035 (0.024–0.045)</td>
<td>0.31 (0.19–0.42)</td>
<td>0.60 (0.34–0.85)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>324</td>
<td>1.85</td>
<td>0.041 (0.034–0.050)</td>
<td>F</td>
<td>0.040 (0.031–0.049)</td>
<td>0.28 (0.076–0.49)</td>
<td>F</td>
</tr>
</tbody>
</table>

---

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.
### Table 12.7.10
9-Hydroxyphenanthrene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2464</td>
<td>5.86</td>
<td>0.039 (0.024–0.044)</td>
<td>0.010 (0.0069–0.013)</td>
<td>0.032 (0.026–0.039)</td>
<td>0.22 (0.16–0.28)</td>
<td>0.34 (0.28–0.42)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2294</td>
<td>3.66</td>
<td>0.037 (0.034–0.041)</td>
<td>0.011 (0.0095–0.012)</td>
<td>0.032 (0.028–0.037)</td>
<td>0.17 (0.13–0.21)</td>
<td>0.29 (0.22–0.36)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1245</td>
<td>5.44</td>
<td>0.037 (0.030–0.045)</td>
<td>0.0099 (0.0077–0.012)</td>
<td>0.029 (0.022–0.035)</td>
<td>0.23 (0.14–0.33)</td>
<td>0.38 (0.27–0.48)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1155</td>
<td>2.60</td>
<td>0.033 (0.028–0.039)</td>
<td>0.0097 (0.0079–0.012)</td>
<td>0.030 (0.023–0.037)</td>
<td>0.16 (0.11–0.21)</td>
<td>0.26 (0.16–0.30)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1219</td>
<td>6.29</td>
<td>0.041 (0.035–0.048)</td>
<td>0.010 (0.0060–0.014)</td>
<td>0.034 (0.027–0.043)</td>
<td>0.21 (0.13–0.29)</td>
<td>0.29 (0.18–0.39)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1139</td>
<td>4.74</td>
<td>0.041 (0.037–0.046)</td>
<td>0.012 (0.010–0.013)</td>
<td>0.035 (0.030–0.039)</td>
<td>0.21 (0.12–0.30)</td>
<td>0.39 (0.25–0.53)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>489</td>
<td>11.43</td>
<td>0.032 (0.027–0.037)</td>
<td>&lt;LOD</td>
<td>0.037 (0.030–0.043)</td>
<td>0.11 (0.086–0.13)</td>
<td>0.14 (0.086–0.20)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>425</td>
<td>4.46</td>
<td>0.037 (0.035–0.040)</td>
<td>0.017 (0.013–0.020)</td>
<td>0.036 (0.032–0.040)</td>
<td>0.081 (0.066–0.095)</td>
<td>0.10 (0.086–0.12)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>500</td>
<td>5.78</td>
<td>0.022 (0.018–0.027)</td>
<td>0.0068 (0.000–0.010)</td>
<td>0.025 (0.021–0.029)</td>
<td>0.053 (0.044–0.063)</td>
<td>0.071 (0.050–0.093)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>447</td>
<td>4.92</td>
<td>0.025 (0.022–0.028)</td>
<td>0.012 (0.0068–0.015)</td>
<td>0.023 (0.020–0.025)</td>
<td>0.057 (0.046–0.069)</td>
<td>0.082 (0.037–0.13)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>497</td>
<td>5.41</td>
<td>0.021 (0.018–0.023)</td>
<td>0.0076 (0.0060–0.0092)</td>
<td>0.020 (0.017–0.023)</td>
<td>0.059 (0.037–0.082)</td>
<td>0.087 (0.043–0.13)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>480</td>
<td>3.75</td>
<td>0.019 (0.017–0.022)</td>
<td>0.0087 (0.0071–0.010)</td>
<td>0.016 (0.014–0.018)</td>
<td>0.056 (0.030–0.082)</td>
<td>0.097 (0.042–0.15)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>346</td>
<td>3.45</td>
<td>0.037 (0.029–0.047)</td>
<td>0.010 (0.0047–0.015)</td>
<td>0.028 (0.020–0.035)</td>
<td>0.26 (0.11–0.41)</td>
<td>0.36 (0.22–0.51)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>331</td>
<td>2.11</td>
<td>0.030 (0.023–0.040)</td>
<td>0.010 (0.0066–0.013)</td>
<td>0.026 (0.017–0.033)</td>
<td>0.12 (0.046–0.20)</td>
<td>0.17 (0.093–0.25)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>348</td>
<td>3.14</td>
<td>0.049 (0.040–0.060)</td>
<td>0.012 (0.0067–0.018)</td>
<td>0.043 (0.030–0.056)</td>
<td>0.25 (0.18–0.31)</td>
<td>0.40 (0.25–0.55)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>287</td>
<td>4.18</td>
<td>0.048 (0.038–0.060)</td>
<td>0.011 (0.0076–0.015)</td>
<td>0.042 (0.024–0.061)</td>
<td>0.24 (0.10–0.37)</td>
<td>0.39 (0.23–0.56)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>284</td>
<td>3.51</td>
<td>0.051 (0.040–0.064)</td>
<td>0.013 (0.0078–0.019)</td>
<td>0.041 (0.031–0.051)</td>
<td>0.25 (0.14–0.36)</td>
<td>0.37 (0.21–0.54)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.
Pyrene is a polycyclic aromatic hydrocarbon (PAH) with four fused benzene rings. Pyrene is used as an intermediate in the synthesis of dyes and fluorescent molecular probes for biomedical research (WHO, 1998).

Pyrene absorption occurs rapidly in the respiratory tract, but more slowly through the gastrointestinal tract and skin (Faust, 1993). After oral administration in rats, pyrene has been found predominantly in the gastrointestinal tract (Mitchell and Tu, 1979). 1-Hydroxypyrene has been identified as the primary metabolite of pyrene (IARC, 2010). In humans, urinary elimination of 1-hydroxypyrene is triphasic with half-lives of 5, 22, and 408 hours (ACGIH, 2005). Monitoring studies of pyrene exposure can measure urinary levels of 1-hydroxypyrene to assess recent and chronic exposures (Becker et al., 2003; CDC, 2009; Hopf et al., 2009; Jongeneelen et al., 1985). Urinary 1-hydroxypyrene may also serve as a useful biomarker for total PAH exposure, given that pyrene is found in most PAH mixtures (Hopf et al., 2009; WHO, 1998).

Subchronic oral exposure to pyrene results in kidney and liver effects in laboratory animals, and the liver has been suggested as the main target organ for toxicity.
(Faust, 1993; TRL, 1989). Because the carcinogenic evidence is limited, the International Agency for Research on Cancer has classified pyrene as Group 3, not classifiable as to its carcinogenicity to humans (IARC, 2010).

1-Hydroxypyrene was measured in the urine of 73 non-smoking, non-occupationally exposed residents (aged 16 to 64 years) living approximately 1 km from an aluminum plant in Baie-Comeau, Quebec. The geometric mean levels ranged from 0.090 to 0.111 µg/g creatinine, compared with 0.048 to 0.077 µg/g creatinine for 71 control individuals living at least 11 km from the plant (Bouchard et al., 2009). Firefighters from Toronto, Ontario, were assessed for their exposure to PAHs from firefighting operations while wearing protective equipment (Caux et al., 2002). Urine was collected from 43 individuals for 20 hours after exposure, and urinary 1-hydroxypyrene levels ranged from <0.043 to 7.00 µg/g creatinine (Caux et al., 2002). In a pilot biomonitoring study carried out in Hamilton, Ontario, with 19 pregnant women aged 19 to 42 years, the geometric means for 1-hydroxypyrene in urine was 0.1359 µg/g creatinine (Nethery et al., 2012).

1-Hydroxypyrene was analyzed in the urine of Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years and is presented as both µg/L and µg/g creatinine. Finding a measurable amount of 1-hydroxypyrene in urine is an indicator of exposure to pyrene and does not necessarily mean that an adverse health effect will occur.
Table 12.8.1
1-Hydroxypyrene — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2422</td>
<td>0.04</td>
<td>0.11 (0.099–0.12)</td>
<td>0.031 (0.027–0.034)</td>
<td>0.10 (0.082–0.11)</td>
<td>0.35 (0.31–0.39)</td>
<td>0.57 (0.47–0.68)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2410</td>
<td>0.04</td>
<td>0.086 (0.076–0.10)</td>
<td>0.027 (0.020–0.035)</td>
<td>0.087 (0.078–0.098)</td>
<td>0.31 (0.26–0.35)</td>
<td>0.46 (0.36–0.55)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1206</td>
<td>0.12</td>
<td>0.12 (0.11–0.14)</td>
<td>0.040 (0.034–0.045)</td>
<td>0.12 (0.10–0.13)</td>
<td>0.38 (0.25–0.50)</td>
<td>0.59 (0.46–0.73)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1178</td>
<td>0.08</td>
<td>0.10 (0.090–0.12)</td>
<td>0.033 (0.023–0.042)</td>
<td>0.094 (0.088–0.10)</td>
<td>0.36 (0.30–0.43)</td>
<td>0.52 (0.45–0.68)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1216</td>
<td>0.08</td>
<td>0.095 (0.088–0.10)</td>
<td>0.026 (0.021–0.031)</td>
<td>0.095 (0.085–0.10)</td>
<td>0.33 (0.28–0.37)</td>
<td>0.48 (0.34–0.62)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1232</td>
<td>0.077 (0.064–0.092)</td>
<td>0.022 (0.014–0.031)</td>
<td>0.077 (0.061–0.093)</td>
<td>0.26 (0.21–0.30)</td>
<td>0.36 (0.25–0.48)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>504</td>
<td>0.12</td>
<td>0.12 (0.11–0.13)</td>
<td>0.050 (0.041–0.059)</td>
<td>0.11 (0.10–0.12)</td>
<td>0.27 (0.20–0.34)</td>
<td>0.40 (0.30–0.51)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>493</td>
<td>0.093 (0.077–0.11)</td>
<td>0.029 (0.023–0.036)</td>
<td>0.098 (0.081–0.12)</td>
<td>0.26 (0.21–0.31)</td>
<td>0.31 (0.25–0.37)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>507</td>
<td>0.13</td>
<td>0.13 (0.11–0.15)</td>
<td>0.049 (0.039–0.058)</td>
<td>0.12 (0.096–0.14)</td>
<td>0.34 (0.25–0.42)</td>
<td>0.47 (0.34–0.60)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>501</td>
<td>0.092 (0.084–0.10)</td>
<td>0.032 (0.024–0.039)</td>
<td>0.097 (0.089–0.11)</td>
<td>0.21 (0.16–0.26)</td>
<td>0.28 (0.22–0.33)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>480</td>
<td>0.15</td>
<td>0.15 (0.14–0.17)</td>
<td>0.050 (0.031–0.069)</td>
<td>0.15 (0.13–0.17)</td>
<td>0.44 (0.36–0.52)</td>
<td>0.62 (0.45–0.79)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>473</td>
<td>0.12</td>
<td>0.12 (0.097–0.14)</td>
<td>0.040 (0.024–0.057)</td>
<td>0.12 (0.092–0.13)</td>
<td>0.34 (0.24–0.43)</td>
<td>0.47 (0.34–0.60)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>327</td>
<td>0.13</td>
<td>0.13 (0.11–0.15)</td>
<td>0.041 (0.027–0.054)</td>
<td>0.12 (0.10–0.14)</td>
<td>0.35 (0.29–0.42)</td>
<td>0.48 (0.27–0.69)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>308</td>
<td>0.12</td>
<td>0.12 (0.10–0.15)</td>
<td>0.037 (0.025–0.048)</td>
<td>0.11 (0.077–0.15)</td>
<td>0.36 (0.25–0.47)</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>329</td>
<td>0.30</td>
<td>0.10 (0.084–0.12)</td>
<td>0.026 (0.012–0.039)</td>
<td>0.094 (0.076–0.11)</td>
<td>0.44 (0.32–0.65)</td>
<td>0.58 (0.47–0.69)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>296</td>
<td>0.080 (0.067–0.095)</td>
<td>0.027 (0.016–0.039)</td>
<td>0.079 (0.062–0.095)</td>
<td>0.26 (0.14–0.38)</td>
<td>0.43 (0.26–0.68)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>275</td>
<td>0.067 (0.057–0.079)</td>
<td>0.024 (0.018–0.030)</td>
<td>0.062 (0.048–0.076)</td>
<td>0.20 (0.16–0.24)</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>339</td>
<td>0.29</td>
<td>0.064 (0.051–0.081)</td>
<td>0.015 (0.0066–0.022)</td>
<td>0.060 (0.041–0.079)</td>
<td>0.31 (0.20–0.41)</td>
<td>0.50 (0.29–0.71)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.
### Table 12.8.2
1-Hydroxypyrene (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2412</td>
<td>0.04</td>
<td>0.11 (0.10–0.12)</td>
<td>0.045 (0.042–0.048)</td>
<td>0.099 (0.096–0.10)</td>
<td>0.28 (0.24–0.33)</td>
<td>0.40 (0.31–0.50)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2409</td>
<td>0.04</td>
<td>0.094 (0.084–0.10)</td>
<td>0.034 (0.028–0.040)</td>
<td>0.088 (0.079–0.098)</td>
<td>0.25 (0.20–0.29)</td>
<td>0.36 (0.24–0.47)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1202</td>
<td>0</td>
<td>0.11 (0.093–0.12)</td>
<td>0.042 (0.036–0.047)</td>
<td>0.089 (0.081–0.10)</td>
<td>0.31 (0.24–0.39)</td>
<td>0.43E (0.28–0.59)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1178</td>
<td>0.08</td>
<td>0.069 (0.076–0.10)</td>
<td>0.030 (0.020–0.039)</td>
<td>0.087 (0.075–0.099)</td>
<td>0.25 (0.18–0.31)</td>
<td>0.35 (0.26–0.44)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1210</td>
<td>0.08</td>
<td>0.11 (0.10–0.12)</td>
<td>0.048 (0.044–0.052)</td>
<td>0.099 (0.094–0.11)</td>
<td>0.26 (0.21–0.31)</td>
<td>0.38 (0.28–0.49)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1231</td>
<td>0</td>
<td>0.099 (0.087–0.11)</td>
<td>0.038 (0.027–0.049)</td>
<td>0.088 (0.071–0.11)</td>
<td>0.25 (0.19–0.30)</td>
<td>0.42E (0.23–0.60)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>503</td>
<td>0</td>
<td>0.21 (0.20–0.23)</td>
<td>0.09 (0.089–0.12)</td>
<td>0.20 (0.18–0.23)</td>
<td>0.41 (0.35–0.46)</td>
<td>0.51 (0.42–0.60)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>492</td>
<td>0</td>
<td>0.18 (0.16–0.20)</td>
<td>0.094 (0.078–0.11)</td>
<td>0.17 (0.15–0.20)</td>
<td>0.34 (0.28–0.41)</td>
<td>0.43 (0.38–0.49)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>505</td>
<td>0</td>
<td>0.15 (0.13–0.16)</td>
<td>0.074 (0.063–0.085)</td>
<td>0.14 (0.12–0.15)</td>
<td>0.28 (0.22–0.34)</td>
<td>0.37 (0.26–0.49)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>501</td>
<td>0</td>
<td>0.12 (0.11–0.13)</td>
<td>0.066 (0.057–0.074)</td>
<td>0.11 (0.091–0.12)</td>
<td>0.21 (0.17–0.25)</td>
<td>0.27 (0.23–0.31)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>478</td>
<td>0</td>
<td>0.12 (0.10–0.13)</td>
<td>0.047 (0.035–0.065)</td>
<td>0.10 (0.089–0.12)</td>
<td>0.28 (0.20–0.37)</td>
<td>0.39F (0.21–0.57)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>473</td>
<td>0</td>
<td>0.099 (0.073–0.11)</td>
<td>0.044 (0.031–0.057)</td>
<td>0.087 (0.074–0.10)</td>
<td>0.19F (0.12–0.26)</td>
<td>0.26F (0.15–0.37)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>325</td>
<td>0</td>
<td>0.12 (0.096–0.14)</td>
<td>0.050 (0.035–0.065)</td>
<td>0.10 (0.083–0.12)</td>
<td>0.28 (0.18–0.38)</td>
<td>0.41 (0.27–0.54)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>308</td>
<td>0</td>
<td>0.10 (0.087–0.12)</td>
<td>0.036 (0.026–0.047)</td>
<td>0.099 (0.087–0.11)</td>
<td>0.26E (0.083–0.44)</td>
<td>0.54F (0.20–0.88)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>327</td>
<td>0.30</td>
<td>0.10 (0.090–0.12)</td>
<td>0.043 (0.039–0.047)</td>
<td>0.094 (0.085–0.10)</td>
<td>0.33 (0.25–0.41)</td>
<td>0.59F (0.24–0.94)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>296</td>
<td>0</td>
<td>0.093 (0.088–0.11)</td>
<td>0.033E (0.020–0.046)</td>
<td>0.088 (0.074–0.10)</td>
<td>0.26E (0.15–0.37)</td>
<td>0.38F (0.20–0.56)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>274</td>
<td>0</td>
<td>0.079 (0.068–0.091)</td>
<td>0.035 (0.028–0.042)</td>
<td>0.078 (0.072–0.084)</td>
<td>0.16 (0.13–0.20)</td>
<td>0.23E (0.11–0.36)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>339</td>
<td>0.29</td>
<td>0.073 (0.060–0.090)</td>
<td>0.028 (0.023–0.034)</td>
<td>0.062 (0.050–0.075)</td>
<td>0.23 (0.16–0.30)</td>
<td>0.35 (0.23–0.48)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.
REFERENCES

ACGIH (American Conference of Governmental Industrial Hygienists) (2005). Biological exposure indices (BEI): Polycyclic aromatic hydrocarbons (PAHs). ACGIH, Cincinnati, OH.


13.1 BENZENE AND BENZENE METABOLITES

Benzene (CASRN 71-43-2) is a colorless liquid and volatile organic compound (VOC) that is naturally present in ambient air at low concentrations (Health Canada, 2009). It was first isolated and synthesized in the early 1800s and presently is commercially recovered from both coal and petroleum sources for industrial applications (ATSDR, 2007).

Benzene is used widely in industry as a solvent and as an intermediate in the production of a variety of chemicals, with typical end-products including plastics and elastomers, phenol and acetone, and nylon resins (ATSDR, 2007; Environment Canada and Health Canada, 1993). Benzene is also used at various stages in the manufacturing of synthetic fibres, rubbers, lubricants, dyes, detergents, drugs, and pesticides (ATSDR, 2007).

Benzene is released to the environment from natural and anthropogenic sources. It is naturally present in crude oil, and is formed during the incomplete combustion of organic materials (Environment Canada and Health Canada, 1993). Benzene enters the environment as a result of natural processes including petroleum seepage, weathering of rock and soil, volcanic activity, forest fires, and releases from plant life (Environment Canada and Health Canada, 1993). Anthropogenic sources include the production, storage, use, and transport of isolated benzene, crude oil, and other petroleum products. Examples include evaporative releases from gasoline at service stations and combustion by-products in the form of motor vehicle exhaust (Health Canada, 2009). Natural sources are generally considered to contribute less benzene to the environment than anthropogenic sources (Environment Canada and Health Canada, 1993).

The general population is exposed to benzene mainly through inhalation of ambient air; higher exposures occur particularly in areas of heavy vehicle traffic and at gasoline service stations, and from tobacco smoke (ATSDR, 2007). Exposure to benzene in ambient air accounts for an estimated 98% to 99% of total benzene intake for Canadian non-smokers (Health Canada, 2009). Inside residences, benzene levels in air have been shown to be higher for homes with attached garages, or where smoking occurs (Héroux et al., 2008; Héroux et al., 2010; Wheeler et al., 2013). Various marketplace products containing benzene can also contribute to its presence in indoor air (Environment Canada and Health Canada, 1993). Although benzene has been detected in tap water and in certain foods and beverages, these are not considered to constitute major sources of exposure for the general population (ATSDR, 2007; Health Canada, 2009).

Following inhalation, benzene is readily absorbed into the blood and is distributed throughout the body, concentrating in adipose tissue (EPA, 2002). In the lung and liver, benzene is metabolized into several reactive metabolites including benzene oxide (EPA, 2002; McHale et al., 2012). Benzene metabolism can branch into several alternative metabolic pathways: spontaneous rearrangement of benzene oxide produces phenol, a major product; reaction with glutathione...
ultimately forms S-phenylmercapturic acid (S-PMA); and an iron-catalyzed reaction leads to the formation of trans,trans-muconic acid (t,t-MA) (EPA, 2002). Excretion of benzene occurs via exhalation of benzene from the lungs and as conjugated metabolites in urine; all benzene metabolites may be conjugated with sulphate or glucuronic acid (EPA, 2002). Phenol, S-PMA, and t,t-MA are considered urinary biomarkers of recent benzene exposure (Boogaard and van Sittert, 1995; Qu et al., 2005; Weisel, 2010). Measurements of t,t-MA and S-PMA are more sensitive and reliable indicators of benzene exposure because urinary phenol may be a result of dietary or environmental exposure to phenol or other phenolic compounds (ATSDR, 2007). Benzene levels in blood are a reliable biomarker of benzene exposure and reflect recent exposure (Arnold et al., 2013; Weisel, 2010).

Benzene is known to cause a number of health effects in humans with the specific adverse effects dependent upon the concentration and duration of benzene exposure. Exposure to benzene can be hematotoxic in humans and laboratory animals, with bone marrow the principal target organ (EPA, 2002). Available data indicate that benzene metabolites produced in the liver may be carried to bone marrow where hematotoxicity occurs (EPA, 2002). In rodents, chronic inhalation exposure to benzene has been shown to cause leukemia (EPA, 2002). Epidemiologic studies and case studies provide strong evidence of an association between exposure to high levels of benzene and leukemia risk in occupationally exposed humans (EPA, 2002).

Benzene has been classified as carcinogenic to humans by Environment Canada and Health Canada (Group 1) and the International Agency for Research on Cancer (Group 1) (Environment Canada and Health Canada, 1993; IARC, 2012). A common mode of action has not been established for hematotoxic and carcinogenic effects; however, it is generally accepted that acute myelogenous leukemia and non-cancer effects are caused by one or more reactive metabolites of benzene (ATSDR, 2007; McHale et al., 2012; Meek and Klaunig, 2010; Smith, 2010).

Globally, benzene has become one of the most intensively regulated substances (Capleton and Levy, 2005). In Canada, regulations have been put in place to limit the concentration of benzene in gasoline as well as emissions from vehicles (Canada, 1997; Environment Canada, 2014). Benzene is listed on Schedule 1, List of Toxic Substances, under the Canadian Environmental Protection Act, 1999 (CEPA 1999) and is a candidate for full lifecycle management to prevent or minimize its release into the environment (Canada, 1999; Environment Canada and Health Canada, 1993). In 2000–2001, the Canadian Council of Ministers of the Environment endorsed the Canada-wide standard for benzene requiring industry reduction of total benzene emissions and use of best management practices (CCME, 2000; CCME, 2001). With the implementation of these standards, emissions of benzene from industry to ambient air fell by 71% between 1995 and 2008 (CCME, 2012). Benzene is also included as a prohibited ingredient on the List of Prohibited and Restricted Cosmetic Ingredients (more commonly referred to as the Cosmetic Ingredient Hotlist or simply the Hotlist). The Hotlist is an administrative tool that Health Canada uses to communicate to manufacturers and others that certain substances, when present in a cosmetic, may contravene the general prohibition found in section 16 of the Food and Drugs Act or a provision of the Cosmetic Regulations (Canada, 1985; Health Canada, 2014).

The Government of Canada has also taken a number of actions to address VOCs, a large class of compounds that includes benzene. As a class, they are environmental and health concerns because of their contribution to the formation of smog. The Government of Canada has taken and proposed a number of actions to address VOC emissions resulting from the use of consumer and commercial products in Canada (Canada, 2009a; Canada, 2009b; Environment Canada, 2002; Environment Canada, 2013).

Health Canada, in collaboration with the Federal-Provincial-Territorial Committee on Drinking Water, has developed a guideline for Canadian drinking water quality that establishes the maximum acceptable concentration for benzene in drinking water based on cancer endpoints, and that is considered protective of both cancer and non-cancer effects (Health Canada, 2009). Health Canada has identified benzene as a priority indoor air contaminant and has developed a guidance document for benzene in residential indoor air (Health Canada, 2013). On the basis of a low but non-negligible cancer risk at indoor exposure levels, the guidance recommends that individuals take actions to reduce exposure to benzene indoors as much as possible. In particular, exposure reduction strategies have been
recommended targeting attached garages and indoor smoking as primary sources of benzene indoors.

Exposure to benzene was assessed in firefighters in Montréal, Quebec, by means of urinary measurements of \( t,t\text{-MA} \). Urine samples were collected from 43 firefighters over a period of 20 hours following the end of a fire (Caux et al., 2002). Among the 43 firefighters in this study, six had \( t,t\text{-MA} \) concentrations exceeding 1700 µg/g creatinine. This value corresponds to a benzene air concentration approximately 1,000 times greater than the average concentration in ambient air (Boogaard and van Sittert, 1995; Environment Canada and Health Canada, 1993).

Benzene was analyzed in the whole blood of Canadian Health Measures Survey (CHMS) cycle 3 (2012–2013) participants aged 12 to 79 years. Benzene metabolites, \( t,t\text{-MA} \) and \( S\text{-PMA} \), were analyzed in the urine of CHMS cycle 2 (2009–2011) and cycle 3 (2012–2013) participants aged 3 to 79 years. Data are presented as µg/L blood for benzene and µg/L and µg/g creatinine for \( t,t\text{-MA} \) and \( S\text{-PMA} \). Finding a measurable amount of benzene in blood or \( t,t\text{-MA} \) and \( S\text{-PMA} \) in urine can be an indicator of exposure to benzene and does not necessarily mean that an adverse health effect will occur. These data provide baseline levels for blood benzene in the Canadian population.

Benzene was also analyzed in indoor air from households of CHMS participants in cycle 2 (2009–2011) (Statistics Canada, 2012; Wheeler et al., 2013; Zhu et al., 2013) and cycle 3 (2012–2013) and in tap water from households in cycle 3. Further details on the indoor air and tap water studies are available in the Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015). Indoor air and tap water data are available through Statistics Canada’s Research Data Centres or upon request by contacting Statistics Canada at info@statcan.gc.ca.

### Table 13.1.1

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>2488</td>
<td>12.58</td>
<td>0.036 (0.025–0.050)</td>
<td>&lt;LOD</td>
<td>0.039 (0.030–0.049)</td>
<td>0.15 (0.12–0.19)</td>
<td>0.24 (0.18–0.29)</td>
</tr>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1245</td>
<td>11.57</td>
<td>0.037 (0.026–0.052)</td>
<td>&lt;LOD</td>
<td>0.040 (0.030–0.049)</td>
<td>0.15 (0.13–0.18)</td>
<td>0.24 (0.18–0.30)</td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1243</td>
<td>13.60</td>
<td>0.035E (0.024–0.051)</td>
<td>&lt;LOD</td>
<td>0.038 (0.028–0.049)</td>
<td>0.17E (0.093–0.24)</td>
<td>0.23E (0.11–0.35)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>750</td>
<td>14.00</td>
<td>0.028 (0.019–0.040)</td>
<td>&lt;LOD</td>
<td>0.034 (0.025–0.043)</td>
<td>0.084 (0.063–0.10)</td>
<td>0.12 (0.078–0.16)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>548</td>
<td>10.40</td>
<td>0.037F (0.023–0.059)</td>
<td>F</td>
<td>0.040 (0.027–0.054)</td>
<td>0.13 (0.089–0.17)</td>
<td>0.18 (0.14–0.22)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>598</td>
<td>8.70</td>
<td>0.040 (0.030–0.055)</td>
<td>&lt;LOD</td>
<td>0.039 (0.028–0.050)</td>
<td>0.23 (0.16–0.31)</td>
<td>0.40F (0.24–0.56)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>592</td>
<td>16.72</td>
<td>0.031I (0.021–0.047)</td>
<td>&lt;LOD</td>
<td>0.038 (0.026–0.051)</td>
<td>0.13 (0.085–0.17)</td>
<td>0.20 (0.16–0.24)</td>
</tr>
</tbody>
</table>

\( a \) If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

\( E \) Use data with caution.

\( F \) Data is too unreliable to be published.
### Table 13.1.2

S-Phenylmercapturic acid (S-PMA) — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>2525</td>
<td>22.10</td>
<td>0.20 (0.16–0.23)</td>
<td>&lt;LOD</td>
<td>1.3 (0.95–1.5)</td>
<td>3.5 (2.5–4.5)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>2472</td>
<td>34.67</td>
<td>0.17 (0.14–0.21)</td>
<td>&lt;LOD</td>
<td>0.10E (≤LOD–0.16)</td>
<td>F</td>
<td>3.4 (2.3–4.5)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1267</td>
<td>20.21</td>
<td>0.23 (0.20–0.26)</td>
<td>&lt;LOD</td>
<td>0.13 (0.10–0.16)</td>
<td>F</td>
<td>3.9E (2.3–4.5)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1223</td>
<td>31.07</td>
<td>0.20 (0.16–0.25)</td>
<td>&lt;LOD</td>
<td>0.19E (0.080–0.30)</td>
<td>1.9E (0.51–3.3)</td>
<td>4.0 (2.7–5.3)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1258</td>
<td>24.01</td>
<td>0.18 (0.15–0.22)</td>
<td>&lt;LOD</td>
<td>0.11 (≤LOD–0.14)</td>
<td>1.1E (0.66–1.6)</td>
<td>2.5E (0.89–4.1)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1249</td>
<td>38.19</td>
<td>0.14 (0.10–0.19)</td>
<td>&lt;LOD</td>
<td>0.099 (≤LOD–0.12)</td>
<td>F</td>
<td>3.3E (1.4–5.2)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>507</td>
<td>20.32</td>
<td>0.15 (0.13–0.17)</td>
<td>&lt;LOD</td>
<td>0.12 (0.094–0.14)</td>
<td>0.40 (0.29–0.52)</td>
<td>0.64E (0.40–0.88)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>491</td>
<td>28.51</td>
<td>0.11 (0.10–0.12)</td>
<td>&lt;LOD</td>
<td>0.099 (0.096–0.10)</td>
<td>0.32 (0.26–0.37)</td>
<td>0.51E (0.30–0.72)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>511</td>
<td>25.24</td>
<td>0.14 (0.11–0.17)</td>
<td>&lt;LOD</td>
<td>0.099 (0.083–0.12)</td>
<td>0.38 (0.28–0.49)</td>
<td>0.58E (0.33–0.82)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3 (2012–2013)</td>
<td>491</td>
<td>38.90</td>
<td>0.099 (0.094–0.12)</td>
<td>&lt;LOD</td>
<td>0.099 (0.092–0.11)</td>
<td>0.31 (0.23–0.39)</td>
<td>0.41 (0.35–0.47)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2 (2009–2011)</td>
<td>506</td>
<td>18.97</td>
<td>0.17 (0.15–0.20)</td>
<td>&lt;LOD</td>
<td>0.13 (0.098–0.16)</td>
<td>0.62 (0.45–0.78)</td>
<td>1.1E (0.63–1.6)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>497</td>
<td>32.19</td>
<td>0.14 (0.11–0.19)</td>
<td>&lt;LOD</td>
<td>0.10E (≤LOD–0.15)</td>
<td>F</td>
<td>2.3E (0.74–4.0)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2 (2009–2011)</td>
<td>355</td>
<td>19.44</td>
<td>0.21 (0.17–0.27)</td>
<td>&lt;LOD</td>
<td>0.12 (≤LOD–0.16)</td>
<td>1.4 (1.1–1.8)</td>
<td>3.0E (1.5–4.5)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>345</td>
<td>35.07</td>
<td>0.20E (0.14–0.30)</td>
<td>&lt;LOD</td>
<td>0.17E (≤LOD–0.29)</td>
<td>F</td>
<td>3.3E (1.4–5.3)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2 (2009–2011)</td>
<td>359</td>
<td>25.91</td>
<td>0.24 (0.18–0.30)</td>
<td>&lt;LOD</td>
<td>0.13E (≤LOD–0.20)</td>
<td>2.9E (1.1–4.7)</td>
<td>5.2E (2.2–7.3)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>306</td>
<td>35.62</td>
<td>0.20E (0.14–0.30)</td>
<td>&lt;LOD</td>
<td>0.17E (≤LOD–0.29)</td>
<td>F</td>
<td>3.4E (1.8–5.0)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>287</td>
<td>23.69</td>
<td>0.19 (0.15–0.23)</td>
<td>&lt;LOD</td>
<td>0.12 (0.094–0.15)</td>
<td>1.1E (0.55–1.7)</td>
<td>3.4E (1.3–5.4)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>342</td>
<td>39.77</td>
<td>0.14 (0.11–0.18)</td>
<td>&lt;LOD</td>
<td>0.093 (0.087–0.099)</td>
<td>F</td>
<td>5.1E (2.0–9.3)</td>
</tr>
</tbody>
</table>

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**Notes:**
- If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
- Use data with caution.
- Data is too unreliable to be published.
### Table 13.1.3

S-Phenylmercapturic acid (S-PMA) (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>2</td>
<td>2515</td>
<td>22.10</td>
<td>0.20 (0.17–0.24)</td>
<td>&lt;LOD</td>
<td>0.19 (0.13–0.26)</td>
<td>1.2E (0.82–1.8)</td>
<td>3.1 (2.9–4.2)</td>
</tr>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3</td>
<td>2471</td>
<td>34.67</td>
<td>0.18 (0.15–0.22)</td>
<td>&lt;LOD</td>
<td>0.14 (0.11–0.16)</td>
<td>1.4E (0.86–2.0)</td>
<td>2.9 (1.9–4.0)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>2</td>
<td>1263</td>
<td>20.21</td>
<td>0.19 (0.16–0.23)</td>
<td>&lt;LOD</td>
<td>0.13E (0.089–0.20)</td>
<td>1.8E (0.54–2.8)</td>
<td>3.5E (1.0–5.0)</td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3</td>
<td>1223</td>
<td>31.07</td>
<td>0.17 (0.14–0.21)</td>
<td>&lt;LOD</td>
<td>0.12 (0.089–0.16)</td>
<td>1.4 (0.94–1.9)</td>
<td>2.2E (1.2–3.3)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2</td>
<td>1252</td>
<td>24.01</td>
<td>0.20 (0.16–0.26)</td>
<td>&lt;LOD</td>
<td>0.19 (0.14–0.24)</td>
<td>0.91E (0.57–1.2)</td>
<td>3.1E (1.1–5.2)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>3</td>
<td>1248</td>
<td>38.19</td>
<td>0.18 (0.14–0.24)</td>
<td>&lt;LOD</td>
<td>0.14 (0.12–0.16)</td>
<td>F</td>
<td>3.4E (1.7–5.1)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2</td>
<td>506</td>
<td>20.32</td>
<td>0.26 (0.23–0.29)</td>
<td>&lt;LOD</td>
<td>0.29 (0.19–0.39)</td>
<td>0.69 (0.56–0.82)</td>
<td>0.91 (0.71–1.1)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3</td>
<td>490</td>
<td>28.51</td>
<td>0.22 (0.20–0.24)</td>
<td>&lt;LOD</td>
<td>0.20 (0.18–0.24)</td>
<td>0.52 (0.39–0.65)</td>
<td>0.75E (0.50–1.1)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2</td>
<td>509</td>
<td>25.24</td>
<td>0.15 (0.13–0.19)</td>
<td>&lt;LOD</td>
<td>0.17E (0.089–0.28)</td>
<td>0.46 (0.31–0.61)</td>
<td>0.60 (0.40–0.80)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>3</td>
<td>491</td>
<td>38.90</td>
<td>0.13 (0.11–0.15)</td>
<td>&lt;LOD</td>
<td>0.13 (0.10–0.15)</td>
<td>0.32 (0.27–0.37)</td>
<td>0.41 (0.26–0.45)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>2</td>
<td>504</td>
<td>18.97</td>
<td>0.13 (0.11–0.15)</td>
<td>&lt;LOD</td>
<td>0.10 (0.09–0.11)</td>
<td>0.50 (0.34–0.68)</td>
<td>0.76E (0.50–1.1)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3</td>
<td>497</td>
<td>32.19</td>
<td>0.11 (0.087–0.14)</td>
<td>&lt;LOD</td>
<td>0.092 (0.089–0.11)</td>
<td>F</td>
<td>1.3E (0.59–2.0)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>2</td>
<td>353</td>
<td>19.44</td>
<td>0.11 (0.14–0.25)</td>
<td>&lt;LOD</td>
<td>F</td>
<td>1.6E (0.59–2.6)</td>
<td>2.9E (1.7–4.1)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3</td>
<td>345</td>
<td>35.07</td>
<td>0.15 (0.11–0.21)</td>
<td>&lt;LOD</td>
<td>0.12 (0.081–0.16)</td>
<td>1.1E (0.43–1.8)</td>
<td>1.7E (0.86–2.6)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>2</td>
<td>357</td>
<td>25.91</td>
<td>0.23 (0.17–0.31)</td>
<td>&lt;LOD</td>
<td>0.19 (0.13–0.24)</td>
<td>F</td>
<td>4.2E (1.5–7.0)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3</td>
<td>306</td>
<td>35.62</td>
<td>0.24 (0.17–0.34)</td>
<td>&lt;LOD</td>
<td>0.17 (0.12–0.23)</td>
<td>2.0E (0.60–3.5)</td>
<td>3.5E (1.8–5.3)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2</td>
<td>286</td>
<td>23.69</td>
<td>0.21 (0.17–0.27)</td>
<td>&lt;LOD</td>
<td>0.19 (0.13–0.23)</td>
<td>1.2E (0.55–1.9)</td>
<td>2.9E (1.3–4.5)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3</td>
<td>342</td>
<td>39.77</td>
<td>0.17 (0.13–0.23)</td>
<td>&lt;LOD</td>
<td>0.12 (0.080–0.16)</td>
<td>2.1E (0.64–3.5)</td>
<td>3.5E (2.2–4.9)</td>
</tr>
</tbody>
</table>

---

**a** If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

**E** Use data with caution.

**F** Data is too unreliable to be published.
### Table 13.1.4

**trans,trans-Muconic acid (t,t-MA)** — Geometric means and selected percentiles of urine concentrations (μg/L) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD</th>
<th>GM</th>
<th>10th</th>
<th>50th</th>
<th>90th</th>
<th>95th</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1231</td>
<td>0</td>
<td>64 (53–78)</td>
<td>17 (14–20)</td>
<td>59 (45–73)</td>
<td>260 (140–380)</td>
<td>400 (140–650)</td>
</tr>
<tr>
<td>Females</td>
<td>3–79</td>
<td>2 (2009–2011)</td>
<td>1256</td>
<td>0.16</td>
<td>59 (51–70)</td>
<td>13 (9.2–17)</td>
<td>56 (47–64)</td>
<td>320 (220–420)</td>
<td>610 (330–880)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>489</td>
<td>0</td>
<td>65 (57–75)</td>
<td>14 (12–17)</td>
<td>51 (41–61)</td>
<td>440 (390–490)</td>
<td>730 (440–1000)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>511</td>
<td>0.20</td>
<td>71 (57–87)</td>
<td>17 (13–21)</td>
<td>63 (41–85)</td>
<td>380 (240–510)</td>
<td>540 (360–720)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>2 (2009–2011)</td>
<td>286</td>
<td>0</td>
<td>54 (43–67)</td>
<td>14 (7.6–21)</td>
<td>52 (37–87)</td>
<td>240 (120–370)</td>
<td>400 (300–500)</td>
</tr>
</tbody>
</table>

*a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.
### Table 13.1.5

*trans, trans*-Muconic acid (t,t-MA) (creatinine adjusted) — Geometric means and selected percentiles of urine concentrations (μg/g creatinine) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011) and cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>1231</td>
<td>0</td>
<td>54 (48–60)</td>
<td>19 (16–21)</td>
<td>51 (44–57)</td>
<td>160f (97–210)</td>
<td>290f (110–470)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>2 (2009–2011)</td>
<td>505</td>
<td>0.40</td>
<td>130 (110–160)</td>
<td>36 (31–41)</td>
<td>110 (87–130)</td>
<td>590 (420–750)</td>
<td>990f (580–1400)</td>
</tr>
<tr>
<td>Total</td>
<td>3–5</td>
<td>3 (2012–2013)</td>
<td>488</td>
<td>0</td>
<td>130 (110–150)</td>
<td>34 (31–37)</td>
<td>87 (70–100)</td>
<td>910 (650–1200)</td>
<td>1500f (810–2100)</td>
</tr>
<tr>
<td>Total</td>
<td>6–11</td>
<td>2 (2009–2011)</td>
<td>509</td>
<td>0.20</td>
<td>82 (68–99)</td>
<td>24 (20–28)</td>
<td>69 (52–87)</td>
<td>380 (290–470)</td>
<td>490 (360–620)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>506</td>
<td>0</td>
<td>49 (40–61)</td>
<td>15 (13–17)</td>
<td>38 (27–49)</td>
<td>230f (140–310)</td>
<td>450 (290–600)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>347</td>
<td>0</td>
<td>50 (38–66)</td>
<td>16 (10–21)</td>
<td>46f (22–70)</td>
<td>160 (120–200)</td>
<td>240f (90–390)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>307</td>
<td>0</td>
<td>59 (47–75)</td>
<td>22 (19–24)</td>
<td>54 (41–62)</td>
<td>190f (95–280)</td>
<td>290f (120–450)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.


Ethylbenzene (CASRN 100-41-4) is a colourless liquid and a volatile organic compound (VOC). It is a high-production volume industrial chemical produced commercially primarily by alkylating benzene with ethylene (ATSDR, 2010; IARC, 2000). The quantity of ethylbenzene manufactured in Canada has remained relatively stable since 1999 (Environment Canada and Health Canada, 2014a).

Major uses of ethylbenzene include manufacturing of styrene and synthetic rubber (ATSDR, 2010; Environment Canada and Health Canada, 2014a; IARC, 2000). It is also used in the production of diethylbenzene, acetophenone, and other chemicals, as a solvent in the semiconductor industry, and as a general solvent used in manufactured products (ATSDR, 2010). Ethylbenzene is a constituent of asphalt, naphtha, and automotive and aviation fuels, including gasoline which typically contains about 2% ethylbenzene by weight (ATSDR, 2010). Commercial mixed xylenes contain ethylbenzene at levels up to 25% and, as such, ethylbenzene may be present in significant amounts in some paints, including spray paints and primers, lacquers, printing inks, insecticides, and solvents comprising xylenes (ATSDR, 2010; Environment Canada and Health Canada, 2014a; IARC, 2000).

Ethylbenzene is released to the environment, primarily to the atmosphere, from natural and anthropogenic sources. It has been measured in emissions from...
volcanoes, forest fires, crude petroleum, and coal deposits (ATSDR, 2010; Environment Canada and Health Canada, 2014a; IARC, 2000). Anthropogenic sources include the manufacture, processing, storage, use, transportation and disposal of fuels, solvents, petrochemicals, and polymers. Releases of ethylbenzene to air, especially as a product of fuel combustion, may be increasing as well, with increasing population and demand for energy (Environment Canada and Health Canada, 2014a).

For the general population, most exposure to ethylbenzene originates from the inhalation of indoor air (Environment Canada and Health Canada, 2014a; Health Canada, 2007). Inside residences, ethylbenzene levels in air have been shown to be higher for homes with a garage on the property, with a higher number of occupants, with recent renovations, and in which fragrances and paint remover have been recently used (Wheeler et al., 2013). Use of consumer products such as lacquers, stains, varnishes, and concrete floor sealers can also result in inhalation exposures of short duration but potentially high concentration. Although cigarette smoke may contribute to the concentration of ethylbenzene in the home, it is unlikely a significant source (Environment Canada and Health Canada, 2014a; Health Canada, 2010). Various other marketplace products containing ethylbenzene can also contribute to its presence in indoor air (ATSDR, 2010; Environment Canada and Health Canada, 2014a). Although ethylbenzene has been detected in outdoor air, drinking water, soil, and food, they are not considered to constitute major sources of exposure for the general population (Health Canada, 2007).

Following inhalation, oral, and dermal exposures, ethylbenzene is readily absorbed and distributed throughout the body (ATSDR, 2010; IARC, 2000). Absorption of ethylbenzene by inhalation is approximately 49% to 64%, in humans (ATSDR, 2010). Once absorbed, ethylbenzene is eliminated from the blood and body mostly in the urine with minor amounts exhaled in the breath, and has an elimination half-life ranging from less than 1 to 25 hours (ATSDR, 2010). Following oral exposure, absorption of ethylbenzene is approximately 72% to 92% in laboratory animals and elimination is rapid, occurring predominantly via urinary excretion (ATSDR, 2010). In contrast, following uptake through the skin only a small proportion of absorbed ethylbenzene is eliminated in the urine and none in exhaled air (ATSDR, 2010). Ethylbenzene levels in blood are the most accurate biomarker of ethylbenzene exposure and are reflective of recent exposures (ATSDR, 2010).

In humans, ethylbenzene can be irritating to the eyes, nose, throat, lungs, and skin, and it has been associated with symptoms of headaches, dizziness, vertigo, and feelings of intoxication (ATSDR, 2010; Environment Canada and Health Canada, 2014a). Acute inhalation exposure has been generally associated with reversible neurological symptoms and respiratory tract irritation whereas chronic exposure has been associated with impaired neurological function, including cognitive and neuromuscular performance (ATSDR, 2010; Environment Canada and Health Canada, 2014a). Studies in laboratory animals exposed by inhalation to ethylbenzene provide supporting evidence for central nervous system effects, neuromuscular and behavioural changes, and hearing loss (ATSDR, 2010; Environment Canada and Health Canada, 2014a). In laboratory animals, chronic exposure to high levels of ethylbenzene in air and via the oral route has been associated with kidney and liver damage, some minor developmental effects, and effects in blood, pituitary, thyroid, and respiratory tissues (ATSDR, 2010; Environment Canada and Health Canada, 2014a). Ethylbenzene is classified as possibly carcinogenic to humans (Group 2B carcinogen) according to the International Agency for Research on Cancer (IARC, 2000). However, the more recent evaluation by Health Canada and Environment Canada concludes that ethylbenzene is likely to be a non-linear threshold carcinogen, indicating that there is a threshold below which tumour formation would not be expected (Environment Canada and Health Canada, 2014a).

Health Canada and Environment Canada have jointly reviewed ethylbenzene in a draft screening assessment and have proposed to conclude that it is entering or may enter the environment in a quantity or concentration or under conditions that constitute or may constitute a danger in Canada to human life or health (Environment Canada and Health Canada, 2014a). Following from this, as part of the proposed risk management plan for ethylbenzene, the Government of Canada is considering risk management activities to minimize releases of ethylbenzene during the indoor use of lacquers, stains, varnishes, and concrete floor sealers (Environment Canada and Health Canada, 2014b).
The Government of Canada has also taken a number of actions to address VOCs, a large class of compounds that includes ethylbenzene. As a class, they are environmental and health concerns because of their contribution to the formation of smog. The Government of Canada has taken and proposed a number of actions to address VOC emissions resulting from the use of consumer and commercial products in Canada (Canada, 2009a; Canada, 2009b; Environment Canada, 2002; Environment Canada, 2013).

The current guideline for Canadian drinking water quality for ethylbenzene establishes an aesthetic objective for ethylbenzene based on its odour threshold (Health Canada, 1986; Health Canada, 2012). This guideline was deemed protective for acute exposure, but a health-based value has not yet been established (Health Canada, 2012). Recently, Health Canada released for public comment a revised guideline technical document by the Federal-Provincial-Territorial Committee on Drinking Water, based on the most current available scientific information on ethylbenzene (Health Canada, 2014). A final guideline technical document is expected to be available in the Summer of 2015.

Ethylbenzene was analyzed in the whole blood of Canadian Health Measures Survey (CHMS) participants aged 12 to 79 years in cycle 3 (2012–2013). Data are presented as µg/L blood. Finding a measurable amount of ethylbenzene in blood can be an indicator of recent exposure to ethylbenzene and does not necessarily mean that an adverse health effect will occur. These data provide baseline levels for blood ethylbenzene in the Canadian population.

Ethylbenzene was also analyzed in indoor air from households of CHMS participants in cycle 2 (2009–2011) (Statistics Canada, 2012; Wheeler et al., 2013) and cycle 3 (2012–2013) and in tap water from households in cycle 3. Further details on the indoor air and tap water studies are available in the Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015). Indoor air and tap water data are available through Statistics Canada’s Research Data Centres or upon request by contacting Statistics Canada at info@statcan.gc.ca.

### Table 13.2.1
Ethylbenzene — Geometric means and selected percentiles of whole blood concentrations (µg/L) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>2441</td>
<td>17.90</td>
<td>0.026 (0.020–0.033)</td>
<td>&lt;LOD</td>
<td>0.025 (0.017–0.033)</td>
<td>0.084 (0.070–0.098)</td>
<td>0.12 (0.095–0.15)</td>
</tr>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1212</td>
<td>17.49</td>
<td>0.028 (0.022–0.034)</td>
<td>&lt;LOD</td>
<td>0.026 (0.018–0.034)</td>
<td>0.088 (0.063–0.11)</td>
<td>0.14 (0.096–0.18)</td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1229</td>
<td>18.31</td>
<td>0.025 (0.018–0.033)</td>
<td>&lt;LOD</td>
<td>0.025 (0.016–0.033)</td>
<td>0.080 (0.057–0.10)</td>
<td>0.11 (0.076–0.14)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>731</td>
<td>19.64</td>
<td>0.020 (0.016–0.027)</td>
<td>&lt;LOD</td>
<td>0.021 (0.015–0.027)</td>
<td>0.064 (0.044–0.084)</td>
<td>0.081 (0.056–0.11)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>532</td>
<td>17.29</td>
<td>0.026 (0.019–0.035)</td>
<td>&lt;LOD</td>
<td>0.026E (0.012–0.041)</td>
<td>0.077F (0.040–0.11)</td>
<td>0.12F (0.058–0.17)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>591</td>
<td>14.89</td>
<td>0.029 (0.024–0.037)</td>
<td>&lt;LOD</td>
<td>0.027 (0.020–0.034)</td>
<td>0.10 (0.082–0.12)</td>
<td>0.14 (0.10–0.18)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>587</td>
<td>19.08</td>
<td>0.025 (0.019–0.032)</td>
<td>&lt;LOD</td>
<td>0.024 (0.016–0.032)</td>
<td>0.079 (0.064–0.094)</td>
<td>0.12F (0.062–0.17)</td>
</tr>
</tbody>
</table>

*a  If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E  Use data with caution.
Styrene (CASRN 100-42-5) is a colourless liquid classified as a volatile organic compound (VOC) and a high-production volume industrial chemical. Styrene was first recovered by distillation of a natural resin (storax balsam), sapwood, and bark tissues of trees (ATSDR, 2010; IARC, 2002).

Styrene has been synthetically produced since the early 19th century and is a well-known impurity of coal tar industrial processing and petroleum cracking (IARC, 2002). Styrene is available as a commercial product and is used worldwide in the manufacture of plastics, glass fiber-reinforced resins, protective coatings, ion-exchange resins, and synthetic rubber (ATSDR, 2010; IARC, 2002).
Styrene is released to the environment from natural and anthropogenic sources. Styrene releases to the environment are mainly atmospheric and occur as a result of the manufacture, use, and disposal of styrene-containing products, industrial releases, vehicle exhaust, incineration, and tobacco smoke (Environment Canada and Health Canada, 1993; ATSDR, 2010). Production, use, and disposal of styrene and styrene-containing products can also result in releases to the aquatic environment via wastewater. Natural sources of styrene releases to the environment include biodegradation of vegetation and organic material (ATSDR, 2010; Environment Canada and Health Canada, 1993).

The most common route of exposure to styrene in the general population is inhalation, with levels of styrene often higher in indoor air than outdoor (ATSDR, 2010; Environment Canada and Health Canada, 1993). Styrene is a minor and natural component of tobacco smoke, and tobacco smoke is the major contributor to the total styrene exposure in smokers (Environment Canada and Health Canada, 1993; ATSDR, 2010). In addition to tobacco smoke, common sources of styrene present in air are automobile exhaust, the use and manufacturing of styrene, and the use of photocopiers and laser printers (ATSDR, 2010; Environment Canada and Health Canada, 1993). Further, it is not uncommon for short-term inhalation exposures to styrene to occur as a result of indoor air releases from new building materials made with polymer resins, synthetic rubbers, laminated materials, and from fresh adhesives and surface coatings. Additional exposures in the general population may occur through ingestion of food and beverages; however, most styrene associated with food is residue of styrene monomer leached from packaged food in polystyrene containers (ATSDR, 2010; Genualdi et al., 2014). Intake of styrene from drinking water is generally negligible (Environment Canada and Health Canada, 1993). Exposure through skin and eye contact can also occur when handling liquid styrene-containing products.

Styrene is readily absorbed and distributed throughout the body following inhalation, with the highest concentrations measured in adipose tissue (ATSDR, 2010; Environment Canada and Health Canada, 1993). Following oral exposure in laboratory animals, styrene absorption was rapid and complete with distribution to the kidney, liver, pancreas, adipose tissue and, to a lesser extent, the stomach, and small and large intestines (ATSDR, 2010). Styrene absorbed into the body was rapidly eliminated from all tissues within 1 to 3 days (ATSDR, 2010). Half-lives are estimated to range between 1 and 13 hours depending on the phase of elimination; in adipose tissue, an elimination half-life of 2 to 5 days has been estimated (ATSDR, 2010). In humans, approximately 97% of the styrene absorbed is excreted as urinary metabolites, with the remainder eliminated unchanged in expired air (ATSDR, 2010; Environment Canada and Health Canada, 1993). The primary intermediate metabolite of styrene is styrene-7, 8-oxide, which is hydrolyzed to styrene glycol and further metabolized to mandelic and phenylglyoxylic acids, the principal urinary metabolites (ATSDR, 2010; Environment Canada and Health Canada, 1993). The major site of styrene metabolism is the liver. At high exposures that saturate metabolic enzymes, increased amounts of unchanged styrene are excreted in expired air (ATSDR, 2010; Environment Canada and Health Canada, 1993). In laboratory animals, following oral exposure styrene was rapidly excreted in urine with 90% eliminated within 24 hours, and less than 2% in the feces (ATSDR, 2010). The most reliable biomarker of recent exposure to styrene is measurement of styrene in blood, urine, and breath (ATSDR, 2010).

Acute exposure to styrene is irritating to the eyes, nose, and throat, and induces dermatitis (ATSDR, 2010; IARC, 2002). In humans, acute exposure to high levels of styrene in air is associated with central nervous system effects, including nausea, headache, tiredness, and concentration problems, similar to the narcotic effects of other organic solvents; effects are generally reversible after the source of exposure is eliminated (ATSDR, 2010; Environment Canada and Health Canada, 1993).
Chronic exposure to styrene is associated with central and peripheral nervous system effects, slower reaction times, decreased colour discrimination, hearing problems, altered hand-eye coordination, and impairment of verbal learning skills (ATSDR, 2010; ATSDR, 2012; IARC, 2002). Whether chronic styrene exposure results in permanent damage to the nervous system in humans has not been determined (ATSDR, 2010). Data from studies in humans and laboratory animals exposed via inhalation and the oral route to high levels of styrene also suggest styrene can be immunosuppressive (ATSDR, 2010; Environment Canada and Health Canada, 1993; IARC, 2002). Chronic exposure to high levels of styrene in air in the presence of other chemicals, including carcinogens, has been weakly associated with lymphomas and other cancers and chromosomal alterations (ATSDR, 2010; IARC, 2002). Styrene has been classified as possibly carcinogenic to humans, on the basis of limited evidence in animals and humans by Environment Canada and Health Canada (Group III) and the International Agency for Research on Cancer (IARC; Group 2B) (Environment Canada and Health Canada, 1993; IARC, 2002). The styrene primary intermediate metabolite styrene-7, 8-oxide is classified by IARC as a Group 2A carcinogen, probably carcinogenic to humans (IARC, 2002). Recently, the U.S. National Toxicology Program listed styrene as reasonably anticipated to be a human carcinogen based on human cancer studies, laboratory animal studies, and supporting mechanistic data (ATSDR, 2011; NTP, 2011).

Health Canada and Environment Canada concluded that levels of styrene normally found in the Canadian environment are not a concern to human health (Environment Canada and Health Canada, 1993). Styrene is also part of a larger class of compounds called VOCs that, as a group, are environmental and health concerns because of their contribution to the formation of smog. The Government of Canada has taken and proposed a number of actions to address VOC emissions resulting from the use of consumer and commercial products in Canada (Canada, 2009a; Canada, 2009b; Environment Canada, 2002; Environment Canada, 2013). Because styrene has not been detected in Canadian drinking water supplies, no guideline for Canadian drinking water quality has been established by the Federal-Provincial-Territorial Committee on Drinking Water.

Styrene was analyzed in the whole blood of Canadian Health Measures Survey (CHMS) participants aged 12 to 79 years in cycle 3 (2012–2013). Data are presented as µg/L blood. Finding a measurable amount of styrene in blood can be an indicator of exposure to styrene and does not necessarily mean that an adverse health effect will occur. These data provide baseline levels for blood styrene in the Canadian population.

Styrene was also analyzed in indoor air from households of CHMS participants in cycle 2 (2009–2011) (Zhu et al., 2013) and cycle 3 (2012–2013) and in tap water from households in cycle 3. Further details on the indoor air and tap water studies are available in the Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015). Indoor air and tap water data are available through Statistics Canada’s Research Data Centres or upon request by contacting Statistics Canada at info@statcan.gc.ca.
Table 13.3.1
Styrene — Geometric means and selected percentiles of whole blood concentrations (μg/L) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>2063</td>
<td>7.61</td>
<td>0.043E (0.029–0.062)</td>
<td>F</td>
<td>0.043 (0.029–0.055)</td>
<td>0.12 (0.078–0.16)</td>
<td>0.17E (0.10–0.23)</td>
</tr>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1036</td>
<td>6.95</td>
<td>0.043E (0.029–0.056)</td>
<td>F</td>
<td>0.045 (0.033–0.057)</td>
<td>0.12 (0.079–0.15)</td>
<td>0.17E (0.099–0.24)</td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1027</td>
<td>8.28</td>
<td>0.042E (0.028–0.061)</td>
<td>F</td>
<td>0.041 (0.028–0.055)</td>
<td>0.11E (0.062–0.17)</td>
<td>0.16E (0.092–0.23)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>626</td>
<td>8.47</td>
<td>0.037E (0.024–0.057)</td>
<td>F</td>
<td>0.040 (0.029–0.052)</td>
<td>0.094E (0.029–0.16)</td>
<td>0.15E (0.063–0.24)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>435</td>
<td>7.36</td>
<td>0.043E (0.029–0.065)</td>
<td>&lt;LOD</td>
<td>0.043E (0.024–0.061)</td>
<td>0.12E (0.055–0.18)</td>
<td>0.18E (0.10–0.26)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>493</td>
<td>5.68</td>
<td>0.045E (0.031–0.066)</td>
<td>0.016E (0.003–0.026)</td>
<td>0.044 (0.032–0.056)</td>
<td>0.13 (0.090–0.16)</td>
<td>0.18E (0.11–0.25)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>509</td>
<td>8.64</td>
<td>0.041E (0.027–0.063)</td>
<td>F</td>
<td>0.044 (0.029–0.058)</td>
<td>0.11 (0.069–0.15)</td>
<td>0.14E (0.049–0.24)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.

REFERENCES


13.4 TETRACHLOROETHYLENE (PERCHLOROETHYLENE)

Tetrachloroethylene (CASRN 127-18-4), commonly known as perchloroethylene, is a colourless liquid classified as a volatile organic compound (Canada, 2011a; Canada, 2011b; Environment Canada and Health Canada, 1993; IARC, 2014). It is an industrial chemical produced commercially by chlorination of other hydrocarbons, including acetylene, via trichloroethylene (IARC, 2014). The use of tetrachloroethylene has changed over the years. In the mid-20th century, tetrachloroethylene was primarily used in the dry-cleaning industry and was the primary organic solvent used for vapour degreasing in metal-cleaning operations (IARC, 2014). In the 1980s, changes in use coincided with the introduction of environmental regulations and improved technology controls in Canada and internationally (Canada, 2011a; Canada, 2011b; IARC, 2014). Since the 1990s, the most common use of tetrachloroethylene was as a feedstock for producing fluorocarbons (IARC, 2014). However, under the Montreal Protocol on Substances that Deplete the Ozone layer, the production of chlorofluorocarbons is being phased out by 2030 (IARC, 2014; UNEP, 2007). In Canada, tetrachloroethylene production ceased in 1992 and, since then, importation has continued primarily for domestic use as a chemical feedstock and as a solvent in the dry-cleaning and metal-cleaning industries (Environment Canada and Health Canada, 1993; Health Canada, 1996).

Releases of tetrachloroethylene are mainly to the atmosphere by evaporative losses from anthropogenic sources (ATSDR, 1997; Environment Canada and Health Canada, 1993). Production, use, and disposal of tetrachloroethylene and tetrachloroethylene-containing products can also result in releases to the environment via wastewater. A small amount of tetrachloroethylene is produced naturally in the environment by marine algae (Abrahamsson et al., 1995).

The primary route of exposure to tetrachloroethylene for the general population is through inhalation of indoor air containing tetrachloroethylene emitted by freshly dry-cleaned clothes, automotive products, and other consumer products containing tetrachloroethylene (Environment Canada and Health Canada, 1993). Tetrachloroethylene has been detected in drinking water; the ingestion of drinking water is, generally, a minor contributor to overall tetrachloroethylene exposure (Environment Canada and Health Canada, 1993). Exposure can also occur during the use of consumer products containing tetrachloroethylene, and from ambient air and food (ATSDR, 1997; Environment Canada and Health Canada, 1993). Living near a dry-cleaning facility may also increase the potential for exposure (ATSDR, 1997; CDC, 2009; IARC, 2014).

Tetrachloroethylene is rapidly absorbed into the blood and is distributed throughout the body with some concentration in adipose tissue (ATSDR, 1997; Environment Canada and Health Canada, 1993; IARC, 2014). Tetrachloroethylene is metabolized in the kidney, liver, and lungs forming the major metabolite trichloroacetic acid (TCA) and other minor metabolites including trichloroethanol (IARC, 2014). Absorbed tetrachloroethylene is rapidly eliminated unchanged from the body within minutes and hours via exhalation, followed by a slower excretion of metabolites in urine (IARC, 2014). The half-lives of tetrachloroethylene in vessel-rich tissue, muscle tissue, and adipose tissue are estimated to be 12 to 16 hours, 30 to 40...
hours, and 55 hours, respectively (ATSDR, 1997). Tetrachloroethylene metabolites can be measured in urine whereas tetrachloroethylene can be measured in exhaled air and blood; the latter is considered the most reliable biomarker of recent exposure (ATSDR, 1997; IARC, 2014).

Exposure to tetrachloroethylene is known to cause a number of health effects in humans. Acute exposure via inhalation, ingestion, and skin contact can result in irritation of membranes (ATSDR, 1997). At very high concentrations, acute inhalation and oral exposure to tetrachloroethylene can induce atrophy of olfactory nerves, tremors, and central nervous system depression, as well as kidney and liver dysfunction in laboratory animals; these symptoms are similar to those observed in humans following accidental poisonings and solvent abuse (ATSDR, 1997; Environment Canada and Health Canada, 1993). Tetrachloroethylene exposure is also associated with narcotic and anesthetic effects increasing in severity with increasing exposure (ATSDR, 1997; Environment Canada and Health Canada, 1993; EPA, 2012). These neurological symptoms may be reversible following cessation of acute exposure; however, chronic exposures may result in more persistent neurological impairments (ATSDR, 1997; Environment Canada and Health Canada, 1993; IARC, 2014). Multiple cancer sites of interest have been evaluated by the International Agency for Research (IARC) on Cancer Expert Working Group and positive associations with prior exposure to tetrachloroethylene in the bladder in humans are consistently found (IARC, 2014). Tetrachloroethylene has been classified by IARC as probably carcinogenic to humans (Group 2A), on the basis of limited evidence in humans and sufficient evidence in laboratory animals, and as possibly carcinogenic to humans (Group III) by Environment Canada and Health Canada (Environment Canada and Health Canada, 1993; IARC, 2014).

The Government of Canada conducted a scientific assessment on the impact of tetrachloroethylene exposure on humans and the environment and concluded that it is toxic to the environment, but not to human health, as per criteria set out under the Canadian Environmental Protection Act (Environment Canada and Health Canada, 1993). Tetrachloroethylene is listed on Schedule 1, List of Toxic Substances, under the Canadian Environmental Protection Act, 1999 and is a risk-managed substance involving a full life cycle management approach to prevent or minimize its release into the environment (Canada, 1999). In Canada, Regulations for Tetrachloroethylene Use in Dry Cleaning and Reporting Requirements have been introduced to reduce releases of tetrachloroethylene from dry-cleaning facilities (Canada, 2011a; Canada, 2011b). The Government of Canada has also introduced Solvent Degreasing Regulations to reduce total Canadian consumption of trichloroethylene and tetrachloroethylene used in solvent-degreasing operations (Canada, 2011b; Environment Canada, 2013c). Tetrachloroethylene is included as a prohibited ingredient on the List of Prohibited and Restricted Cosmetic Ingredients (more commonly referred to as the Cosmetic Ingredient Hotlist or simply the Hotlist). The Hotlist is an administrative tool that Health Canada uses to communicate to manufacturers and others that certain substances, when present in a cosmetic, may contravene the general prohibition found in section 16 of the Food and Drugs Act or a provision of the Cosmetic Regulations (Canada, 1985; Health Canada, 2014a). In addition, Health Canada has developed a guideline for Canadian drinking water quality that establishes the maximum acceptable concentration for tetrachloroethylene in drinking water (Health Canada, 1996). Recently, Health Canada published for public comment a revised guideline technical document by the Federal-Provincial-Territorial Committee on Drinking Water, based on the most current available scientific information on tetrachloroethylene (Health Canada, 2014b). A final guideline technical document is expected to be available in the Fall of 2015.

Tetrachloroethylene was analyzed in the whole blood of Canadian Health Measures Survey (CHMS) participants aged 12 to 79 years in cycle 3 (2012–2013). Data are presented as µg/L blood. Finding a measurable amount of tetrachloroethylene in blood can be an indicator of exposure to tetrachloroethylene and does not necessarily mean that an adverse health effect will occur. These data provide baseline levels for blood tetrachloroethylene in the Canadian population.

Tetrachloroethylene was also analyzed in indoor air from households of CHMS participants in cycle 2 (2009–2011) (Zhu et al., 2013) and cycle 3 (2012–2013) and in tap water from households in cycle 3. Further details on the indoor air and tap water studies are available in the Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015). Indoor air and tap water data are available through Statistics Canada’s Research Data Centres or upon request by contacting Statistics Canada at info@statcan.gc.ca.
Table 13.4.1
Tetrachloroethylene (Perchloroethylene) — Geometric means and selected percentiles of whole blood concentrations (μg/L) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>2453</td>
<td>60.82</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.10</td>
<td>0.17E</td>
<td>(0.067–0.14)</td>
</tr>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1228</td>
<td>58.96</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.13</td>
<td>0.19</td>
<td>(0.096–0.17)</td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1225</td>
<td>62.69</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.096E</td>
<td>0.13E</td>
<td>(0.069–0.13)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>739</td>
<td>60.76</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>543</td>
<td>60.04</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.083E</td>
<td>0.15E</td>
<td>(0.052–0.13)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>587</td>
<td>65.08</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.10E</td>
<td>0.13</td>
<td>(0.058–0.13)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>584</td>
<td>57.36</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.16E</td>
<td>F</td>
<td>(0.062–0.25)</td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.

REFERENCES


Toluene is used widely as an industrial solvent and an intermediate in the production of a variety of chemicals. Major uses of toluene have included the manufacture of benzene, benzene derivatives, trinitrotoluene and toluene diisocyanate, and in the blending of gasoline fuels as octane boosters (ATSDR, 2000; CDC, 2009). It has also been widely used as a solvent in paints and finishes, adhesives, polymers and resins, dyes, automotive products, and some personal care products (ATSDR, 2000; Environment Canada and Health Canada, 1992; Health Canada, 2012a). The use of toluene in solvent-based products and processes has decreased as alternative formulations with lower VOC content, as well as alcohol-based and water-based products and processes, are now available.

Toluene is released to the environment from natural and anthropogenic sources. It has been measured in emissions from volcanoes, forest fires, natural gas deposits, and crude oil (ATSDR, 2000; Environment Canada and Health Canada, 1992). Anthropogenic sources of atmospheric toluene include primarily the volatilization of petroleum fuels, toluene-based solvents and thinners, motor vehicle exhaust, and the off-gassing of toluene from some building materials, consumer, and automotive products (ATSDR, 2000; Environment Canada and Health Canada, 1992). Toluene can also be released to the environment in waste from manufacturing and processing facilities, from spills and accidental releases, and from the disposal of toluene-containing products (ATSDR, 2000; CCME, 2004; Environment Canada and Health Canada, 1992).

The general population is exposed to toluene mainly through the inhalation of indoor air (Health Canada, 2011). Cigarette smoking may significantly increase exposure and, in smokers, inhalation of cigarette smoke is expected to be a major contributor to the total toluene exposure (ATSDR, 2000; Health Canada, 2011; Health Canada, 2012b). Inside residences, toluene levels in air have been shown to be higher in newer homes and homes with a garage on the property and in homes where painting or paint remover has been used in the previous week (Wheeler et al., 2013). Toluene is also found in tobacco smoke, and regular smoking in the home is a significant predictor of toluene in indoor air (Health Canada, 2012b). Although toluene has been detected in drinking water and in certain foods, they are not considered to constitute major sources of exposure for the general population (Environment Canada and Health Canada, 1992).

13.5 TOLUENE

Toluene (CASRN 108-88-3) is a colourless liquid and volatile organic compound (VOC). It is produced commercially, primarily through the conversion of petroleum to gasoline and other fuels or recovered as a by-product in the coke oven and styrene-manufacturing industries (ATSDR, 2000; Environment Canada and Health Canada, 1992).
Following inhalation, toluene is readily absorbed and distributed throughout the body (ATSDR, 2000; Environment Canada and Health Canada, 1992). The majority of absorbed toluene is rapidly eliminated from the body with a small amount in adipose tissues eliminated more slowly (ATSDR, 2000). Up to 20% of absorbed toluene is exhaled unchanged and less than 1% is excreted unchanged in the urine (ATSDR, 2000; Donald et al., 1991). The elimination of toluene following inhalation has half-lives ranging from less than 3 minutes to 12 hours in blood and from 0.5 to 3 days in subcutaneous adipose tissues of humans (ATSDR, 2000). Toluene levels in blood are the most accurate biomarker of toluene exposure and are reflective of recent exposure (ATSDR, 2000; CDC, 2009).

Toluene exposure can be irritating to the eye, nose, throat, lungs and skin, and has been associated with symptoms of headaches, dizziness, reduced coordination, and feelings of intoxication (ATSDR, 2000; CCOHS, 2013; Health Canada, 2011; Health Canada, 2012b; IARC, 1999). Acute inhalation exposure has been generally associated with reversible neurological symptoms whereas chronic exposure is associated with impaired neurological function including cognitive and neuromuscular performance, as well as negative effects on colour vision and hearing (ATSDR, 2000; CCOHS, 2013; CDC, 2009; Health Canada, 2011; IARC, 1999). Studies in laboratory animals exposed to toluene provide supporting evidence for behavioural changes, hearing loss and subtle changes in brain structure, brain electrophysiology and brain chemistry (ATSDR, 2000; Bowen and Hannigan, 2006; Gospe and Zhou, 2000). Exposure to high levels of toluene in humans during pregnancy has been associated with fetal toxicity and developmental effects in children, at levels associated with potential maternal toxicity such as in solvent abuse (ATSDR, 2000; Bowen and Hannigan, 2006; Donald et al., 1991; Yücel et al., 2008). Toluene carcinogenicity to humans is not classifiable according to the International Agency for Research on Cancer (Group 3) and the US Environmental Protection Agency (Group D) (EPA, 2005; IARC, 1999).

Under the Canadian Environmental Protection Act, Health Canada and Environment Canada concluded that at current environmental concentrations, toluene is not a concern for human life or health (Environment Canada and Health Canada, 1992). Toluene is also part of a larger class of compounds called VOCs that, as a group, are environmental and health concerns because of their contribution to the formation of smog. The Government of Canada has taken and proposed a number of actions to address VOC emissions resulting from the use of consumer and commercial products in Canada (Canada, 2009a; Canada, 2009b; Environment Canada, 2002; Environment Canada, 2013).

In 2011, Health Canada released a residential indoor air quality guideline for both short- and long-term exposure to toluene (Health Canada, 2011). The current guideline for Canadian drinking water quality establishes aesthetic objectives for toluene based upon its odour threshold (Health Canada, 1986; Health Canada, 2012c). This guideline was deemed protective of acute exposure, but a health-based value has not been established (Health Canada, 1986; Health Canada, 2012c). Recently, Health Canada released for public comment a revised guideline technical document by the Federal-Provincial-Territorial Committee on Drinking Water, based on the most current available scientific information on toluene (Health Canada, 2014). A final guideline technical document is expected to be available in the Summer of 2015.

Toluene was analyzed in the whole blood of Canadian Health Measures Survey participants aged 12 to 79 years in cycle 3 (2012–2013). Data are presented as µg/L blood. Finding a measurable amount of toluene in blood can be an indicator of recent exposure to toluene and does not necessarily mean that an adverse health effect will occur. These data provide baseline levels for blood toluene in the Canadian population.

Toluene was also analyzed in indoor air from households of CHMS participants in cycle 2 (2009–2011) (Wheeler et al., 2013) and cycle 3 (2012–2013) and in tap water from households in cycle 3. Further details on the indoor air and tap water studies are available in the Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015). Indoor air and tap water data are available through Statistics Canada’s Research Data Centres or upon request by contacting Statistics Canada at info@statcan.gc.ca.
Table 13.5.1
Toluene — Geometric means and selected percentiles of whole blood concentrations (μg/L) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12–79</td>
<td>3</td>
<td>2449</td>
<td>0.69</td>
<td>0.096 (0.083–0.11)</td>
<td>0.036 (0.030–0.042)</td>
<td>0.079 (0.067–0.090)</td>
<td>0.39 (0.32–0.46)</td>
<td>0.58 (0.46–0.71)</td>
</tr>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3</td>
<td>1224</td>
<td>0.65</td>
<td>0.098 (0.081–0.12)</td>
<td>0.034 (0.028–0.043)</td>
<td>0.081 (0.068–0.096)</td>
<td>0.42 (0.33–0.51)</td>
<td>0.59 (0.42–0.77)</td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3</td>
<td>1225</td>
<td>0.73</td>
<td>0.083 (0.081–0.11)</td>
<td>0.037 (0.034–0.041)</td>
<td>0.077 (0.064–0.089)</td>
<td>0.35 (0.24–0.46)</td>
<td>0.55E (0.34–0.76)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3</td>
<td>732</td>
<td>0.55</td>
<td>0.074 (0.066–0.083)</td>
<td>0.034 (0.030–0.042)</td>
<td>0.070 (0.058–0.086)</td>
<td>0.19 (0.14–0.24)</td>
<td>0.26 (0.19–0.32)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3</td>
<td>533</td>
<td>0.94</td>
<td>0.089 (0.069–0.11)</td>
<td>0.036 (0.028–0.045)</td>
<td>0.074 (0.050–0.098)</td>
<td>0.29E (0.16–0.43)</td>
<td>0.42E (0.23–0.61)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3</td>
<td>594</td>
<td>0.51</td>
<td>0.12 (0.10–0.14)</td>
<td>0.041 (0.033–0.049)</td>
<td>0.085 (0.071–0.10)</td>
<td>0.58 (0.38–0.79)</td>
<td>0.86 (0.64–1.1)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3</td>
<td>590</td>
<td>0.85</td>
<td>0.086 (0.070–0.11)</td>
<td>0.031 (0.024–0.039)</td>
<td>0.080 (0.065–0.096)</td>
<td>0.31 (0.22–0.40)</td>
<td>0.46 (0.39–0.53)</td>
</tr>
</tbody>
</table>

a  If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E  Use data with caution.

REFERENCES


Trichloroethylene (CASRN 79-01-6) is a colourless liquid classified as a volatile organic compound. It has been produced commercially by chlorination of acetylene and ethylene since the 1920s (ATSDR, 1997; IARC, 1995). There has been a general decline in demand for trichloroethylene over the years (Health Canada, 2005; IARC, 2014). This decline may be due to several factors, including use of alternative solvents, an increase in solvent recovery/recycling by users, and the introduction of regulations and controls to address concerns about environmental, health, and safety implications of chlorinated solvents (Health Canada, 2005; IARC, 2014). In Canada, production of trichloroethylene stopped in 1985 (Health Canada, 2005). Since then, it continues to be imported for use primarily as a solvent in the vapour-degreasing and cold-cleaning of metal parts and, in smaller amounts, in dry-cleaning operations, specialty paints and paint removers, and various other household products (Environment Canada, 2013a; Environment Canada, 2013b; Health Canada, 2005). Trichloroethylene is also used as a chemical intermediate in the production of other chemicals (IARC, 2014).

Trichloroethylene enters the environment primarily through evaporation from anthropogenic sources (ATSDR, 1997; Environment Canada, 2013b). Although the majority of anthropogenic releases enter the atmosphere, production, use, and disposal of trichloroethylene and trichloroethylene-containing products can also result in releases to the environment via wastewater. A small amount of trichloroethylene is produced naturally in the environment by marine algae (Abrahamsson et al., 1995).

The most common exposure route to trichloroethylene for the general population is inhalation of indoor air containing trichloroethylene emitted from specialty
paints, adhesives, and household products (CDC, 2009; Environment Canada and Health Canada, 1993). Canadians may also be exposed to trichloroethylene through its presence in drinking water, air, and food (Health Canada, 2005).

Following all routes of exposure, trichloroethylene is rapidly and nearly completely absorbed into the blood and distributed throughout the body (ATSDR, 1997; Environment Canada and Health Canada, 1993; EPA, 2011). Absorbed trichloroethylene is rapidly distributed mainly to the brain, kidney, liver, muscle, and adipose tissue (ATSDR, 1997). Trichloroethylene is metabolized in the kidney, liver, and lungs forming the major metabolites trichloroacetic acid (TCA) and trichloroethanol (TCOH) (ATSDR, 1997; EPA, 2011). Absorbed trichloroethylene is rapidly eliminated from the body, within minutes and hours, via exhalation of trichloroethylene and urinary excretion of the metabolites along with minimal amounts of unchanged trichloroethylene (ATSDR, 1997; EPA, 2011). The most reliable biomarker of recent exposure to trichloroethylene is its measurement in blood and breath (ATSDR, 1997; IARC, 1995). Measurement of the metabolites TCA and TCOH in blood and urine are less reliable because of intra-individual differences in urinary concentrations and a lack of specificity for trichloroethylene exposure (ATSDR, 1997; IARC, 1995).

Exposure to trichloroethylene is known to cause a number of health effects in humans. Acute exposure via inhalation, ingestion, and skin contact can result in irritation of membranes (ATSDR, 1997; Health Canada, 2005; IARC, 1995). Trichloroethylene exposure is also associated with narcotic and anesthetic effects increasing in severity with increasing exposure (Environment Canada and Health Canada, 1993; IARC, 1995). These neurological symptoms may be reversible following cessation of acute exposure; however, chronic exposures may result in more persistent neurological impairments (ATSDR, 1997; Environment Canada and Health Canada, 1993; EPA, 2011). Recently, the International Agency for Research on Cancer updated its classification for trichloroethylene to Group 1 carcinogenic to humans, on the basis of new and sufficient evidence for cancer of the kidney in humans, with strong support from studies in laboratory animals (IARC, 2014). A positive association has also been shown between trichloroethylene exposure and cancer of the liver and biliary tract, and non-Hodgkin lymphoma (EPA, 2011; IARC, 2014; WHO, 2000).

The Government of Canada conducted a scientific assessment on the impact of trichloroethylene exposure on humans and the environment and concluded that it may enter the environment in quantities or under conditions that may constitute a danger in Canada to human life or health as per criteria set out under the Canadian Environmental Protection Act (Environment Canada and Health Canada, 1993). Trichloroethylene is listed on Schedule 1, List of Toxic Substances, under the Canadian Environmental Protection Act, 1999 (CEPA 1999) (Canada, 1999). Under CEPA 1999, the Government of Canada published Solvent Degreasing Regulations to reduce total Canadian consumption of trichloroethylene and tetrachloroethylene used in solvent-degreasing operations (Environment Canada, 2013c). Improvements have also been implemented in the commercial dry-cleaning industry to prevent and minimize releases of dry-cleaning solvents, particularly trichloroethylene and tetrachloroethylene (Canada, 2011a; Canada, 2011b; IARC, 2014). The current guideline for Canadian drinking water quality, established by the Federal-Provincial-Territorial Committee on Drinking Water, sets out the maximum acceptable concentration for trichloroethylene in drinking water (Health Canada, 2005).

Trichloroethylene was analyzed in the whole blood of Canadian Health Measures Survey (CHMS) participants aged 12 to 79 years in cycle 3 (2012–2013). Data are presented as µg/L blood. Finding a measurable amount of trichloroethylene in blood can be an indicator of exposure to trichloroethylene and does not necessarily mean that an adverse health effect will occur. These data provide baseline levels for blood trichloroethylene in the Canadian population.

Trichloroethylene was also analyzed in indoor air from households of CHMS participants in cycle 2 (2009–2011) (Zhu et al., 2013) and cycle 3 (2012–2013) and in tap water from households in cycle 3. Further details on the indoor air and tap water studies are available in the Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015). Indoor air and tap water data are available through Statistics Canada’s Research Data Centres or upon request by contacting Statistics Canada at info@statcan.gc.ca.
### Table 13.6.1
Trichloroethylene — Geometric means and selected percentiles of whole blood concentrations (μg/L) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1240</td>
<td>99.35</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1234</td>
<td>99.68</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>746</td>
<td>99.73</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

a. If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

### REFERENCES


13.7 TRIHALOMETHANES

Disinfection by-products are a group of chemical compounds formed when water disinfection agents (e.g. chlorine, chloramines, ozone, chlorine dioxide) interact with organic precursors or bromide naturally present in water (CCME, 1999; CDC, 2009; Health Canada, 2006). Disinfection by-products include, among others, trihalomethanes (THMs), haloacetic acids, haloacetanitriiles, haloketones, and chlorophenols. THM formation increases as a function of the concentration of chlorine and organic matter; in the presence of bromides, brominated THMs are formed (Health Canada, 2006). In cycle 3 of the Canadian Health Measures Survey (CHMS), four THMs were measured: chloroform, bromoform, bromodichloromethane, and dibromochloromethane. Each of these compounds consists of three halogen groups attached to a single carbon atom and are classified as volatile organic compounds (CCME, 1999). Chloroform is the most common THM and the most frequently measured disinfection by-product in chlorinated drinking water in Canada (ATSDR, 2005; Health Canada, 2006).

### Table 13.7.1

<table>
<thead>
<tr>
<th>Trihalomethanes measured in the Canadian Health Measures Survey cycle 3 (2012–2013).</th>
<th>CASRN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromodichloromethane</td>
<td>75-27-4</td>
</tr>
<tr>
<td>Dibromochloromethane</td>
<td>124-48-1</td>
</tr>
<tr>
<td>Tribromomethane (Bromoform)</td>
<td>75-25-2</td>
</tr>
<tr>
<td>Trichloromethane (Chloroform)</td>
<td>67-66-3</td>
</tr>
</tbody>
</table>

The four THMs are also commercially produced chemicals (ATSDR, 1999; ATSDR, 2005). Chloroform and bromodichloromethane are used as chemical intermediates in the manufacturing of organic chemicals and as solvents, although chloroform has not been manufactured in Canada since 1978 (ATSDR, 2005; Health Canada, 2006). In Canada, the use of chloroform as an anaesthetic has been discontinued and its use in dentifrices, liniments, and antitussives has been banned (CCME, 1999; Environment Canada and Health Canada, 2000). Dibromochloromethane is used as an intermediate in the manufacture of refrigerants, pesticides, propellants, and other organic chemicals (Health Canada, 2006). Bromoform is used as a solvent in the synthesis of pharmaceuticals and in fire-resistant chemicals, as well as gauge fluid used in the aircraft and shipbuilding industries (Health Canada, 2006).

A small proportion of THMs present in the environment may be due to natural production by marine algae and natural degradation and transformation processes (ATSDR, 1999; ATSDR, 2005). Anthropogenic sources are generally considered to be larger contributors of THMs in the environment than natural ones. In Canada, the major anthropogenic sources of THMs are disinfected water from drinking water treatment plants, chlorinated effluents from municipal wastewater treatment plants and industrial plants, and cooling waters from power plants and industrial plants (Environment Canada and Health Canada, 1993). Chlorine use in the treatment of drinking water has virtually eliminated waterborne diseases because of its ability to kill or inactivate most microorganisms commonly found in water (Health Canada, 2006). It is used in the majority of drinking water treatment plants in Canada to treat the water directly in the treatment plant and/or to maintain a chlorine residual in the distribution system to prevent bacterial regrowth (Health Canada, 2006). Effluent wastewaters are disinfected to protect downstream...
municipal water supplies, recreational waters, and shellfish-growing areas from bacterial contamination and other microorganisms causing water-borne disease (Environment Canada and Health Canada, 1993). In addition to drinking water, disinfection effluents, and cooling waters, anthropogenic sources of THMs include chemical manufacturing plants and industrial sites, swimming pools, hot tubs, and water parks (ATSDR, 2005; CCME, 1999; Health Canada, 2006).

The general population is exposed to THMs primarily by drinking chlorinated water (CDC, 2009; Environment Canada and Health Canada, 2000; Health Canada, 2006). Exposure also occurs through inhalation during showering and bathing and by skin absorption during bathing and swimming (CDC, 2009; Health Canada, 2006). Minor exposures may occur from the consumption of food and beverages (Health Canada, 2006). Swimming pools and hot tubs are additional sources of THM exposure (Aggazzotti et al., 1998).

Following ingestion, all four THMs are rapidly absorbed into the blood and distributed throughout the body, primarily in the fat, blood, liver, kidney, lungs, and nervous system (ATSDR, 1989; Health Canada, 2006; WHO, 2004). THMs are well absorbed following both oral and inhalation exposure, with dermal exposure as another potentially significant route of exposure (ATSDR, 1989; Health Canada, 2006; IPCS, 2000; WHO, 2004). Estimated half-lives for THMs in the body generally range from 1.5 hours to 6 hours; about 95% of absorbed bromodichloromethane is eliminated from the body in 8 hours (ATSDR, 1989; Health Canada, 2006; WHO, 2004). Absorbed THMs are mainly eliminated from the body by exhalation of unchanged compounds and volatile metabolites, with only minor amounts excreted in the urine, and less in the feces (Health Canada, 2006; IPCS, 2000). Unchanged disinfection by-products measured in blood are the most accurate biomarkers of exposure to disinfection by-products and reflect recent exposures (CDC, 2009).

Each of the four THMs is irritating to the eye and respiratory tract, and acute inhalation exposure has been associated with reddening of the face (Health Canada, 2006; IPCS, 2000; WHO, 2004). Acute high-level inhalation and oral exposures to these disinfection by-products in laboratory animals induce general narcotic and anesthetic effects increasing in severity with exposure level and are generally reversible following cessation of exposure (Health Canada, 2006; IPCS, 2000; WHO, 2004). Some studies in laboratory animals indicate that THMs containing bromine, such as bromodichloromethane, may be more toxic than chloroform and other chlorine-containing disinfection by-products (Health Canada, 2006). Chronic exposures to THMs in drinking water are weakly and inconsistently associated with cancer of liver, kidney, colon, rectal, brain, pancreas, and bladder (Health Canada, 2006; IPCS, 2000; WHO, 2004). Results of studies in laboratory animals chronically exposed by the oral route to high levels of individual THMs provide supporting evidence of an association between cancers of the kidney, liver, and intestines with exposures to disinfection by-products (ATSDR, 1989; Health Canada, 2006; WHO, 2004). Based upon available evidence in laboratory animals, chloroform and bromodichloromethane have been classified as possibly carcinogenic to humans (Group 2B) by the International Agency for Research on Cancer (IARC, 1999a; IARC, 1999b). There is insufficient evidence to determine whether or not bromoform, dibromochloromethane, and chlorinated drinking water are carcinogenic (IARC, 1991; IARC, 1999a).

Health Canada and Environment Canada have reviewed and assessed chlorinated wastewater effluents, defined as those effluents to which chlorine or chlorination agents are added for disinfection, under the Canadian Environmental Protection Act. The screening assessment concluded that chlorinated wastewater effluents discharged to the Canadian environment by municipal wastewater treatment plants are a concern for the environment (Environment Canada and Health Canada, 1993). However, there is insufficient information to determine whether chlorinated wastewater effluents are harmful to human health. Chlorinated wastewater effluents are listed on Schedule 1, List of Toxic Substances, under the Canadian Environmental Protection Act, 1999 (Canada, 1999). Under Canada’s Food and Drugs Act, manufacturers are not permitted to import or sell a drug for human use in Canada that contains chloroform (Canada, 2012; Environment Canada and Health Canada, 2000).

The Federal-Provincial-Territorial Committee on Drinking Water has developed a guideline for Canadian drinking water quality that establishes a maximum acceptable concentration for total THMs (defined as the sum of chloroform, bromoform, dibromochloromethane, and bromodichloromethane) in
drinking water (Health Canada, 2006). The Canadian guideline states that utilities should make every effort to maintain concentrations as low as reasonably achievable without compromising the effectiveness of disinfection (Health Canada, 2006). The approach to reducing THM exposure is generally focused on reducing the formation of chlorinated disinfection by-products. This can be achieved by removing organic matter from the water before chlorine is added, by optimizing the disinfection process or using alternative disinfection strategies, or by using a different water source.

Four THMs—chloroform, bromoform, dibromochloromethane, and bromodichloromethane—were analyzed in the whole blood of CHMS cycle 3 (2012–2013) participants aged 12 to 79 years. Data are presented as µg/L blood. Finding a measurable amount of THMs in blood can be an indicator of exposure to THMs and does not necessarily mean that an adverse health effect will occur. These data provide baseline levels for blood THMs in the Canadian population.

### Table 13.7.2

Bromodichloromethane — Geometric means and selected percentiles of whole blood concentrations (µg/L) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>2499</td>
<td>98.88</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1245</td>
<td>98.96</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1254</td>
<td>98.80</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>744</td>
<td>98.12</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>556</td>
<td>98.92</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>604</td>
<td>99.01</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

*If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

### Table 13.7.3

Dibromochloromethane — Geometric means and selected percentiles of whole blood concentrations (µg/L) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LOD</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>2527</td>
<td>97.07</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1263</td>
<td>96.52</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1264</td>
<td>97.63</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>757</td>
<td>96.83</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>557</td>
<td>97.13</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.0155 (LOD–0.023)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>604</td>
<td>98.01</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>609</td>
<td>96.39</td>
<td>–</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
</tr>
</tbody>
</table>

*If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E  Use data with caution.
## Table 13.7.4
Trihalomethane (Bromoform) — Geometric means and selected percentiles of whole blood concentrations (μg/L) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% Cl)</th>
<th>10th (95% Cl)</th>
<th>50th (95% Cl)</th>
<th>90th (95% Cl)</th>
<th>95th (95% Cl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>2496</td>
<td>94.79</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.010E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.015)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1244</td>
<td>95.02</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.012E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.016)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1252</td>
<td>94.57</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.012E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.013)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>744</td>
<td>94.49</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.021E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.031)</td>
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</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>554</td>
<td>94.40</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.022E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.033)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>595</td>
<td>96.47</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.011E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.016)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>603</td>
<td>93.86</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>F</td>
<td></td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
F Data is too unreliable to be published.

## Table 13.7.5
Trichloromethane (Chloroform) — Geometric means and selected percentiles of whole blood concentrations (μg/L) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% Cl)</th>
<th>10th (95% Cl)</th>
<th>50th (95% Cl)</th>
<th>90th (95% Cl)</th>
<th>95th (95% Cl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>2527</td>
<td>77.44</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.021E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.026)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.029</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.019–0.033)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1263</td>
<td>77.51</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.021E</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.027)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0.035E</td>
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<td></td>
<td></td>
<td></td>
<td>(0.018–0.052)</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1264</td>
<td>77.37</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.021E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.027)</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
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<td>(0.019–0.053)</td>
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<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>757</td>
<td>77.81</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.020E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.028)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0.031E</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(&lt;LOD–0.049)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>557</td>
<td>76.48</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.023E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.029)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.015–0.053)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>595</td>
<td>78.81</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.025)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.019–0.036)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>603</td>
<td>76.52</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>0.020E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(95% CI)</td>
<td>(&lt;LOD–0.027)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0.028E</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(&lt;LOD–0.041)</td>
<td></td>
</tr>
</tbody>
</table>

a If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.
E Use data with caution.
REFERENCES


13.8 XYLENES

Xylenes (CASRN 1330-20-7) are classified as volatile organic compounds (VOCs) (ATSDR, 2007; CCOHS, 2013; Environment Canada and Health Canada, 1993). The three isomers of xylene are ortho-xylene (o-xylene; CASRN 95-47-6), meta-xylene (m-xylene; CASRN 108-38-3) and para-xylene (p-xylene; CASRN 106-42-3); they differ from each other in the position of the two methyl group substitutions on the aromatic ring. The term “total xylenes” refers to all three isomers of xylene, whereas “mixed xylene” is a mixture of total xylenes and ethylbenzene (6% to 15%) (CCOHS, 2013). Xylenes are primarily produced either directly or as by-products of petroleum and coal refining and as by-products of olefin manufacturing (ATSDR, 2007; Environment Canada and Health Canada, 1993).

Xylene has been extensively and increasingly used in a wide range of applications as a solvent, as a replacement for benzene in the solvent components of various commercial products, and as a mixture in gasoline (ATSDR, 2007). Xylene may be widely used as a solvent in paint thinners, varnishes, lacquers, stains, concrete sealers, cleaning products, adhesives, inks, cleaning and degreasing agents, and in the production of dyes, perfumes, plastics, pharmaceuticals, and pesticides (ATSDR, 2007; Environment Canada and Health Canada, 1993; IPCS, 1997).

Xylenes are released to the environment from natural and anthropogenic sources. Xylenes have been measured in emissions from volcanoes, forest fires, and in volatiles from plants and vegetation (ATSDR, 2007; CCME, 2004). Anthropogenic sources of atmospheric xylene include volatilization of petroleum fuels and xylene-based solvents and thinners, gasoline use and motor vehicle exhaust, and the off-gassing of xylene from some building materials, and consumer and automotive products containing xylenes (ATSDR, 2007; Environment Canada and Health Canada, 1993). Xylenes are also released to the environment in waste from manufacturing and processing facilities, from spills and accidental releases, and from the disposal of xylene-containing products (ATSDR, 2007; CCME, 2004; Environment Canada, 2014). In the past, predominant sources of releases to the atmosphere included emissions from petroleum refineries and chemical manufacturing facilities of styrene-butadiene, rubber, solvents, paints, plastics, synthetic fabric polymers, and polyesters. As new emissions-free and low VOC technologies are being implemented, and changes in industrial and consumer use patterns and increases in fuel efficiency occur, releases of VOCs, including xylenes, are expected to continue their decline.

The general population is exposed to xylenes mainly through inhalation of indoor air (Environment Canada and Health Canada, 1993). Cigarette smoking may significantly increase levels in indoor air and, in smokers, inhalation of cigarette smoke is expected to be a major contribution to the total source of xylene exposure (ATSDR, 2007). In addition to smoking, xylene levels in air have been shown to be higher for homes with a garage on the property, with a higher number of occupants, with recent renovations, and in which fragrances and paint remover have been recently used (Wheeler et al., 2013). Additional exposure may result from the use of consumer products containing xylenes, from the use of gasoline-powered engines, such as lawn mowers and outboard motors, and from ambient air, water, soil, drinking water, and food (ATSDR, 2007; IARC, 1999; Wheeler et al., 2013). As xylenes are present as a mixture in gasoline and commercial products, the general population is expected to be primarily exposed to xylenes as a mixture, not to the separate xylene isomers (ATSDR, 2007).

Xylene is rapidly absorbed by all routes of exposure and distributed throughout the body following exposure, primarily into adipose tissues and those tissues with higher lipid content, such as the liver and the brain (ATSDR, 2007; EPA, 2003; Health Canada, 1986). Elimination of xylene from blood and most tissue compartments following inhalation is generally rapid, and in humans has a half-life ranging from about 1 to 20 hours (ATSDR, 2007). The major route of excretion of absorbed xylene in the blood and body is excretion of metabolites in urine, with minor elimination by exhalation of unchanged chemical from the lungs (ATSDR, 2007). Xylene levels in the blood are the most accurate biomarker of xylene exposure and reflect recent exposure (ATSDR, 2007; IARC, 1999).

Adverse health effects have been observed in humans and laboratory animals following xylene exposure via inhalation, ingestion, and dermal routes. In humans, xylene can be irritating to the eyes, nose, throat, lungs, and skin, and has been associated with symptoms of headaches, dizziness, reduced coordination, and feelings of intoxication (ATSDR, 2007; CCOHS, 2013). Acute inhalation exposure has been associated with reversible neurological symptoms whereas chronic exposure is associated with impaired neurological function,
including cognitive and neuromuscular performance, as well as hearing deficits and dermatitis in humans (ATSDR, 2007; IARC, 1999). In humans, acute exposure to xylenes by ingestion has been associated with stomach discomfort, and changes in liver and kidney function; ingestion of petroleum solvents can be fatal (ATSDR, 2007; IPCS, 1997). Exposure to high levels of mixed xylenes (and other solvents) in humans during pregnancy has been associated with fetal toxicity and developmental effects in children at levels associated with potential maternal toxicity, such as in solvent abuse (ATSDR, 2007; EPA, 2003; IPCS, 1997). Xylene is not classifiable as to its carcinogenicity in humans according to Environment Canada and Health Canada (Group IV), the International Agency for Research on Cancer (Group 3) and the U.S. Environmental Protection Agency (Group D) (Environment Canada and Health Canada, 1993; EPA, 2003; IARC, 1999).

Under the Canadian Environmental Protection Act, Health Canada and Environment Canada concluded that xylenes are not entering the environment in quantities or under conditions that may constitute a danger to human life or health (Environment Canada and Health Canada, 1993). Xylenes also part of a larger class of compounds called VOCs that, as a group, are environmental and health concerns because of their contribution to the formation of smog. The Government of Canada has taken and proposed a number of actions to address VOC emissions resulting from the use of consumer and commercial products in Canada (Canada, 2009a; Canada, 2009b; Environment Canada, 2002; Environment Canada, 2013). The current guideline for Canadian drinking water quality establishes an aesthetic objective for xylene based on its odour threshold (Health Canada, 1986; Health Canada, 2012). This guideline was deemed protective of short-term exposure, but a health-based value had not been established (Health Canada, 1986). Recently, Health Canada released for public comment a revised guideline technical document by the Federal-Provincial-Territorial Committee on Drinking Water, based on the most current available scientific information on xylenes (Health Canada, 2014). A final guideline technical document is expected to be available in the summer of 2015.

Xylenes were analyzed in the whole blood of Canadian Health Measures Survey (CHMS) participants aged 12 to 79 years in cycle 3 (2012–2013). Data are presented as µg/L blood for \( o \)-xylene and the sum of \( m \)-xylene and \( p \)-xylene. Finding a measurable amount of xylenes in blood can be an indicator of recent exposure to xylene and does not necessarily mean that an adverse health effect will occur. These data provide baseline levels for blood xylenes in the Canadian population.

Xylenes were also analyzed in indoor air from households of CHMS participants in cycle 2 (2009–2011) (Statistics Canada, 2012; Wheeler et al., 2013) and cycle 3 (2012–2013) and in tap water from households in cycle 3. Further details on the indoor air and tap water studies are available in the Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3 (Statistics Canada, 2015). Indoor air and tap water data are available through Statistics Canada’s Research Data Centres or upon request by contacting Statistics Canada at info@statcan.gc.ca.
### Table 13.8.1
*m*-Xylene and *p*-xylene — Geometric means and selected percentiles of whole blood concentrations (μg/L) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>2326</td>
<td>14.53</td>
<td>0.062 (0.050–0.079)</td>
<td>&lt;LOD</td>
<td>0.063 (0.047–0.080)</td>
<td>0.20 (0.14–0.26)</td>
<td>0.30 (0.20–0.39)</td>
</tr>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1172</td>
<td>13.31</td>
<td>0.065 (0.051–0.082)</td>
<td>&lt;LOD</td>
<td>0.062 (0.045–0.080)</td>
<td>0.21 (0.15–0.28)</td>
<td>0.34 (0.19–0.49)</td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1154</td>
<td>15.77</td>
<td>0.060 (0.047–0.078)</td>
<td>&lt;LOD</td>
<td>0.064 (0.046–0.082)</td>
<td>0.19 (0.12–0.26)</td>
<td>0.27 (0.18–0.36)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>701</td>
<td>16.83</td>
<td>0.049 (0.037–0.065)</td>
<td>&lt;LOD</td>
<td>0.055 (0.039–0.071)</td>
<td>0.14 (0.086–0.19)</td>
<td>0.18 (0.14–0.23)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>500</td>
<td>14.00</td>
<td>0.058 (0.045–0.074)</td>
<td>&lt;LOD</td>
<td>0.057 (0.036–0.088)</td>
<td>0.16 (0.11–0.22)</td>
<td>0.25 (0.17–0.32)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>559</td>
<td>11.99</td>
<td>0.074 (0.056–0.096)</td>
<td>&lt;LOD</td>
<td>0.068 (0.052–0.084)</td>
<td>0.28 (0.17–0.39)</td>
<td>0.42 (0.29–0.54)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>566</td>
<td>14.66</td>
<td>0.060 (0.045–0.079)</td>
<td>&lt;LOD</td>
<td>0.061 (0.043–0.078)</td>
<td>0.18 (0.15–0.21)</td>
<td>0.25 (0.12–0.37)</td>
</tr>
</tbody>
</table>

*a* If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.

### Table 13.8.2
*o*-Xylene — Geometric means and selected percentiles of whole blood concentrations (μg/L) for the Canadian population aged 12–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>%&lt;LODa</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>2336</td>
<td>41.05</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.022 (0.019–0.034)</td>
<td>0.087 (0.061–0.11)</td>
<td>0.11 (0.083–0.14)</td>
</tr>
<tr>
<td>Males</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1164</td>
<td>40.55</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.022 (0.0097–0.033)</td>
<td>0.088 (0.061–0.11)</td>
<td>0.12 (0.082–0.14)</td>
</tr>
<tr>
<td>Females</td>
<td>12–79</td>
<td>3 (2012–2013)</td>
<td>1172</td>
<td>41.55</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.022 (0.011–0.034)</td>
<td>0.081 (0.052–0.11)</td>
<td>0.11 (0.082–0.14)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>692</td>
<td>43.93</td>
<td>–</td>
<td>&lt;LOD</td>
<td>F</td>
<td>0.057 (0.041–0.072)</td>
<td>0.075 (0.053–0.098)</td>
</tr>
<tr>
<td>Total</td>
<td>20–39</td>
<td>3 (2012–2013)</td>
<td>515</td>
<td>42.14</td>
<td>–</td>
<td>&lt;LOD</td>
<td>0.020 (0.0095–0.030)</td>
<td>0.077 (0.038–0.12)</td>
<td>0.11 (0.053–0.17)</td>
</tr>
<tr>
<td>Total</td>
<td>40–59</td>
<td>3 (2012–2013)</td>
<td>565</td>
<td>38.94</td>
<td>0.022 (0.014–0.034)</td>
<td>&lt;LOD</td>
<td>0.029 (0.012–0.045)</td>
<td>0.099 (0.075–0.12)</td>
<td>0.13 (0.095–0.17)</td>
</tr>
<tr>
<td>Total</td>
<td>60–79</td>
<td>3 (2012–2013)</td>
<td>564</td>
<td>38.65</td>
<td>0.016 (0.010–0.023)</td>
<td>&lt;LOD</td>
<td>0.016 (LOD–0.027)</td>
<td>0.076 (0.055–0.098)</td>
<td>0.10 (0.030–0.17)</td>
</tr>
</tbody>
</table>

*a* If >40% of samples were below the LOD, the percentile distribution is reported but means were not calculated.

E Use data with caution.

F Data is too unreliable to be published.
REFERENCES


Laboratory analyses of environmental chemicals and creatinine were performed at analytical laboratories within Health Canada, l’Institut national de santé publique du Québec (INSPQ), and the ALS Laboratory Group. Laboratories developed standardized operating procedures for the analytical methods used to measure environmental chemicals or their metabolites in biological samples. The limit of detection (LOD) is defined as the lowest concentration of the analyte whose analytical response is measured to be greater than the noise level with 99% confidence and evaluated using EPA methodology (EPA, 2015).

## APPENDIX

### LIMITS OF DETECTION

<table>
<thead>
<tr>
<th></th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metals and Trace Elements in Blood</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.04 µg/L</td>
<td>0.04 µg/L</td>
<td>0.08 µg/L</td>
</tr>
<tr>
<td>Lead</td>
<td>0.02 µg/dL</td>
<td>0.1 µg/dL</td>
<td>0.2 µg/dL</td>
</tr>
<tr>
<td>Methylmercury</td>
<td>—</td>
<td>—</td>
<td>0.2 µg Hg/L</td>
</tr>
<tr>
<td>Total mercury</td>
<td>0.1 µg/L</td>
<td>0.1 µg/L</td>
<td>0.4 µg/L</td>
</tr>
<tr>
<td><strong>Metals and Trace Elements in Urine</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenate</td>
<td>—</td>
<td>0.8 µg As/L</td>
<td>0.8 µg As/L</td>
</tr>
<tr>
<td>Arsenite</td>
<td>—</td>
<td>0.8 µg As/L</td>
<td>0.8 µg As/L</td>
</tr>
<tr>
<td>Arsenocholine</td>
<td>—</td>
<td>—</td>
<td>0.8 µg As/L</td>
</tr>
<tr>
<td>Arsenocholine and arsenobetaine</td>
<td>—</td>
<td>0.8 µg As/L</td>
<td>0.8 µg As/L</td>
</tr>
<tr>
<td>Dimethylarsinic acid</td>
<td>—</td>
<td>0.8 µg As/L</td>
<td>0.8 µg As/L</td>
</tr>
<tr>
<td>Monomethylarsenic acid</td>
<td>—</td>
<td>0.8 µg As/L</td>
<td>0.8 µg As/L</td>
</tr>
<tr>
<td>Fluoride</td>
<td>—</td>
<td>20 µg/L</td>
<td>10 µg/L</td>
</tr>
<tr>
<td>Inorganic mercury</td>
<td>0.1 µg/L</td>
<td>—</td>
<td>0.2 µg/L</td>
</tr>
<tr>
<td><strong>Benzene Metabolites</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-Phenylmercapturic acid</td>
<td>—</td>
<td>0.08 µg/L</td>
<td>0.08 µg/L</td>
</tr>
<tr>
<td>trans,trans-Muconic acid</td>
<td>—</td>
<td>0.8 µg/L</td>
<td>0.6 µg/L</td>
</tr>
<tr>
<td><strong>Environmental Phenols</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bisphenol A</td>
<td>0.2 µg/L</td>
<td>0.2 µg/L</td>
<td>0.2 µg/L</td>
</tr>
<tr>
<td>Triclosan</td>
<td>—</td>
<td>3 µg/L</td>
<td>5 µg/L</td>
</tr>
<tr>
<td><strong>Nicotine Metabolite</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotinine</td>
<td>1 µg/L</td>
<td>1 µg/L</td>
<td>1 µg/L</td>
</tr>
</tbody>
</table>
### Volatile Organic Compounds

<table>
<thead>
<tr>
<th>Compound</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>—</td>
<td>—</td>
<td>0.007 µg/L</td>
</tr>
<tr>
<td>Bromodichloromethane</td>
<td>—</td>
<td>—</td>
<td>0.01 µg/L</td>
</tr>
<tr>
<td>Dibromochloromethane</td>
<td>—</td>
<td>—</td>
<td>0.007 µg/L</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>—</td>
<td>—</td>
<td>0.01 µg/L</td>
</tr>
<tr>
<td>m-Xylene and p-xylene</td>
<td>—</td>
<td>—</td>
<td>0.02 µg/L</td>
</tr>
<tr>
<td>o-Xylene</td>
<td>—</td>
<td>—</td>
<td>0.009 µg/L</td>
</tr>
<tr>
<td>Styrene</td>
<td>—</td>
<td>—</td>
<td>0.01 µg/L</td>
</tr>
<tr>
<td>Tetrachloroethylene (Perchloroethylene)</td>
<td>—</td>
<td>—</td>
<td>0.02 µg/L</td>
</tr>
<tr>
<td>Toluene</td>
<td>—</td>
<td>—</td>
<td>0.01 µg/L</td>
</tr>
<tr>
<td>Tribromomethane (Bromoform)</td>
<td>—</td>
<td>—</td>
<td>0.01 µg/L</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>—</td>
<td>—</td>
<td>0.03 µg/L</td>
</tr>
<tr>
<td>Trichloromethane (Chloroform)</td>
<td>—</td>
<td>—</td>
<td>0.01 µg/L</td>
</tr>
</tbody>
</table>

### Acrylamide

<table>
<thead>
<tr>
<th>Compound</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylamide haemoglobin adduct</td>
<td>—</td>
<td>—</td>
<td>10 pmol/g haemoglobin</td>
</tr>
<tr>
<td>Glycidamide haemoglobin adduct</td>
<td>—</td>
<td>—</td>
<td>20 pmol/g haemoglobin</td>
</tr>
</tbody>
</table>

### Polycyclic Aromatic Hydrocarbon Metabolites

#### Benzo[a]pyrene Metabolite

<table>
<thead>
<tr>
<th>Metabolite</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Hydroxybenzo[a]pyrene</td>
<td>—</td>
<td>—</td>
<td>0.002 µg/L</td>
</tr>
</tbody>
</table>

#### Chrysene Metabolites

<table>
<thead>
<tr>
<th>Metabolite</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Hydroxychrysene</td>
<td>—</td>
<td>0.004 µg/L</td>
<td>0.005 µg/L</td>
</tr>
<tr>
<td>3-Hydroxychrysene</td>
<td>—</td>
<td>0.003 µg/L</td>
<td>0.003 µg/L</td>
</tr>
<tr>
<td>4-Hydroxychrysene</td>
<td>—</td>
<td>0.003 µg/L</td>
<td>0.002 µg/L</td>
</tr>
<tr>
<td>6-Hydroxychrysene</td>
<td>—</td>
<td>0.006 µg/L</td>
<td>0.002 µg/L</td>
</tr>
</tbody>
</table>

#### Fluoranthene Metabolite

<table>
<thead>
<tr>
<th>Metabolite</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Hydroxyfluoranthene</td>
<td>—</td>
<td>—</td>
<td>0.008 µg/L</td>
</tr>
</tbody>
</table>

#### Fluorene Metabolites

<table>
<thead>
<tr>
<th>Metabolite</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Hydroxyfluorene</td>
<td>—</td>
<td>0.003 µg/L</td>
<td>0.006 µg/L</td>
</tr>
<tr>
<td>3-Hydroxyfluorene</td>
<td>—</td>
<td>0.001 µg/L</td>
<td>0.002 µg/L</td>
</tr>
<tr>
<td>9-Hydroxyfluorene</td>
<td>—</td>
<td>0.003 µg/L</td>
<td>0.004 µg/L</td>
</tr>
</tbody>
</table>

#### Naphthalene Metabolites

<table>
<thead>
<tr>
<th>Metabolite</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Hydroxynaphthalene</td>
<td>—</td>
<td>—</td>
<td>0.1 µg/L</td>
</tr>
<tr>
<td>2-Hydroxynaphthalene</td>
<td>—</td>
<td>—</td>
<td>0.05 µg/L</td>
</tr>
</tbody>
</table>

#### Phenanthrene Metabolites

<table>
<thead>
<tr>
<th>Metabolite</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Hydroxyphenanthrene</td>
<td>—</td>
<td>—</td>
<td>0.005 µg/L</td>
</tr>
<tr>
<td>2-Hydroxyphenanthrene</td>
<td>—</td>
<td>—</td>
<td>0.003 µg/L</td>
</tr>
<tr>
<td>3-Hydroxyphenanthrene</td>
<td>—</td>
<td>—</td>
<td>0.003 µg/L</td>
</tr>
<tr>
<td>4-Hydroxyphenanthrene</td>
<td>—</td>
<td>—</td>
<td>0.001 µg/L</td>
</tr>
<tr>
<td>9-Hydroxyphenanthrene</td>
<td>—</td>
<td>—</td>
<td>0.004 µg/L</td>
</tr>
</tbody>
</table>

#### Pyrene Metabolite

<table>
<thead>
<tr>
<th>Metabolite</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Hydroxypyrene</td>
<td>—</td>
<td>—</td>
<td>0.002 µg/L</td>
</tr>
</tbody>
</table>

#### Adjustment Factor

<table>
<thead>
<tr>
<th>Compound</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creatinine</td>
<td>3 mg/dL</td>
<td>4 mg/dL</td>
<td>5 mg/dL</td>
</tr>
</tbody>
</table>

---

*a In the Second Report on Human Biomonitoring of Environmental Chemicals in Canada, all speciated arsenic was reported as µg of arsenic species per litre (e.g., µg arsenate/L). For this reason, the values presented in this report may differ from those in the Second Report.*
REFERENCES

Units of measurement are important. Results are reported here using standard units; however, units can be converted using the conversion factors presented below for comparison of data with other data sets.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Abbreviation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>litre</td>
<td>L</td>
<td>—</td>
</tr>
<tr>
<td>decilitre</td>
<td>dL</td>
<td>$10^{-1}$ L</td>
</tr>
<tr>
<td>millilitre</td>
<td>mL</td>
<td>$10^{-3}$ L</td>
</tr>
<tr>
<td>microlitre</td>
<td>µL</td>
<td>$10^{-6}$ L</td>
</tr>
<tr>
<td>gram</td>
<td>g</td>
<td>—</td>
</tr>
<tr>
<td>milligram</td>
<td>mg</td>
<td>$10^{-3}$ g</td>
</tr>
<tr>
<td>microgram</td>
<td>µg</td>
<td>$10^{-6}$ g</td>
</tr>
<tr>
<td>nanogram</td>
<td>ng</td>
<td>$10^{-9}$ g</td>
</tr>
<tr>
<td>picogram</td>
<td>pg</td>
<td>$10^{-12}$ g</td>
</tr>
</tbody>
</table>

Data can be converted from µg/L to µmol/L using the molecular weight (MW) of the chemical using the formula:

$$Y \ \mu\text{mol/L} = X \ \mu\text{g/L} \times \text{conversion factor (CF)}$$

where the CF is equivalent to $1/\text{MW}$. 
### Metals and Trace Elements

<table>
<thead>
<tr>
<th>Substance</th>
<th>MW (g/mol)</th>
<th>CF (µg/L → µmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenate</td>
<td>—</td>
<td>0.01335a</td>
</tr>
<tr>
<td>Arsenite</td>
<td>—</td>
<td>0.01335a</td>
</tr>
<tr>
<td>Arsenocholine</td>
<td>—</td>
<td>0.01335a</td>
</tr>
<tr>
<td>Arsenocholine and arsenobetaine</td>
<td>—</td>
<td>0.01335a</td>
</tr>
<tr>
<td>Dimethylarsinic acid</td>
<td>—</td>
<td>0.01335a</td>
</tr>
<tr>
<td>Monomethylarsinic acid</td>
<td>—</td>
<td>0.01335a</td>
</tr>
<tr>
<td>Cadmium</td>
<td>112.41</td>
<td>0.00896</td>
</tr>
<tr>
<td>Fluoride</td>
<td>19.00</td>
<td>0.05263</td>
</tr>
<tr>
<td>Lead</td>
<td>207.20</td>
<td>0.04826a</td>
</tr>
<tr>
<td>Methylmercury</td>
<td>—</td>
<td>0.00499d</td>
</tr>
<tr>
<td>Mercury</td>
<td>200.59</td>
<td>0.00499</td>
</tr>
</tbody>
</table>

### Benzene Metabolites

<table>
<thead>
<tr>
<th>Substance</th>
<th>MW (g/mol)</th>
<th>CF (µg/L → µmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>trans,trans-Muconic acid</td>
<td>142.11</td>
<td>0.00704</td>
</tr>
<tr>
<td>S-Phenylmercapturic acid</td>
<td>239.29</td>
<td>0.00418</td>
</tr>
</tbody>
</table>

### Environmental Phenols

<table>
<thead>
<tr>
<th>Substance</th>
<th>MW (g/mol)</th>
<th>CF (µg/L → µmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bisphenol A</td>
<td>228.29</td>
<td>0.00438</td>
</tr>
<tr>
<td>Triclosan</td>
<td>289.54</td>
<td>0.00345</td>
</tr>
</tbody>
</table>

### Nicotine Metabolite

<table>
<thead>
<tr>
<th>Substance</th>
<th>MW (g/mol)</th>
<th>CF (µg/L → µmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotinine</td>
<td>176.22</td>
<td>0.00567</td>
</tr>
</tbody>
</table>

### Volatile Organic Compounds

<table>
<thead>
<tr>
<th>Substance</th>
<th>MW (g/mol)</th>
<th>CF (µg/L → µmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>78.11</td>
<td>0.01280</td>
</tr>
<tr>
<td>Bromodichloromethane</td>
<td>163.83</td>
<td>0.00610</td>
</tr>
<tr>
<td>Dibromochloromethane</td>
<td>208.28</td>
<td>0.00480</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>106.17</td>
<td>0.00942</td>
</tr>
<tr>
<td>m-Xylene and p-xylene</td>
<td>106.17</td>
<td>0.00942</td>
</tr>
<tr>
<td>o-Xylene</td>
<td>106.17</td>
<td>0.00942</td>
</tr>
<tr>
<td>Styrene</td>
<td>104.15</td>
<td>0.00960</td>
</tr>
<tr>
<td>Tetrachloroethylene (Perchloroethylene)</td>
<td>165.83</td>
<td>0.00603</td>
</tr>
<tr>
<td>Toluene</td>
<td>92.14</td>
<td>0.01085</td>
</tr>
<tr>
<td>Tribromomethane (Bromoform)</td>
<td>252.73</td>
<td>0.00396</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>131.39</td>
<td>0.00761</td>
</tr>
<tr>
<td>Trichloromethane (Chloroform)</td>
<td>119.38</td>
<td>0.00838</td>
</tr>
</tbody>
</table>

### Acrylamide

<table>
<thead>
<tr>
<th>Substance</th>
<th>MW (g/mol)</th>
<th>CF (µg/L → µmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylamide haemoglobin adduct</td>
<td>—</td>
<td>NAa</td>
</tr>
<tr>
<td>Glycidamide haemoglobin adduct</td>
<td>—</td>
<td>NAa</td>
</tr>
</tbody>
</table>

### Polycyclic Aromatic Hydrocarbon Metabolites

#### Benzo[a]pyrene Metabolite

<table>
<thead>
<tr>
<th>Substance</th>
<th>MW (g/mol)</th>
<th>CF (µg/L → µmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Hydroxybenzo[a]pyrene</td>
<td>268.31</td>
<td>0.00373</td>
</tr>
</tbody>
</table>

#### Chrysene Metabolites

<table>
<thead>
<tr>
<th>Substance</th>
<th>MW (g/mol)</th>
<th>CF (µg/L → µmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Hydroxychrysene</td>
<td>244.29</td>
<td>0.00409</td>
</tr>
<tr>
<td>3-Hydroxychrysene</td>
<td>244.29</td>
<td>0.00409</td>
</tr>
<tr>
<td>4-Hydroxychrysene</td>
<td>244.29</td>
<td>0.00409</td>
</tr>
<tr>
<td>6-Hydroxychrysene</td>
<td>244.29</td>
<td>0.00409</td>
</tr>
<tr>
<td>Metabolite</td>
<td>MW (g/mol)</td>
<td>CF (µg/L → µmol/L)</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------</td>
<td>--------------------</td>
</tr>
<tr>
<td><strong>Fluoranthene Metabolite</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-Hydroxyfluoranthene</td>
<td>218.25</td>
<td>0.00458</td>
</tr>
<tr>
<td><strong>Fluorene Metabolites</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-Hydroxyfluorene</td>
<td>182.22</td>
<td>0.00549</td>
</tr>
<tr>
<td>3-Hydroxyfluorene</td>
<td>182.22</td>
<td>0.00549</td>
</tr>
<tr>
<td>9-Hydroxyfluorene</td>
<td>182.22</td>
<td>0.00549</td>
</tr>
<tr>
<td><strong>Naphthalene Metabolites</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hydroxynaphthalene</td>
<td>144.17</td>
<td>0.00694</td>
</tr>
<tr>
<td>2-Hydroxynaphthalene</td>
<td>144.17</td>
<td>0.00694</td>
</tr>
<tr>
<td><strong>Phenanthrene Metabolites</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hydroxyphenanthrene</td>
<td>194.23</td>
<td>0.00515</td>
</tr>
<tr>
<td>2-Hydroxyphenanthrene</td>
<td>194.23</td>
<td>0.00515</td>
</tr>
<tr>
<td>3-Hydroxyphenanthrene</td>
<td>194.23</td>
<td>0.00515</td>
</tr>
<tr>
<td>4-Hydroxyphenanthrene</td>
<td>194.23</td>
<td>0.00515</td>
</tr>
<tr>
<td>9-Hydroxyphenanthrene</td>
<td>194.23</td>
<td>0.00515</td>
</tr>
<tr>
<td><strong>Pyrene Metabolite</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hydroxypyrene</td>
<td>218.25</td>
<td>0.00458</td>
</tr>
<tr>
<td><strong>Adjustment Factor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creatinine</td>
<td>113.12</td>
<td>88.4&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

- For converting arsenic species from µg As/L to µmol As/L
- For converting Pb from µg/dL to µmol/L
- For converting methylmercury from µg Hg/L to µmol Hg/L
- Not applicable
- For converting creatinine from mg/dL to µmol/L
Creatinine — Geometric means and selected percentiles of urine concentrations (mg/dL) for the Canadian population aged 6–79 years by age group, Canadian Health Measures Survey cycle 1 (2007–2009).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
</table>
Creatinine — Geometric means and selected percentiles of urine concentrations (mg/dL) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 2 (2009–2011).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
</table>
Creatinine — Geometric means and selected percentiles of urine concentrations (mg/dL) for the Canadian population aged 3–79 years by age group, Canadian Health Measures Survey cycle 3 (2012–2013).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Cycle</th>
<th>n</th>
<th>GM (95% CI)</th>
<th>10th (95% CI)</th>
<th>50th (95% CI)</th>
<th>90th (95% CI)</th>
<th>95th (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3–79</td>
<td>3 (2012–2013)</td>
<td>5704</td>
<td>97 (93–100)</td>
<td>33 (29–37)</td>
<td>100 (100–110)</td>
<td>240 (220–250)</td>
<td>280 (250–300)</td>
</tr>
<tr>
<td>Total</td>
<td>12–19</td>
<td>3 (2012–2013)</td>
<td>998</td>
<td>130 (120–150)</td>
<td>52 (37–66)</td>
<td>150 (140–160)</td>
<td>280 (260–300)</td>
<td>320 (290–360)</td>
</tr>
</tbody>
</table>