Systematic Review of Human Biomonitoring Studies of Environmental Contaminants in Canada
January 1990 - January 2007

Final Report

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Prepared for:
National Collaborating Centre for Environmental Health

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Preface and Acknowledgements

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The authors wish to acknowledge the key researchers across Canada who provided through interviews, information used in an earlier report used as a starting point for the current one. In particular, we thank Dr. Donald Cole (University of Toronto), Dr. Warren Foster and Dr. Bruce Wainman (McMaster University), Dr. Tom Kosatsky (Santé Quebec / McGill University), and Dr. Jay van Oostdam (Health Canada).

This literature review extends our earlier work (Review of Human Biomonitoring Studies of Environmental Contaminants in Canada, 1990-2005; Smith L; Do M; Archbold J) carried out under contract to Health Canada, Federal-Provincial-Territorial Committee on Health and the Environment (CHE). By abstracting key information from studies of biological markers of exposure to environmental contaminants in Canada, we bring toggrther greater detail in a single report. This serves to fulfil the general goals of the CHE and the NCCEH to to facilitate the integration of health and environment issues at the national level by making synthesized information more accessible to public health practitioners.

Dr. Viorica Padure, Community Medicine Resident, University of Toronto, assisted with the abstraction of information from published papers and with the compilation of the results for this report. Josephine Archbold was coauthor on our previous report and reviewed draft reports of our current work.

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Executive Summary

"Systematic Review of Human Biomonitoring Studies of Environmental Contaminants in Canada" is carried out under contract to the National Collaborating Centre for Environmental Health (NCCEH) hosted by the British Columbia Centre for Disease Control ("the Centre").

The objective of this project is to provide synthesized information on biological markers of exposure to environmental contaminants in Canada through a systematic search of the published and grey literature from January 1990 through to January 2007; to evaluate the studies and summarize the information provided. This report may be called more correctly a collection and assessment of studies of Canadian populations which have been tested at least once for a biological marker of exposure to an environmental contaminant in any biological matrix. The most common marker of exposure is the contaminant itself or its metabolite. . The current work hopes to make the Canadian work on markers of exposure to environmental contaminants more accessible to public health practitioners and assist in the interpretation of results of biomarkers of exposure in the light of other reported values in Canadian population groups, their validity and potential significance to public health practice.

The studies included in this report were selected from several search approaches as used and reported in our previous report (Review of Human Biomonitoring Studies of Environmental Contaminants in Canada, 1990-2005; Smith et al., 2006, not yet published; done under contract to Federal-Provincial-Territorial Committee on Health and the Environment (FTP CHE). The first two search approaches used terms defined *a priori* in MEDLINE and EMBASE and through Google™ web-based search to identify monographs, unpublished reports, and scientific presentations related to studies of biomarkers of exposure in Canada. The second two approaches included back referencing and author name searches to complete the list of papers to be reviewed for inclusion into the EndNote™ database. To supplement the systematic searches, one member of the team (LS) carried out a series of interviews with 21 key informants who have contributed to the area of measurment of markers of exposure to environmental contaminants in Canada to ensure that the search reflected work done in Canada and to pursue sources of grey literature.

The present literature review extends our earlier work. We updated the previous search for this project and identified an additional 51 studies published up to January 2007. After detailed review of the contents of each of the 51 newly found papers, 12 were added to the data base for inclusion into this report. Duplicates or repeated publications were excluded and updated ones were added. In total, the results from 130 studies were abstracted for this report. Additional references were used for discussion of abstracted studies. Two publications were suggested for inclusion after external peer review. One did not provide relevant material, while the other provided highly detailed and synthesized information useful in its own right, and was thus only included in the discussion and referenced.

Each study that qualified for entry into the database had to meet the following criteria: *Canadian populations, results for an environmental contaminant, biological medium (urine, blood, serum or plasma, breast milk, fat(adipose) or other tissue, saliva, semen, nails, and hair), as well as the names of selected environmental contaminants (see search stategy, Appendix 2).*

All results were abstracted into a specially designed form (Appendix 3), and then converted into a Microsoft Excel™ spreadsheet. Overall, over 2000 entries (datalines) were abstracted. Information abstracted included: author, year of publication, year of sampling, population sampled, geographic region, contaminant, laboratory analytic method, detection limits, and number of participants, age, sex, body tissue, contaminant levels, and useful comments (study objectives and conclusions).

The Microsoft Excel™ database was then used to create tables for each contaminant. A final evaluation of all studies on a given contaminant reflected the usefulness of the study for the development of policy: regulations, advisories, or to guide interventions and future research.

Unless the units are readily converted and in use (e.g., lead in blood), the units reported here correspond to the units reported in the original studies. If adjustment was done for fat or creatinine in the published report, this was reported here as the author presented the results. Studies reported results in many ways, and many could not be made uniform here. Where results were presented in multiple tables, by age, sex, percentiles and other adjustments, the reader is referred to the original publication for details which could not be easily incorporated into this report.

Biological measures of environmental contaminants in Canadians have been reported for persistent organochlorines (polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins and dibenzofurans (PCDD/PCDF), organo-chlorine pesticides (OCs), non-OC pesticides**,** perfluorooctane sulfonate/ perfluorooctanoic acid (PFOS/PFOA), PAH metabolites (1-hydroxy P), and metals (lead, arsenic, mercury and methyl-mercury, cadmium, manganese, selenium, and zinc). In 2003, the *Institut National de Sante Publique de Quebec* published a report of metals in blood, serum and urine of a sample of the Quebec population (Etude sur l'établissement des valeurs de référence des éléments traces et des métaux dans le sang, le sérum et l'urine dans la population de la Grande Région de Québec, Direction toxicologie humaine, direction risques biologiques, environnementaux, et occupationnelles, 2003 - http://www.inspq.qc.ca/pdf/publications/289-ValeursReferenceMetaux.pdf). This report presented levels of antimony, arsenic (total and non alimentary), beryllium, cadmium, chrome, cobalt, manganese, mercury, molybdenum, nickel, lead, selenium, tellurium and thallium. This was the only report of environmental contaminant measures from a population sample for the specific purpose of establishing norms in a particular population (Quebec).

Biological samples examined in studies include capillary and venous blood, cord blood, urine, breast milk, hair, adipose tissue (omental and breast), placenta, and follicular fluid.

Rarely, toe nails and feces were examined.

Among special targeted populations examined were First Nations (Inuit, Mohawk, Métis, Cree and Dene), Quebec populations, children, pregnant women, Asian ethnicity (Asian-Canadian, Chinese, Filipino, Vietnamese and Bangladeshi), Europeans and non-Europeans and "control" general populations (including pooled samples). Many studies of specific populations reflected hot spot contaminated areas, while others were intended to measure "general environmental" exposures.

All geographic locations of Canada were represented in studies except for Prince Edward Island, Manitoba and the Yukon Territories which were represented in cross Canada surveys only (*e.g.*, breast milk).

Most studies were of cross sectional design but there were also a few cohort studies with serial sampling, some case control studies whose results appeared useful as representing values in Canadian women (*e.g.*, breast cancer and organochlorine levels in breast tissue) or men (uranium in urine) or as "controls".

Systematic research in Canada has focussed on persistent organic contaminants in the North, and in particular, First Nations populations in circumpolar Canada. Limited work is published specifically on children's and women's exposures such as farm pesticides and organochlorines. Much work has been carried out on MeHg exposure dating back to 1970s, and synthesized in the 1990s. However, little was found by way of etiologic research looking into the measurement of actual health effects in the affected populations.

This report includes reliable information on markers of exposure to environmental contaminants in Canada. With few exceptions, information collated in this report could not be used to calculate "background levels" or "reference levels" because most of the measurements are not systematically collected on randomly selected members of the general population. Most are "hot spot" studies or specifically targetted to populations that are expected tohave the highest eanvironmental exposures. Given these limitations, some studies are not generalizable to the general Canadian population. Notwithstanding, the levels reported here can guide public health practitioners in the interpretation of values obtained in their selected populations and can be used in the communication of risks to local situations involving environmental contamination. "Background levels" of some contaminants (Cd, Se, Pb, Mn, MeHg) have been reported for large populations (Germany, US), and where applicable, were provided in this report.

Some important issues arose out of this review. Biomarkers of exposure are considered a reliable measure for tracking exposure to environmental contaminants in polulations. Very few studies in this database have used random sampling techniques to reflect the full range of overall population exposures. As a result, we do not have quantitative measures of population exposure to most contaminants. At best, studies used sample frames that reflected *a priori* populations at risk. Most often, sample frames were convenience samples. Serial analyses for contaminants in singular populations or in cohorts are not common, but are most useful in interpreting declines in contaminant

concentrations after interventions. The process of obtaining, storing, transporting, and analyzing biological specimens is complex. Studies require careful ethical oversight, and interpretation of results is not always meaningful for the participant. These appear to be major challenges for the conduct of these studies. The units of contaminant concentrations varied considerably, creating a challenge for comparison of values across studies. Units are reproduced here as reported in each publication. Conversion to a common unit such as SI, or as a function of creatinine in urine (where indicated), is not universally possible without additional information. In addition, the conversion of many results may lead to unanticipated errors. We therefore chose to leave the units as reported. Conversion factors are provided when they are standard, as for lead in blood.

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1.0 Introduction

"Systematic Review of Human Biomonitoring Studies of Environmental Contaminants in Canada" is carried out under contract to the National Collaborating Centre for Environmental Health (NCCEH) hosted by the British Columbia Centre for Disease Control ("the Centre"). The scope of activity for the NCCEH is environmental health, with environmental health being defined at least initially as environmental health services and programs delivered by regional and local health agencies across Canada.

Environmental health knowledge translation activities are expected to serve the needs of environmental health practitioners and policy makers. This review is in keeping with the Centre's mandate to provide information to policy makers and/or evidence-based practices for practitioners.

1.1 Structure of this report

Section 1 covers the background and context of this project, describes the contents and objectives of this report, and where they can be found within the report.

Section 2 gives a background to biomonitoring studies including rationale and uses.

Section 3 describes the approach and methodology, including data gathering, database design and data management.

Section 4 describes the results of the literature search, and the contaminant-specific findings.

Section 5 *identifies gaps and discusses strengths and limitations of this review.*

Section 6 provides summary comments.

1.2 Objectives and requirements of this project

In keeping with the general objectives of the National Collaborating Centre for Environmental Health, below are questions the NCCEH and responses needed to justify the current systematic review:

i. What is the environmental health practice or policy question to be answered?

> *What is the level of exposure in Canadians in specific populations to specific environmental contaminants of concern?*

ii. Why is this question relevant to environmental health practitioners/policymakers?

> *Environmental health practitioners and policy makers are often asked by distraught individuals about levels of contaminants found in their blood, urine, hair, breast milk, etc. A single reference manual of available information could be helpful to medical officers, public health nurses, public health inspectors, and others, in dealing with these issues with their publics. A systematic review of publications on biomonitoring will assist public heath practitioners in the interpretation of results.*

iii. How will environmental health practitioners/policymakers be involved in the project?

> *Environmental health practitioners and policy makers will serve as the key informants in this project. For example, epidemiologists from local health departments can very quickly identify gaps and chemicals of potential interest. They are also the end-users of this product; therefore, their input in the review process will make the end product relevant to the end users.*
>
> *In our earlier review, and subsequently, we interviewed 21 practitioners and researchers to gain information on work being carried, out, utility and gaps on human monitoring for environmental contaminants.*

iv. What is the project plan, including the search strategy and inclusion/exclusion criteria?

> *The proponents have already conducted an environmental scan of Biomonitoring Studies for Environmental Contaminants in Canada for Health Canada (Project #1000058381). The current project updates and extends the work done previously in order to address the research question: What is the level of exposure in Canadians in specific populations to specific environmental contaminants of concern?*
>
> *To achieve this goal, the proposed workplan for this project included three tasks:*
>
> *Update the literature search;*
> *Abstract data on biological levels of chemicals of interest; and,*
> *Report*

This report, therefore, carries out these tasks:

1. Searches the literature systematically for studies which report biological measurements of environmental contaminants in Canadian populations from 1990 to January 2007. (Section 3)

2. Identifies studies analysis according to *a priori* criteria paying particular attention to the contaminant, location of the population, biological medium evaluated, sampling methods for the population and the contaminant, laboratory methods, and validity of the results. (Section 3)

3. Reports synthesized information on biological markers of exposure to environmental contaminants in Canada (in the form of tables for each contaminant and population identified) to make the results of human biomonitoring for environmental contaminants in Canadian populations more accessible to Canadian public health practitioners. (Section 4)

2.0 Background on biomonitoring studies

Biological monitoring (or biomonitoring) is a continuous or repeated measurement of potentially toxic substances, their metabolites or their biochemical effects in tissues, in secreta, excreta, expired air or any combination of these. Its purpose is to evaluate occupational or environmental exposure and potential associated health risk by comparison with appropriate reference values based on knowledge of the probable relationship between ambient exposure and resultant adverse health effects. Biomonitoring could also be used to monitor trends, compare levels in different geographic areas or people. This report may more correctly be called a collection and assessment of studies of Canadian populations which have been tested at least once for a biological marker of exposure in any biological matrix. Them most common marker of exposure is the contaminant itself or its metabolite.

Chemicals enter the body through various pathways including ingestion, inhalation, and dermal contact, and may be excreted at various rates, some so slowly as to be essentially stored in the body. Others leave the body quickly without much metabolic transformation and most are somewhere in between. Once absorption has occurred, distribution, metabolic transformation, target tissue effects and excretion represent the areas where measurements can shed light on the life of chemicals absorbed into the body. Environmental sources include air, water, soil, and food; medications, personal care products, and therapeutic agents may also be important sources. Chemicals which only occur in industrial settings, if found in a human, may be attributed to a workplace or industrial emissions, or local contamination. Similarly, chemicals, which occur in children who have no occupational exposures, must be attributed to non-occupational ambient environmental sources such as foods or post natal breast milk intake or prenatal conditions. Except in exceptional circumstances, chemicals measured in the body are

generally not marked as to their source. Therefore, inferences about the source of exposure must be made from studies other than biomarkers, such as knowledge of the distribution of the chemical in the environment, potential pathways of exposure, determining the structural or physical characteristics of the chemical and relationship of a measurement in the body to measurements in the purported source. These activities can be conducted in isolation or as part of a risk assessment. The sources of environmental contaminants in Canada are generally known as are risk factors which render certain populations at risk (*e.g.*, fish eaters and exposure to PCBs).

2.1 Biomarkers

A biomarker is whatever measurable characteristic in a biological system reflects the interaction of the organism and environmental factors. Biomarkers are generally classified as those which reflect exposure, effect and susceptibility. Measurements of internal dose have dominated the field of environmental and occupational health insofar as laboratory methods have advanced greatly in quantifying very small amounts of chemicals in human tissues. These measures, along with knowledge of how the chemical is metabolized in the body, reflect internal dose and this in turn, have a relationship to risk of adverse effects. Exposure measures are therefore useful in determining integrated total exposure, reflect exposure interventions and forecast risk in populations especially when linked with other studies.

The usefulness of a biomarker depends on the specificity of the marker to the exposure, availability of an analytic method to detect the marker, time to appearance of the marker after exposure, persistence of the marker in the body, intra- and inter-person variability, and knowledge of the multiple factors affecting biological variability in the dose response relationship.

Accessibility of biological samples plays a strong role in choosing the matrix examined, and therefore some common biological samples used in environmental settings are blood (including cord blood), urine, breast milk, hair and nails, semen and saliva. Fat (adipose tissue or omental fat) and other internal tissues (liver, brain, kidney, bone and bone marrow) are less accessible for direct measurement as they require an invasive technique (i.e. biopsy or aspiration). Autopsies can provide opportunities for testing these internal tissues and thus be useful for environmental exposure measurement in the case of long term bioaccumulative contaminants, best tested in the tissue where it is stored. (i.e. Cd in kidney, Pb in bone, organochlorines in fat tissues).

Ease of acquisition or invasiveness in obtaining the biological sample plays a role in its availability, though not necessarily its usefulness. This must be considered in the interpretation of biomonitoring as a process: what is measured, what it means, and what its value for policy may be.

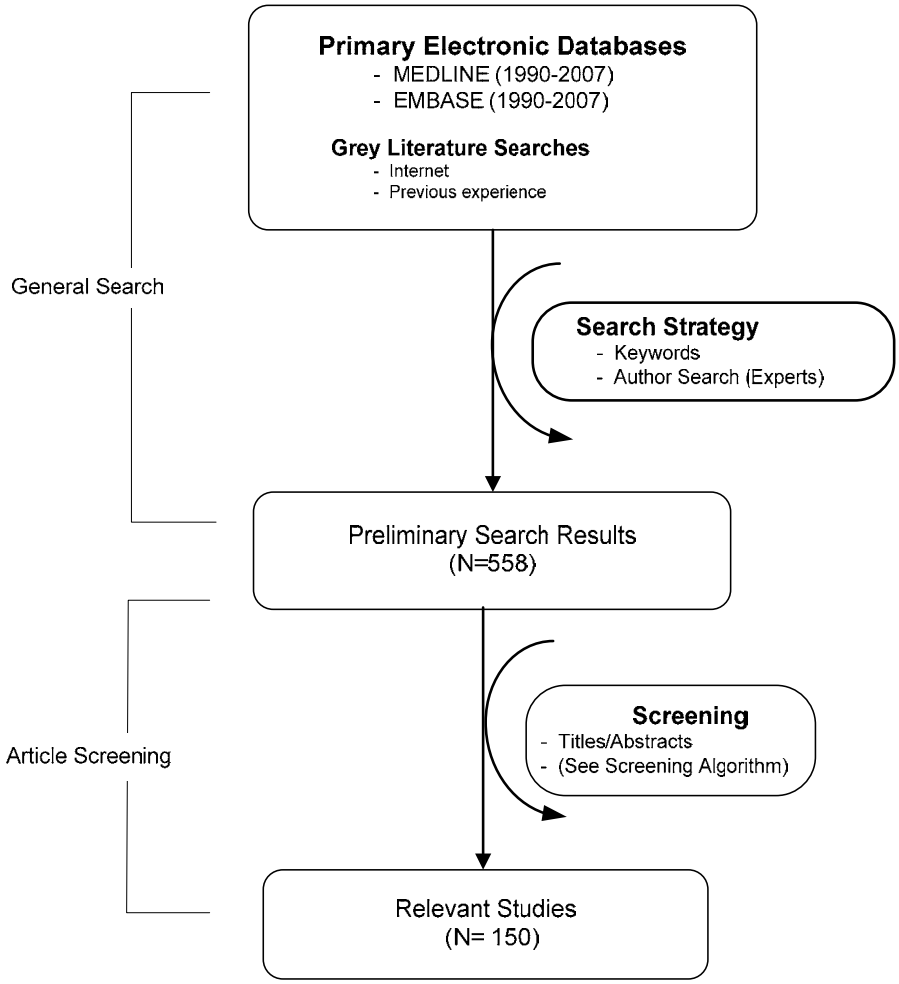
3.0 Approach and Methodology

The current review of studies on human biomonitoring for environmental contaminants in Canada took place between January and March 2007 extending a previous search made to January 2006. Experts were consulted extensively in the course of the previous review (N=16), and also during this review (N=5).

3.1 Electronic and other searches

The electronic literature search was conducted using two primary tools: 1) MEDLINE and EMBASE for published research of peer reviewed studies and 2) Internet searches of other types of documents (monographs, unpublished reports, scientific presentations, etc.). An overview of the search strategy is shown in Figure 3.1 below.

Figure 3.1: Overview of literature search strategy. (Screening algorithm is in section 3.1, Figure 3.2)



Index Medicus (US National Library of Medicine) and Excerpta Medica (Elsevier) are indexes of healthcare journals that are available in electronic forms as MEDLINE and EMBASE, respectively. These two bibliographic databases were selected since they index a vast number of journals published from different countries, therefore, providing a comprehensive overview of published literature. Furthermore, they can be searched electronically using standardized subject terms. The search strategy, including key words used, can be found in Appendix 2 (Search Strategy).

In addition to indexed databases, Internet searches were also necessary since not all biomonitoring reports are included on electronic bibliographic databases. Google™ web-based search engine was used to identify monographs, unpublished reports, and scientific presentations related to biomonitoring studies in Canada. An advanced search strategy was used using similar key words to that shown in Appendix 2.

In addition to electronic searches, back referencing of key papers and author search of key investigators were also conducted. These searches yielded additional studies that would otherwise be missed by using standardized subject terms alone. As a precaution, spot-checks were also conducted by the principal investigator for completeness doing specific searches using contaminant and author names.

There are likely many studies which have gathered some data on human exposure to environmental contaminants; however, these are not readily retrievable from our searches or other enquiries.

3.1.1 Screening for relevant studies

The title and abstract of all studies (N= 558) that were identified by electronic searches were screened by the principal investigator (LFS) who had the most experience in the area of biomonitoring studies. When relevance (the presence of contaminant levels in a Canadian population) could not be determined based on the information in the title/abstract alone, the full article of each of these studies was obtained and screened for this information. The following inclusion and exclusion criteria were used to identify potential relevant studies for review.

Inclusion Criteria:

- Studies published between January 1990 and January 2007 (18 years)
- Studies contained biomonitoring data for any environmental contaminant (i.e. contaminants enumerated in the search)
- Human biomonitoring studies of Canadian populations
- Studies contained data on Canadian populations
- Studies published in English or French

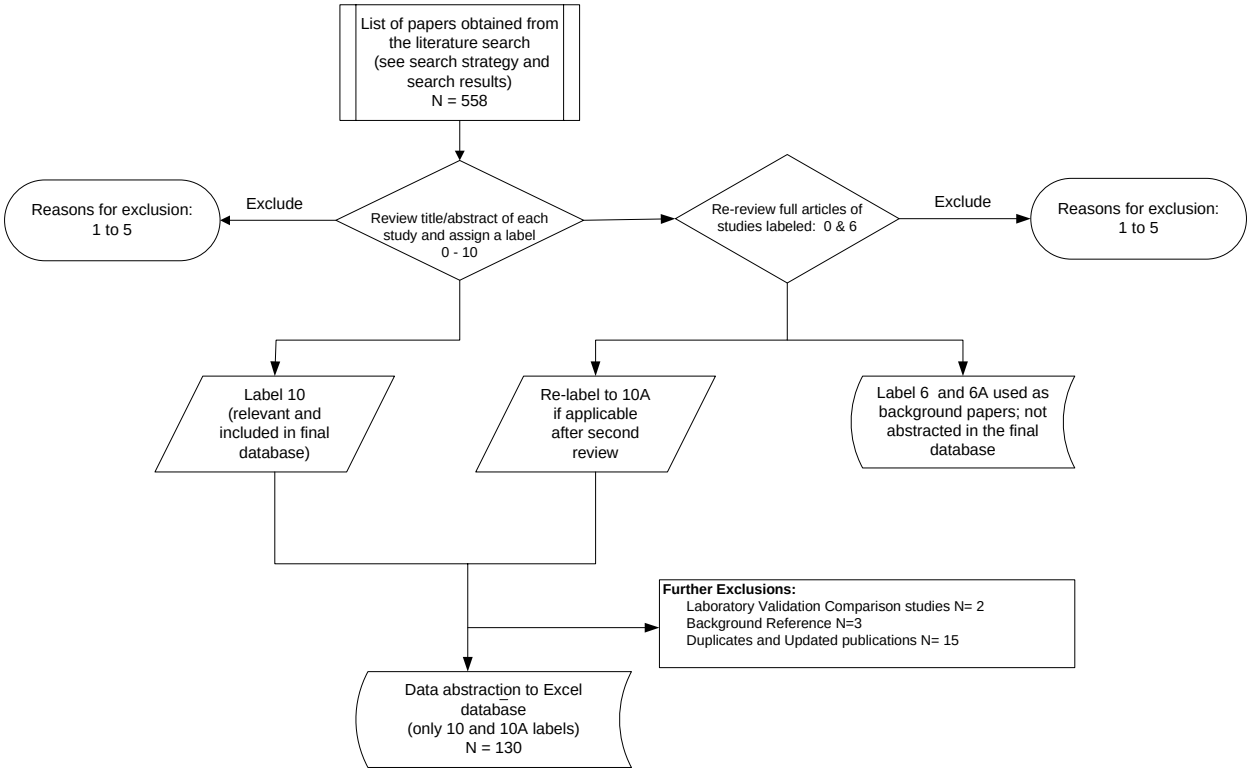
Exclusion Criteria:

- Not original studies (*e.g.*, review articles, editorial comments, letters, duplicate publications)

- Studies not published between 1990-January 2007
- Animal studies
- Studies exclusively focused on occupational exposures
- Studies not on Canadian populations
- Excluded cotinine (this report only)

Studies were assigned an identification number after they were considered potentially acceptable for abtstraction. To assign a label indicating relevance for the next step, an algorithm was used to systematically determine the relevance of each article that met the aforementioned inclusion and exclusion criteria. The algorithm assigns a coding from 0 to 10. Each label corresponds to an exclusion or inclusion criterion so that studies found on initial search are accounted for. All studies with a coding of 10 or 10A were then abstracted into an abstraction form which could be entered into an Excel database. A summary of the algorithm is shown in Figure 3.2 which follows. Of the 558 studies identified by the search strategy, 150 studies were retrieved for full review, and data from 130 studies were abstracted.

Figure 3.2: Screening algorithm for studies identified through searches.



Note: For explanations of codes 1-5, 6, 6A, 10, and 10A, please refer to adjacent text.

3.3 Data Abstraction

3.3.1 Electronic databases and data dictionaries

Two types of databases were created for two different purposes: 1) to keep track of the results electronic searches; and 2) to abstract detailed information from the study.

EndNote (Version 8.0) was used to keep track of all references for studies. Additional customized fields within EndNote were created to classified studies according to: 1) relevance, 2) source (*e.g.*, electronic search, author search, etc), and 3) status of article (*e.g.*, on order, received, electronic availability, etc.).

3.3.2 Data Abstraction

The authors of this report (LFS, MTD, and VP) carried out the detailed abstractions of data from identified relevant studies into a specially designed form. Double abstractions were carried out for a small sample of papers (N=10) to ensure that material was being abstracted consistently. Each form was imported into an Excel spreadsheet. Due to time and budget limitations, double abstraction for all studies was not possible. Readers are advised to refer to original publications referenced for more detail than is found in the collated data presented.

Information abstracted included[1]:

- Unique ID number
- First author*
- Year of publication*
- Study period
- Study design
- Geographic area
- Population studied*
- Age*
- Sex*
- Number of participants*
- Laboratory methods
- Limits of detection for each method
- Biological tissues/fluids*
- Contaminant *
- Contaminant concentrations* (as reported by authors)
- Unit of concentration*
- contaminant and method
- Study conclusions
- Comments from author
- Comments from abstractor

The data abstraction form (DAF) is in Appendix 3.

[1] * To make this report more manageable, only fields indicated with a (*) are reported in Tables in Section 4 of this report.

3.3.3 Screening of Literature Search Output

The literature search (Section 3.0) identified 558 publications using the keywords and databases referenced in Appendix 2.0 (Search Strategy). The citation parameters and the abstracts of these publications were imported into EndNote ™ Version 8.0. The 558 abstracts were screened and the publications were classified into relevance categories 0, 1, 2, 3, 4, 5, 6, and 10. Research Notes below summarizes the results of the screening processes and reasons for inclusions and exclusions. All zero-category papers were re-screened using the full article, resulting in additional articles identified as relevant to include in the database. Some label 10 or 10A papers reflected duplications of studies; duplicates were removed and the most recent publication was abstracted at the appropriate level of detail. Below is the complete coding algorithm used to determine the inclusion/exclusion of published articles after screening.

Research notes = key to why the study was included or excluded

0 (possible to include in data base as judged from title or abstract); read the full study to decide if it should be included (if to be included, re-label to new category - 10A or 6A, or to 1,2,3,4,5.
1 no human biomonitoring data for environmental contaminants presented
2 not a Canadian population (though it may have biomonitoring for environmental contaminants)
3 year does not qualify (i.e., published before 1990)
4 no environmental contaminant data presented
5 occupational with no environmental linkage
6 general study or review which may be relevant for writing the report and understanding the results of studies;
7 Not assigned
8 Not assigned
9 Not assigned
10 Included in compendium data base (as judged from the abstract or from full review of the report

4.0 Results of Biomonitoring Studies for Environmental Contaminants in Canada

One hundred and thirty biomonitoring studies were abstracted. Over the 18 years covered by the literature search, many chemicals and chemical classes were studied in the biological tissues of Canadian populations. Pb, PCBs, other organochlorines (OCs), and mercury (Hg), are the most commonly studied contaminants. The most commonly studied tissue is blood, whether cord, maternal, child, or adult. However, nails, placental tissue, hair and adipose tissue are also reported. The results are summarized in the respective sections below.

4.1 Lead (Pb)

Biological monitoring for Pb has been carried out in Canada since the 1970s when Health Canada initiated the only national survey of blood Pb levels in the population. There have been numerous surveys in selected populations since then, but not a Canadian national survey. Many surveys have not been published in peer reviewed literature but are available as reviewed documents, which have provided much information on Pb exposures in specific at risk and general populations across Canada.

The accepted matrix to measure Pb exposure in populations remains the blood, whether cord, venous or finger stick capillary sample. Finger stick and venous blood samples have a high degree of correlation; hence they are interchangeable for interpretation purposes provided that contamination risk from the finger stick sampling has been eliminated.

Laboratory methods for the analysis of Pb in blood have been standardized to detect very low concentrations of Pb (.1 µg/dl or .005 µmol/L). Generally two analytic methods are reported: graphite furnace AAS and ICPMS. Levels of detection are comparable, and the publications cited here report detection limits consistently. Bone lead can be measured by x-ray fluorescence, and this estimate of exposure is useful in epidemiologic studies relating lead exposure to health effects. However, the method is labor intensive and expensive compared to blood sampling and not useful for population screening purposes.

Three surveys have provided extensive population based data on children since 1990: Ontario (Smith et al. 1995), British Columbia (Jin et al. 1995), and Quebec (Levallois et al., 1991); one on adults (women in particular) (Smargiassi et al. 2002), Quebec (women) (Levallois et al., 1991). Only a few studies address strategic samples which may be generalizable to larger populations: children < 7 years (Smith et al. 1995, Jin et al. 1995, Decou et al. 2001), newborns (Koren 1990, Baldwin et al. 1999, Muckle et al. 2001, Smargiassi et al. 2002, St. Amour et al. 2006, Walker et al. 2006, and Direction toxicologie humaine, direction risques biologiques, environnementaux et occupationnelles, 2003); and pregnant women (Walker et al. 2006).Two larger studies were excluded because they were done prior to 1990 (Ontario 1984, Ontario 1987). Many studies of children residing near emissions sites have reported blood Pb from single surveys or serial surveys as part of a risk assessment (Hertzman 1991, Nova Scotia Health Authority 2001, New Brunswick Health and Wellness 2004 and 2005, in order to

track site-related exposures, remedial actions, and other interventions (Hilts 1992).

Recent surveys on newborns (cord blood and or maternal blood) have demonstrated the Pb levels are in the lower range <5 ug/dl (.48 umol/L) with geometric means below 2 ug/dl (.1 umol/L) (Rhainds 1993, Belle Isles 2002, St. Amour 2006).

One study (Despres et al. 2005) reported original research on health effects of environmental Pb exposures, with most surveys discussing epidemiologic studies carried out elsewhere (mostly the US) which link lead exposure and health effects. Gross motor development in Inuit preschool children exposed to Pb, PCBs, and Hg was not linked to prenatal exposures. However, significant associations were observed between blood Pb concentration at testing time and changes in reaction time, sway oscillations, alternating arm movements and action tremor (Despres et al. 2005).

Data on Pb exposure in Canada in children, pregnant or lactating women, newborns, and adults in specific communities do not represent a national perspective but do allow inferences to be made about exposure groups tested. Overall, the Canadian literature supports decreasing exposure to Pb as measured in blood Pb in many communities and special groups.

Although one can make inferences about the average blood lead level in Canadian children from the hot spot surveys reported, the national perspective on background blood Pb levels remains elusive without a national survey representative of all ages. One such survey is being carried out in 2008 (Canadian National Health Measures Survey). However, children <6 years will not be sampled. Cord blood samples and targeted samples of children generally in hot spots will remain the measure of Pb exposure to children for the foreseeable future to track real environmental exposure commitments to lead.

The tables below outline the values found in the publications included in this review. The units are reported here as they are reported in the original publication. Conversion factor is provided for lead.

Table 4.1: Lead (Pb) levels in biological samples (10 µg/dl = 100 µg/L= 0.48 µmol/L)
To convert µg/dl to µmol/L multiply by 0.048

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
St Amour et al. (2006)	Northern, QC	Mean: 5.4 (0.4)	NS	78	Blood	Mean, (SD)	0.2 (0.2)	µmol/L
						Range	0.1–1.8	µmol/L
		Newborn	NS	78	Cord Blood	Mean, (SD)	0.3 (0.2)	µmol/L
						Range	0.1–1.3	µmol/L
Walker et al. (2006)	Arctic, Canada	NS	F	385	Blood	GM	26.7	µg/L
						Mean	33.6	µg/L
						Range	2.07 - 178	µg/L
Despres et al. (2005)	Northern, QC	10 – 6	M & F	110	Blood	GM (SD)	4.1 (5)	µg/dl
						Mean	5.4	µg/dl
						Range	1.0 – 37.1	µg/dl
New Brunswick Health (2005)	Rural, NB (All areas)	Adult	F (Pregnant)	7	Blood	GM (SD)	0.66 (0.17)	µg/dl
	Rural, NB (Closest to smelter)	1 – 5	M & F	16	Blood	GM (SD)	1.91 (0.92)	µg/dl
						Range	0.68 - 3.69	µg/dl
	Rural, NB (closest to smelter)	1 – 5	M & F	4	Blood	GM (SD)	1.83 (0.75)	µg/dl
						Range	1.18 - 2.80	µg/dl
	Rural, NB (More distant from smelter)	1 – 5	M & F	12	Blood	GM (SD)	1.55 (0.42)	µg/dl
						Range	0.81 - 2.20	µg/dl
	Rural, NB (Most distant from smelter)	1 – 5	M & F	15	Blood	GM (SD)	1.45 (0.55)	µg/dl
						Range	0.31 - 2.45	µg/dl
Bussières et al. (2004)	Cree, QC (Controls, assumed background not affected by site contamination)	Mean 11.2 (Range: 8-14)	M & F	11	Blood	GM (95% CI)	0.085 (0.068-0.107)	µmol/L
	Cree, QC (Exposed)	Mean 10.6 (Range: 8-14)	M & F	21	Blood	GM (95% CI)	0.097 (0.067-0.139)	µmol/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
Lucas et al. (2004)	Northern Community, QC	NA	NS	439	Cord Blood	GM (95% CI)	0.19 (0.18-0.21)	µmol/L
	Southern Community, QC	NA	NS	29	Cord Blood	GM (95% CI)	0.08 (0.07-0.10)	µmol/L
New Brunswick Health (2004)	Rural, NB (Finger prick method)	3 – 5	M & F	10	Blood	GM	0.17	µmol/L
		3 – 15	M & F	23	Blood	GM	0.14	µmol/L
Dellaire et al. (2003)	Northern, QC	Newborns (mothers age 23.5(4.5))	M(52%) F(48%)	238	Cord Blood	Mean	8.2	% decrease
Dellaire et al. (2003)						Range	(3.5-12.5)	% decrease
Smargiassi et al. (2002)	Urban, QC	29.27 (5.02)	F	100	Blood	Mean (SD)	2.1 (1.7)	µg/dl
		NS	NS	NS	Cord Blood	Mean (SD)	1.7 (1.7)	µg/dl
Belles-Isles et al. (2002)	Coastal Community, NF	23.9 (5.6)	F	48	Cord Blood	GM (95% CI)	79 (67-92)	nmol/L
						Range	<50-480	nmol/L
	Urban, QC	26.9 (3.8)	F	60	Cord Blood	GM (95% CI)	64 (59-71)	nmol/L
						Range	<50-220	nmol/L
Nadon et al. (2002)	Urban, QC	< 45	M	17	Blood	Mean (SD)	47.91 (22.45)	µg/L
				17		GM	42.99	ug/L
Nadon et al. (2002)	Urban, QC	< 45	F	8	Blood	Mean (SD)	24.8 (8.66)	µg/L
				8		GM	23.64	µg/L
Audette et al. (2001)	Urban, AB	>21	M & F	102	Blood	Median	0.11	µmol/L
						Range	<.05 – 0.50	µmol/L
		1 - 6	M & F	54	Blood	Median	0.11	µmol/L
						Range	<.05 – 0.20	µmol/L
		7 - 12	M & F	40	Blood	Median	0.07	µmol/L
						Range	<.05 – 0.24	µmol/L
		12 - 21	M & F	35	Blood	Median	0.08	µmol/L
						Range	<.05 – 0.26	µmol/L
Dewailly et al.(2001)	Northern, QC	35	M & F	209 & 283	Blood	GM	0.42	nmol/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
						Mean	0.49	nmol/L
						Range	0.4 – 2.28	nmol/L
	Northern, QC	35	F	283	Blood	GM	0.38	nmol/L
	Northern, QC	35.7	M	209	Blood	GM	0.48	nmol/L
Muckle et al. (2001)	Northern Community, QC	NS	NA	95	Cord Blood	GM	0.2	µmol/L
						Mean (SD)	0.2 (2.0)	µmol/L
						Range	0.0-0.9	µmol/L
New Brunswick Health (2001)	Urban, NS (Exposed)	All	M & F	372	Blood	GM	1.88	µg/dL
						Mean	2.22	µg/dL
						Median	1.87	µg/dL
						Range	0.41 - 15.33	µg/dL
New Brunswick Health (2001)	Urban, NS (Exposed)	1- 5	M & F	186	Blood	GM	1.96	µg/dL
						Mean	2.18	µg/dL
						Median	1.87	µg/dL
						Range	0.62 8.70	µg/dL
New Brunswick Health (2001)	Urban, NS (Non-exposed)	All	M & F	37	Blood	GM	1.77	µg/dL
						Mean	2.1	µg/dL
						Median	1.66	µg/dL
						Range	0.62 - 8.91	µg/dL
New Brunswick Health (2001)	Urban, NS (Non-exposed)	1- 5	M & F	14	Blood	GM	1.51	µg/dL
						Mean	1.61	µg/dL
						Median	1.35	µg/dL
						Range	1.04- 3.12	µg/dL
Ellis et al. (2000)	Urban, ON (All)	0 – 3	M & F	147	Blood	GM	0.091	µmol/L
						Mean	0.116	µmol/L
						Range	.04 - .58	µmol/L
Ellis et al. (2000)	Urban, ON (All)	4 – 6	M & F	145	Blood	GM	0.08	µmol/L
						Mean	NS	µmol/L
						Range	0.04 – 0.32	µmol/L
Ellis et al. (2000)	Urban, ON (All)	0 – 6	M & F	292	Blood	GM	0.09	µmol/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
						Mean	0.113	µmol/L
						Range	0.04 – 0.76	µmol/L
Ellis et al. (2000)	Urban, ON	4 – 6	M & F	145	Blood	GM	0.09	µmol/L
						Mean	0.11	µmol/L
						Range	0.04 – 0.76	µmol/L
Ellis et al. (2000)	Urban, ON (Exposed without mine tailings)	4 – 6	M & F	31	Blood	GM	0.1	µmol/L
Ellis et al. (2000)						Mean	0.095	µmol/L
Ellis et al. (2000)						Range	0.04 – 0.20	µmol/L
Ellis et al. (2000)	Urban, ON (Exposed with mine tailings)	4 – 6	M & F	26	Blood	GM	0.09	µmol/L
						Mean	0.12	µmol/L
						Range	0.04 – 0.51	µmol/L
Ellis et al. (2000)	Urban, ON (Non- Exposed without mine tailings)	4 – 6	M & F	24	Blood	GM	0.09	µmol/L
Ellis et al. (2000)						Mean	0.095	µmol/L
Ellis et al. (2000)						Range	0.04 – 0.32	µmol/L
Ellis et al. (2000)	Urban, ON (Non- Exposed with mine tailings)	4 – 6	M & F	15	Blood	GM	0.08	µmol/L
Ellis et al. (2000)						Mean	0.14	µmol/L
Ellis et al. (2000)						Range	0.04 – 0.72	µmol/L
Baldwin et al. (1999)	Rural, QC	20-69	M & F	294	Serum	GM	3.25	µg/L
						Mean	3.67	µg/L
						Range	Nd-19.25	µg/L
Baldwin et al. (1999)	Rural, QC	20-69	F	156	Blood	GM	2.71	µg/L
						Mean	3.01	µg/L
						Range	Nd-9.74	µg/L
Baldwin et al. (1999)	Rural, QC	20-69	M	138	Blood	GM	3.98	µg/L
						Mean	4.43	µg/L
						Range	Nd-19.25	µg/L
Rhainds et al. (1999)	Urban, QC	newborn	M & F	1109	Cord Blood	GM (95% CI)	0.076 (.074 - 0.079)	µmol/L
Mergler et al. (1998)	Coastal residence/QC (Fish eaters)	20-69	NA	306	Blood	Mean (SD)	4.4(2.7)	µg/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
	Coastal residence/QC (Non-fish eaters)	20-69	NA	306	Blood	Mean (SD)	3.1(1.0)	µg/L
Alder et al. (1996)	Urban, ON	NS- children	M & F	164	Blood	GM	4.7	µg/dl
Goulet et al. (1996)	Urban, QC	6 months – 10 years	M & F	101	Blood	GM	5	µg/dl
Jin et al. (1995)	Urban, BC	24 – 36 months	M & F	172	Blood	% ≥.48 µmol/ l	8	
						GM (SD)	.26 (1.6)	µmol/ l
Smith et al. (1995)	Rural, ON	1-6	M & F	395	Blood	Mean	3.91	µg/dl
	Rural, ON	6	M & F	78	Blood	GM	2.96	µg/dl
						Mean	3.73	µg/dl
Smith et al. (1995)	Rural, ON	5	M & F	71	Blood	GM	3.51	µg/dl
						Mean	4.28	µg/dl
	Rural, ON	4	M & F	67	Blood	GM	2.55	µg/dl
						Mean	3.47	µg/dl
	Rural, ON	3	M & F	63	Blood	GM	3.07	µg/dl
						Mean	3.61	µg/dl
	Rural, ON	1	M & F	59	Blood	GM	3.03	µg/dl
						Mean	3.62	µg/dl
	Rural, ON	2	M & F	57	Blood	GM	3.76	µg/dl
						Mean	4.87	µg/dl
Gagne et al. (1994)	Urban, QC	NA	NA	NA	Blood	GM	7	µg/dl
Kosatsky et al. (1994)	Urban, QC	NS	M	28	Blood	GM (95 % CI)	0.29 (0.25-0.35)	µmol/L
			F	24	Blood	GM (95 % CI)	0.24 (0.20-0.28)	µmol/L
Gagne et al. (1993)	Urban, QC	NA	NA	NA	Blood	GM	11.1	µg/dl
Rhainds et al. (1993)	Urban, ON	newborns	M & F	823	Cord Blood	GM (95% CI)	0.094 (.088-0.099)	µmol/L
Hilts et al. (1992)	Urban, BC	6 – 60 months	M & F	vary with year of samplin g LS	Blood	Mean	5.9	µg/dl

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
		24 – 72 months	M & F	vary with year of samplin g	Blood	Mean	14.2	µg/dl
		6 – 60 months	M & F	vary with year of samplin g	Blood	Mean	11.9	µg/dl
ON Ministry of Env (1992)	Urban, ON	4 – 6	M & F	Not stated	Blood	% at above 0.48 µmol/L	7	
	Urban, ON	4 – 6	M & F	Not stated	Blood	Geometric Mean	0.19	µmol/L
	Urban, ON	4 – 6	M & F	227	Blood	% at or above 0.48 µmol/L	4	
	Urban, ON	4 – 6	M & F	227	Blood	GM	0.17	µmol/L
Hertzman et al. (1991)	Urban, BC	NS	M & F	vary with yr of sampling	Blood	GM	13.8	µg/dl
						Range	4 to 30	µg/dl
Levallois et al. (1991)	Urban, QC (High exposure area)	Ages 0 - 5 yrs	M & F	NS	Blood	GM	0.49	µmol/L
	Urban, QC (Medium exposure area)	Ages 0 - 5 yrs	M & F	NS	Blood	GM	0.35	µmol/L
	Urban, QC (Low exposure area)	Ages 0 - 5 yrs	M & F	NS	Blood	GM	0.28	µmol/L
	Urban, QC (Pregnant women)	NS	F	NS	Blood	Range	0.13 - 0.15	µmol/L
Koren et al. (1990)	Urban, ON (Pregnant women)	Adult	F	95	Blood	0.99	< 0.34	µmol/L
	Urban, ON	Neonates	M & F	95	Blood	0.99	< 0.34	µmol/L
	Urban, ON	Neonates	M & F	95	Blood	11/95	< 0.01	µmol/L

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); umol/L (micro-mole per litre); ug/dl (micro-gram per deciliter)

4.2 Arsenic (As)

In Canada, published reports of biological monitoring for As are not prominent until the 1990s when laboratory analytic methods for As in urine were developed at sufficiently low level of detection to reflect current environmental exposure. Blood and hair analysis were and are carried out frequently in clinical and environmental settings. Hair As is useful as a confirmatory feature in chronic high exposure and in As poisoning provided external contamination by As can be excluded. Arsenic in hair cannot distinguish external contamination from As derived from ingestion (Hindmarsh 2002). Arsenic has a very short half life in blood, hence blood As levels are transitory; urine levels reflect longer term (about two weeks), and are useful for monitoring ongoing environmental exposure.

Laboratory methods for the analysis of As in blood have been standardized to detect very low concentrations of inorganic As and its organic metabolites, as well as total As. The method generally used now is ICPMS with detection limits of 0.007 umol/L (0.5 ug/L). One study reports use of graphite furnace AAS but no detection limit is included (Kosatsky et al. 1999).

Arsenic in urine has been reported in Canada in only three provinces, Ontario (OMOE 1999, Goss Gilroy Inc. 2001, Goss Gilroy Inc. 2005), Quebec (Bussières et al. 2004, Kosatsky et al. 1999), and Nova Scotia (Nova Scotia Department of Health 2001).

Only three reports included unexposed "control" populations (Do et al. in press), a Northern Ontario community with little to no documented environmental exposure from air, soil or water, Bussières et al. 2004 (Cree in Québec) and Kosatsky et al. 1999 (Montréal community) .

Levels of inorganic As in urine have been demonstrated to be essentially the same in means and distributions in several communities with As in soil as in those communities without (OMOE 1999, Goss Gilroy Inc. 2001, Goss Gilroy Inc. 2005, Kosatsky et al. 1999, Bussières et al. 2004).

No study reported original research on health effects of environmental As exposures in Canada. Surveys used comparison populations without unusual exposures. "Population reference values" were derived for As in urine for children (*e.g.* 15 ug/l) (Wilhelm et al. 2006), based on German Environmental Survey results for 95th percentile. The US Survey of Exposure to Environmental Contaminants (2005) does not cover urinary arsenic. No figures are available for the Canadian population as a whole.

Canadian studies report urinary As in different ways, as concentration units per gram of creatinine or as concentration units per liter of urine. For population studies, adjustment for creatinine may not be necessary if means and distributions are presented for the purpose of characterizing the population or making correlations with environmental media such as water concentrations. Conversion of values from the literature is not straightforward and adjustment for creatinine or for specific gravity must be done carefully if used in the analysis of relationships with environmental media (Barr et al

2005; Gamble et al 2005. Values are reported in the tables as in the original publications.

Notwithstanding, inorganic As levels on average do not exceed 8 ug/L urine (14 ug/gram creatinine) (Kosatsky et al. 1999, Nova Scotia Department of Health 2001) while total As will depend on recent fish consumption and can be many times higher than inorganic As (Kosatsky et al. 1999). Normative levels reported from Quebec are: serum (GM 0.24 µmol/L; 95% CI 0.1-3.9 µmol/L adjusted for specific gravity on a sample of 318 persons from various areas of Quebec). The Quebec normative study does not suggest a value for blood or serum non alimentary arsenic; the suggested reference value for non-alimentary arsenic in urine is 0.1 - 0.38 µmol/l (95% limits). The values for total arsenic are 0.1 – 3.9 µmol/l (95% limits). (Direction toxicologie humaine, direction risques biologiques, environnementaux et occupationnelles. 2003).

The national perspective on As levels in urine (as with Pb in blood) remains elusive without a national survey representative of all ages. One such survey is being implemented in 2007-2008 (Canadian National Health Measures Survey) (Personal communication. D. Haines, Health Canada, December 2007). However, children <6 years will not be sampled. Nova Scotia Health (2001) and Do et al. (in press) report urine As in 179 and 35 children ages 0 – 5 years respectively, which to date, are the only large groups of children (including toddlers) so reported for As in urine. The results of these surveys can be seen in the tables below.

Table 4.2: Arsenic (As) levels in biological samples

First Authors (Year)	Population	Age	Sex	N	AS Type	Biological Sample	Measure	Concentration (units)[2]	
Goss Gilroy Inc (2005) Ref: Do et al. in press 2008	Rural, ON (Non-exposed)	0-5	M & F	17	AsI	Urine	Mean (SD)	7.53 (3.69)	µg/L
							Median	6.74	µg/L
							Range	2.25-15.73	µg/L
							GM	6.64	µg/L
	Rural, ON (Non-exposed)	6-12	M & F	61	AsI	Urine	Mean (SD)	9.30 (6.24)	µg/L
							Median	7.49	µg/L
							Range	3-38.20	µg/L
							GM	7.94	µg/L
	Rural, ON (Non-exposed)	13-17	M & F	17	AsI	Urine	Mean (SD)	7.89 (4.18)	µg/L
							Median	6.74	µg/L
							Range	3.75-17.23	µg/L
							GM	6.99	µg/L
	Rural, ON (Non-exposed)	18+	M & F	226	AsI	Urine	Mean (SD)	6.54 (5.56)	µg/L
							Median	5.24	µg/L
							Range	1.50-67.41	µg/L
							GM	5.48	µg/L
	Rural, ON (Non-exposed)	All	M & F	321	AsI	Urine	Mean (SD)	7.19 (5.63)	µg/L
							Median	5.99	µg/L
							Range	1.50-67.4	µg/L
							GM	6.02	µg/L

[2] Arsenic concentration in urine cannot be converted to concentration per gram of creatinine unless individual values of creatinine are provided.

First Authors (Year)	Population	Age	Sex	N	AS Type	Biological Sample	Measure	Concentration (units)[2]	
Goss Gilroy Inc (2005) Ref. Do et al. in press. 2008	Rural, ON (Exposed)	0-5	M & F	18	AsI	Urine	Mean (SD)	8.66(4.65)	µg/L
							Median	8.23	µg/L
							Range	2.25-20.22	µg/L
							GM	7.5	µg/L
	Rural, ON (Exposed)	6-12	M & F	53	AsI	Urine	Mean (SD)	9.51 (6.45)	µg/L
							Median	8.24	µg/L
							Range	2.25-32.96	µg/L
							GM	8.04	µg/L
Goss Gilroy Inc (2005) Ref. Do et al. in press 2008	Rural, ON (Exposed)	13-17	M & F	29	AsI	Urine	Mean (SD)	7.77 (4.32)	µg/L
							Median	7.49	µg/L
							Range	3-26.96	µg/L
							GM	7.03	µg/L
	Rural, ON (Exposed)	18+	M & F	269	AsI	Urine	Mean (SD)	6.46 (3.87)	µg/L
							Median	5.99	µg/L
							Range	1.50-32.21	µg/L
							GM	5.62	µg/L
	Rural, ON (Exposed)	All	M & F	369	AsI	Urine	Mean (SD)	7.11 (4.53)	µg/L
							Median	5.99	µg/L
							Range	1.50-32.96	µg/L
							GM	6.10	µg/L
Bussières et al. (2004)	Cree, QC (Non-exposed)	Mean (11.2), Range (8-14)	M & F	11	As	Urine	GM	0.085	µmol/gm creatinine
	Cree, QC (Exposed)	Mean (10.6), Range (8-14)	M & F	21	As	Urine	GM	0.067 (0.052-0.088)	µmol/gm creatinine
Goss Gilroy Inc (2001)	Rural, ON	< 13	M & F	44	AsI	Urine	Mean (SD)	10.44 (6.57)	µg/L
							Median	8.77	µg/L
							Range	.90 - 24.60	µg/L
Goss Gilroy Inc (2001)	Rural, ON	14 - 19	M & F	18	AsI	Urine	Mean (SD)	7.34 (3.59)	µg/L

First Authors (Year)	Population	Age	Sex	N	AS Type	Biological Sample	Measure	Concentration (units)[2]	
							Median	6.09	µg/L
							Range	2.90– 14.53	µg/L
Goss Gilroy Inc (2001)	Rural, ON	>20	M & F	184	AsI	Urine	Mean (SD)	9.97 (10.74)	µg/L
							Median	7.25	µg/L
							Range	.9 - 94.27	µg/L
Nova Scotia Health (2001)	Urban, NS (Non-exposed, Tar Ponds)	1- 5	M & F	14	As	Urine	Mean	3.85	µg/L
							GM	3.43	µg/L
							Median	3.75	µg/L
							Range	0.75 - 6.74	µg/L
Nova Scotia Health (2001)	Urban, NS (Non-exposed, Tar Ponds)	0 – 6	M & F	35	As	Urine	Mean	5.59	µg/L
							GM	4.65	µg/L
							Median	5.24	µg/L
							Range	0.75 - 14.98	µg/L
Nova Scotia Health (2001)	Urban, NS (Exposed, Tar Ponds)	1- 5	M & F	179	As	Urine	Mean	6.6	µg/L
							GM	3.75	µg/L
							Median	3.75	µg/L
							Range	0.75 - 71.16	µg/L
Nova Scotia Health (2001)	Urban, NS (Exposed, Tar Ponds)	All	M & F	372	As	Urine	Mean	6.4	µg/L
							GM	4.11	µg/L
							Median	4.49	µg/L
							Range	0.75 - 71.16	µg/L
Kosatsky et al. (1999)	Urban, QC (Bangladeshi)	Median (34), Range (28 – 41)	M	9	AsI	Urine	Median	26.7	µg/gm creatinine
					AsT	Urine	Median	54.8	µg/gm creatinine
Kosatsky et al. (1999)	Urban, QC	NS	25	25	AsI	Urine	NA	NA	µg/gm creatinine
					AsT	Urine	NA	NA	µg/gm creatinine
Kosatsky et al. (1999)	Urban, QC (Vietnamese)	Median (30) Range (27 – 70)	M & F	3 & 6	AsI	Urine	Median	14	µg/gm creatinine
					AsT	Urine	Median	39.7	µg/gm creatinine

First Authors (Year)	Population	Age	Sex	N	AS Type	Biological Sample	Measure	Concentration (units)[2]	
Ontario Ministry of Env (1999)	Rural, ON (Non-exposed to mine tailings) "controls"	All	M& F	53	As	Urine	GM (SD)	4.57 (3.98)	µg/L
							Range	3 - 19	µg/L
Ontario Ministry of Env (1999)	Rural, ON (Exposed to mine tailings)	All	M & F	121	As	Urine	GM (SD)	4.36 (4.0)	µg/L
							Range	3 - 23	µg/L

Note: As (Arsenic); AsI (Inorganic Arsenic); AsT (Total Arsenic); M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter)

4.3 Mercury (Hg)

Biological monitoring for mercury in Canadian populations dates back to the 1970s. At that time, contamination from industrial sources (pulp and paper mills) and mobilization of geological mercury because of acid deposition provided increased loads of inorganic mercury to lake and river sediments. Methylation of mercury to methylmercury by microorganisms within sediments and biomagnification through the food chain produced high mercury levels in edible fresh water fish species. Mercury levels in fish eating and fish-dependent populations in Canada became a cause of concern because of the demonstrated neurotoxicity of methylmercury.

Exposure to methylmercury in aboriginal fish-dependent populations have been examined as part of ongoing surveillance by Health Canada (Wheatley et al. 1998), as part of examination of potential hazard (Mahaffey et al. 1998, Cole et al. 2004) and interventions in changing diet, and as part of studies to examine the effects of increased methylmercury intake (Beuter et al. 2004, Despres et al. 2005, St. Amour et al. 2006) and of determining risk factors for increased exposure (Muckle et al. 1998).

Hair and blood are the matrices of choice to examine methylmercury exposure. Urine is the preferred matrix for inorganic mercury, although hair can be used for historical reconstruction of exposure. Studies of hair mercury (in centimeter segments) are able to trace exposures longitudinally as mercury is deposited in hair as it grows, at an estimated average rate of one centimeter a month. Analysis of long hair, centimeter by centimeter, can reconstruct exposure for a year or longer. Hence, many studies examine hair either scalp end 1 cm (for current exposure), or longitudinally in segments, for historical reconstruction of exposure.

Mercury exposure (blood and hair) has been studied in coastal and Arctic aboriginal communities, urban sportfishers, fisheaters and non fisheaters, women of childbearing age, nursing women, cord blood, and infants.

Among Canadian populations, the Inuit of Nunavik and the NWT exhibited the highest exposure to methylmercury (Muckle et al. 1998. Fish and seal meat consumption was associated with increased Hg concentrations in hair (Muckle et al. 2001).

Mean total mercury has been shown to increase with age in both sexes in Arctic communities. Older ages >45 had 2.7 times higher total mercury than younger age groups < 25 (Dewailly et al. 2001).

Mercury levels in the Cree of James Bay have decreased in the recent past. Nevertheless, this decrease in mercury levels may not be permanent and some authors state that this decrease does not necessarily imply that the problem of increased exposure is resolved (Dumont et al.1998).

Low Hg intakes and body burden in New Brunswick coastal communities can be attributed to the low Hg levels found in the species commonly consumed: haddock,

canned tuna, lobster, and pollock (all below 0.2 mg/g wet weight). The results showed that Hg exposure in these Canadian coastal communities is low; fish with higher levels of Hg (shark, tuna, swordfish, pickerel, and bass) are not consumed locally (Legrand et al. 2004).

In Ontario, a recent study shows that two broad country-of-origin fish eaters, Euro-Canadians (EC) and Asian-Canadians (AC) EC in areas of concern (AOC), consumed a median of 174 total fish meals/year and had a geometric mean total mercury level of 2.0 mg/L. Corresponding AC figures were 325 total fish meals/year and 7.9 mg/L (Cole et al. 2004).

Few Montreal-area women, of childbearing age consume local sport fish frequently or for extended periods. However, among the small proportion that consumes sport fish frequently or for extended periods, blood mercury concentrations approach levels of concern for fetal protection (Nadon et al. 2002).

The subtle differences in motor performance detected in one preliminary study suggest that further work is warranted to determine whether the differences can be unambiguously associated with exposure to MeHg from fresh water fish (Beuter et al. 1999).

Among studies of health effects in methylmercury exposed Canadian populations, tremor amplitude was related to blood Hg concentrations at testing time, which corroborate an effect already reported among adults (Despres et al. 2005).

Newborn cord lymphocyte studies show that subtle functional alterations of the developing human immune system may result from in utero exposure to OCs and mercury. However, the effect of OCs could not be distinguished from the effect of methylmercury. The authors state that more epidemiological studies are needed to determine the relevance of these alterations in predicting detrimental health effects in the developing child (Belle Isles et al. 2002).

Similarly, chronic exposure to PCBs and MeHg (measured at birth) on was associated with alterations of VEP responses in Inuit children from Nunavik (St. Amour 2006).

On the other hand, Vancouver immigrant children eating imported fish may be considered at increased risk of neurotoxicity caused by Hg exposure from fish as increased levels of meHg were demonstrated in some children in the Chinese community (Innis 2006).

Mercury exposure from dental amalgam and fish eating in children was studied by Levy et al. 2004. Urinary inorganic Hg (UHg) in 60 children aged 4–8 years old revealed that children with amalgam fillings had significantly higher UHg levels than children without amalgams (GM=1.412 mg Hg/g versus 0.436 mg Hg/g). Subjects with reported higher fish consumption also had significantly higher Hug (P ¼ 0:004). After adjusting for fish consumption, the authors found that amalgam fillings lead to increased odds of high

urinary Hg in children (Levy et al. 2004).

During1993 to 1995, Rhainds et al. (1999) carried out a survey in 10 hospitals located in southern Quebec. They observed a statistically significant relationship between maternal age and cord blood concentrations of Hg. The cord blood concentrations of Hg (as well as Pb, Hg, polychlorinated biphenyls, and dichlorodiphenyl dichloroethylene) measured in this study were the lowest levels recently reported in industrialized countries (Rhainds et al. 1999). Nunavik cord blood Hg levels remain much higher (Lucas et al. 2004).

In summary, MeHg from fish has been demonstrated to be high in all fish eating populations. Most at risk of exposure are fish dependent communities in Arctic Canada and some coastal communities, as well as some select immigrant groups who fish for food and recreation or eat imported fish as a cultural preference. Neurotoxic effects of MeHg exposure have been suggested in several Canadian studies. Advisories to limit fish consumption have had some impact in lowering Hg levels in blood. Currently, cord blood Hg has been shown to be very low. Given the nutritional and social benefits of fish consumption, prudent species and location choices have been suggested to some populations where possible to do so (Cole et al. 2004).

The normative study from Quebec found that urinary values in a sample of 316 Quebec residents was 5.2 nmol/L (95% CI <1-45.3 nmol/L) (Direction toxicologie humaine, direction risques biologiques, environnementaux et occupationnelles. 2003). Wilhelm reports background levels for blood mercury in the non-fish eating German population: 2.0 ± 1.8 nmol/L (10 ± 9.0 nmol/L). The US reports blood Hg in children ages 1– 5 years [2.30 (1.20-3.50)] µg/L (CDC 2005.) Results for other ages, both sexes, and ethinicty are also presented. The Quebec normative study suggested normal range for mercury in urine is 1 – 45 nmol/L and for whole blood <1 – 16 nmol/L (95% limits).) (Direction toxicologie humaine, direction risques biologiques, environnementaux et occupationnelles. 2003).

Table 3: Mercury (Hg) levels in biological samples
1 µg/L = ppb = .001 ppm = 100 ng/L

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
Innis et al. (2006)	Urban, BC (Caucasians)	NS	NS	56	Hg	Blood	Median	0.9	nmol/L
							Range	0.0–18.1	nmol/L
							5th-95th per	0.0 - 9.8	nmol/L
Innis et al. (2006)	Urban, BC (Chinese)	NS	NS	68	Hg	Blood	Median	10.7	nmol/L
							Range	0.5–67.9	nmol/L
							5th-95th per	1.98 - 47.0	nmol/L
Innis et al. (2006)	Urban, BC (Other)	NS	NS	72	Hg	Blood	Median	3.5	nmol/L
							Range	0.0–13.1	nmol/L
							5th-95th per	0.0 - 10.8	nmol/L
Innis et al. (2006)	Urban, BC (All children)	NS	NS	201	Hg	Blood	Mean (SD)	7.8 (11)	nmol/L
							Median	4.6	nmol/L
							Range	0.00–67.9	nmol/L
							5th-95thper	0.0 - 36.0	nmol/L
St Amour et al. (2006)	Northern, QC	Mean (SD): 5.4 (0.4)	NS	78	Hg	Blood	GM (95%CI)	29.50 (22.70–38.40)	nmol/L
							Mean (SD)	49.30 (45.50)	nmol/L
							Range	1.00–191.00	nmol/L
St Amour et al. (2006)	Northern, QC	Newborn	NS	78	Hg	Cord Blood	GM (95%CI)	82.40 (67.00–101.50)	nmol/L
							Mean (SD)	119.30 (101.50)	nmol/L
							Range	9.00–520.00	nmol/L
Walker et al. (2006)	Arctic, Canada (Kivalliq)	NS	F	17	HgI	Blood	Mean (SD)	1.02 (0.59)	µg/L
							GM (SD)	0.81 (1.04)	µg/L
							Range	ND - 2.20	µg/L
	Arctic, Canada (Baffin)	NS	F	31	HgI	Blood	Mean (SD)	1.68 (1.02)	µg/L

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
							GM (SD)	1.39 (1.45)	µg/L
							Range	ND - 4.61	µg/L
Walker et al. (2006)	Arctic, Canada (Inuvik)	NS	F	31	HgI	Blood	Mean (SD)	0.79 (0.65)	µg/L
							GM (SD)	0.55 (1.17)	µg/L
							Range	ND - 3.01	µg/L
	Arctic, Canada (Kitikmeot)	NS	F	63	HgI	Blood	Mean (SD)	0.99 (0.77)	µg/L
							GM (SD)	0.69 (1.43)	µg/L
							Range	ND - 4.21	µg/L
	Arctic, Canada (Dene/Metis)	NS	F	92	HgI	Blood	Mean (SD)	1 0.68 (0.54)	µg/L
							GM (SD)	0.47 (1.09)	µg/L
							Range	ND - 3.0	µg/L
	Arctic, Canada (Caucasians)	NS	F	134	HgI	Blood	Mean (SD)	0.54 (0.38)	µg/L
							GM (SD)	0.39 (0.66)	µg/L
							Range	NDb - 2.21	µg/L
	Arctic, Canada (other)	NS	F	13	HgI	Blood	Mean (SD)	0.47 (0.21)	µg/L
							GM (SD)	0.42 (0.26)	µg/L
							Range	0.20 - 0.80	µg/L
	Arctic, Canada (Inuit)	NS	F	146	HgI	Blood	Mean (SD)	1.09 (0.84)	µg/L
							GM (SD)	0.77 (1.47)	µg/L
							Range	ND - 4.61	µg/L
	Arctic, Canada	NS	F	385	HgI	Blood	Mean	0.78	µg/L
							GM	0.53	µg/L
							Range	ND - 4.6	µg/L
	Arctic, Canada	NS	F	385	HgT	Blood	Mean	2.96	µg/L
							GM	1.66	µg/L
							Range	ND - 33.9	µg/L
Auger et al. (2005)	Northern, QC	18-82	52%M+ 48% F	302	HgT	Blood	Mean (SD)	37.7(31.4)	ppb(µg/L)
							Median	31.8	ppb (µg/L)

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
							Range	1-150	ppb(µg/L)
Auger et al. (2005)	Northern, QC	18-82	52%M+ 48% F	302	HgT	Hair	Mean (SD)	6.4(5.9)	ppm
							Median	4.3	ppm
							Range	0.5-40.6	ppm
	Northern, QC	18-82	52%M+ 48% F	302	HgT	Peak hair	Mean (SD)	10(8.1)	ppm
							Median	7.7	ppm
							Range	0.6-48.5	ppm
	Northern, QC	18-82	52%M+ 48% F	302	HgT	Scalp hair	Mean (SD)	8.8(7.3)	ppm
							Median	6.7	ppm
							Range	0.5-46.1	ppm
Despres et al. (2005)	Northern, QC	4 – 6	M & F	110	Hg	Blood	Mean	9.6	µg/L
							Range	0.2 – 38.2	µg/L
							GM (SD)	5.9 (8.9)	µg/L L
	Northern, QC	7 – 6	M & F	110	Hg	Hair	Mean	2.7	ug/g
							Range	0.1 -13 .9	ug/g
							GM (SD)	1.7 (2.6)	ug/g
Takser et al. (2005)	Urban, QC (First trimester)	NS	F	39	HgO	Blood	Median (5th - 95th%)	0.40 (ND-2.20)	µg/L
					HgT	Blood	Median (5th - 95th%)	0.80 (0.40-2.20)	µg/L
	Urban, QC (Second trimester)	NS	F	145	HgO	Blood	Median (5th - 95th%)	0.20 (ND-1.2)	µg/L
					HgT	Blood	Median (5th - 95th%)	0.60 (ND-2.0)	µg/L
	Urban, QC (At delivery)	NS	F	101	HgO	Blood	Median (5th - 95th%)	0.2 (ND-0.80)	µg/L
					HgT	Blood	Median (5th - 95th%)	0.6 (ND-1.2)	µg/L
	Urban, QC	NS	F	92	HgO	Cord Blood	Median (5th -	0.3 (ND-1.3)	µg/L

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
							95th%)		
Takser et al. (2005)					HgT	Cord Blood	Median (5th - 95th%)	0.6 (ND-1.6)	µg/L
Cole et al. (2004)	Urban, ON (Fish eaters)	NS	NA	176	Hg	Blood	Median	2.3	µg/L
							Mean (SD)	2.8 (2.1)	µg/L
							GM (SD)	2.2 (2)	µg/L
							Range	<1.1-16.3	µg/L
Cole et al. (2004)	Urban, ON (Non-fish eaters)	NS	NA	56	Hg	Blood	Median	1.5	µg/L
							Mean (SD)	1.8 (1.2)	µg/L
							GM (SD)	1.5 (2)	µg/L
							Range	<1.1-5.4	µg/L
Cole et al. (2004)	Urban, ON (Fish eaters)	NS	F	60	Hg	Blood	GM (SD)	1.9 (1.8)	µg/L
			M	116	Hg	Blood	GM (SD)	2.4 (2.1)	µg/L
	Urban, ON (Non-fish eaters)	NS	F	26	Hg	Blood	GM (SD)	1.3 (2.1)	µg/L
			M	30	Hg	Blood	GM (SD)	1.7 (1.8)	µg/L
	Urban, ON (Fish eaters/Asian CDN)	NS	F	27	Hg	Blood	GM (SD)	9.4 (2.2)	µg/L
			M	14	Hg	Blood	GM (SD)	7.2 (1.8)	µg/L
	Urban, ON (Fish eaters/Euro CDN)	NS	F	15	Hg	Blood	GM (SD)	2.2 (1.9)	µg/L
			M	30	Hg	Blood	GM (SD)	2.0 (1.9)	µg/L
	Urban, ON (Fish eaters)	17-30	NA	23	Hg	Blood	GM (SD)	1.9 (1.8)	µg/L
		31-43	NA	60	Hg	Blood	GM (SD)	2 .0 (1.9)	µg/L
		44-64	NA	93	Hg	Blood	GM (SD)	2.4 (2.1)	µg/L
	Urban, ON (Non-fish eaters)	17-30	NA	8	Hg	Blood	GM (SD)	1.6 (1.8)	µg/L
		31-43	NA	29	Hg	Blood	GM (SD)	1.5 (1.5)	µg/L
		44-64	NA	19	Hg	Blood	GM (SD)	1.4 (2.3)	µg/L
	Urban, ON (Fish eaters/Euro CDN)	17-30	NA	12	Hg	Blood	GM (SD)	1.9 (1.6)	µg/L

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
		31-43	NA	23	Hg	Blood	GM (SD)	1.8 (2.0)	µg/L
		44-64	NA	10	Hg	Blood	GM (SD)	3.0 (1.9)	µg/L
Cole et al. (2004)	Urban, ON (Fish eaters/Asian CDN)	17-30	NA	10	Hg	Blood	GM (SD)	7.2 (2.3)	µg/L
		31-43	NA	20	Hg	Blood	GM (SD)	8.5 (1.5)	µg/L
		44-64	NA	11	Hg	Blood	GM (SD)	7.6 (2.6)	µg/L
	Urban, ON (Asian CDN)	NS	NA	41	Hg	Blood	Median	8.4	µg/L
							Mean (SD)	9.6 (5.7)	µg/L
							GM (SD)	7.9 (2)	µg/L
							Range	39108	µg/L
	Urban, ON (Euro CDN)	NS	NA	45	Hg	Blood	Median	2.2	µg/L
							Mean (SD)	2.5 (1.6)	µg/L
							GM (SD)	2 (1.9)	µg/L
							Range	0.4-7.2	µg/L
Harada et al. (2004)	Northern, ON	NS	NS	47	Hg	Hair	Mean	2.07	mg/k
					Hg	Hair	SD	2.87	mg/k
					Hg	Hair	Range	0.11 – 18.1	mg/k
Legrand et al. (2004)	Coastal, NB (St. Andrews/Stevens)	18+	M & F	52	Hg	Hair	Mean (SD)	0.42 (0.15)	mg/k
	Coastal, NB (Grand Manan)	18+	M & F	92	Hg	Hair	Mean (SD)	0.70 (0.55)	mg/k
Levy et al. (2004)	Urban, QC (amaogams/fish eaters)	4-8	M & F	34	Hg	Urine	Mean (CI)	1.7 (1.36 - 2.05)	µg Hg/gm creatinine
Levy et al. (2004)	Urban, QC						GM (CI)	1.41 (1.13 – 1.76)	µg Hg/gm creatinine
Levy et al. (2004)	Urban, QC (No amaogams/Non-fish eaters)	4-8	M & F	26	Hg	Urine	Mean (CI)	0.61 (0.34 – 0.87)	µg Hg/gm creatinine
Levy et al. (2004)							GM (CI)	0.44 (0.32 – 0.60)	µg Hg/gm creatinine

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
Lucas et al. (2004)	Southern Community, QC	NA	NS	29	Hg	Cord Blood	GM (95% CI)	3.8 (2.9-5.1)	nmol/L
Lucas et al. (2004)	Northern Community, QC	NA	NS	439	Hg	Cord Blood	GM (95% CI)	70.5 (65.3-76.0)	nmol/L
Morrisette et al. (2004)	Urban, QC (First trimester)	NS	F	39	HgI	Blood	GM	0.45	µg/L
				39	HgI	Blood	Mean	0.51	µg/L
				39	HgO	Blood	GM	0.36	µg/L
				39	HgO	Blood	Mean	0.48	µg/L
				39	HgT	Blood	GM	0.85	µg/L
				39	HgT	Blood	Mean	0.99	µg/L
Morrisette et al. (2004)	Urban, QC (Second trimester)	NS	F	147	HgI	Blood	GM	0.3	µg/L
				147	HgI	Blood	Mean	0.4	µg/L
				147	HgO	Blood	GM	0.3	µg/L
				147	HgO	Blood	Mean	0.34	µg/L
				147	HgT	Blood	GM	0.56	µg/L
				147	HgT	Blood	Mean	0.74	µg/L
	Urban, QC (At delivery)	NS	F	101	HgI	Blood	GM	0.24	µg/L
				101	HgI	Blood	Mean	0.35	µg/L
				101	HgO	Blood	GM	0.23	µg/L
				101	HgO	Blood	Mean	0.26	µg/L
				101	HgT	Blood	GM	0.48	µg/L
				101	HgT	Blood	Mean	0.61	µg/L
	Urban, QC	NS	NS	92	HgI	Cord Blood	GM	0.19	µg/L
				92	HgI	Cord Blood	Mean	0.24	µg/L
				92	HgO	Cord Blood	GM	0.39	µg/L
				92	HgO	Cord Blood	Mean	0.45	µg/L
				92	HgT	Cord Blood	GM	0.52	µg/L
				92	HgT	Cord Blood	Mean	0.69	µg/L
Bilrha et al. (2003)	Rural, QC (Exposed)	24 (4.9)	F	47	Hg	Cord Blood	GM (95% CI)	9 (7.3-11)	nmol/L

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
	Rural, QC (Reference)	NS	F	65	Hg	Cord Blood	GM (95% CI)	5.4 (4.6-6.2)	nmol/L
Dellaire et al. (2003)	Northern, QC	Newborns	M(52%) F(48%)	238	Hg	Cord Blood	Mean	9.4	% decrease
							Range	(5 -13.6)	% decrease
Belles-Isles et al. (2002)	Coastal Community, NF	23.9 (5.6)	F	48	Hg	Cord Blood	GM (95% CI)	9.1 (7.2-11.3)	nmol/L
							Range	1-55	nmol/L
	Urban, QC	26.9 (3.8)	F	60	Hg	Cord Blood	GM (95% CI)	4.5 (3.9-5.2)	nmol/L
							Range	1-20	nmol/L
Nadon et al. (2002)	Urban, QC	< 45	F	8	Hg	Blood	Mean (SD)	1.45 (0.49)	µg/L
							GM	1.36	µg/L
	Urban, QC	< 45	M	17	Hg	Blood	Mean (SD)	1.40 (1.12)	µg/L
							GM	1.09	µg/L
Dewailly et al. (2001)	Northern, QC	35.7	M	209	HgT	Blood	GM	75	nmol/L
		35	F	283	HgT	Blood	GM	83.2	nmol/L
		35	M& F	209 & 283	HgT	Blood	GM	79.6	nmol/L
							Mean	109.3	nmol/L
							Range	4 – 560	nmol/L
Muckle et al. (2001) a	Northern Community, QC	NS	F	74	Hg	Blood	Mean (SD)	59.1 (36.8)	nmol/L
							Median	48	nmol/L
							Range	17.0-221.0	nmol/L
	Northern Community, QC	NS	NA	95	Hg	Cord Blood	Mean (SD)	22.7 (0.4)	µg/L
							GM	18.5	µg/L
							Range	2.8-97.0	µg/L
	Northern Community, QC (All trimesters)	NS	F	107	Hg	Hair	Mean (SD)	4.5 (2.8)	µg/gm
							Median	4	µg/gm
							Range	0.3-14.0	µg/gm

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
	Northern Community, QC (1st trimester)	NS	F	108	Hg	Hair	Mean (SD)	4.3 (3.1)	µg/gm
							Median	3.7	µg/gm
							Range	0.2-18.5	µg/gm
Muckle et al. (2001) a	Northern Community, QC (2nd trimester)	NS	F	108	Hg	Hair	Mean (SD)	4.6 (3.2)	µg/gm
							Median	4	µg/gm
							Range	0.4-16.3	µg/gm
	Northern Community, QC (3rd trimester)	NS	F	109	Hg	Hair	Mean (SD)	4.4 (2.6)	µg/gm
							Median	4.1	µg/gm
							Range	0.3-12.8	µg/gm
Muckle et al. (2001) b	Northern Community, QC (All trimesters)	NS	NA	123	Hg	Hair	Mean (SD)	4.5 (1.9)	µg/gm
							GM	3.7	µg/gm
							Range	0.3-14.0	µg/gm
	Northern Community, QC	NS	NA	124	Hg	Hair	Mean (SD)	4.4 (2.0)	µg/gm
							GM	3.5	µg/gm
							Range	0.2-18.5	µg/gm
	Northern Community, QC	NS	NA	124	Hg	Hair	Mean (SD)	4.6 (2.1)	µg/gm
							GM	3.6	µg/gm
							Range	0.4-16.3	µg/gm
	Northern Community, QC	NS	NA	125	Hg	Hair	Mean (SD)	4.4 (1.9)	µg/gm
							GM	3.7	µg/gm
							Range	0.3-12.8	µg/gm
	Northern Community, QC	NS	NA	130	Hg	Blood	Mean (SD)	12.6 (0.4)	µg/L
							GM	10.4	µg/L
							Range	2.6-44.2	µg/L
Kosatsky et al. (2000)	Urban, QC (>= 1 meal/wk)	19+	M & F	60	Hg	Blood	GM (SD)	3.03 (2.43)	µg/L

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
		19+	M & F	60	Hg	Hair	GM (SD)	0.82 (2.54)	µg/L
	Urban, QC (<= 1 meal/wk)	19+	M & F	71	Hg	Hair	GM (SD)	0.83 (2.28)	µg/L
		19+	M & F	71	Hg	Blood	GM (SD)	1.44 (2.23)	µg/L
Kosatsky et al. (2000)	Urban, QC	19-34	M & F	132	Hg	Blood	GM (95% CI)	1.94 (1.31-2.38)	µg/L
		35-49	M & F	132	Hg	Blood	GM (95% CI)	1.84 (1.48-2.28)	µg/L
		50-64	M & F	132	Hg	Blood	GM (95% CI)	2.27 (1.64-3.15)	µg/L
		65+	M & F	132	Hg	Blood	GM (95% CI)	2.18 (1.33-3.60)	µg/L
	Urban, QC	19+	F	NS	Hg	Blood	GM (95% CI)	2.23 (1.31-3.78)	µg/L
	Urban, QC	19+	M	NS	Hg	Blood	GM (95% CI)	1.99 (1.69-2.36)	µg/L
Baldwin et al. (1999)	Rural, QC	20-69	M	136	HgT	Blood	GM	0.93	µg/L
							Range	Nd-4.21	µg/L
							Mean	1.2	µg/L
	Rural, QC	20-69	F	153	HgT	Blood	GM	0.77	µg/L
							Range	Nd-4.81	µg/L
							Mean	1	µg/L
	Rural, QC	20-69	M & F	289	HgT	Blood	GM	0.84	µg/L
							Range	Nd-4.81	µg/L
							Mean	1.09	µg/L
Kosatsky et al. (1999)	Urban, QC (Bangladeshi)	Med/Rg (34/28 – 41)	M	9	Hg	Hair	Median	1.1	µg Hg/k of hair
							90th percentile	2.3	µg Hg/k of hair
	Urban, QC (Vietnamese)	Med/Rg (30/27 – 70)	M & F	3 & 6	Hg	Hair	Median	1.2	µg Hg/k of hair
							90th percentile	4.6	µg Hg/k of hair
	Urban, QC	NS	NS	NS	Hg	Hair	Median	0.7	µg Hg/k of hair
							90th percentile	1.9	µg Hg/k of hair
Rhainds et al. (1999)	Urban, QC	Newborns	M & F	1109	Hg	Cord Blood	GM (95% CI)	4.82 (4.56 - 5.08)	nmol/L
Beuter et al. (1998)	Northern, QC	NA	NS	1 of 36	HgO	Hair	Max/Mean of annual Max*	12.70/6.02	mg Hg/k of hair

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
		NA	NS	2 of 36	HgO	Hair	Max/Mean of annual Max*	13.20/9.38	mg Hg/k of hair
Beuter et al. (1998)		NA	NS	3 of 36	HgO	Hair	Max/Mean of annual Max*	2.50/2.50	mg Hg/k of hair
		NA	NS	4 of 36	HgO	Hair	Max/Mean of annual Max*	5.10/2.93	mg Hg/k of hair
		NA	NS	5 of 36	HgO	Hair	Max/Mean of annual Max*	14/7.10	mg Hg/k of hair
		NA	NS	6 of 36	HgO	Hair	Max/Mean of annual Max*	2.50/2.27	mg Hg/k of hair
		NA	NS	7 of 36	HgO	Hair	Max/Mean of annual Max*	12.90/7.85	mg Hg/k of hair
		NA	NS	8 of 36	HgO	Hair	Max/Mean of annual Max*	12/6.91	mg Hg/k of hair
		NA	NS	9 of 36	HgO	Hair	Max/Mean of annual Max*	10.60/6.40	mg Hg/k of hair
		NA	NS	10 of 36	HgO	Hair	Max/Mean of annual Max*	na/na	mg Hg/k of hair
		NA	NS	11 of 36	HgO	Hair	Max/Mean of annual Max*	28.60/10.18	mg Hg/k of hair
		NA	NS	12 of 36	HgO	Hair	Max/Mean of annual Max*	9/6.90	mg Hg/k of hair
		NA	NS	13 of 36	HgO	Hair	Max/Mean of annual Max*	52.40/24.34	mg Hg/k of hair
		NA	NS	14 of 36	HgO	Hair	Max/Mean of annual Max*	22.80/11.87	mg Hg/k of hair
		NA	NS	15 of 36	HgO	Hair	Max/Mean of annual Max*	56.90/25.48	mg Hg/k of hair
		NA	NS	16 of 36	HgO	Hair	Max/Mean of annual Max*	12.70/6.06	mg Hg/k of hair
		NA	NS	17 of 36	HgO	Hair	Max/Mean of annual Max*	15.30/8.49	mg Hg/k of hair
		NA	NS	18 of 36	HgO	Hair	Max/Mean of	10.40/7.29	mg Hg/k of hair

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
							annual Max*		
		NA	NS	19 of 36	HgO	Hair	Max/Mean of annual Max*	10.90/6.73	mg Hg/k of hair
Beuter et al. (1998)		NA	NS	20 of 36	HgO	Hair	Max/Mean of annual Max*	21.40/11.89	mg Hg/k of hair
		NA	NS	21 of 36	HgO	Hair	Max/Mean of annual Max*	23.80/12.52	mg Hg/k of hair
		NA	NS	22 of 36	HgO	Hair	Max/Mean of annual Max*	7.30/6.35	mg Hg/k of hair
		NA	NS	23 of 36	HgO	Hair	Max/Mean of annual Max*	2.20/2.20	mg Hg/k of hair
		NA	NS	24 of 36	HgO	Hair	Max/Mean of annual Max*	5.40/5.40	mg Hg/k of hair
		NA	NS	25 of 36	HgO	Hair	Max/Mean of annual Max*	12.90/6.56	mg Hg/k of hair
		NA	NS	26 of 36	HgO	Hair	Max/Mean of annual Max*	25/12.10	mg Hg/k of hair
		NA	NS	27 of 36	HgO	Hair	Max/Mean of annual Max*	5.30/3.40	mg Hg/k of hair
		NA	NS	28 of 36	HgO	Hair	Max/Mean of annual Max*	14.10/9.83	mg Hg/k of hair
		NA	NS	29 of 36	HgO	Hair	Max/Mean of annual Max*	19.70/10.29	mg Hg/k of hair
		NA	NS	30 of 36	HgO	Hair	Max/Mean of annual Max*	29.80/17.07	mg Hg/k of hair
		NA	NS	31 of 36	HgO	Hair	Max/Mean of annual Max*	7.80/4.80	mg Hg/k of hair
		NA	NS	32 of 36	HgO	Hair	Max/Mean of annual Max*	10.60/9.10	mg Hg/k of hair
		NA	NS	33 of 36	HgO	Hair	Max/Mean of annual Max*	61/30.80	mg Hg/k of hair
		NA	NS	34 of 36	HgO	Hair	Max/Mean of annual Max*	42/31.10	mg Hg/k of hair

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
		NA	NS	35 of 36	HgO	Hair	Max/Mean of annual Max*	43.80/26.30	mg Hg/k of hair
Beuter et al. (1998)		NA	NS	36 of 36	HgO	Hair	Max/Mean of annual Max*	58.80/27.10	mg Hg/k of hair
Dumont et al. (1998)	Northern, QC	4-14	M	503	Hg	Hair (1st cm)	92.50%**	≥ 2.5	mg Hg/k of hair
							6.40%**	2.6 – 5.9	mg Hg/k of hair
							1.10%**	6.0 – 14.9	mg Hg/k of hair
							0.00%**	15.0 – 29.9	mg Hg/k of hair
							0.00%**	≥ 30	mg Hg/k of hair
	Northern, QC	4-14	F	582	Hg	Hair (1st cm)	94.60%**	≥ 2.5	mg Hg/k of hair
							4.80%**	2.6 – 5.9	mg Hg/k of hair
							0.60%**	6.0 – 14.9	mg Hg/k of hair
							0.00%**	15.0 – 29.9	mg Hg/k of hair
							0.00%**	≥ 30	mg Hg/k of hair
	Northern, QC	15 – 39	M	742	Hg	Hair (1st cm)	79.90%**	≥ 2.5	mg Hg/k of hair
							17.10%**	2.6 – 5.9	mg Hg/k of hair
							3.80%**	6.0 – 14.9	mg Hg/k of hair
							0.20%**	15.0 – 29.9	mg Hg/k of hair
							0.00%**	≥ 30	mg Hg/k of hair
	Northern, QC	15 – 39	F	850	Hg	Hair (1st cm)	86.70%**	≥ 2.5	mg Hg/k of hair
							11.70%**	2.6 – 5.9	mg Hg/k of hair
							1.60%**	6.0 – 14.9	mg Hg/k of hair
							0.00%**	15.0 – 29.9	mg Hg/k of hair
							0.00%**	≥ 30	mg Hg/k of hair
	Northern, QC	≥ 40	M	430	Hg	Hair (1st cm)	28.70%**	≥ 2.5	mg Hg/k of hair
							27.20%**	2.6 – 5.9	mg Hg/k of hair
							32.10%**	6.0 – 14.9	mg Hg/k of hair
							11.10%**	15.0 – 29.9	mg Hg/k of hair
							0.90%**	≥ 30	mg Hg/k of hair
	Northern, QC	≥ 40	F	492	Hg	Hair (1st cm)	33.60%**	≥ 2.5	mg Hg/k of hair
							31.40%**	2.6 – 5.9	mg Hg/k of hair

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
							25.90%**	6.0 – 14.9	mg Hg/k of hair
							9.00%**	15.0 – 29.9	mg Hg/k of hair
							0.10%	≥ 30	mg Hg/k of hair
Mahaffey et al. (1998)	Urban, QC (Fish eaters)	Adult	F	29	HgO	Blood	Mean	0.24	µg/L
	Urban, QC (Fish eaters)	Adult	M	37	HgO	Blood	Mean	0.3	µg/L
	Urban, QC (Fish eaters)	Adult	M & F	288	HgI	Blood	Mean	0.4	µg/L
					HgI	Blood	Range	(0.10–2.40)	µg/L
					HgO	Blood	Mean	0.7	µg/L
					HgO	Blood	Range	(0.00-4.01)	µg/L
					HgT	Blood	Mean	1.1	µg/L
					HgT	Blood	Range	(0.10– 2.14)	µg/L
	Urban, QC (Non-fish eaters)	Adult	M	76	HgO	Blood	Mean	0.18	µg/L
					HgO	Blood	(std dev)	0.15	µg/L
					HgO	Blood	(std error)	0.02	µg/L
	Urban, QC (Non-fish eaters)	Adult	F	99	HgO	Blood	Mean	0.16	µg/L
					HgO	Blood	(std dev)	0.12	µg/L
					HgO	Blood	(std error)	0.01	µg/L
	Urban, QC (Non-fish eaters)	Adult	M & F	175	HgI	Blood	Mean	0.4	µg/L
					HgI	Blood	Range	(0.10–2.00)	µg/L
					HgO	Blood	Mean	0.6	µg/L
					HgO	Blood	Range	(0.00-3.00)	µg/L
					HgT	Blood	Mean	1	µg/L
					HgT	Blood	Range	(0.10– 4.21)	µg/L
Mergler et al. (1998)	Coastal residence/QC (Fish eaters)	20-69	NA	306	HgI	Blood	Mean (SD)	0.32(0.42)	µg/L
Mergler et al. (1998)	Coastal residence/QC (Non-fish eaters)	20-69	NA	306	HgI	Blood	Mean (SD)	0.4(0.34)	µg/L
Mergler et al.	Coastal residence/QC	20-69	NA	306	HgO	Blood	Mean (SD)	0.97(0.9)	µg/L

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
(1998)	(Fish eaters)								
Mergler et al. (1998)	Coastal residence/QC (Non-fish eaters)	20-69	NA	306	HgO	Blood	Mean (SD)	0.58(0.56)	µg/L
Mergler et al. (1998)	Coastal residence/QC (Fish eaters)	20-69	NA	306	HgT	Blood	Mean (SD)	1.4(1.1)	µg/L
Mergler et al. (1998)	Coastal residence/QC (Non-fish eaters)	20-69	NA	306	HgT	Blood	Mean (SD)	0.98(0.7)	µg/L
Muckle et al. (1998)	Northern, QC	Newborns	M & F	NS	Hg	Cord Blood	GM	1.0 - 14.2	µg/L
Wheatley et al. (1998)	Arctic, Canada	NS	M & F	38571	Hg	Blood	GM	29.8	µg/L
							Range	1-225.7	µg/L

Note: *(Max value of 25 years of followup/Mean of annual max of 25 years of follow-up); **(Percent of measured concentration in the respective category, i.e. 92.5% of Hg concentration in male hair wHg at leHgt 2.5 mg/k); Hg (Mercury); HgI (Inorganic Mercury); HgO (Organic Mercury); HgT (Total Mercury); M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); umol/L (micro-mole per litre); ug/dl (micro-gram per deciliter)

Table 3a: Methylmercury (MeHg) levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
Belanger et al. (2006)	Northern, QC	NS	NS	98	MeHg	Blood	Mean(SE)	106.2 (9.8)	nmol/L
Canuel et al. (2006)	Shore residence, NF & LB	NS	NS	118	MeHg	Hair	Mean (SD)	0.4 (0.36)	ppm
Canuel et al. (2006)	Shore residence, QC	NS	NS	146	MeHg	Hair	Mean (SD)	1.2 (1.40)	ppm
Canuel et al. (2006)	Shore residence, QC	NS	NS	130	MeHg	Hair	Mean (SD)	0.83 (0.97)	ppm
Walker et al. (2006)	Arctic, Canada (Dene/Metis)	NS	F	92	MeHg	Blood	Range	0.00 - 4.01	µg/L
							Mean (SD)	1.05 (0.90)	µg/L

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
							GM (GSD)	0.80 (2.01)	µg/L
Walker et al. (2006)	Arctic, Canada (Other)	NS	F	13	MeHg	Blood	Range	0.00 - 3.01	µg/L
							Mean (SD)	1.29 (1.09)	µg/L
							GM (GSD)	1.15 (1.81)	µg/L
Walker et al. (2006)	Arctic, Canada (Caucasian)	NS	F	134	MeHg	Blood	Range	0.00 - 3.61	µg/L
							Mean (SD)	0.76 (0.78)	µg/L
							GM (GSD)	0.69 (1.97)	µg/L
Walker et al. (2006)	Arctic, Canada (Inuit)	NS	F	146	MeHg	Blood	Range	0.00- 29.29	µg/L
							Mean (SD)	4.32 (4.72)	µg/L
							GM (GSD)	2.87 (6.91)	µg/L
Walker et al. (2006)	Arctic, Canada	NS	F	385	MeHg	Blood	Range	0.00b - 29.3	µg/L
							Mean	2.2	µg/L
							GM	1.3	µg/L
							Max/Mean of annual		mg Hg/k of
Beuter et al. (1999)	Northern, QC	NS	NS	1 of 36	MeHg	Hair	Max	12.70(6.02)	hair
							Max/Mean of annual		mg Hg/k of
				2 of 36	MeHg	Hair	Max	13.20(9.38)	hair
							Max/Mean of annual		mg Hg/k of
				3 of 36	MeHg	Hair	Max	2.50(2.50)	hair
							Max/Mean of annual		mg Hg/k of
Beuter et al. (1999)	Northern, QC	NS	NS	4 of 36	MeHg	Hair	Max	5.10(2.93)	hair
							Max/Mean of annual		mg Hg/k of
				5 of 36	MeHg	Hair	Max	14(7.10)	hair
							Max/Mean of annual		mg Hg/k of
				6 of 36	MeHg	Hair	Max	2.50(2.27)	hair
							Max/Mean of annual		mg Hg/k of
				7 of 36	MeHg	Hair	Max	12.90(7.85)	hair
							Max/Mean of annual		mg Hg/k of
				8 of 36	MeHg	Hair	Max	12(6.91)	hair
							Max/Mean of annual		mg Hg/k of
				9 of 36	MeHg	Hair	Max	10.60(6.40)	hair

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
				10 of 36	MeHg	Hair	Max/Mean of annual Max	NA	mg Hg/k of hair
				11 of 36	MeHg	Hair	Max/Mean of annual Max	28.6(10.18)	mg Hg/k of hair
				12 of 36	MeHg	Hair	Max/Mean of annual Max	9(6.90)	mg Hg/k of hair
				13 of 36	MeHg	Hair	Max/Mean of annual Max	52.40(24.34)	mg Hg/k of hair
				14 of 36	MeHg	Hair	Max/Mean of annual Max	22.80(11.87)	mg Hg/k of hair
				15 of 36	MeHg	Hair	Max/Mean of annual Max	56.90(25.48)	mg Hg/k of hair
				16 of 36	MeHg	Hair	Max/Mean of annual Max	12.70(6.06)	mg Hg/k of hair
				17 of 36	MeHg	Hair	Max/Mean of annual Max	15.30(8.49)	mg Hg/k of hair
				18 of 36	MeHg	Hair	Max/Mean of annual Max	10.40(7.29)	mg Hg/k of hair
				19 of 36	MeHg	Hair	Max/Mean of annual Max	10.90(6.73)	mg Hg/k of hair
				20 of 36	MeHg	Hair	Max/Mean of annual Max	21.40(11.89)	mg Hg/k of hair
Beuter et al. (1999)	Northern, QC	NS	NS	21 of 36	MeHg	Hair	Max/Mean of annual Max	23.80(12.52)	mg Hg/k of hair
				22 of 36	MeHg	Hair	Max/Mean of annual Max	7.30(6.35)	mg Hg/k of hair
				23 of 36	MeHg	Hair	Max/Mean of annual Max	2.20(2.20)	mg Hg/k of hair
				24 of 36	MeHg	Hair	Max/Mean of annual Max	5.40(5.40)	mg Hg/k of hair
				25 of 36	MeHg	Hair	Max/Mean of annual Max	12.90(6.56)	mg Hg/k of hair
				26 of 36	MeHg	Hair	Max/Mean of annual	25(12.10)	mg Hg/k of

First Authors (Year)	Population	Age	Sex	N	Hg Type	Biological Sample	Measure	Concentration (units) As reported	
							Max		hair
							Max/Mean of annual		mg Hg/k of
				27 of 36	MeHg	Hair	Max	5.30(3.40)	hair
							Max/Mean of annual		mg Hg/k of
				28 of 36	MeHg	Hair	Max	14.10(9.83)	hair
							Max/Mean of annual		mg Hg/k of
				29 of 36	MeHg	Hair	Max	19.70(10.29)	hair
							Max/Mean of annual		mg Hg/k of
				30 of 36	MeHg	Hair	Max	29.80(17.07)	hair
							Max/Mean of annual		mg Hg/k of
				31 of 36	MeHg	Hair	Max	7.80(4.80)	hair
							Max/Mean of annual		mg Hg/k of
				32 of 36	MeHg	Hair	Max	10.60(9.10)	hair
							Max/Mean of annual		mg Hg/k of
				33 of 36	MeHg	Hair	Max	61(30.80)	hair
							Max/Mean of annual		mg Hg/k of
				34 of 36	MeHg	Hair	Max	42(31.10)	hair
							Max/Mean of annual		mg Hg/k of
				35 of 36	MeHg	Hair	Max	43.80(26.30)	hair
							Max/Mean of annual		mg Hg/k of
				36 of 36	MeHg	Hair	Max	58.80(27.10)	hair
Wheatley et al. (1997)	Grassy Narrows, in 1976	NS	NS	NS	MeHg	Hair	Mean	23.8	ppb
							Range	1.50-322.90	ppb
	Grassy Narrows, in 1995	NS	NS	NS	MeHg	Hair	Mean	7.46	ppb
							Range	1.67-46.67	ppb
	Whitedog, in 1976	NS	NS	NS	MeHg	Hair	Mean	12.87	ppb
							Range	1.50-172.00	ppb
	Whitedog, in 1995	NS	NS	NS	MeHg	Hair	Mean	6.08	ppb
							Range	1.67-33.33	ppb
Wheatley et al. (1996)	Canada	15-45	M & F	492	MeHg	Blood	Mean (SD)	8.62 (6.39)	ppm
							Range	0.30-46.50	ppm

Note: *(Max value of 25 years of followup/Mean of annual max of 25 years of follow-up); MeHg (Methylmercury); M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter); ppm/b (parts per million/billion)

4.4 Selenium

Seven studies specifically measure selenium in blood, cord blood, and toe nails, though not as an environmental contaminant, rather as a nutrient, when other contaminants were also analyzed (Muckle et al. 2001, Butler Walker et al. 2006, St. Amour et al. 2006, Innis et al. 2006, Bussières et al. 2004, Belanger et al. 2006, and Morris et al. 2001. The most appropriate matrix is blood although toe nails are also reported here and urine may be used as an indicator of nutritional status.

Morris found no differences in toe nail Se between a large sample of Vancouver and Toronto adults (Morris et al. 2001). Bussières et al. (2004) found no difference in exposed and unexposed Cree in a mine tailing area of Quebec.

Levels found in these populations are shown in the Selenium tables below.

Herber (1999) reviewed the literature for reference values for selenium. Many reports he found were rejected because of measurments in inhomogeneous populations, and samples too small to reflect the population. Residential location, time, age and diet were important determinants of plasma/serum concentrations. Herber suggests that other influences on selenium level were gender, liver and kidney dysfunction, acute infection, supplements, and medication (*e.g.*, oral contraceptives, corticosteroids).

Herber reports that reference values for Se vary, due to the large geographical variation in selenium intake, and that one universal reference range cannot be given. A tentative value for omnivorous adults, 0.5±2.5 umol/l (39 – 197 µ/L), is provided (Herber 1999). Selenium deficiency is considered at serum or plasma levels of 50 – 120 µ/L (Lacour et al. 2004).

Many of the values reported in these few Canadian studies are higher than those given by Herber (1999). The normative study from Quebec found that Se urine values in a sample of 316 Quebec residents were 1.15µmol/L (95% CI 0.53-2.3 µmol/L). Corresponding values in blood were 2.8µmol/L (95% CI 2.1-3.6 µmol/L).) (Direction toxicologie humaine, direction risques biologiques, environnementaux et occupationnelles. 2003).

Table 4.4: Selenium levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units)	
Belanger et al. (2006)	Northern, QC	NS	NS	98	Blood	Mean(SE)	635.5 (38.7)	µg/L
Innis et al. (2006)	Urban, BC	NS	NS	206	Blood	Mean (SD)	1.6 (0.3)	nmol/L
						Median	1.5	nmol/L
						Range	0.78–3.34	nmol/L
St Amour et al. (2006)	Northern, QC	Newborn	NS	39	Cord Blood	GM (95%CI)	4.04 (3 .52–4.64)	µmol/L
						Mean (SD)	4.44 (2.08)	µmol/L
						Range	2.07–9.80	µmol/L
St Amour et al. (2006)	Northern, QC	Mean (SD): 5.4 (0.4)	NS	78	Blood	GM (95%CI)	4.19 (3.64–4.84)	µmol/L
						Mean (SD)	5.43 (5.40)	µmol/L
						Range	2.00–32.50	µmol/L
Walker et al. (2006)	Arctic, Canada	NS	F	381	Plasma	Range	67 - 184	µg/L
					Plasma	Mean	21	µg/L
					Plasma	GM	120	µg/L
Bussières et al. (2004)	Cree, QC (Non-exposed)	Mean (Rg): 11.2(8-14)	M & F	11	Plasma	GM	1.41 (1.32-1.50)	µmol/L
Bussières et al. (2004)	Cree, QC (Exposed)	Mean (Rg): 10.6(8-14)	M & F	21	Plasma	GM	1.34 (1.27-1.40)	µmol/L
Morris et al. (2001)	Monreal, QC	Adult	M & F	184	Toe nails	Mean (SD)	0.896 (0.127)	mg/k
	Vancouver, BC	Adult	M & F	186	Toe nails	Mean (SD)	0.968 (0.177)	mg/k
	Edmonton, AB	Adult	M & F	188	Toe nails	Mean (SD)	0.950 (0.148)	mg/k
	Toronto, ON	Adult	M & F	197	Toe nails	Mean (SD)	0.932 (0.135)	mg/k
Muckle et al. (2001)	Northern Community, QC	NS	F	74	Blood	Mean (SD)	4.3 (1.8)	nmol/L
						Median	4	nmol/L
						Range	2.3-12.4	nmol/L
Muckle et al. (2001)	Northern Community, QC	NS	NA	93	Cord Blood	GM (SD)	3.5 (1.4)	µmol/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units)
Muckle et al. (2001)	Northern Community, QC	NS	NA	130	Maternal Blood	Range	1.9-11.6 µmol/L
						GM (SD)	4.1 (1.4) µmol/L
						Range	1.9-15.6 µmol/L

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); SE (Standard error); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter)

4.5 Manganese

Biological monitoring focuses on blood manganese in exposed (urban, coastal fish eaters) and unexposed groups (rural residents with low air Mn concentrations). The laboratory method reported for Mn is GFAAS with a limit of detection of 2 nmol/L (0.1 µg/L) (Takser et al. 2004), AAS (Audrey et al.). Not all reports give a laboratory analytic method or limit of detection. The matrices used are blood (recommended) and placental tissue.

Tissues examined include blood (Takser et al. 2004, Bolte et al. 2004, Baldwin et al. 1999, Mergler et al. 1998, Audrey et al. 2002), cord blood (Takser et al. 2004, Audrey et al. 2002) and placental tissue (Takser et al. 2004).

Bolte et al. (2004) found that in urban women >21 years, values for blood Mn were not different from rural women even though air concentrations of Mn were much higher in urban than rural areas. [One outliner was excluded (15.4 µg/L)]. Outdoor and indoor air Mn concentrations are 5 - 2.5 fold higher in urban than rural areas with no significant differences in blood Mn of study participants residing in areas with different ambient air concentrations.

Baldwin et al. (1999) found that blood Mn in women was significantly higher than in men. This sample consisted of persons with no history of neurotoxic workplace exposure in Southwest Quebec, drawn from seven postal code regions, defining a set of geographically contiguous zones. This study uses a large sample of adults, and can be considered “representative”.

Takser et al. (2004) examined Mn status in pregnant women and their newborns with respect to socio-demographic and environmental variables. Results showed that mothers’ Mn blood levels increased significantly during pregnancy and cord blood Mn levels were significantly higher than those for mothers’ blood. There was no relation to age of mother. Smokers had significantly lower Mn blood levels compared to non-smokers at the second trimester. Those who lived in urban and/or agricultural areas had significantly higher levels of Mn in blood compared to those who lived in small villages. Those who reported pesticide spraying less than 1 km from their house likewise had significantly higher levels compared to the others. The authors infer that lifestyle and environmental factors may interfere with the delicate balance and homeostatic mechanisms required to maintain Mn at optimal levels for physiological changes during pregnancy. Therefore, Mn levels in blood of pregnant women must be interpreted cautiously.

Mergler et al. (1998) examined the relationship between fish consumption from St. Lawrence River and nervous system outcomes. Those who ate fish displayed diminished capacity on tasks which involve higher levels of information processing auditory recall and naming. There was no difference in blood Mn level between fish eaters and non fish eaters. This study also examined lead and mercury in blood. Differences in heath outcomes could not be explained on the basis of the other contaminants tested (lead and mercury).

Mn is an essential element necessary for blood clotting and for the manufacture of enzymes required for the metabolism of proteins and fats. However, it has been associated with neurotoxic effects under specific exposure conditions. Exposures may be brief or chronic, or to special compounds of Mn under different physical states on exposure (aerosols, particulates, etc.) making exposure measurement difficult (Aschner et al. 2006).

The studies abstracted below indicate blood Mn levels are likely to vary with lifestyle and potentially, some environmental factors. Evidence from Canadian studies is not consistent as to which factors are most important to reflect exposure status. It is uncertain that the health effects examined are related in any way to Mn under the conditions of general environmental exposure.

The normative study from Quebec found that manganese urine values in a sample of 318 Quebec residents was <2 nmol/L (95% CI <2 - 7.44 nmol/). Corresponding values in blood in a sample of 427 were 170 nmol/L (95% CI 88-304 nmol/L). Suggested normal reference values are 8 – 300 nmol/L in blood; 7.8 – 17 in serum; and 2 – 7.4 nmol/L in urine. (Direction toxicologie humaine, direction risques biologiques, environnementaux et occupationnelles. 2003).

Table 4.5: Manganese levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Manganese Type	Biological Sample	Measure	Concentration (units) As reported	
Bolte et al. (2004)	Urban, QC (Urban)	>21	F	5	Manganese	Blood	Mean (SD)	8.4(2.3)	µg/L
	Urban, QC (Rural)	>21	F	5	Manganese	Blood	Mean (SD)	7.8(3.0)	µg/L
Takser et al. (2004)	Urban, QC (1st Trimester)	26.7 (15.0 – 39.0)	F	40	Manganese	Blood	GM	8.5	µg/L
							Mean	9	µg/L
							5^{th}-95^{th} (%)	5-5-14.5	µg/L
							Range	4.6-25.0	µg/L
Takser et al. (2004)	Urban, QC	26.7 (15.0 – 39.0)	F	149	Manganese	Blood	GM	9.5	µg/L
								9.9	µg/L
								5.9-15.3	µg/L
								3.7-25.3	µg/L
Takser et al. (2004)	Urban, QC	26.7 (15.0 – 39.0)	F	101	Manganese	Blood	GM	15.6	µg/L
							Mean	16.3	µg/L
							5^{th}-95^{th} (%)	10.0-25.9	µg/L
							Range	9.2-37.1	µg/L
Takser et al. (2004)	Urban, QC	26.7 (15.0 – 39.0)	F	91	Manganese	Cord Blood	GM	32.3	µg/L
							Mean	34.3	µg/L
							5^{th}-95^{th} (%)	19.0-64.2	µg/L
							Range	16.7-89.4	µg/L
Takser et al. (2004)	Urban, QC	26.7 (15.0 – 39.0)	F	110	Manganese	Placenta	GM	0.05	µg/g dry weight
							Mean	0.06	µg/g dry weight

First Authors (Year)	Population	Age	Sex	N	Manganese Type	Biological Sample	Measure	Concentration (units) As reported	
							5^{th}-95^{th} (%)	0.03-0.09	µg/g dry weight
							Range	0.02-0.15	µg/g dry weight
Smargiassi et al. (2002)	Urban, QC	29.27 (5.02)	F	100	Manganese	Blood	Mean (SD)	2.3 (1.3)	µg/dl
	Urban, QC	NS	NS	NS	Manganese	Cord Blood	Mean (SD)	4.5 (2.0)	µg/dl
Baldwin et al. (1999)	Rural, QC	20-69	M	141	Manganese	Blood	GM	6.7	µg/L
					Manganese	Blood	Range	2.5-13.9	µg/L
					Manganese	Blood	Mean	7	µg/L
					Manganese (total)	Blood	GM	6.75	ug/L
Baldwin et al. (1999)	Rural, QC	20-69	F	156	Manganese	Blood	GM	7.5	µg/L
					Manganese	Blood	Range	2.8-15.9	µg/L
					Manganese	Blood	Mean	7.9	µg/L
					Manganese (total)	Blood	GM	7.5	ug/L
Baldwin et al. (1999)	Rural, QC	20-69	M & F	297	Manganese	Blood	GM	7.1	µg/L
						Blood	Range	2.5-15.9	µg/L
						Blood	Mean	7.5	µg/L
Mergler et al. (1998)	Coastal residence/QC (Fish eaters)	20-69	NA	306	Manganese	Blood	Mean (SD)	17.2(5.4)	µg/L
	Coastal residence/QC (Non-fish eaters)	20-69	NA	306	Manganese	Blood	Mean (SD)	17.0(6.0)	µg/L

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); umol/L (micro-mole per litre); ug/dL (micro-gram per liter)

4.6 Cadmium (Cd)

We found three studies which specifically targeted Cd as a contaminant of interest in surveys (Benedetti et al. 1992, Benedetti et al. 1994, Rey et al. 1997). Other studies analyzed blood Cd in the course of other contaminant analysis and to correlate with the known major exposure source, cigarette smoking. The appropriate biological matrix to analyze is blood; urinary Cd is not a valid measure of exposure given the retention of Cd in tissues. Laboratory analyses for Cd in blood were reported in these studies: ICPMS (LOD 0.1 nmol/L blood and QL 0.3 nmol/L blood) and GFAAS (LOD 0.2 µg/L) and flameless AAS (no LOD provided).

Geometric means Cd were not significantly different for subjects or controls 15 yr and older or children (8-14 yr old) in the Ouje-Bougoumou area of Quebec. Blood Cd increased with age and smoking ($R^2 = 0.61$). No influence of mine tailings was observed among residents of the "exposed" area residents (Ouje-Bougoumou, Quebec), but lifestyle exposure associations were noted for both exposed to mine tailings and non-exposed communities (Bussières et al. 2004). Exposure to Cd has been found to have little relation to dietary patterns. Exposure of the population to Cd is primarily through smoking (Benedetti et al. 1994).

Cd blood measurements are useful to differentiate smokers, second hand exposed smokers, and non-smokers. Among nonsmoking Inuit, blood Cd levels are comparable with those reported in nonsmokers elsewhere in the world. In reference to "international standards", blood Cd concentrations are high enough among the Inuit to warrant energetic public health interventions against smoking (Rey et al. 1997).

Cadmium levels are reported in the Belgian population (tabled in Herber 1999, page 282), and as a composite from publications in Europe (Herber 1999). Non smokers blood values are GM <0.08 µ/L (females 0.64 – 1.09; males 0.75 – 1.12 ug/L). Wilhelm reports 95th percentile values for non-smokers as 0.78 (CI 0.83-0.90 ug/L) (Wilhelm et al. 2006).

The normative study from Quebec found that blood cadmium values in a sample of 228 Quebec non-smoking residents was GM= 10 nmol/L (95% CI 2.1-61 mol/L). Corresponding values in serum were somewhat lower. Their suggested reference range is 1.8 – 55 nmol/L in blood and <1 – 4 nmol/L in serum. Values in ruine are also suggested as <3 – 35 nmol/L. (Direction toxicologie humaine, direction risques biologiques, environnementaux et occupationnelles. 2003). We note however, that urinary Cd is not a reliable marker of exposure for Cd.

Table 4.6: Cadmium (Cd) levels in biological samples
Creatinine adjustment cannot be done without individual measurements of creatinine.

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
Walker et al. (2006)	Arctic, Canada	NS	F	385	Blood	Mean	1.72	µg/L
						Range	ND - 8.5	µg/L
						GM	0.76	µg/L
Bussières et al. (2004)	Cree, QC (Non-exposed)	Mean (Rg) 11.2 (8 – 14)	M & F	11	Blood	GM (95% CI)	5.05 (2.58-9.88)	µmol/L
	Cree, QC (Exposed)	Mean (Rg) 10.6 (8 – 14)	M & F	21	Blood	GM (95% CI)	5.61 (4.37-7.19)	µmol/L
Cole et al. (1997)	Urban, ON (Non-smokers)	Adult	M-majority	59	Blood	GM	0.14	µg/L
	Urban, ON (Smokers > 31 Cig./day)	Adult	M-majority	6	Blood	GM	7.54	µg/L
	Urban, ON (Non-smokers)	Adult	M-majority	59	Blood	GM	0.14	µg/L
	Urban, ON (Smokers)	Adult	M-majority	65	Blood	GM	3.94	µg/L
Rey et al. (1997)	Arctic, Canada (Ex-smokers)	18-24	M & F	10	Blood	GM	31.3	nmol/L
		25-44	M & F	41	Blood	GM	15.7	nmol/L
		45-74	M & F	37	Blood	GM	14.3	nmol/L
		NS	M	32	Blood	GM	15.3	nmol/L
		NS	F	56	Blood	GM	17	nmol/L
		NS	M & F	88	Blood	GM	16.3	nmol/L
Rey et al. (1997)	Arctic, Canada (Non-smokers)	18-24	NS	18	Blood	GM	7.6	nmol/L
		25-44	NS	12	Blood	GM	10.6	nmol/L
		45-74	NS	16	Blood	GM	10.4	nmol/L
		NS	M	22	Blood	GM	8.4	nmol/L
		NS	F	24	Blood	GM	10	nmol/L
		NS	M & F	46	Blood	GM	9.2	nmol/L
Rey et al. (1997)	Arctic, Canada	18-24	NS	67	Blood	GM	46.9	nmol/L
		25-44	NS	137	Blood	GM	53.7	nmol/L
		45-74	NS	66	Blood	GM	53	nmol/L
		NS	M	96	Blood	GM	57.5	nmol/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
		NS	F	176	Blood	GM	48.8	nmol/L
		NS	M & F	280	Blood	GM	51.7	nmol/L
Rey et al. (1997)	Arctic, Canada	18-24	NS	11	Blood	GM	19.6	nmol/L
		25-44	NS	20	Blood	GM	38.3	nmol/L
		45-74	NS	27	Blood	GM	33.2	nmol/L
		NS	M	32	Blood	GM	33	nmol/L
		NS	F	26	Blood	GM	29.9	nmol/L
		NS	M & F	58	Blood	GM	31.6	nmol/L
Benedetti et al. (1992)	Inuit, QC	9-14	NS	16	Blood	Mean	6.8	µmol/mol creatinine.
						GM	2.1	µmol/mol creatinine.
						Median	1	µmol/mol creatinine.
Benedetti et al. (1992)	Inuit, QC	9-14	NS	16	Urine	Mean	2.7	µmol/mol creatinine.
						GM	2.3	µmol/mol creatinine.
						Median	2.3	µmol/mol creatinine.
Benedetti et al. (1992)	Inuit, QC	20-39	NS	24	Blood	Mean	50.1	µmol/mol creatinine.
						GM	29.1	µmol/mol creatinine.
						Median	49	µmol/mol creatinine.
Benedetti et al. (1992)	Inuit, QC	20-39	NS	24	Urine	Mean	2.2	µmol/mol creatinine.
						GM	0.8	µmol/mol creatinine.
						Median	0.9	µmol/mol creatinine.
Benedetti et al.	Inuit, QC	40-59	NS	32	Blood	Mean	52	µmol/mol

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported
(1992)							creatinine. µmol/mol
						GM	37.6 creatinine. µmol/mol
						Median	51 creatinine. µmol/mol
Benedetti et al. (1992)	Inuit, QC	40-59	NS	32	Urine	Mean	4.2 creatinine. µmol/mol
						GM	3 creatinine. µmol/mol
						Median	3.2 creatinine. µmol/mol
Benedetti et al. (1992)	Inuit, QC	60-83	NS	12	Blood	Mean	27.6 creatinine. µmol/mol
						GM	14.5 creatinine. µmol/mol
						Median	20 creatinine. µmol/mol
Benedetti et al. (1992)	Inuit, QC	60-83	NS	12	Urine	Mean	4.6 creatinine. µmol/mol
						GM	3.4 creatinine. µmol/mol
						Median	4.1 creatinine. µmol/mol
Benedetti et al. (1992)	Inuit, QC	15-83	NS	68	Blood	Mean	47 creatinine. µmol/mol
						GM	29.1 creatinine. µmol/mol
						Median	45 creatinine. µmol/mol
Benedetti et al. (1992)	Inuit, QC	15-83	NS	68	Urine	Mean	3.5 creatinine. µmol/mol
						GM	2.8 creatinine.
						Median	2.4 µmol/mol

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
								creatinine.
Benedetti et al. (1992)	Inuit, QC	9-83	NS	84	Blood	Mean	39.4	µmol/mol creatinine.
						GM	17.5	µmol/mol creatinine.
						Median	36	µmol/mol creatinine.
Benedetti et al. (1992)	Inuit, QC	9-83	NS	84	Urine	Mean	3.4	µmol/mol creatinine.
						GM	1.9	µmol/mol creatinine.
						Median	2.3	µmol/mol creatinine.
Benedetti et al. (1994)	Arctic, Canada (Caucasian Rural)	20-29	NA	34	Blood	Mean (95% CI)	14.1(8.3-20)	nmol/L
		30-39	NA	42	Blood	Mean (95% CI)	11.2 (6.8-18.5)	nmol/L
		40-49	NA	69	Blood	Mean (95% CI)	7.5 (5.2-10.8)	nmol/L
		50-59	NA	25	Blood	Mean (95% CI)	11.4 (6.4-20.5)	nmol/L
	Arctic, Canada (Caucasian Rural) 1-10 cig/d	NS	NA	20	Blood	Mean (95% CI)	16.7 (9.8-28.8)	nmol/L
	Arctic, Canada (Caucasian Rural) 11-20 cig/d	NS	NA	26	Blood	Mean (95% CI)	48.3 (40.3-57.9)	nmol/L
	Arctic, Canada (Caucasian Rural) 21-30 cig/d	NS	NA	19	Blood	Mean (95% CI)	56.9 (49.1-66)	nmol/L
	Arctic, Canada (Caucasian Rural) 31-40 cig/d	NS	NA	10	Blood	Mean (95% CI)	71.9 (65.2-79.4)	nmol/L
	Arctic, Canada (Caucasian Rural) cigarette smokers	NS	NA	75	Blood	Mean (95% CI)	40 (32.7-48.9)	nmol/L
	Arctic, Canada (Caucasian Rural) ex-smokers	NS	NA	41	Blood	Mean (95% CI)	6.7(4.8-9.1)	nmol/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
	Arctic, Canada (Caucasian Rural) non-smokers	NS	NA	61	Blood	Mean (95% CI)	2.7(2.1-3.4)	nmol/L
Benedetti et al. (1994)	Arctic, Canada (Caucasian Urban)	20-29	NA	36	Blood	Mean (95% CI)	26 (16.9-40.1)	nmol/L
		30-39	NA	61	Blood	Mean (95% CI)	25.6 (18.4-35.7)	nmol/L
		40-49	NA	52	Blood	Mean (95% CI)	23.9 (17.4-33)	nmol/L
		50-59	NA	32	Blood	Mean (95% CI)	25.4 (17-38.2)	nmol/L
	Arctic, Canada (Caucasian Urban) 1-10 cig/d	NS	NA	37	Blood	Mean (95% CI)	30 (24.7-36.5)	nmol/L
	Arctic, Canada (Caucasian Urban) 11-20 cig/d	NS	NA	43	Blood	Mean (95% CI)	50.2 (44-57)	nmol/L
	Arctic, Canada (Caucasian Urban) 21-30 cig/d	NS	NA	43	Blood	Mean (95% CI)	52 (44.8-60.3)	nmol/L
	Arctic, Canada (Caucasian Urban) 31-40 cig/d	NS	NA	38	Blood	Mean (95% CI)	55.31 (49.1-62.3)	nmol/L
	Arctic, Canada (Caucasian Urban) cigarette smokers	NS	NA	161	Blood	Mean (95% CI)	46.1 (42.4-50)	nmol/L
	Arctic, Canada (Caucasian Urban) ex-smokers	NS	NA	0	Blood	Mean (95% CI)	Nil	nmol/L
	Arctic, Canada (Caucasian Urban) non-smokers	NS	NA	45	Blood	Mean (95% CI)	3.3(2.7-4)	nmol/L
Benedetti et al. (1994)	Arctic, Canada (Inuit)	20-29	NA	27	Blood	Mean (95% CI)	56.9 (40.9-79.1)	nmol/L
		30-39	NA	42	Blood	Mean (95% CI)	37.2 (27.5-50.2)	nmol/L
		40-49	NA	28	Blood	Mean (95% CI)	38.8 (24-62.8)	nmol/L
		50-59	NA	27	Blood	Mean (95% CI)	24.1 (14.9-39.2)	nmol/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
	Arctic, Canada (Inuit) 1-10 cig/d	NS	NA	27	Blood	Mean (95% CI)	32.5 (23.1-45.8)	nmol/L
	Arctic, Canada (Inuit) 11-20 cig/d	NS	NA	34	Blood	Mean (95% CI)	48.1 (39.4-58.6)	nmol/L
	Arctic, Canada (Inuit) 21-30 cig/d	NS	NA	51	Blood	Mean (95% CI)	54 (43-67.7)	nmol/L
	Arctic, Canada (Inuit) 31-40 cig/d	NS	NA	5	Blood	Mean (95% CI)	82.5 (54.6-124.7)	nmol/L
	Arctic, Canada (Inuit) cigarette smokers	NS	NA	117	Blood	Mean (95% CI)	47.3 (41.1-54.5)	nmol/L
	Arctic, Canada (Inuit) ex-smokers	NS	NA	16	Blood	Mean (95% CI)	5.3(3.1-8.9)	nmol/L
	Arctic, Canada (Inuit) non-smokers	NS	NA	7	Blood	Mean (95% CI)	2.4(1.3-4.5)	nmol/L

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); umol/L (micro-mole per litre); ug/dl (micro-gram per deciliter); ug/L (microgram/litre); umol/mol cre. (micromole per mole of creatinine); 95% CI (95 percent confidence interval)

4.7 Copper (Cu)

Three studies in this data base examined Cu levels in blood (plasma) (Butler Walker et al. 2006, Innis et al. 206 and Bussières et al. 2004) in Arctic Canada females, urban BC residents, and Cree exposed and unexposed to mining in Quebec. Both Butler Walker (383 females) and Innis (206 males and female children) had large samples. Copper was analyzed as part of a multiple chemical profile (including trace essential nutrients Se and Zn) and were not necessarily of interest as an environmental contaminant in any of these studies. Butler Walker data are part of a NWT and Nunavut survey for multiple contaminants in populations at risk and establish a baseline upon which future comparisons can be made. By contrast, Bussières examined Cu as a contamiant and found that Cu levels were similar in mine-tailings-exposed Cree and in Cree controls. Mean maternal Cu (2097 mg/L) for all participants was comparable to that reported for Disko, Greenland (2070 mg/L) and within the range of means reported for five communities in Norway (2090–2140 mg/L) (Butler Walker et al. 2006).

Copper is an essential element. Uptake by the body is highly controlled by physiologic mechanisms. The Food and Nutrition Board of the Institute of Medicine recommends dietary allowances (RDAs) of 340 micrograms (340 µg) of Cu per day for children aged 1-3 years, 440 g/day for children aged 4-8 years, 700 µg/day for children aged 9-13 years, 890 µg/day for children aged 14-18 years, and 900 g/day for adults. Copper is toxic only under very specific exposure circumstances, as from very high levels in drinking water. Plasma levels vary considerably and cannot indicate the level of exposure and of risk. Therefore biomonitoring for Cu to measure direct non-dietary environmental exposure is not very useful. These studies are useful in relating metal levels to the toxicity of other environmental chemicals whose exposure is known to be harmful.

Table 4.7: Copper levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Chemical	Biological Sample	Measure	Concentration (units) As reported	
Innis et al. (2006)	Urban, BC	NS	NS	206	Copper	Blood	Mean (SD)	20.5 (5.1)	nmol/L
					Copper	Blood	Median	19.5	nmol/L
					Copper	Blood	Range	9.1–42.6	nmol/L
Walker et al. (2006)	Arctic, Canada	NS	F	383	Copper	Plasma	Mean	2160	µg/L
					Copper	Plasma	GM	2097	µg/L
					Copper	Plasma	Range	172 - 3598	µg/L
Bussières et al. (2004)	Cree, QC (Exposed)	Mean 10.6 (8-14)	M & F	21	Copper	Blood	GM	16 (15-16)	µmol/L
	Cree, QC (Non-exposed)	Mean 11.2 (8 – 14)	M & F	11	Copper	Blood	GM	16.2 (14-18.8)	µmol/L
Baldwin et al. (1999)	Rural, QC	20-69	F	155	Iron	Serum	GM	15	µg/L
					Iron	Serum	Range	5.4-31.9	µg/L
					Iron	Serum	Mean	15.8	µg/L
Baldwin et al. (1999)	Rural, QC	20-69	M	140	Iron	Serum	GM	17.4	µg/L
					Iron	Serum	Range	6.3-48	µg/L
					Iron	Serum	Mean	18.4	µg/L
Baldwin et al. (1999)	Rural, QC	20-69	M & F	295	Iron	Serum	GM	16.1	µg/L
					Iron	Serum	Range	5.4-48	µg/L
					Iron	Serum	Mean	17.1	µg/L
Mergler et al. (1998)	Coastal residence/QC (Fish eaters)	20-69	NA	306	Iron	Blood	Mean (SD)	7.3(2.4)	µg/L
	Coastal residence/QC (Fish non-eaters)	20-69	NA	306	Iron	Blood	Mean (SD)	7.9(2.5)	µg/L

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter)

4.8 Zinc (Zn)

In the studies reporting copper, above, (Butler Walker et al. 2006, Innis et al. 206 and Bussières et al. 2004) in Arctic Canada females, urban BC residents, and Cree exposed and unexposed to mining in Quebec, zinc was also analyzed as part of a multiple chemical analyses (including trace essential nutrients Cu and selenium) and were not necessarily of interest as an environmental contaminant. Butler Walker data are part of a NWT and Nunavut survey for multiple contaminants in populations at risk and does establish a baseline upon which future comparisons can be made. Bussières et al. found that zinc levels were similar in mine tailings exposed Cree and in Cree controls.

Zinc is an essential element. Uptake by the body is highly controlled. Biomonitoring for zinc to measure direct non-dietary environmental exposure is not useful. These studies are useful in relating metal levels to the toxicity of other environmental chemicals whose exposure is known to be harmful.

Table 4.8: Zinc levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units)	
Innis et al. (2006)	Urban, BC	NS	NS	206	Blood	Mean (SD)	11.4 (2.1)	nmol/L
						Median	11.1	nmol/L
						Range	6.8–18.9	nmol/L
Walker et al. (2006)	Arctic, Canada	NS	F	380	Plasma	Mean	581	µg/L
						GM	555	µg/L
						Range	180 - 5207	µg/L
Bussières et al. (2004)	Cree, QC (Exposed)	8 – 14 mean 10.6	M & F	21	Plasma	GM (95% CI)	14.3 (13.7-15)	µmol/L
	Cree, QC (Non-exposed)	8 – 14 mean 11.2	M & F	11	Plasma	GM (95% CI)	13 (12.2-13.8)	µmol/L

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified);; Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per decilitre; 95% CI (95% confidence interval)

4.9 PAH (1-hydroxyprene)

Three studies report biological monitoring results for PAHs (Gilbert et al. 1997, Vyskocil et al. 2000, and St. Amour et al. 2006). The appropriate matrix to measure is urine, as 1-hydroxyprene is a metabolite of PAHs that is excreted in urine.

St. Amour et al., (2000) shows that the environmental levels of PAH produced by an aluminum Soderberg plant do not contribute significantly to the body burden of PAH as measured by 1-OHP. Among the exposed group (n=78), the geometric mean of urinary concentration of 1-OHP was 0.073 umol/mol creatinine compared to 0.060 umol/mol creatinine for the control group (n=40). The difference did not reach statistical significance (p=0.09). Geometric means among the three groups of exposure (high, low, none) were respectively 0.079, 0.067 and 0.060 umol/mol creatinine (p=0.13). This study is a more extensive study of an earlier one which indicated there may be a difference in PAH-exposed and unexposed subjects (Gilbert et al. 1997).

Children 3 – 6 years old were examined by Vyskocil et al. (2000) for PAH exposure and various potential sources. The contribution to the total pyrene absorbed dose from food consumption (estimated daily absorbed dose of 167 and 186 ng, respectively, in 'polluted' and 'non polluted' area) was much more important than that from inhalation (8.4 and 5.4 ng, respectively) in both areas. The estimated daily absorbed doses of pyrene from the soil were 0.061 and 0.104 ng in 'polluted' and 'non polluted' kindergarten, respectively, which correspond to 0.032 and 0.059% of the total absorbed dose.

Higher urinary concentrations of 1-OHP were found in children from 'polluted' kindergarten. In both groups of children, there was no difference in 1-OHP concentrations between urine samples collected in the morning and in the evening. These results suggest that the contribution of exposure to PAH during the stay in the kindergarten (by all routes of entry) was not different from that resulting from exposure outside kindergarten even for children going to the 'polluted' kindergarten.

The authors conclude that in this group of children, food seems to be a main source of the total pyrene and total PAH uptake, even under a relative high PAH air exposure in the city. Pyrene concentration in soil had a negligible contribution to the total pyrene absorbed dose.

Because of the much larger contribution to PAH exposure from food, the usefulness of the urinary 1-OHP as an indicator of other environmental sources of exposure to PAH needs further research.

Table 4.9: 1Hydroxypyrene levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units)	
Vyskocil et al. (2000)	Urban, QC -Morning Day 1 (Exposed)	3-6	NA	11	Urine	GM	0.21	µmol/mol creatinine
						Range	0.07-0.99	µmol/mol creatinine
	Urban, QC -Morning Day 2 (Exposed)	3-6	NA	11	Urine	GM	0.17	µmol/mol creatinine
						Range	0.05-0.77	µmol/mol creatinine
	Urban, QC -Morning Day 3 (Exposed)	3-6	NA	10	Urine	GM	0.21	µmol/mol creatinine
						Range	0.002-0.70	µmol/mol creatinine
	Urban, QC -Morning Day 1-3 (Exposed)	3-6	NA	32	Urine	GM	0.2	µmol/mol creatinine
						Range	0.002-0.77	µmol/mol creatinine
	Urban, QC -Morning Day 1 (Non-exposed)	3-6	NA	32	Urine	GM	0.11	µmol/mol creatinine
						Range	0.003-0.22	µmol/mol creatinine
	Urban, QC -Morning Day 2 (Non-exposed)	3-6	NA	32	Urine	GM	0.17	µmol/mol creatinine
						Range	0.06-0.41	µmol/mol creatinine
	Urban, QC -Morning Day 3 (Non-exposed)	3-6	NA	32	Urine	GM	0.1	µmol/mol creatinine
						Range	0.01-0.24	µmol/mol creatinine
	Urban, QC -Morning Day 1-3 (Non-exposed)	3-6	NA	32	Urine	GM	0.12	µmol/mol creatinine
						Range	0.01-0.41	µmol/mol creatinine
	Urban, QC -Evening Day 1 (Exposed)	3-6	NA	11	Urine	GM	0.22	µmol/mol creatinine
						Range	0.1-0.77	µmol/mol creatinine
	Urban, QC -Evening Day 2 (Exposed)	3-6	NA	11	Urine	GM	0.16	µmol/mol creatinine
						Range	0.03-0.54	µmol/mol creatinine
	Urban, QC -Evening Day 3 (Exposed)	3-6	NA	10	Urine	GM	0.19	µmol/mol creatinine
							0.03-0.70	µmol/mol creatinine
	Urban, QC -Evening Day 1-3 (Exposed)	3-6	NA	32	Urine	GM	0.19	µmol/mol creatinine
						Range	0.03-0.77	µmol/mol creatinine

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units)	
Vyskocil et al. (2000)	Urban, QC -Evening Day 1 (Non-exposed)	3-6	NA	32	Urine	GM	0.12	µmol/mol creatinine
						Range	0.03-0.26	µmol/mol creatinine
	Urban, QC -Evening Day 2 (Non-exposed)	3-6	NA	32	Urine	GM	0.14	µmol/mol creatinine
						Range	0.04-0.25	µmol/mol creatinine
	Urban, QC -Evening Day 3 (Non-exposed)	3-6	NA	32	Urine	GM	0.14	µmol/mol creatinine
						Range	0.09-0.26	µmol/mol creatinine
	Urban, QC -Evening Day 1-3 (Non-exposed)	3-6	NA	32	Urine	GM	0.13	µmol/mol creatinine
						Range	0.03-0.26	µmol/mol creatinine
Gilbert et al. (1997)	Urban, QC (Non-exposed)	30 – 45	M & F	13	Urine	GM	0.057	umol/mol creatinine
	Urban, QC (Exposed)	30 – 45	M & F	20	Urine	GM	0.103	umol/mol creatinine
St Amour et al. (2000)	Urban, QC (Non-exposed)	Adult	M & F	78	Urine	GM	0.073	umol/mol creatinine
	Urban, QC (Exposed)	Adult	M & F	40	Urine	GM	0.06	umol/mol creatinine

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter); µmol/mol cre. (micromole per mole of creatinine)

4.10 2,4-D and MCPA

Phenoxyacetic acids including 2,4-dichlorophenoxyacetic acid (2,4-D) and 4-chloro-2-methylphenoxyacetic acid (MCPA) are widely utilized organic acid herbicides. The potential health impacts of exposure to these chemicals are topics of much discussion in the published literature. In Canada, three studies were identified that examined the internal exposure of 2,4-D and MCPA in urine samples using gas chromatography. All of these studies were based on farming communities in Ontario Canada. In one study (Arbuckle et al. 2002), internal exposure among children age 3 to 18 years was examined. This study shows that boys and the younger age-group (3-8 years) had higher exposure than older age-groups. For example, average (arithmetic mean) urinary 2,4-D level was 4.7 ug/L in boys compared to 0.5 ug/L for girls age 3 to 8 years. A similar trend was observed for MCPA.

The exact levels found in all of these studies are shown in Tables 4.10 and 4.11 for 2,4-D and MCPA respectively.

Table 4.10: Phenoxyacetic acids including 2,4-dichlorophenoxyacetic acid (2,4-D) levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Chemical	Biological Sample	Measure	Concentration (units) As reported	
Arbuckle et al. (2005)	Rural, ON (Pre-exposure)	39 (28 – 49)	F	115	2,4 D	Urine	Mean (SD)	.7 (1.2)	µg/L
							Median	<LOD	µg/L
							GM	0.55	µg/L
	Rural, ON (24 hr post-exposure)	39 (28 – 49)	F	125	2,4 D	Urine	Mean (SD)	1.32 (5.6)	µg/L
							Median	<LOD	µg/L
							GM	0.61	µg/L
	Rural, ON (48 hrs post-exposure)	39 (28 – 49)	F	125	2,4 D	Urine	Mean (SD)	2 (9.7)	µg/L
							Median	<LOD	µg/L
							GM	0.66	µg/L
Arbuckle et al. (2004)	Rural, ON	3-8	F	11	2,4 D	Urine	Mean (SD)	0.5(0)	µg/L
							Max	0.5	µg/L
		9-12	F	11	2,4 D	Urine	Mean (SD)	0.5(0)	µg/L
							Max	0.5	µg/L
		13-18	F	9	2,4 D	Urine	Mean (SD)	0.7(0.5)	µg/L
							Max	2	µg/L
Arbuckle et al. (2004)	Rural, ON	3-8	M	15	2,4 D	Urine	Mean (SD)	4.7(14.2)	µg/L
							Max	56	µg/L
		9-12	M	22	2,4 D	Urine	Mean (SD)	0.8(0.9)	µg/L
							Max	4	µg/L

First Authors (Year)	Population	Age	Sex	N	Chemical	Biological Sample	Measure	Concentration (units) As reported	
Arbuckle et al. (2004)		13-18	M	21	2,4 D	Urine	Mean (SD)	0.8(0.5)	µg/L
							Max	2	µg/L
Arbuckle et al. (2004)	Rural, ON	3-8	M & F	26	2,4 D	Urine	Mean (SD)	2.9(10.8)	µg/L
							Max	56	µg/L
		9-12	M & F	33	2,4 D	Urine	Mean (SD)	0.7(0.7)	µg/L
							Max	4	µg/L
		13-18	M & F	30	2,4 D	Urine	Mean (SD)	0.7(0.5)	µg/L
							Max	2	µg/L
Arbuckle et al. (2002)	Rural, ON	All	F	31	2,4 D	Urine	Mean (SD)	0.5(0.3)	µg/L
							Max	2	µg/L
		All	M	58	2,4 D	Urine	Mean (SD)	1.8(7.3)	µg/L
							Max	56	µg/L
Arbuckle et al. (2002)	Rural, ON (Self-reported use of 2,4-D)	NS	NS	43	2,4 D	Urine	Mean(SD)	27.63(72.48)	µg/L
							GM(SD)	5.36(5.84)	µg/L
							Median	6	µg/L
							Range	0.5-410	µg/L
Arbuckle et al. (2002)	Rural, ON (Self-reported non-use of 2,4-D)	NS	NS	83	2,4 D	Urine	Mean(SD)	2.58(7.99)	µg/L
							GM(SD)	0.9(2.93)	µg/L
							Median	0.5	µg/L
							Range	0.5-66	µg/L
Arbuckle et al.	Rural, ON (Reported exposure (< 24 hrs) to 2,4D and	NS	M	3	2,4 D	Semen	Mean	9.6(15.47)	ppb

First Authors (Year)	Population	Age	Sex	N	Chemical	Biological Sample	Measure	Concentration (units) As reported	
(1999)	MPCA)						(SD)		
							Median	0.8	ppb
							Range	0.6-27.5	ppb
Arbuckle et al. (1999)	Rural, ON (Reported exposure (< 24 hrs) to 2,4D)	NS	M	8	2,4 D	Semen	Mean (SD)	106.9(223.87)	ppb
							Median	8.8	ppb
							Range	0-650	ppb
Arbuckle et al. (1999)	Rural, ON (No exposure (< 24 hrs) reported)	NS	M	9	2,4 D	Semen	Mean (SD)	21.4(45.21)	ppb
							Median	2.5	ppb
							Range	0-140	ppb
Arbuckle et al. (1999)	Rural, ON (Reported exposure (=> 24 hrs) to 2,4D and MPCA)	NS	M	11	2,4 D	Semen	Mean (SD)	29.5(89.79)	ppb
							Median	0.5	ppb
							Range	0-300	ppb
Arbuckle et al. (1999)	Rural, ON (Reported exposure (=> 24 hrs) to 2,4D)	NS	M	15	2,4 D	Semen	Mean (SD)	55.3(100.96)	ppb
							Median	25	ppb
							Range	0.2-400	ppb
Arbuckle et al. (1999)	Rural, ON (No exposure (=> 24 hrs) reported)	NS	M	44	2,4 D	Semen	Mean (SD)	12.7(18.77)	ppb
							Median	6.4	ppb
							Range	0-75	ppb
Arbuckle et al. (1999)	Rural, ON (Reported exposure to 2,4D and MPCA)	NS	M	14	2,4 D	Semen	Mean (SD)	25.2(79.44)	ppb
							Median	0.7	ppb
							Range	0-300	ppb
Arbuckle et al. (1999)	Rural, ON (Reported exposure to 2,4D)	NS	M	23	2,4 D	Semen	Mean (SD)	73.2(151.87)	ppb

First Authors (Year)	Population	Age	Sex	N	Chemical	Biological Sample	Measure	Concentration (units) As reported	
Arbuckle et al. (1999)	Rural, ON (No exposure reported)	NS	M	53	2,4 D	Semen	Median	13.8	ppb
							Range	0-650	ppb
							Mean (SD)	14.2(24.83)	ppb
							Median	5	ppb
							Range	0-140	ppb
Arbuckle et al. (1999)	Rural, ON (Day 2 exposure)	NS	M	NS	2,4 D	Urine	Mean (SD)	26.6(57.02)	ppb
							Median	9.6	ppb
							Range	0-312	ppb

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per decilitre; ppb (parts per billion)

Table 4.11: 4-chloro-2-methylphenoxyacetic acid (MCPA) levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units)	
Arbuckle et al. (2005)	Rural, ON (Pre-exposure)	39 (28 – 49)	F	115	Urine	Mean (SD)	0.63 (0.85)	µg/L
						Median	<LOD	µg/L
						GM	0.54	µg/L
	Rural, ON (24 hr post-exposure)	39 (28 – 49)	F	125	Urine	Mean (SD)	0.64 (0.56)	µg/L
						Median	<LOD	µg/L
						GM	0.56	µg/L
	Rural, ON (48 hrs post-exposure)	39 (28 – 49)	F	125	Urine	Mean (SD)	1.11 (2.4)	µg/L
						Median	<LOD	µg/L
						GM	0.67	µg/L
Arbuckle et al. (2002)	Rural, ON (Self-reported use of 2,4-D)	NS	NS	89	Urine	Mean (SD)	44.9(110.36)	µg/L
						GM (SD)	8.76(6.91)	µg/L
						Median	11	µg/L
						Range	0.5-790.0	µg/L
Arbuckle et al. (2002)	Rural, ON (Self-reported non-use of 2,4-D)	NS	NS	37	Urine	Mean (SD)	1.27(2.28)	µg/L
					Urine	GM (SD)	0.72(2.26)	µg/L
					Urine	Median	0.5	µg/L
					Urine	Range	0.5-12.0	µg/L
Arbuckle et al. (2004)	Rural, ON	3-8	F	11	Urine	Mean (SD)	0.7(0.70	µg/L
						Max	3	µg/L
		9-12	F	11	Urine	Mean (SD)	0.8(0.4)	µg/L
						Max	2	µg/L
		13-18	F	9	Urine	Mean (SD)	0.5(0)	µg/L
						Max	0.5	µg/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units)
Arbuckle et al. (2004)		All	F	31	Urine	Mean (SD)	0.7(0.5) µg/L
						Max	3 µg/L
		3-8	M	15	Urine	Mean (SD)	3.1 (7.2) µg/L
						Max	28 µg/L
		9-12	M	22	Urine	Mean (SD)	1.0(1.7) µg/L
						Max	8 µg/L
		13-18	M	21	Urine	Mean (SD)	1.1(2.0) µg/L
						Max	9 µg/L
		All	M	58	Urine	Mean (SD)	1.6(4.0) µg/L
						Max	28 µg/L
		3-8	M & F	26	Urine	Mean (SD)	2.1(5.5) µg/L
						Max	28 µg/L
		9-12	M & F	33	Urine	Mean (SD)	0.9(1.4) µg/L
						Max	8 µg/L
		13-18	M & F	30	Urine	Mean (SD)	0.9(1.7) µg/L
						Max	8 µg/L

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter

4.11 Persistent contaminants: Organochlorine pesticides (OCs) and Polycholorinated biphenyls (PCBs)

The largest number of studies resulting from our search of the literature referred to persistent organic contaminants. Nearly all of the studies that examine one persistent contaminant usually examine related others, as the analytic method applies to the lipohilic persistent contaminants such as OCs, PCBs, dioxins and furans.

The Northern Contaminants Program of Health Canada has produced many studies of persistent organic contaminants human biomonitoring in the North and circumpolar regions of Canada. In fact, the majority of studies of organochlorines published in Canada refer to northern communities because they appear to be at the highest risk of exposure by virtue of their dependence on sea mammals and fish.

The contaminants tested include p,p'DDT. P,p'DDE, chlordane, oxychlordane (a stable metabolite of chlordane), transnonachlor, cisnonachlor, hexachlorobenzene (HCB), βHexachlorohexane (βHCH), Aldrin, Dieldrin, mirex, and toxaphene. Tissues tested include breast milk, maternal blood and blood cord blood, adipose tissue, and amniotic fluid. Studies compare groups and examine trends in exposure and health outcomes.

Transnonachlor (TNC), a minor component of technical chlordane, and oxychlodane (OXY), a stable metabolite of chlordanes and nonachlors, can contribute over 75% to the chlordane-related residues found in marine mammal blubber (Muir et al. 2000). A report of levels of these contaminants by each aboriginal group and in great detail is published by van Oostdam et al. (2005), a, extensive and thorough review which also discusses health implications.

National surveys to examine breast milk contaminant trends were published by Mes (Mes 1994) and Newsome (Newsome et al. 1992) include chlorobenzenes (CBs), hexachlorocyclohexane isomers (HCH), and PCBs. Mes (1993) also presents data for 25 hydrocarbons; only PCB (Aroclor 1260) was abstracted and shown in the tables below. Trans-nonachlor and oxychlordane account for more than 90% of the chlordane residues found in human milk samples (Newsome and Ryan, 1999).

Several authors examine organochlorine contaminants in breast milk (Dewailly et al. 1996, Frank et al. 1993); blood in infants and children (Dallaire et al. 2003, Despres et al. 2005, Rhainds et al. 1999); and in special groups: fish eaters (Nadon et al. 2002, Kearney et al. 1999); ethnic group fish eaters (Bilrha et al. 2003, Cole et al. 2002); as well as the general population as "background" (Tsuji et al. 2006) and rural residents (Bjerregaard et al. 2001).

Measurements of amniotic fluid (Jarrell et al. 2005) and of breast tissue (Woolcott et al. 2001, McCready et al. 2004, and Aronson et al. 2000) are used to examine hypotheses (fertility and breast cancer risk and relationship to organochlorine and congener concentrations).

Analytic methods

Several methods have been used for organochlorine residues. The table below shows some methods reported in most studies included in this review (where they were specifically stated within the publication). They are reported here as they appear in the studies.

Contaminant of Concern	Method of analysis	Level of Detection
PCB and congeners	GC electron capture detection	0.3 ug/k lipids
PCBs	Gas chromatography	0.3 ug/k
PCB, OC pesticides	High resolution GC	0.02 µg/L
P,p'DDE	GC electron capture detection	0.3 ug/k lipids
PCBs	Gas Chromatography	0.2 ug/L
PCBs	GC-MS	0.02 ug/L
PCBs	GC electron capture	3 ug/k ww
DDE	GC electron capture	0.3 ug/k ww
DDT	GC electron capture	0.6 ug/k ww
Cis-Nonachlor	GC electron capture	0.3 ug/k ww
Trans-Nonachlor	GC electron capture	0.3 ug/k ww
HCB	GC electron capture	0.3 ug/k ww
β-HCH	GC electron capture	0.6 ug/k ww
Dioxin-like compounds	GC-MS	1-10 ng/k
Chlorinated pesticides	GC-MS	0.02 ug/L
Toxaphene	GC-MS Fisous 8000 with positive electron ionization mode	Reference standard by Promochem GmbH Ge 1pgµ/L cong 26, 50 and 2µg/L cong 62

The detection limits obviously vary, and results are applicable to specific matrix analyzed (i.e. breast tissue reported as wet weight – ww). In order to make meaningful comparisons of results of each study, it would be necessary to calculate values for each that are comparable. This was not done for this report.

Reflecting the general results of studies, fish eaters and northern communities have organochlorine levels much time higher than non fish eaters and southern communities. These differences are highlighted in that even coastal communities who eat low concentration fish have lower levels of organochlorines comparable to the non-fisheating populations.

Considering the studies in this compendium, health effects of organic contaminant exposure are uncertain with respect to breast cancer risk (Aronson et al. 2000, Woolcott 2001) while there are indications that they may be a fertility risk as measured by time to

pregnancy (Jarrell et al. 2005).

There are no national norms for exposure levels in Canada. The US Report on Exposure to Environmental Contaminants (2005) has results for these contaminanants in the US population.

Table 4.12: DDE and DDT levels in biological samples

First Authors (Year)	Population	Age	Sex	N	DDE & DDT Types	Biological Sample	Measure	Concentration (units) As reported	
Tsuji et al. (2006)	Arctic, Canada (Hamilton)	NS	M	25	DDT + DDE	Plasma	Mean (SD)	254.2 (299.9)	µg/k lipids
	Arctic, Canada (Hamilton)	NS	F	27	DDT + DDE	Plasma	Mean (SD)	255.0 (372.3)	µg/k lipids
							Range	29.2- 1514.3	µg/k lipids
	Arctic, Canada (Kashechewan)	NS	M	50	DDT + DDE	Plasma	Mean (SD)	517.6 (410.3)	µg/k lipids
							Range	102.2 -1506.4	µg/k lipids
	Arctic, Canada (Kashechewan)	NS	F	48	DDT + DDE	Plasma	Mean (SD)	560.5 (681.4)	µg/k lipids
							Range	59.9- 3488.7	µg/k lipids
	Arctic, Canada (Fort Albany)	NS	M	51	DDT + DDE	Plasma	Mean (SD)	425.2 (384.2)	µg/k lipids
							Range	88.2- 2396.0	µg/k lipids
			F	48	DDT + DDE	Plasma	Mean (SD)	489.7 (483.6)	
Tsuji et al. (2005)	Urban, ON (Hamilton)	18+	M	25	DDT + DDE	Plasma	Mean (SD)	1.84 (2.67)	µg/L ww
							Range	0.3 - 12.73	µg/L ww
							GM (95% CI)	1.28 (0.79 - 1.9)	µg/L ww
	Urban, ON (Hamilton)	>18	F	27	DDT + DDE	Plasma	Mean (SD)	1.74 (3.01)	µg/L ww
							Range	0.21 -14.14	µg/L ww
							GM (95% CI)	1.12 (0.68 - 1.68)	µg/L ww
	Arctic, Canada (Kashechewan)	18+	M	50	DDT + DDE	Plasma	Mean (SD)	3.26 (2.42)	µg/L ww

First Authors (Year)	Population	Age	Sex	N	DDE & DDT Types	Biological Sample	Measure	Concentration (units) As reported	
							Range	0.54 - 9.56	µg/L ww
							GM (95% CI)	2.66 (2.13 - 3.28)	µg/L ww
	Arctic, Canada (Kashechewan)	>18	F	48	DDT + DDE	Plasma	Mean (SD)	3.58 (4.3)	µg/L ww
							Range	0.32 -20.14	µg/L ww
							GM (95% CI)	2.38 (1.74 - 3.18)	µg/L ww
	Urban, ON (Fort Albany)	18+	M	51	DDT + DDE	Plasma	Mean (SD)	2.74 (2.92)	µg/L ww
							Range	0.35 - 19.04	µg/L ww
							GM (95% CI)	2.17 (1.73 -2.68)	µg/L ww
	Urban, ON (Fort Albany)	>18	F	48	DDT + DDE	Plasma	Mean (SD)	3.01 (3.25)	µg/L ww
							Range	0.3 - 12.43	µg/L ww
							GM (95% CI)	2.14 (1.58 - 2.82)	µg/L ww
Lebel et al. (1998)	Urban, QC	18 – 50 (Cases)	F	70	DDT + DDE	Blood	GM (95% CI)	229.0 (195.6–268.1)	µg/k lipids
		18 – 50 (Controls)	F	156	DDT + DDE	Blood	GM (95% CI)	238.2 (209.8-270.6)	µg/k lipids
Tsuji et al. (2006)	Arctic, Canada (Hamilton)	NS	F	27	p'DDT+ p'DDE	Plasma	Mean (SD)	255.0 (372.3)	µg/k lipids
							Range	29.2- 1514.3	µg/k lipids
	Arctic, Canada (Kashechewan)	NS	F	48	p'DDT+ p'DDE	Plasma	Mean (SD)	560.5 (681.4)	µg/k lipids
							Range	59.9- 3488.7	µg/k lipids
	Arctic, Canada (Hamilton)	NS	M	25	p'DDT+ p'DDE	Plasma	Mean (SD)	254.2 (299.9)	µg/k lipids
							Range	52.9 -1314.4	µg/k lipids

First Authors (Year)	Population	Age	Sex	N	DDE & DDT Types	Biological Sample	Measure	Concentration (units) As reported	
	Arctic, Canada (Fort Albany)	NS	M	51	p'DDT+ p'DDE	Plasma	Mean (SD)	425.2 (384.2)	µg/k lipids
							Range	88.2- 2396.0	µg/k lipids
	Arctic, Canada (Kashechewan)	NS	M	50	p'DDT+ p'DDE	Plasma	Mean (SD)	517.6 (410.3)	µg/k lipids
							Range	102.2 -1506.4	µg/k lipids

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter)

Table 4.13a: DDE levels in biological samples

First Authors (Year)	Population	Age	Sex	N	DDE Types	Biological Sample	Measure	Concentration (units) As reported	
Jarrell et al. (2005)	Urban, AB	NS	F	107	DDE	Blood	Mean	164.09	ng/g lipid
							Range	2.55 - 1392.19	ng/g lipid
							GM	110.93	ng/g lipid
	Urban, AB	NS	F	209	DDE	Amniotic fluid	Mean	153.23	ng/g lipid
							Range	3.68 - 1625.00	ng/g lipid
							GM	109.85	ng/g lipid
Hamel et al. (2003)	Urban, QC	NS	F	30	DDE	Cord Blood	Mean (SEM)	0.18 (0.02)	µg/L
							Median	0.16	µg/L
							75th percentile	0.21	µg/L
Hamel et al. (2003)	Urban, QC	NS	F	30	DDE	Maternal Blood	Mean (SEM)	0.55 (0.05)	µg/L
							Median	0.48	µg/L
							75th percentile	0.7	µg/L
Hamel et al. (2003)	Urban, QC	NS	F	30	DDE	Placenta	Mean (SEM)	58.56 (5.93)	ug/k
							Median	48	ug/k
							75th percentile	71	ug/k
Dellaire et al. (2003)	Northern, QC	Newborns	M(52%) F(48%)	238	DDE	Cord Blood	Mean	6.7	% decrease
							Range	(6.4 – 11.5)	% decrease
Nadon et al. (2002)	Urban, QC	< 45	F	8	DDE	Plasma	Mean (SD)	180.70 (135.40)	µg/L
							GM	151.2	µg/L

First Authors (Year)	Population	Age	Sex	N	DDE Types	Biological Sample	Measure	Concentration (units) As reported	
		< 45	M	17	DDE	Plasma	Mean (SD)	249.70 (175.10)	µg/L
							GM	203.7	µg/L
Buck et al. (2002)	Urban, ON	Mean(SD/Range) 30.1(2.5/18-34)	F	102	DDE	Serum	Mean (SD)	1.0978 (0.52)	ng/g sample
							Median	0.9933	ng/g sample
Frank et al. (1993)	Urban, ON	Adult	M & F	169	DDE	Blood	Mean (SD)	3.2 (3.2)	ug/k
							Max	16	ug/k
	Urban, ON	Adult	M & F	581	DDE	Blood	Mean (SD)	3.8 (4.0)	ug/k
							Max	51	ug/k
	Urban, ON	Adult	M & F	750	DDE	Blood	Mean (SD)	3.7 (3.9)	ug/k
							Max	51	ug/k

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); umol/L (micro-mole per litre); ug/dl (micro-gram per deciliter)

Table 4.13b: p,p'DDE levels in biological samples

First Authors (Year)	Population	Age	Sex	N	DDE Types	Biological Sample	Measure	Concentration (units)	
Tsuji et al. (2006)	Canada (Hamilton)	NS	F	27	p,p' DDE	Plasma	GM	142	µg/k lipids
	Canada (Fort Albany)	NS	F	48	p,p' DDE	Plasma	GM	306	µg/k lipids
	Canada (Kashechewan)	NS	F	48	p,p' DDE	Plasma	GM	316	µg/k lipids
	Canada (NWT)	NS	F	67	p,p' DDE	Plasma	GM	133	µg/k lipids
Despres et al. (2005)	Northern, QC	4 – 6	M & F	110	p,p' DDE	Blood	Mean	496	ug/k
							Range	37.9 – 3081.0	ug/k
							GM (SD)	286.7 (581)	ug/k
Ayotte et al. (2005)	Northern, QC	25-75	23F+ 17M	40	p,p' DDE	Plasma	Mean (SD)	1,681(1,576)	µg/k lipids

First Authors (Year)	Population	Age	Sex	N	DDE Types	Biological Sample	Measure	Concentration (units)	
							Median	1086	µg/k lipids
							Range	56-6,262	µg/k lipids
Jarrell et al. (2005)	Urban, AB	NS	F	47	p,p' DDE	Breast milk	Mean	101.9	ng/g lipid
							Range	16.13 - 989.05	ng/g lipid
							GM	68.06	ng/g lipid
Jarrell et al. (2005)	Urban, AB	NS	F	47	p,p' DDE	Breast milk	Mean	2.57	ng/ml
							Range	0.15 - 20.80	ng/ml
							GM	1.63	ng/ml
Jarrell et al. (2005)	Urban, AB	NS	F	97	p,p' DDE	Umbilical cord	Mean	121.79	ng/g lipid
							Range	10.42 - 1073.33	ng/g lipid
							GM	76.59	ng/g lipid
Jarrell et al. (2005)	Urban, AB	NS	F	97	p,p' DDE	Umbilical cord	Mean	0.25	ng/ml
							Range	0.03 - 2.00	ng/ml
							GM	0.16	ng/ml
Jarrell et al. (2005)	Urban, AB	NS	F	107	p,p' DDE	Blood	Mean	1.1	ng/ml
							Range	0.30 - 8.90	ng/ml
							GM	0.76	ng/ml
Jarrell et al. (2005)	Urban, AB	NS	F	209	p,p' DDE	Amniotic fluid	Mean	1.06	ng/ml
							Range	0.30 - 10.40	ng/ml
							GM	0.76	ng/ml
Dellaire et al. (2004)	Nunavik, QC (Inuit)	NS	F	172	p,p' DDE	Infant Plasma	GM (95%CI)	256 (214-307)	µg kg lipid
							Range	15.6-4386	µg /k lipid
	Nunavik, QC (Inuit)	NS	F	199	p,p' DDE	Maternal Plasma	GM (95%CI)	294 (267-324)	µg /k lipid
							Range	54.3-2269	µg /k lipid
McCready et al. (2004)	Urban, ON (Controls)	48 (9.9)	F	69	p,p' DDE	Breast tissue	GM (SD)	616.13 (456.88)	µg/k lipid
	Urban, ON (Cases)	52.5 (10.0)	F	70	p,p' DDE	Breast tissue	GM (SD)	1241.75 (1544.90)	µg/k lipid
Bilrha et al. (2003)	Rural, QC (Exposed)	24 (4.9)	F	47	p,p' DDE	Cord Blood	GM (95%	144 (114-182)	µg/L plasma

First Authors (Year)	Population	Age	Sex	N	DDE Types	Biological Sample	Measure	Concentration (units)	
							CI)		lipid
							GM (95%		µg/L plasma
Bilrha et al. (2003)	Rural, QC (Reference)	NS	F	65	p,p' DDE	Cord Blood	CI)	84 (73-96)	lipid
Walker et al. (2003)	Arctic Canada	NS	F	385	p,p' DDE	Blood Plasma	Mean	1.75	µg /L
							GM	1.05	ug/L
							Range	0.12-34.43	µg /L
Walker et al. (2003)	Arctic Canada	NS	NS	400	p,p' DDE	Cord Plasma	Mean	0.53	µg /L
							GM	0.34	µg /L
							Range	0.05-9.25	µg /L
Cole et al. (2002)	Fish eaters, ON	NS	M & F	89	p,p' DDE	Plasma	Mean (SD)	9.50 (13.20)	µg /L
							GM (SD)	4.10 (3.97)	µg /L
							Range	0.41-84.91	µg /L
							Median	3.93	µg /L
Belles-Isles et al. (2002)	Coastal Community, NF	23.9 (5.6)	F	48	p,p' DDE	Cord Blood	GM (95% CI)	167 (138-203)	ug/k
							Range	42-743	ug/k
Belles-Isles et al. (2002)	Urban, QC	26.9 (3.8)	F	60	p,p' DDE	Cord Blood	GM (95% CI)	105 (90-122)	ug/k
							Range	22-430	ug/k
Muckle et al. (2001)	Northern Community, QC	NS	NA	98	p,p' DDE	Breast Milk	Mean (SD)	514.9 (1.9)	ug/k
							GM	419.7	ug/k
							Range	85.9-2295.4	ug/k
Muckle et al. (2001)	Northern Community, QC	NS	NA	98	p,p' DDE	Cord Plasma	Mean (SD)	387.9 (2.0)	ug/k
							GM	305.2	ug/k
							Range	55.7-1773.4	ug/k
Muckle et al. (2001)	Northern Community, QC	NS	NA	98	p,p' DDE	Maternal Plasma	Mean (SD)	389.3 (1.9)	ug/k
							GM	307.3	ug/k
							Range	58.8-2268.1	ug/k
Woolcott et al. (2001)	Urban, ON (Case 1)	58.8 (11.6)	F	51	p,p' DDE	Breast tissue	GM	638	mg/k lipid

First Authors (Year)	Population	Age	Sex	N	DDE Types	Biological Sample	Measure	Concentration (units)	
							95% CI	(557-730)	mg/k lipid
	Urban, ON (Case 2)	54.2 (11.0)	F	150	p,p' DDE	Breast tissue	GM	906	mg/k lipid
							95% CI	(682-1203)	mg/k lipid
	Urban, ON (Controls)	53.9 (10.9)	F	213	p,p' DDE	Breast tissue	GM	596	µg/k lipid
							95% CI	(530-670)	µg/k lipid
Rhainds et al. (1999)	Urban, QC	newborn	M & F	1109	p,p' DDE	Cord Blood	GM (95% CI)	0.412 (.390 - 0.435)	ug/L
Newsome et al. (1999)	NWT	Median 25	F	12	p,p' DDE	Milk	Mean	441	ng/g liquid
							Median	324	ng/g liquid
Newsom et al. (1996)	Canada	NS	NS	497	p,p' DDE	Milk fat	Mean	222	ng/g
						Milk fat	Median	169	ng/g
Newsom et al. (1996)	Canada	NS	NS	497	p,p' DDE	Whole milk	Mean	6.78	ng/g
						Whole milk	Median	4.85	ng/g
Kearney et al. (1999)	Urban, ON (Non-fish eaters)	NS	F	35	p,p' DDE	Plasma	Mean	2.7	µg /L
							Range	0.07 – 29.0	µg /L
	Urban, ON (Non-fish eaters)	NS	M	45	p,p' DDE	Plasma	Mean	2.3	µg /L
							Range	0.4 - 16	µg /L
	Urban, ON (Fish eaters)	NS	F	51	p,p' DDE	Plasma	Mean	2.9	µg /L
							Range	.02 – 26.0	µg /L
	Urban, ON (Non-fish eaters)	23-69	M & F	80	p,p' DDE	Plasma	Mean	4.4	µg /L
							Median	2.5	µg /L
	Urban, ON (Fish eaters)	NS	M	101	p,p' DDE	Plasma	Mean	3.8	µg /L
							Range	0.5 - 51	µg /L
	Urban, ON (Fish eaters)	23-69	M & F	152	p,p' DDE	Plasma	Mean	5.6	µg /L
	Urban, BC	NS	M & F	41	p,p' DDE	Adipose	Mean	709	ng/g lipid
							Range	71.1-479.2	ng/g lipid

First Authors (Year)	Population	Age	Sex	N	DDE Types	Biological Sample	Measure	Concentration (units)	
Dewailly et al. (1996)	Northern, QC	27.9 (4.2)	F	536	p,p' DDE	Breast milk	GM (SD) Mean 95% CI Range	454 (2.54) 0.34 0.32 – 0.35 0.02 – 2.89	ng/g lipid mg/ k lipids

Table 4.13c: DDT levels in biological samples

First Authors (Year)	Population	Age	Sex	N	DDT Types	Biological Sample	Measure	Concentration (units)	
Dellaire et al. (2003)	Northern, QC	Newborns (mothers age 23.5+/-4.5)	M(52%) FeM48%	238	DDT	Cord Blood	Mean	5.9 (1.1 – 10.4)	% decrease
							Range		% decrease
Hamel et al. (2003)	Urban, QC	NS	F	30	DDT	Cord Blood	Mean (SEM)	0.013 (0.002)	µg /L
							Median	0.01	µg /L
							75th percentile	0.01	µg /L
	Urban, QC	NS	F	30	DDT	Maternal Blood	Mean (SEM)	0.038 (0.004)	µg /L
						Maternal Blood	Median	0.03	µg /L
						Maternal Blood	75th percentile	0.04	µg /L
	Urban, QC	NS	F	30	DDT	Placenta	Mean (SEM)	0.774 (0.774)	µg /k
						Placenta	Median	0	µg /k
						Placenta	75th percentile	0	µg /k
Bjerregaard et al. (2001)	Rural, QC	18+	NA	408	Total DDT	Plasma	Median	9.37	µg/L wet
Mes et al. (1994)	Central Canada, 1967	NS	NS	NS	Total DDT	Whole milk	Mean	154	ng/g
	Central Canada, 1975	NS	NS	NS	Total DDT	Whole milk	Mean	26	ng/g
	Central Canada, 1982	NS	NS	NS	Total DDT	Whole milk	Mean	31	ng/g
	Central Canada, 1986	NS	NS	NS	Total DDT	Whole milk	Mean	9	ng/g

First Authors (Year)	Population	Age	Sex	N	DDT Types	Biological Sample	Measure	Concentration (units)	
Mes et al. (1994)	Eastern Canada, 1967	NS	NS	NS	Total DDT	Whole milk	Mean	132	ng/g
	Eastern Canada, 1975	NS	NS	NS	Total DDT	Whole milk	Mean	37	ng/g
	Eastern Canada, 1982	NS	NS	NS	Total DDT	Whole milk	Mean	35	ng/g
	Eastern Canada, 1986	NS	NS	NS	Total DDT	Whole milk	Mean	13	ng/g
	Ontario Canada, 1967	NS	NS	NS	Total DDT	Whole milk	Mean	182	ng/g
	Ontario Canada, 1975	NS	NS	NS	Total DDT	Whole milk	Mean	46	ng/g
	Ontario Canada, 1982	NS	NS	NS	Total DDT	Whole milk	Mean	43	ng/g
	Ontario Canada, 1986	NS	NS	NS	Total DDT	Whole milk	Mean	10	ng/g
	Quebec Canada, 1967	NS	NS	NS	Total DDT	Whole milk	Mean	127	ng/g
	Quebec Canada, 1975	NS	NS	NS	Total DDT	Whole milk	Mean	42	ng/g
	Quebec Canada, 1982	NS	NS	NS	Total DDT	Whole milk	Mean	53	ng/g
	Quebec Canada, 1986	NS	NS	NS	Total DDT	Whole milk	Mean	15	ng/g
	Western Canada, 1967	NS	NS	NS	Total DDT	Whole milk	Mean	125	ng/g
	Western Canada, 1975	NS	NS	NS	Total DDT	Whole milk	Mean	44	ng/g
	Western Canada, 1982	NS	NS	NS	Total DDT	Whole milk	Mean	31	ng/g
	Western Canada, 1986	NS	NS	NS	Total DDT	Whole milk	Mean	12	ng/g
Teshke et al. (1993)	Urban, BC	NS	M & F	41	Total DDT	Adipose	Mean	779	ng/g lipid

First Authors (Year)	Population	Age	Sex	N	DDT Types	Biological Sample	Measure	Concentration (units)	
Teshke et al. (1993)							Range	76.0-6883	ng/g lipid
							GM (GSD)	480 (2.55)	ng/g lipid

Table 4.13d: p,p'DDT levels in biological samples

First Authors (Year)	Population	Age	Sex	N	DDE Types	Biological Sample	Measure	Concentration (units)
Tsuji et al. (2006)	Canada (Hamilton)	NS	F	27	p,p' DDT	Plasma	GM	6.9 µg/k lipids
	Canada (Fort Albany)	NS	F	48	p,p' DDT	Plasma	GM	10.5 µg/k lipids
	Canada (Kashechewan)	NS	F	48	p,p' DDT	Plasma	GM	8.6 µg/k lipids
	Canada (NWT)	NS	F	67	p,p' DDT	Plasma	GM	7.9 µg/k lipids
McCready et al. (2004)	Urban, ON (Controls)	48 (SD 9.9)	F	69	p,p'DDT	Breast tissue	GM (SD)	19.49 (14.05) µg/k lipid
	Urban, ON (Cases)	52.5 (SD 10.0)	F	70	p,p'DDT	Breast tissue	GM (SD)	47.31 (73.83) µg/k lipid
Woolcott et al. (2001)	Urban, ON (Case 1)	58.8 (11.6)	F	51	p,p'DDT	Breast tissue	GM	21.3 mg/k lipid
							95% CI	(18.8-24.1) mg/k lipid
Woolcott et al. (2001)	Urban, ON (Case 2)	54.2 (11.0)	F	150	p,p'DDT	Breast tissue	GM	23.5 mg/k lipid
Woolcott et al. (2001)							95% CI	(17.3-32.0) mg/k lipid
Woolcott et al. (2001)	Urban, ON (Controls)	53.9 (10.9)	F	213	p,p'DDT	Breast tissue	GM	19.3 µg/k lipid
Woolcott et al. (2001)							95% CI	(17.3-21.6)
Aronson et al. (2000)	Urban, ON	57.7 (11.6)	F	217	p,p' DDT	Benign breast tissue	GM (95% CI)	22 (19.6-24.7) µg/k
Demers et al. (2000)	Urban, QC (Controls)	53 (10)	F	219 non cancer community controls	p,p'DDT	Plasma	Mean	11.8 µg k plasma lipid µg /k plasma
							Median	9 lipid
Newsome et al. (1999)	NWT	Median 25	F	12	p,p'DDT	Milk	Mean	24.2 ng/g liquid
							Median	21 ng/g liquid

Table 4.14: HCB levels in biological samples

First Authors (Year)	Population	Age	Sex	N	HCB & HCH Types	Biological Sample	Measure	Concentration (units)	
Tsuji et al. (2006)	Arctic, Canada (Hamilton)	NS	M	25	HCB	Plasma	Mean (SD)	11.5 (4.8)	µg/k lipids
								4.1- 22.5	µg/k lipids
	Arctic, Canada (Hamilton)	NS	F	27	HCB	Plasma	Mean (SD)	17.1 (22.5)	µg/k lipids
							GM	13.3	µg/k lipids
							Range	5.4- 127.4	µg/k lipids
	Arctic, Canada (Fort Albany)	NS	M	51	HCB	Plasma	Mean (SD)	23.9 (14.0)	µg/k lipids
							Range	7.0- 66.1	µg/k lipids
	Arctic, Canada (Fort Albany)	NS	F	48	HCB	Plasma	Mean (SD)	25.8 (21.3)	µg/k lipids
							GM	19.1	µg/k lipids
							Range	1.0 -101.9	µg/k lipids
	Arctic, Canada (Kashechewan)	NS	M	50	HCB	Plasma	Mean (SD)	29.5 (15.1)	µg/k lipids
							Range	6.2 -73.1	µg/k lipids
	Arctic, Canada (Kashechewan)	NS	F	48	HCB	Plasma	Mean (SD)	28.6 (20.7)	µg/k lipids
							GM	22.4	µg/k lipids
							Range	4.6- 79.0	µg/k lipids
Ayotte et al. (2005)	Northern, QC	25-75	23F+ 17M	40	HCB	Plasma	Mean (SD)	101(42)	µg/k lipids
							Median	104	µg/k lipids
							Range	35-223	µg/k lipids
Jarrell et al. (2005)	Urban, AB	NS	F	47	HCB	Breast milk	Mean	6.06	ng/g lipid
							Range	2.55 - 11.25	ng/g lipid
							GM	5.63	ng/g lipid
	Urban, AB	NS	F	47	HCB	Breast milk	Mean	0.16	ng/ml
							Range	0.03 - 0.36	ng/ml
							GM	0.14	ng/ml
	Urban, AB	NS	F	97	HCB	Umbilical cord	Mean	0.03	ng/ml
							Range	0.03 - 0.13	ng/ml

First Authors (Year)	Population	Age	Sex	N	HCB & HCH Types	Biological Sample	Measure	Concentration (units)	
							GM	0.02	ng/ml
	Urban, AB	NS	F	97	HCB	Umbilical cord	Mean	15.6	ng/g lipid
							Range	7.58 - 100.00	ng/g lipid
							GM	13.91	ng/g lipid
	Urban, AB	NS	F	107	HCB	Blood	Mean	0.13	ng/ml
							Range	0.03 - 0.62	ng/ml
							GM	0.11	ng/ml
	Urban, AB	NS	F	107	HCB	Blood	Mean	18.28	ng/g lipid
							Range	3.25 - 177.16	ng/g lipid
							GM	14.37	ng/g lipid
	Urban, AB	NS	F	209	HCB	Amniotic fluid	Mean	0.12	ng/ml
							Range	0.03 - 1.32	ng/ml
							GM	0.1	ng/ml
	Urban, AB	NS	F	209	HCB	Amniotic fluid	Mean	17.23	ng/g lipid
							Range	2.81 - 159.04	ng/g lipid
							GM	14.33	ng/g lipid
McCready et al. (2004)	Urban, ON (Controls)	48 (SD 9.9)	F	69	HCB	Breast tissue	GM (SD)	27.99 (15.12)	µg/k lipid
	Urban, ON (Cases)	52.5 (SD 10.0)	F	70	HCB	Breast tissue	GM (SD)	57.85 (138.57)	µg/k lipid
Bilrha et al. (2003)	Rural, QC (Exposed)	24 (4.9)	F	47	HCB	Cord Blood	GM (95% CI)	14 (12-16)	µg/L plasma lipid
	Rural, QC (Reference)	NS	F	65	HCB	Cord Blood	GM (95% CI)	9 (8-10)	µg/L plasma lipid
Dellaire et al. (2003)	Northern, QC	Newborns	M(52%) FeM48%	238	HCB	Cord Blood	Mean	4. (.03 – 9.0)	% decrease
									% decrease
Walker et al. (2003)	Arctic Canada	NS	F	385	HCB	Blood Plasma	Mean	0.35	µg /L
								0.22	µg /L
								0.2-4.51	µg /L

First Authors (Year)	Population	Age	Sex	N	HCB & HCH Types	Biological Sample	Measure	Concentration (units)	
Belles-Isles et al. (2002)	Coastal Community, NF	23.9 (5.6)	F	48	HCB	Cord Blood	GM (95% CI)	17 (15-19)	µg /k
							Range	21306	µg /k
Belles-Isles et al. (2002)	Urban, QC	26.9 (3.8)	F	60	HCB	Cord Blood	GM (95% CI)	13 (12-14)	µg /k
							Range	6-30	µg /k
Cole et al. (2002)	Fish eaters, ON	NS	M & F	89	HCB	Plasma	Mean (SD)	0.11 (0.08)	µg /L
							GM (GSD)	0.09 (1.83)	µg /L
							Range	0.02-0.50	µg /L
							Median	0.08	µg /L
Dellaire et al. (2002)	Coastal residence/QC (2000)	NS	F	65	HCB	Cord Blood	Mean (95%CI)	11.6 (10.5-12.8)	µg/k
	Coastal residence/QC (1997)	NS	F	50	HCB	Cord Blood	Mean (95%CI)	13.3 (11.9-14.9)	µg/k
	Coastal residence/QC (1996)	NS	F	71	HCB	Cord Blood	Mean (95%CI)	16.9 (15.4-18.6)	µg/k
	Coastal residence/QC (1995)	NS	F	82	HCB	Cord Blood	Mean (95%CI)	17.9 (16.3-19.5)	µg/k
	Coastal residence/QC (1994)	NS	F	62	HCB	Cord Blood	Mean (95%CI)	19.2 (17.3-21.2)	µg/k
	Coastal residence/QC (1993)	NS	F	62	HCB	Cord Blood	Mean (95%CI)	35.5 (32-39.2)	µg/k
	Coastal residence/QC (Natives)	NS	F	168	HCB	Cord Blood	Mean (95%CI)	12.6 (10.0-15.0)	µg/k
	Coastal residence/QC (Caucasians)	NS	F	224	HCB	Cord Blood	Mean (95%CI)	12.3 (9.9-14.6)	µg/k
	Coastal residence/QC (All)	NS	F	392	HCB	Cord Blood	Mean (95%CI)	12.5 (10.8-14.2)	µg/k
Bjerregaard et al. (2001)	Rural, QC	18+	NA	408	HCB	Plasma	Median	2.22	µg/L wet

First Authors (Year)	Population	Age	Sex	N	HCB & HCH Types	Biological Sample	Measure	Concentration (units)	
Muckle et al. (2001)	Northern Community, QC	NS	NA	98	HCB	Cord Plasma	Mean (SD)	55.6 (1.9)	µg /k
							GM	45.6	µg /k
							Range	10.6-233.6	µg /k
Muckle et al. (2001)	Northern Community, QC	NS	NA	98	HCB	Maternal Plasma	Mean (SD)	51.1 (1.9)	µg /k
							GM	42	µg /k
							Range	6.7-352.6	µg /k
Woolcott et al. (2001)	Urban, ON (Case 1)	58.8 (11.6)	F	51	HCB	Breast tissue	GM	31	mg/k lipid
							95% CI	(28.3-33.9)	mg/k lipid
Woolcott et al. (2001)	Urban, ON (Case 2)	54.2 (11.0)	F	150	HCB	Breast tissue	GM	34.9	mg/k lipid
							95% CI	(27.3-44.7)	mg/k lipid
Woolcott et al. (2001)	Urban, ON (Controls)	53.9 (10.9)	F	213	HCB	Breast tissue	GM	30.1	µg/k lipid
							95% CI	(27.8-32.5)	
Aronson et al. (2000)	Urban, ON	57.7 (11.6)	F	217	HCB	Benign breast tissue	GM (95% CI)	32 (29.3-34.8)	µg/k
Newsome et al. (1999)	NWT	Median 25	F	12	HCB	Milk	Mean	43	ng/g liquid
							Median	43.5	ng/g liquid
Newsom et al. (1996)	Canada	NS	NS	497	HCB	Milk fat	Mean	14.5	ng/g
							Median	13	ng/g
Newsom et al. (1996)	Canada	NS	NS	497	HCB	Whole milk	Mean	0.44	ng/g
							Median	0.39	ng/g
Teshke et al. (1993)	Urban, BC	NS	M & F	41	HCB	Adipose	Mean	39.1	ng/g lipid
							Range	9.22-109	ng/g lipid
							GM (GSD)	33.1 (1.77)	ng/g lipid

First Authors (Year)	Population	Age	Sex	N	HCB & HCH Types	Biological Sample	Measure	Concentration (units)
Despres et al. (2005)	Northern, QC	4-6	M & F	110	β-HCB	Blood	Mean	63 µg /k
							Range	9.9 – 275.6 µg /k
							GM (SD)	46.9 (52.7) µg /k
Demers et al. (2000)	Urban, QC (Cases)	53 (9)	F	314	β-HCB	Plasma	Mean	21.1 ug/k plasma lipid
							Median	15.5 ug/k plasma lipid
	Urban, QC (Hosp. Controls)	51 (11)	F	219	β-HCB	Plasma	Mean	19.4 ug/k plasma lipid
							Median	15.3 ug/k plasma lipid
	Urban, QC (Com. Controls)	53 (10)	F	219	β-HCB	Plasma	Mean	17.5 ug/k plasma lipid
							Median	15.1 ug/k plasma lipid
Buck et al. (2002)	Urban, ON	Mean (SD/Rge) 30.1(2.5/18-34)	F	102	β-HCB	Serum	Mean (SD)	0.0016 (0.004) ng/g sample
							Median	0 ng/g sample
Newsome et al. (1999)	NWT	Median 25	F	12	α HCH	Milk	Mean	4.39 ng/g liquid
							Median	1.56 ng/g liquid
Bjerregaard et al. (2001)	Rural, QC	18+	NA	408	β HCH	Plasma	Median	0.31 µg/L wet
Woolcott et al. (2001)	Urban, ON (Controls)	53.9 (10.9)	F	213	β HCH	Breast tissue	GM	41.5 µg/k lipid
							95% CI	(36.1-47.6)
	Urban, ON (Case 1)	54.2 (11.0)	F	150	β HCH	Breast tissue	GM	56.2 mg/k lipid
							95% CI	(38.3-82.3) mg/k lipid
	Urban, ON (Case 2)	58.8 (11.6)	F	51	β HCH	Breast tissue	GM	39.3 mg/k lipid
							95% CI	(334.7-44.5) mg/k lipid
McCready et al. (2004)	Urban, ON (Cases)	52.5 (SD 10.0)	F	70	β HCH	Breast tissue	GM (SD)	116.90 (318.96) µg/k lipid
	Urban, ON (Controls)	48 (SD 9.9)	F	69	β HCH	Breast tissue	GM (SD)	46.55 (57.93) µg/k lipid
Newsome et al. (1999)	NWT	Median 25	F	12	β HCH	Milk	Mean	18.2 ng/g liquid
	NWT	Median 25	F	12	β HCH	Milk	Median	20.7 ng/g liquid

Table 4.15: PCB 118 levels in biological samples

First Authors (Year)	Population	Age	Sex	N	PCB 118	Biological Sample	Measure	Concentration (units)	
Belanger et al. (2006)	Northern, QC	NS	NS	97	PCB 118	Plasma	Mean(SE)	0.57 (0.06)	µg/L
Muckle et al. (2001)	Northern Community, QC	NS	NA	98	PCB 118	Breast Milk	Mean (SD)	23.1 (1.9)	µg/k
							GM	18.6	µg/k
							Range	3.7-108.1	µg/k
Aronson et al. (2000)	Urban, ON	57.7 (11.6)	F	217	PCB 118	Benign breast tissue	GM (95% CI)	30.3 (27.7-33.2)	µg/k
Longnecker et al. (2000)	Canada	17 - 67	M & F	63	PCB 118	Blood	Median	16.7	ng/k lipid
Newsom et al. (1996)	Canada	NS	NS	497	PCB 118	Milk fat	Mean	16.6	ng/g
							Median	14.2	ng/g
Newsom et al. (1996)	Canada	NS	NS	497	PCB 118	Whole milk	Mean	0.51	ng/g
							Median	0.41	ng/g
Dewailly et al. (1994)	Northern, QC (Fishermen)	Adult	M	10	PCB 118	Blood	Mean	568	ng/k
							95% CI	454 – 682	
							TEQ	568	
Dewailly et al. (1994)	Northern, QC (Controls)	Adult	M	51	PCB 118	Blood	Mean	25.4	ng/k
							95% CI	20.1 – 30.6	
							TEQ	25.4	
Dewailly et al. (1994)	Northern, QC	Adult	F	35	PCB 118	Breast milk	Mean	56.7	ng/k
							95% CI	39.1 – 78.3	
							TEQ	58.7	
Dewailly et al. (1994)	Northern, QC (Controls)	Adult	F	16	PCB 118	Breast milk	Mean	17.4	ng/k
							95% CI	14.0 – 20.9	
							TEQ	17.4	
Dellaire et al. (1992)	Fish eaters, QC	NS	M	195	PCB 118	Plasma	Mean (95%CI)	0.87 (0.75-1.00)	ug/L

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter)

Table 4.16: PCDD and PCDF levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Contaminant Type	Biological Sample	Measure	Concentration (units) As reported	
Longnecker et al. (2000)	Canada	17 - 67	M & F	63	PCDD	Blood	Median TEQ	14.4	ng/k lipid
Ryan et al. (1997)	Urban, QC (Exposed)	42.3	F & M	25	PCDD	Plasma lipids	TEQ	37.4	ng/k
	Urban, QC (Non-exposed)	42.3	F & M	30	PCDD	Plasma lipids	TEQ	14.9	ng/k
Dewailly et al. (1991)	Urban, QC (Controls)	Adult	F	16	PCDD	Breast milk	Mean	220	ng/k lipid
							Range	135 - 304	ng/k lipid
Dewailly et al. (1991)	Urban, QC (Breast feeding)	Adult	F	9	PCDD	Breast milk	Mean	293	ng/k lipid
							Range	179 - 420	ng/k lipid
Longnecker et al. (2000)	Canada	17 - 67	M & F	63	PCDF	Blood	Median TEQ	34.9	ng/k lipid
Ryan et al. (1997)	Urban, QC (Exposed)	42.3	F & M	25	PCDF	Plasma lipids	TEQ	19.3	ng/k
	Urban, QC (Non-exposed)	42.3	F & M	30	PCDF	Plasma lipids	TEQ	5.8	ng/k
Dewailly et al. (1991)	Urban, QC	Adult	F	9	PCDF	Breast milk	Mean	24.6	ng/k lipid
	Urban, QC (Controls)	Adult	F	16	PCDF	Breast milk	Mean	22.4	ng/k lipid
							Range	12.7 - 40	ng/k lipid
Ayotte et al. (1997)	Northern, QC (Exposed)	18-74	NA	20	PCDD and PDDF	Plasma	Mean	39.6	mg/k lipids
							Range	17.1-81.8	mg/k lipids
	Northern, QC (Non-exposed)	18-74	NA	3	PCDD and PDDF	Plasma	Mean	14.6	mg/k lipids
	Northern, QC (Non-exposed)	18-74	NA	3	PCDD and PDDF	Plasma	Range	11.5-18.9	mg/k lipids
	Northern, QC (Non-exposed)	18-74	NA	3	PCDD and PDDF	Plasma	Range	2.7-8	mg/k lipids
Dewailly et al. (1992)	Northern, QC (Controls)	NS	F	536	PCDD and PCDF	Breast milk	Mean	13.3	TEQ
	Northern, QC	NS	F	48	PCDD and PDDF	Breast milk	Mean	19.1	ng/k lipids

First Authors (Year)	Population	Age	Sex	N	Contaminant Type	Biological Sample	Measure	Concentration (units) As reported	
Newsome et al. (1999)	NWT	Median 25	F	12	TEQ PCDDs	Milk	Mean	3.6	ng/g liquid
							Median	3.3	ng/g liquid
Newsome et al. (1999)	NWT	Median 25	F	12	TEQ PCDFs	Milk	Mean	1.3	ng/g liquid
							Median	1.2	ng/g liquid

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); umol/L (micro-mole per litre); ug/dl (micro-gram per deciliter)

Table 4.17: PCB 118 levels in biological samples

First Authors (Year)	Population	Age	Sex	N	PCB 118	Biological Sample	Measure	Concentration (units) As reported	
Belanger et al. (2006)	Northern, QC	NS	NS	97	PCB 118	Plasma	Mean(SE)	0.57 (0.06)	µg/L
Muckle et al. (2001)	Northern Community, QC	NS	NA	98	PCB 118	Breast Milk	Mean (SD)	23.1 (1.9)	µg /k
							GM	18.6	µg /k
							Range	3.7-108.1	µg /k
Aronson et al. (2000)	Urban, ON	57.7 (11.6)	F	217	PCB 118	Benign breast tissue	GM (95% CI)	30.3 (27.7-33.2)	µg/k
Longnecker et al. (2000)	Canada	17 - 67	M & F	63	PCB 118	Blood	Median	16.7	ng/k lipid
Newsom et al. (1996)	Canada	NS	NS	497	PCB 118	Milk fat	Mean	16.6	ng/g
							Median	14.2	ng/g
Newsom et al. (1996)	Canada	NS	NS	497	PCB 118	Whole milk	Mean	0.51	ng/g
							Median	0.41	ng/g
Dewailly et al. (1994)	Northern, QC (Fishermen)	Adult	M	10	PCB 118	Blood	Mean	568	ng/k

							95% CI	454 – 682	
							TEQ	568	
Dewailly et al. (1994)	Northern, QC (Controls)	Adult	M	51	PCB 118	Blood	Mean	25.4	ng/k
							95% CI	20.1 – 30.6	
							TEQ	25.4	
Dewailly et al. (1994)	Northern, QC	Adult	F	35	PCB 118	Breast milk	Mean	56.7	ng/k
							95% CI	39.1 – 78.3	
							TEQ	58.7	
Dewailly et al. (1994)	Northern, QC (Controls)	Adult	F	16	PCB 118	Breast milk	Mean	17.4	ng/k
							95% CI	14.0 – 20.9	
							TEQ	17.4	
Dellaire et al. (1992)	Fish eaters, QC	NS	M	195	PCB 118	Plasma	Mean (95%CI)	0.87 (0.75-1.00)	ug/L

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); umol/L (micro-mole per litre); ug/dl (micro-gram per deciliter

Table 4.18: PCB 138 levels in biological samples

First Authors (Year)	Population	Age	Sex	N	PCB Type	Biological Sample	Measure	Concentration (units) As reported	
Belanger et al. (2006)	Northern, QC	NS	NS	97	PCB 138	Plasma	Mean(SE)	1.97 (0.17)	µg/L
Tsuji et al. (2005)	Urban, ON (Hamilton)	18+	M	25	PCB 138	Plasma	Mean (SD)	0.19 (0.17)	ug/L ww
							Range	0.03 - 0.67	ug/L ww
							GM	0.18	ug/L ww
							(95% CI)	0.12 - 0.24	ug/L ww
Tsuji et al. (2005)	Urban, ON (Hamilton)	>18	F	27	PCB 138	Plasma	Mean (SD)	0.23 (0.56)	ug/L ww
							Range	0.03 - 3	ug/L ww
							GM	0.17	ug/L ww
							(95% CI)	0.06 - 0.29	ug/L ww
Tsuji et al. (2005)	Urban, ON (Fort Albany)	18+	M	51	PCB 138	Plasma	Mean (SD)	0.33 (0.35)	ug/L ww
							Range	0.02 - 1.85	ug/L ww
							GM	0.29	ug/L ww
							(95% CI)	0.22 - 0.37	ug/L ww
Tsuji et al. (2005)	Urban, ON (Fort Albany)	>18	F	48	PCB 138	Plasma	Mean (SD)	0.36 (0.55)	ug/L ww
							Range	0.02 - 3.24	ug/L ww
							GM	0.29	ug/L ww
							(95% CI)	0.19 - 0.4	ug/L ww
Tsuji et al. (2005)	Urban, ON (Kashechewan)	18+	M	50	PCB 138	Plasma	Mean (SD)	0.52 (0.46)	ug/L ww
							Range	0.05 - 1.94	ug/L ww
							GM	0.46	ug/L ww
							(95% CI)	0.35 -0.58	ug/L ww
Tsuji et al. (2005)	Urban, ON (Kashechewan)	>18	F	48	PCB 138	Plasma	Mean (SD)	0.46 (0.62)	ug/L ww
							Range	0.02 - 3.33	ug/L ww
							GM	0.37	ug/L ww
							(95% CI)	0.25 - 0.5	ug/L ww

First Authors (Year)	Population	Age	Sex	N	PCB Type	Biological Sample	Measure	Concentration (units) As reported	
McCready et al. (2004)	Urban, ON (Controls)	48 (SD 9.9)	F	69	PCB 138	Breast tissue	GM (SD)	71.07 (47.36)	µg/k lipid
	Urban, ON (Cases)	52.5 (SD 10.0)	F	70	PCB 138	Breast tissue	GM (SD)	84.90 (54.13)	µg/k lipid
Bilrha et al. (2003)	Rural, QC (Exposed)	24 (4.9)	F	47	PCB 138	Cord Blood	GM (95% CI)	36 (27-48)	µg/L plasma lipid
	Rural, QC (Reference)	NS	F	65	PCB 138	Cord Blood	GM (95% CI)	11 (9-12)	µg/L plasma lipid
Walker et al. (2003)	Arctic Canada	NS	F	93	PCB 138	Blood Plasma	Mean (SD)	0.14 (0.13)	µg /L
							GM (SD)	0.10 (0.12)	µg /L
							Range	0.02-0.98	µg /L
	Arctic Canada	NS	F	134	PCB 138	Blood Plasma	Mean (SD)	0.13 (0.08)	µg /L
							GM (SD)	0.11 (0.09)	µg /L
							Range	0.02-0.48	µg /L
	Arctic Canada	NS	F	145	PCB 138	Blood Plasma	Mean (SD)	0.44 (0.42)	µg /L
							GM (SD)	0.30 (0.52)	µg /L
							Range	0.02-3.29	µg /L
	Arctic Canada	NS	F	385	PCB 138	Blood Plasma	Mean	0.25	µg /L
							GM	0.16	µg /L
							Range	0.02-3.29	µg /L
Cole et al. (2002)	Fish eaters, ON	NS	M & F	89	PCB 138	Plasma	Mean (SD)	0.39 (0.332)	µg /L
							GM (GSD)	0.29 (1.32)	µg /L
							Range	0.05-1.81	µg /L
							Median	0.28	µg /L
Demers et al. (2002)	Urban, QC (Controls)	Mean 52 (10)	F	526	PCB 138	Plasma	Mean (Median)	35.4355	µg/k plasma lipid
	Urban, QC (Cases)	Mean 53 (SD 9)	F	314	PCB 138	Plasma	Mean (Median)	38.1 37.2	µg/k plasma lipid
Muckle et al. (2001)	Northern Community, QC	NS	NA	98	PCB 138	Cord Plasma	Mean (SD)	70.7 (2.0)	ug/k
							GM	54.8	ug/k
							Range	10.1-313.1	ug/k

First Authors (Year)	Population	Age	Sex	N	PCB Type	Biological Sample	Measure	Concentration (units) As reported	
Muckle et al. (2001)	Northern Community, QC	NS	NA	98	PCB 138	Maternal Plasma	Mean (SD)	73.8 (2.0)	ug/k
							GM	57.8	ug/k
							Range	10.2-387.1	ug/k
Woolcott et al. (2001)	Urban, ON (Cases 1)	58.8 (11.6)	F	51	PCB 138	Breast tissue	GM	71.7	mg/k lipid
							95% CI	(66.2-77.7)	mg/k lipid
	Urban, ON (Cases 2)	54.2 (11.0)	F	150	PCB 138	Breast tissue	GM	81.8	µg/k lipid
							95% CI	(68.6-97.4)	µg/k lipid
	Urban, ON (Controls)	53.9 (10.9)	F	213	PCB 138	Breast tissue	GM	66.8	µg/k lipid
	Urban, ON	53.9 (10.9)	F	213	PCB 138		95% CI	(62.1-71.9)	µg/k lipid
Dewailly et al. (1996)	Northern, QC	27.9 (4.2)	F	536	PCB 138	Breast milk	Mean	0.046	mg/k lipids
							95% CI	0.044-0.048	mg/k lipids
							Range	0.01- 0/18	mg/k lipids
Dewailly et al. (1994)	Northern, QC (Fishermen)	Adult	M	10 fishermen	PCB 138	Blood	Mean	1677	ng/k
							95% CI	1522-1833	ng/k
							TEQ	33.5	ng/k
	Northern, QC (Controls)	Adult	M	58 controls	PCB 138	Blood	Mean	55.5	ng/k
							95% CI	44.5 – 66.5	ng/k
							TEQ	1.11	ng/k

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); umol/L (micro-mole per litre); ug/dl (micro-gram per deciliter

Table 4.19: PCB 153 levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
Belanger et al. (2006)	Northern, QC	NS	NS	97	Plasma	Mean(SE)	3.17 (0.28)	µg/L
Dellaire et al. (2006)	Northern, QC	Preschool	NS	343	Cord Plasma	GM	93.6	µg/k lipids
St Amour et al. (2006)	Northern, QC	5.4 (0.4)	NS	77	Blood	GM (95%CI)	83.17 (63.85–108.32)	µmol/k lipids
						Mean (SD)	152.45 (175.30)	µmol/k lipids
						Range	7.46–777.80	µmol/k lipids
St Amour et al. (2006)	Northern, QC	Newborn	NS	77	Cord Blood	GM (95%CI)	98.02 (85.76–112.04)	µmol/k lipids
						Mean (SD)	115.96 (70.23)	µmol/k lipids
						Range	23.09–387.05	µmol/k lipids
Tsuji et al. (2005)	Urban, ON (Hamilton)	18+	M	25	Plasma	Mean (SD)	0.29 (0.26)	µg/L ww
						Range	0.04 - 0.93	µg/L ww
						GM	0.26	µg/L ww
						(95% CI)	0.17 - 0.36	µg/L ww
Tsuji et al. (2005)	Urban, ON (Hamilton)	>18	F	27	Plasma	Mean (SD)	0.38 (1.07)	µg/L ww
						Range	0.04 - 5.7	µg/L ww
						GM	0.24	µg/L ww
						(95% CI)	0.09 - 0.43	µg/L ww
Tsuji et al. (2005)	Urban, ON (Fort Albany)	18+	M	51	Plasma	Mean (SD)	0.58 (0.67)	µg/L ww
						Range	0.02 - 3.55	µg/L ww
						GM	0.49	µg/L ww
						(95% CI)	0.37 - 0.63	µg/L ww
Tsuji et al. (2005)	Urban, ON (Fort Albany)	>18	F	48	Plasma	Mean (SD)	0.6 (0.91)	µg/L ww
						Range	0.03 - 4.97	µg/L ww
						GM	0.46	µg/L ww
						(95% CI)	0.3 -0.63	µg/L ww
Tsuji et al. (2005)	Urban, ON (Kashechewan)	18+	M	50	Plasma	Mean (SD)	0.81 (0.74)	µg/L ww
						Range	0.07 - 2.86	µg/L ww

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
						GM	0.7	µg/L ww
						(95% CI)	0.53 - 0.88	µg/L ww
Tsuji et al. (2005)	Urban, ON (Kashechewan)	>18	F	48	Plasma	Mean (SD)	0.67 (0.9)	µg/L ww
					Plasma	Range	0.03 - 4.85	µg/L ww
					Plasma	GM	0.52	µg/L ww
					Plasma	(95% CI)	0.36 - 0.71	µg/L ww
Dellaire et al. (2004)	Inuit, QC	NS	F	172	Infant Plasma	GM (95%CI)	76.1 (62.4-92.9)	ug/k lipid
						Range	ND-1441	ug/k lipid
Dellaire et al. (2004)	Inuit, QC	NS	F	199	Maternal Plasma	GM (95%CI)	102 (91.4-113)	ug/k lipid
						Range	14.6-709	ug/k lipid
McCready et al. (2004)	Urban, ON (Control)	48 (9.9)	F	69	Breast tissue	GM (SD)	105.98 (64.06)	µg/k lipid
	Urban, ON (Cases)	52.5 (10.0)	F	70	Breast tissue	GM (SD)	120.14 (74.15)	µg/k lipid
Ayotte et al. (2003)	Northern, QC (No breastfeeding)	NS	NA	14	Infant Plasma	GM (95%CI)	23.1 (12-44.7)	µg/g lipid
	Northern, QC (Breast feed < 3 mths)	NS	NA	26	Infant Plasma	GM (95%CI)	36 (24-54.1)	µg/g lipid
	Northern, QC (Breast feed >= 3 mths)	NS	NA	50	Infant Plasma	GM (95%CI)	153 (121.4-192.9)	µg/g lipid
	Northern, QC	NS	NA	79	Cord Plasma	GM (95%CI)	82.5 (69.1-98.5)	µg/g lipid
	Northern, QC	NS	F	84	Maternal Milk	GM (95%CI)	129.9 (112.9-149.5)	µg/g lipid
	Northern, QC	NS	NA	90	Infant Plasma	GM (95%CI)	75.1 (58.1-97.1)	µg/g lipid
	Northern, QC	NS	F	128	Plasma	GM (95%CI)	105.1 (92.5-119.5)	µg/g lipid
Bilrha et al. (2003)	Rural, QC (Exposed)	24 (4.9)	F	47	Cord Blood	GM (95% CI)	50 (36-68)	µg/L plasma lipid
	Rural, QC (Reference)	NS	F	65	Cord Blood	GM (95% CI)	14 (12-16)	µg/L plasma lipid
Hamel et al. (2003)	Urban, QC	NS	F	30	Cord Blood	Mean (SEM)	0.02 (0.00)	µg /L
					Cord Blood	Median	0.02	µg /L
					Cord Blood	75th	0.03	µg /L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure		Concentration (units) As reported	
						percentile			
Hamel et al. (2003)	Urban, QC	NS	F	30	Maternal Blood	Mean (SEM)		0.12 (0.01)	µg/L
					Maternal Blood	Median		0.11	µg/L
					Maternal Blood	75th percentile		0.16	µg/L
Hamel et al. (2003)	Urban, QC	NS	F	30	Placenta	Mean (SEM)		9.47 (3.72)	µg/L
					Placenta	Median		0	µg/L
					Placenta	75th percentile		12.75	µg/L
Walker et al. (2003)	Arctic Canada (Dene/Metis)	NS	F	93	Blood Plasma	Mean (SD)		0.22 (0.23)	µg/L
						GM (SD)		0.16 (0.21)	µg/L
						Range		0.03-1.75	µg/L
	Arctic Canada (Caucasians)	NS	F	134	Blood Plasma	Mean (SD)		0.17 (0.11)	µg/L
						GM (SD)		0.14 (0.12)	µg/L
						Range		0.03-0.61	µg/L
	Arctic Canada (Inuit)	NS	F	145	Blood Plasma	Mean (SD)		0.87 (0.97)	µg/L
								0.54 (1.25)	µg/L
								0.02-8.27	µg/L
	Arctic Canada (All mothers(	NS	F	385	Blood Plasma	Mean		0.45	µg/L
						GM		0.24	µg/L
						Range		0.02-8.27	µg/L
Cole et al. (2002)	Fish eaters, ON	NS	M & F	89	Plasma	Mean (SD)		0.53 (0.45)	µg/L
						GM (GSD)		0.39 (1.34)	µg/L
						Range		0.06-2.26	µg/L
						Median		0.38	µg/L
Demers et al. (2002)	Urban, QC (Controls)	52 (10)	F	526	Plasma	Mean (Median)		51.0507	ug/k plasma lipid
	Urban, QC (Cases)	53 (9)	F	314	Plasma	Mean (Median)	54.1	55	ug/k plasma lipid
Muckle et al. (2001)	Northern Community, QC	NS	F	93	Blood	Mean (SD)		1.3 (1.2)	ug/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
						Median	0.8	ug/L
						Range	0.2-6.1	ug/L
Muckle et al. (2001)	Northern Community, QC	NS	F	93	Fat tissue	Mean (SD)	144.9 (126.8)	ug/k of fat
						Median	102.6	ug/k of fat
						Range	18.9-709	ug/k of fat
	Northern Community, QC	NS	NA	98	Breast Milk	Mean (SD)	164.4 (1.9)	ug/k
						GM	131.6	ug/k
						Range	21.7-727.9	ug/k
	Northern Community, QC	NS	NA	98	Cord Plasma	Mean (SD)	116.0 (2.2)	ug/k
						GM	86.9	ug/k
						Range	13.4-550.9	ug/k
	Northern Community, QC	NS	NA	98	Maternal Plasma	Mean (SD)	137.4 (2.1)	ug/k
						GM	105.3	ug/k
						Range	18.9-709.0	ug/k
Woolcott et al. (2001)	Urban, ON (Cases 1)	58.8 (11.6)	F	51	Breast tissue	GM	102.8	mg/k lipid
						95% CI	(95.4-110.9)	mg/k lipid
	Urban, ON (Cases 2)	54.2 (11.0)	F	150	Breast tissue	GM	114.6	µg/k lipid
						95% CI	(96.9-135.5)	µg/k lipid
	Urban, ON (Controls)	53.9 (10.9)	F	213	Breast tissue	GM	98.3	µg/k lipid
						95% CI	(91.8-105.3)	µg/k lipid
Longnecker et al. (2000)	Canada	17 - 67	M & F	63	Blood	Median	57	µg/k lipid
Dewailly et al. (1996)	Northern, QC	27.9 (4.2)	F	536	Breast milk	Mean	0.054	µg/k lipid
					Breast milk	95% CI	0.052-0.057	µg/k lipid
					Breast milk	Range	0.01-0.20	µg/k lipid
Newsom et al. (1996)	Canada	NS	NS	497	Milk fat	Mean	38.3	ng/g
						Median	33.4	ng/g

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units) As reported	
Newsom et al. (1996)	Canada	NS	NS	497	Whole milk	Mean	1.18	ng/g
						Median	0.99	ng/g
Dewailly et al. (1994)	Northern, QC	Adult	M	10 fishermen	Blood	Mean	2457	ng/k
						95% CI	2225– 2690	ng/k
						TEQ	49.1	ng/k
Dewailly et al. (1994)	Northern, QC	Adult	M	58 controls	Blood	Mean	72.6	ng/k
						95% CI	582-86.9	ng/k
						TEQ	1.45	ng/k
Dellaire et al. (1992)	Fish eaters, QC	NS	M	195	Plasma	Mean (95%CI)	3.86 (3.38-4.34)	ug/L

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter)

Table 4.20: PCB 180 levels in biological samples

First Authors (Year)	Population	Age	Sex	N	PCB Type	Biological Sample	Measure	Concentration (units) As reported	
Belanger et al. (2006)	Northern, QC	NS	NS	97	PCB 180	Plasma	Mean(SE)	1.49 (0.15)	µg/L
McCready et al. (2004)	Urban, ON (Controls)	48 (SD 9.9)	F	69	PCB 180	Breast tissue	GM (SD)	74.31 (50.93)	µg/k lipid
	Urban, ON (Cases)	52.5 (SD 10.0)	F	70	PCB 180	Breast tissue	GM (SD)	85.43 (63.08)	µg/k lipid
Bilrha et al. (2003)	Rural, QC (Exposed)	24 (4.9)	F	47	PCB 180	Cord Blood	GM (95% CI)	21 (15-28)	µg/L plasma lipid
	Rural, QC (Reference)	NS	F	65	PCB 180	Cord Blood	GM (95% CI)	6 (5-7)	µg/L plasma lipid
Cole et al. (2002)	Fish eaters, ON	NS	M & F	89	PCB 180	Plasma	Mean (SD)	0.32 (0.254)	µg/L
							GM (GSD)	0.24 (1.372)	µg/L
							Range	0.03-1.16	µg/L
							Median	0.27	µg/L
Demers et al. (2002)	Urban, QC (Controls)	Mean 52 (10)	F	526	PCB 180	Plasma	Mean (Median)	31.1 30.2	µg/k plasma lipid
	Urban, QC (Cases	Mean 53 (9)	F	314	PCB 180	Plasma	Mean (Median)	32.9 32.	µg/k plasma lipid
Muckle et al. (2001)	Northern Community, QC	NS	NA	98	PCB 180	Cord Plasma	Mean (SD)	45.0 (2.2)	µg /k
							GM	33.4	µg /k
							Range	6.1-164.2	µg /k
Muckle et al. (2001)	Northern Community, QC	NS	NA	98	PCB 180	Maternal Plasma	Mean (SD)	58.9 (2.1)	µg /k
							GM	43.8	µg /k
							Range	7.6-383.5	µg /k
Woolcott et al. (2001)	Urban, ON	58.8 (11.6)	F	51	PCB 180	Breast tissue	GM	71.4	mg/k lipid
							95% CI	(66.5-76.7)	mg/k lipid
	Urban, ON	54.2 (11.0)	F	150	PCB 180	Breast tissue	GM	75	mg/k lipid
							95% CI	(63.9-88.1)	mg/k lipid
	Urban, ON	53.9 (10.9)	F	213	PCB 180	Breast tissue	GM	65.7	mg/k lipid
							95% CI	(61.5-70.2)	mg/k lipid

First Authors (Year)	Population	Age	Sex	N	PCB Type	Biological Sample	Measure	Concentration (units) As reported	
Aronson et al. (2000)	Urban, ON	57.7 (11.6)	F	217	PCB 180	Benign breast tissue	GM (95% CI)	71.9 (67.5-76.5)	µg/k
Longnecker et al. (2000)	Canada	17 - 67	M & F	63	PCB 180	Blood	Median	36.8	ng/k lipid
Dewailly et al. (1996)	Northern, QC	27.9 (4.2)	F	536	PCB 180	Breast milk	Mean	0.027	mg/k lipids
							95% CI	0.026-0.027	
							Range	0.01-0.09	
Newsom et al. (1996)	Canada	NS	NS	497	PCB 180	Milk fat	Mean	20.9	ng/g
							Median	17.9	ng/g
	Canada	NS	NS	497	PCB 180	Whole milk	Mean	0.64	ng/g
						Whole milk	Median	0.55	ng/g
Dewailly et al. (1994)	Northern, QC	Adult	M	10	PCB 180	Blood	Mean	1776	ng/k
							95% CI	1569-1984	ng/k
							TEQ	35.5	ng/k
Dewailly et al. (1994)	Northern, QC	Adult	M	57	PCB 180	Blood	Mean	48.2	ng/k
							95% CI	38.3-58.1	ng/k
							TEQ	0.96	ng/k
							Mean (95%CI)	2.80 (2.42-3.18)	µg/L

Table 4.21: PCB Total levels in biological samples

First Authors (Year)	Population	Age	Sex	N	PCB Types	Biological Sample	Measure	Concentration (units) As reported	
Kearney et al. (1999)	Urban, ON (Non-fish eaters)	NS	F	35	PCB	Plasma	Mean	3.2	µg/L
							Range	1.3 -12	µg/L
	Urban, ON (Non-fish eaters)	NS	M	45	PCB	Plasma	Mean	5.5	µg/L
							Range	.09 - 21	µg/L
	Urban, ON (Fish eaters)	NS	F	51	PCB	Plasma	Mean	3.4	µg/L
							Range	.07- 23	µg/L
	Urban, ON (Non-fish eaters)	23-69	M & F	80	PCB	Plasma	Mean	4	µg/L
							Mean	3.9	µg/L
	Urban, ON (Fish eaters)	NS	M	101	PCB	Plasma	Range	1.1 - 12	µg/L
							Mean	6.1	µg/L
Kosatsky et al. (1999)	Urban, QC (Bangladeshi)	Median (Rge) 34 (28-41)	M	9	PCB	Plasma	Median	4.4	µg/L
Muckle et al. (1998)	Northern, QC	Newborns	M & F	NS	PCB	Cord Blood	GM	0.3 - 2.0	µg/L
Mes et al. (1994)	Western, 1986	NS	NS	NS	PCB	Whole milk	Mean	5	ng/g
	Western, 1982	NS	NS	NS	PCB	Whole milk	Mean	24	ng/g
	Western, 1975	NS	NS	NS	PCB	Whole milk	Mean	15	ng/g
	Western, 1967	NS	NS	NS	PCB	Whole milk	Mean	NA	ng/g
	Quebec, 1986	NS	NS	NS	PCB	Whole milk	Mean	7	ng/g
	Quebec, 1982	NS	NS	NS	PCB	Whole milk	Mean	35	ng/g
	Quebec, 1975	NS	NS	NS	PCB	Whole milk	Mean	10	ng/g
	Quebec, 1967	NS	NS	NS	PCB	Whole milk	Mean	NA	ng/g
	Ontario, 1986	NS	NS	NS	PCB	Whole milk	Mean	7	ng/g
	Ontario, 1982	NS	NS	NS	PCB	Whole milk	Mean	27	ng/g
	Ontario, 1975	NS	NS	NS	PCB	Whole milk	Mean	17	ng/g
	Ontario, 1967	NS	NS	NS	PCB	Whole milk	Mean	NA	ng/g
	Eastern Canada, 1986	NS	NS	NS	PCB	Whole milk	Mean	6	ng/g
	Eastern Canada, 1982	NS	NS	NS	PCB	Whole milk	Mean	26	ng/g

First Authors (Year)	Population	Age	Sex	N	PCB Types	Biological Sample	Measure	Concentration (units) As reported	
Mes et al. (1994)	Eastern Canada, 1975	NS	NS	NS	PCB	Whole milk	Mean	8	ng/g
	Eastern Canada, 1967	NS	NS	NS	PCB	Whole milk	Mean	NA	ng/g
	Central, 1986	NS	NS	NS	PCB	Whole milk	Mean	5	ng/g
	Central, 1982	NS	NS	NS	PCB	Whole milk	Mean	16	ng/g
	Central, 1975	NS	NS	NS	PCB	Whole milk	Mean	8	ng/g
	Central, 1967	NS	NS	NS	PCB	Whole milk	Mean	NA	ng/g
Frank et al. (1993)	Urban, ON	Adult	M & F	169	PCB	Blood	Mean (SD)	8.8 (7.0)	µg/k
							Max	43	
	Urban, ON	Adult	M & F	581	PCB	Blood	Mean (SD)	9.3 (16.0)	µg/k
							Max	110	
	Urban, ON	Adult	M & F	750	PCB	Blood	Mean (SD)	9.2 (14.5)	µg/k
							Max	110	
Belanger et al. (2006)	Northern, QC	NS	NS	97	PCB (Total)	Plasma Cord	Mean(SE)	8.78 (0.79)	µg/L
Dellaire et al. (2006)	Northern, QC	Preschool	NS	343	PCB (Total)	Plasma	GM	323.5	µg/k lipids
Tsuji et al. (2006)	Canada (Hamilton)	NS	F	27	PCB (Total)	Plasma	GM	93	µg/k lipids
Tsuji et al. (2006)	Canada (Fort Albany)	NS	F	48	PCB (Total)	Plasma	GM	165	µg/k lipids
Tsuji et al. (2006)	Canada (Kashechwan)	NS	F	48	PCB (Total)	Plasma	GM	186	µg/k lipids
Tsuji et al. (2006)	Canada (NWT)	NS	F	67	PCB (Total)	Plasma	GM	167	µg/k lipids
Ayotte et al. (2005)	Northern, QC	25-75	M & F	40	PCB (Total)	Plasma	Median	2820	µg/k lipids
							Mean (SD)	2,897(1372)	µg/k lipids
							Range	334-5,880	µg/k lipids
Jarrell et al. (2005)	Urban, AB	NS	F	47	PCB (Total)	Breast milk	Mean	38.2	ng/g lipid
							Range	11.95-125.30	ng/g lipid

First Authors (Year)	Population	Age	Sex	N	PCB Types	Biological Sample	Measure	Concentration (units) As reported	
							GM	33.25	ng/g lipid
Jarrell et al. (2005)	Urban, AB	NS	F	47	PCB (Total)	Breast milk	Mean	0.25	ng/ml
							Range	0.37 - 4.85	ng/ml
							GM	1.11	ng/ml
Jarrell et al. (2005)	Urban, AB	NS	F	97	PCB (Total)	Umbilical cord	Mean	131.85	ng/g lipid
							Range	55.83-515.31	ng/g lipid
							GM	122.34	ng/g lipid
Jarrell et al. (2005)	Urban, AB	NS	F	97	PCB (Total)	Umbilical cord	Mean	0.25	ng/ml
							Range	0.16 - 1.88	ng/ml
							GM	0.23	ng/ml
Jarrell et al. (2005)	Urban, AB	NS	F	107	PCB (Total)	Blood	Mean	80.99	ng/g lipid
							Range	11.70-1368.68	ng/g lipid
							GM	59.64	ng/g lipid
Jarrell et al. (2005)	Urban, AB	NS	F	107	PCB (Total)	Blood	Mean	0.72	ng/ml
							Range	0.36 - 4.91	ng/ml
							GM	0.65	ng/ml
Jarrell et al. (2005)	Urban, AB	NS	F	209	PCB (Total)	Amniotic fluid	Mean	75.28	ng/g lipid
							Range	13.75-432.43	ng/g lipid
							GM	61.68	ng/g lipid
Jarrell et al. (2005)	Urban, AB	NS	F	209	PCB (Total)	Amniotic fluid	Mean	0.78	ng/ml
							Range	0.43 - 3.34	ng/ml
							GM	0.73	ng/ml
Takser et al. (2005)	Urban, QC (1st Trimester)	NS	F	39	PCB (Total)	Plasma	Median (5th -95th %)	0.33 (0.16-1.31)	µg/L
	Urban, QC (2nd Trimester)	NS	F	145	PCB	Plasma	Median (5th -95th	0.35 (0.18-1.05)	µg/L

First Authors (Year)	Population	Age	Sex	N	PCB Types	Biological Sample	Measure	Concentration (units) As reported	
					(Total)		%)		
Takser et al. (2005)	Urban, QC (At delivery)	NS	F	101	PCB (Total)	Plasma	Median (5th -95th %)	0.39 (0.20-1.22)	µg/L
	Urban, QC (Cord blood)	NS	F	92	PCB (Total)	Plasma	Median (5th -95th %)	0.16 (ND-0.35)	µg/L
Lucas et al. (2004)	Southern Community, QC	NA	NS	29	PCB (Total)	Cord Blood	GM (95% CI)	129.0 (109.3-152.1)	µg/k lipid
	Northern Community, QC	NA	NS	439	PCB (Total)	Cord Blood	GM (95% CI)	322.1 (303.5-341.9)	µg/k lipid
McCready et al. (2004)	Urban, ON	48 (SD 9.9)	F	69	PCB (Total)	Breast tissue	GM (SD)	0.92 (0.58)	mg/k lipid
	Urban, ON	52.5 (SD 10.0)	F	70	PCB (Total)	Breast tissue	GM (SD)	1.07 (0.67)	mg/k lipid
Schoenroth et al. (2004)	Urban, AB	NS	NS	57	PCB (Total)	Serum	Mean (SD)	1.19 (0.31)	µg/L
							GM	0.6	µg/L
Schoenroth et al. (2004)	Urban, AB	NS	NS	57	PCB (Total)	Serum	Mean (SD)	266 (77)	µg/k lipid
							GM	134	µg/k lipid
Schoenroth et al. (2004)	Urban, AB	NS	NS	57	PCB (Total)	Serum	Mean (SD)	18 (7)	TEQ
Dellaire et al. (2003)	Northern, QC	Newborns	M(52%), F(48%)	238	PCB (Total)	Cord Blood	Mean	6.1	% decrease
							Range	(1.0 – 10.9)	% decrease
Paris-Pombo et al. (2003)	Urban, ON	54	F	190	PCB (Total)	Breast tissue	GM (95% CI)	0.89 (0.82-0.95)	µg/gm
Dellaire et al. (2002)	Coastal residence/QC (2000)	NS	F	65	PCB (Total)	Cord Blood	Mean (95%CI)	153.5 (134.4-175.4)	µg/k
	Coastal residence/QC (1997)	NS	F	50	PCB (Total)	Cord Blood	Mean (95%CI)	188.5 (162.1-219.2)	µg/kg
	Coastal residence/QC (1996)	NS	F	71	PCB (Total)	Cord Blood	Mean (95%CI)	222.5 (195.9-252.8)	µg/k
	Coastal residence/QC (1995)	NS	F	82	PCB (Total)	Cord Blood	Mean (95%CI)	243.5 (216.4-274.2)	µg/k

First Authors (Year)	Population	Age	Sex	N	PCB Types	Biological Sample	Measure	Concentration (units) As reported	
Dellaire et al. (2002)	Coastal residence/QC (1994)	NS	F	62	PCB (Total)	Cord Blood	Mean (95%CI)	345.2 (301.5-395.2)	µg/k
	Coastal residence/QC (1993)	NS	F	62	PCB (Total)	Cord Blood	Mean (95%CI)	252.5 (220.5-289.2)	µg/k
	Coastal residence/QC (Caucasians)	NS	F	224	PCB (Total)	Cord Blood	Mean (95%CI)	9.3 (6.2-12.3)	µg/k
	Coastal residence/QC (Natives)	NS	F	392	PCB (Total)	Cord Blood	Mean (95%CI)	10.0 (7.8-12.2)	µg/k
Bjerregaard et al. (2001)	Rural, QC	18+	NA	408	Σ PCB	Plasma	Median	13.3	µg/L wet weight
Muckle et al. (2001)	Northern Community, QC	NS	F	93	PCB (Total)	Blood	Mean (SD)	3.6 (3.2)	ug/L
							Median	2.4	ug/L
							Range	0.6-15.8	ug/L
Muckle et al. (2001)	Northern Community, QC	NS	F	93	PCB (Total)	Fat tissue	Mean (SD)	414.5 (245.9)	ug/k of fat
							Median	294.1	ug/k of fat
							Range	71.3-1951.3	ug/k of fat
Woolcott et al. (2001)	Urban, ON	58.8 (11.6)	F	51	PCB (Total)	Breast tissue	GM	0.92	mg/k lipid
						Breast tissue	95% CI	(0.85-0.99)	mg/k lipid
Woolcott et al. (2001)	Urban, ON	54.2 (11.0)	F	150	PCB (Total)	Breast tissue	GM	1.02	mg/k lipid
						Breast tissue	95% CI	(0.86-1.21)	mg/k lipid
Woolcott et al. (2001)	Urban, ON	53.9 (10.9)	F	213	PCB (Total)	Breast tissue	GM	0.87	mg/k lipid
						Breast tissue	95% CI	(0.81-0.92)	
Sandau et al. (2000)	Nunavik	NS	NS	10	PCB (Total)	Cord Plasma	GM	1510	pg/g of plasma
							Range	309-6230	pg/g of plasma

First Authors (Year)	Population	Age	Sex	N	PCB Types	Biological Sample	Measure	Concentration (units) As reported	
Sandau et al. (2000)	Lower-North Shore	NS	NS	10	PCB (Total)	Cord Plasma	GM	2710	pg/g of plasma
							Range	525-7720	pg/g of plasma
Sandau et al. (2000)	Quebec City	NS	NS	10	PCB (Total)	Cord Plasma	GM	843	pg/g of plasma
							Range	290-1650	pg/g of plasma
Sandau et al. (2000)	Northern Community, QC	38	M	13	PCB (Total)	Blood	GM	12900	ng/g of whole blood
							Range	2070-65900	ng/g of whole blood
Sandau et al. (2000)	Northern Community, QC	38	F	17	PCB (Total)	Blood	GM	7940	ng/g of whole blood
						Blood	Range	1190-38100	ng/g of whole blood
Newsome et al. (1999)	NWT	Median 25	F	12	PCB (Total)	Milk	Mean	247	ng/g liquid
							Median	235	ng/g liquid
Rhainds et al. (1999)	Urban, QC	newborn	M & F	1109	PCB (Total)	Cord Blood	GM (95% CI)	0.514 (.493-0.536)	ug/L
Lebel et al. (1998)	Urban, QC (Controls)	18 – 50	F	70	PCB (Total)	Blood	GM (95% CI)	119.3 (108.9-130.5)	ug/k lipids
Lebel et al. (1998)	Urban, QC (Cases)	18 – 50	F	156	PCB (Total)	Blood	GM (95% CI)	123.5(113.3-134.7)	ug/k lipids
Newsom et al. (1996)	Canada	NS	NS	497	PCB (Total)	Milk fat	Mean	238	ng/g
							Median	207	ng/g
Newsom et al. (1996)	Canada	NS	NS	497	PCB (Total)	Whole milk	Mean	7.21	ng/g
							Median	6.18	ng/g
Dewailly et al. (1991)	Urban, QC (Breast feed)	Adult	F	9	PCB (Total)	Breast milk	Mean	214.4	ng/g lipid
Dewailly et al. (1991)				9	PCB (Total)	Breast milk	Range	63.9 –398.4	ng/g lipid

First Authors (Year)	Population	Age	Sex	N	PCB Types	Biological Sample	Measure	Concentration (units) As reported	
Dewailly et al. (1991)	Urban, QC (Controls)	Adult	F	16	PCB (Total)	Breast milk	Mean	187.6	ng/k lipid
Dewailly et al. (1991)				16	PCB (Total)	Breast milk	Range	76.4 – 429.9	ng/k lipid

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter)

Table 4.22: PCB Acrolor (1260) levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units)	
Tsuji et al. (2006)	Canada (Hamilton)	NS	F	27	Plasma	GM	236	µg/k lipids
	Canada (Fort Albany)	NS	F	48	Plasma	GM	421	µg/k lipids
	Canada (Kashechewan)	NS	F	48	Plasma	GM	463	µg/k lipids
	Canada (NWT)	NS	F	67	Plasma	GM	439	µg/k lipids
Tsuji et al. (2005)	Urban, ON	18+	M	25	Plasma	Mean (SD)	2.47 (2.18)	µg/L ww
						Range	0.34 - 7.94	µg/L ww
						GM	1.94	µg/L ww
						(95% CI)	1.31 - 2.73	µg/L ww
	Urban, ON	>18	F	27	Plasma	Mean (SD)	3.13 (8.45)	µg/L ww
						Range	0.37 - 45.2	µg/L ww
						GM	1.66	µg/L ww
						(95% CI)	1.06 - 2.44	µg/L ww
	Urban, ON	18+	M	51	Plasma	Mean (SD)	4.73 (5.27)	µg/L ww
						Range	0.21 - 28.05	µg/L ww
						GM	3.43	µg/L ww
						(95% CI)	2.67 - 4.35	µg/L ww
	Urban, ON	>18	F	48	Plasma	Mean (SD)	4.98 (7.55)	µg/L ww
						Range	0.25 - 42.7	µg/L ww
						GM	2.89	µg/L ww
						(95% CI)	2.04 - 3.98	µg/L ww
	Urban, ON	18+	M	50	Plasma	Mean (SD)	7.02 (6.26)	µg/L ww
						Range	0.64 - 24.95	µg/L ww
						GM	5.08	µg/L ww
						(95% CI)	3.9 - 6.54	µg/L ww
	Urban, ON	>18	F	48	Plasma	Mean (SD)	5.83 (7.91)	µg/L ww
						Range	0.25 - 42.5	µg/L ww
						GM	3.43	µg/L ww
						(95% CI)	2.42 - 4.74	µg/L ww
Hamel et al. (2003)	Urban, QC	NS	F	30	Cord Blood	Mean	0.18 (0.03)	ug/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units)	
						(SEM)		
						Median	0.17	µg/L
						75th percentile	0.32	µg/L
Hamel et al. (2003)	Urban, QC	NS	F	30	Maternal Blood	Mean (SEM)	1.10 (0.11)	µg/L
						Median	1	µg/L
						75th percentile	1.48	µg/L
Hamel et al. (2003)	Urban, QC	NS	F	30	Placenta	Mean (SEM)	0.04 (0.01)	µg /k
						Median	0	µg /k
						75th percentile	0.12	µg /k
Walker et al. (2003)	Arctic Canada (Dene/Metis)	NS	F	93	Blood Plasma	Mean (SD)	1.86 (1.89)	µg/L
						GM (SD)	1.34 (1.68)	µg/L
						Range	0.26-14.16	µg/L
	Arctic Canada (Caucasian)	NS	F	134	Blood Plasma	Mean (SD)	1.59 (0.99)	µg/L
						GM (SD)	1.32 (1.09)	µg/L
						Range	0.24-5.67	µg/L
	Arctic Canada (Inuit)	NS	F	145	Blood Plasma	Mean (SD)	6.82 (7.20)	µg/L
						GM (SD)	4.42 (9.03)	µg/L
						Range	0.20-60.12	µg/L
	Arctic Canada (All)	NS	F	385	Blood Plasma	Mean	3.62	µg/L
						GM	2.08	µg/L
						Range	0.2-60.12	µg/L
Nadon et al. (2002)	Urban, QC	< 45	F	8	Plasma	Mean (SD)	1.88 (0.75)	µg/L
						GM	1.73	µg/L
	Urban, QC	< 45	M	17	Plasma	Mean (SD)	4.27 (5.02)	µg/L

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units)	
						GM	3.16	µg/L
Bjerregaard et al. (2001)	Rural, QC	18+	NA	408	Plasma	Median	34.6	µg/L ww
Kosatsky et al. (1999)	Urban, QC (Vietnamese)	Median (Range) 30 (27 – 70)	M & F	9	Plasma	Median	7.82	µg/L
	Urban, QC	NS	M & F	NS	Plasma	Median	5.31	µg/L
Dewailly et al. (1996)	Northern, QC	27.9 (4.2)	F	536	Breast milk	Mean	0.52	mg/ k lipids
						95% CI	0.50 – 0.54	mg/ k lipids
						Range	0.07 – 1.88	mg/ k lipids
Mes et al. (1993)	Canada	NS	F	NS	Milk fat	Mean	2007.7	ng/g
						Range	175.5-1311.2	ng/g
	Canada	NS	F	NS	Whole milk	Mean	6.35	ng/g
						Range	5.77-34.28	ng/g
Dewailly et al. (1992)	Northern, QC	NS	F	48	Breast milk	Mean	32.2	ng/k
						Mean	2.9	mg/k lipid
						95% CI	2.46 -3.31	mg/k lipid
Dewailly et al. (1992)	Northern, QC	NS	F (Controls)	536	Breast milk	Mean	9.8	ng/k
						Mean	0.52	mg/k lipid
						95% CI	0.50 – 0.54	mg/k lipid

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); umol/L (micro-mole per litre); ug/dl (micro-gram per deciliter)

Table 4.23: PCB 138, 153, 180 levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Biological Sample	Measure	Concentration (units)	
Bilrha et al. (2003)	Rural, QC (Exposed)	24 (4.9)	F	47	Cord Blood	GM (95% CI)	107 (79-146)	µg/L plasma lipid
	Rural, QC (Reference)	NS	F	65	Cord Blood	GM (95% CI)	31 (28-35)	µg/L plasma lipid
Belles-Isles et al. (2002)	Coastal Community, NF	23.9 (5.6)	F	48	Cord Blood	GM (95% CI)	122 (93-159)	µg/k
						Range	20-610	µg/k
Belles-Isles et al. (2002)	Urban, QC	26.9 (3.8)	F	60	Cord Blood	GM (95% CI)	42 (36-48)	µg/k
						Range	10-300	µg/k

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter)

Table 4.24: Total HO-PCBs levels in biological samples

First Authors (Year)	Population	Age	Sex	N	PCB Type	Biological Sample	Measure	Concentration (units)
Sandau et al. (2000)	Northern Community, QC	38	F	17	Total HO-PCBs	Blood	GM	1010 ng/g of whole blood
							Range	117-11600 ng/g of whole blood
	Northern Community, QC	38	M	13	Total HO-PCBs	Blood	GM	1730 ng/g of whole blood
							Range	162-10100 ng/g of whole blood
	Nunavik	NS	NS	10	Total HO-PCBs	Cord Plasma	GM	286 pg/g of plasma
							Range	103-788 pg/g of plasma
	Lower-North Shore	NS	NS	10	Total HO-PCBs	Cord Plasma	GM	553 pg/g of plasma
							Range	238-1750 pg/g of plasma
	Quebec City	NS	NS	10	Total HO-PCBs	Cord Plasma	GM	234 pg/g of plasma
							Range	147-464 pg/g of plasma
Ayotte et al. (1997)	Northern, QC (Exposed)	18-74	NA	20	Planar PCBs	Plasma	Mean	26.3 mg/k lipids
							Range	6.4-58.9 mg/k lipids
Ayotte et al. (1997)	Northern, QC (Non-exposed)	18-74	NA	3	Planar PCBs	Plasma	Mean	5.2 mg/k lipids

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter)

Table 4.25: Total HO-PCBs levels in biological samples

First Authors (Year)	Population	Age	Sex	N	Chemical Types	Biological Sample	Measure	Concentration (units) As reported	
Newsome et al. (1999)	NWT	Median 25	F	12	α chlordane	Milk	Mean	1.27	ng/g liquid
							Median	nd(0.16)	ng/g liquid
Newsome et al. (1999)	NWT	Median 25	F	12	β chlordane	Milk	Mean	nd	ng/g liquid
							Median	nd(0.22)	ng/g liquid
Teshke et al. (1993)	Urban, BC	NS	M & F	41	Total Chlordane	Adipose	Mean	54.6	ng/g lipid
							Range	12.1-126	ng/g lipid
							GM (GSD)	47.5 (1.73)	ng/g lipid
Teshke et al. (1993)	Urban, BC	NS	M & F	41	Oxychlordane	Adipose	Mean	20.3	ng/g lipid
							Range	1.54-48.5	ng/g lipid
							GM (GSD)	16.5 (2.08)	ng/g lipid
Despres et al. (2005)	Northern, QC	25 – 6	M & F	110	Oxychlordane	Blood	Mean	76.8	µg/k
							Range	2.9 -0 623.4	µg/k
							GM (SD)	39.5 (105.3)	µg/k
McCready et al. (2004)	Urban, ON (Cases)	52.5 (SD 10.0)	F	70	Oxychlordane	Breast tissue	GM (SD)	35.09 (22.00)	µg/k lipid
	Urban, ON (Controls)	48 (SD 9.9)	F	69	Oxychlordane	Breast tissue	GM (SD)	31.08 (12.01)	µg/k lipid
Newsome et al. (1999)	NWT	Median 25	F	12	Oxychlordane	Milk	Mean	59	ng/g liquid
							Median	43.2	ng/g liquid
Demers et al. (2000)	Urban, QC (Cases)	53 (9)	F	314	Oxychlordane	Plasma	Mean	12.9	µg/k plasma lipid

First Authors (Year)	Population	Age	Sex	N	Chemical Types	Biological Sample	Measure	Concentration (units) As reported	
							Median	11.9	µg/k plasma lipid
Demers et al. (2000)	Urban, QC (Hospital Controls)	51 (11)	F	219	Oxychlordane	Plasma	Mean	13	µg/k plasma lipid
							Median	11.8	µg/k plasma lipid
Demers et al. (2000)	Urban, QC (Community Controls)	53 (10)	F	219	Oxychlordane	Plasma	Mean	12.2	µg/k plasma lipid
							Median	11.8	µg/k plasma lipid
Lebel et al. (1998)	Urban, QC (Cases)	18 – 50	F	156	Chlordane	Blood	GM (95% CI)	22.4 (20.9 – 23.9)	µg/k plasma lipid
	Urban, QC (Controls)	18 – 50	F	70	Chlordane	Blood	GM (95% CI)	22.3 (20.7 – 24.1)	µg/k plasma lipid
Dellaire et al. (2003)	Northern, QC	Newborns	M(52%) F(48%)	238	Chlordane	Cord Blood	Mean	0.04	% decrease
							Range	(-4.9 – 5.4)	% decrease
Dellaire et al. (2003)	Northern, QC	Newborns	M(52%) F(48%)	238	Chlordane Oxychlordane	Cord Blood	Mean	0.9	% decrease
							Range	(-5.4 – 6.7)	% decrease
Dellaire et al. (2003)	Northern, QC	Newborns	M(52%) F(48%)	238	Chlordane Trans nonachlor	Cord Blood	Mean	2.3	% decrease
							Range	(-2.8 – 7.1)	% decrease
Dellaire et al. (2002)	Coastal residence/QC (1993)	NS	F	62	ΣClordanes	Cord Blood	Mean (95%CI)	32.9 (30.7-35.3)	µg/k
	Coastal residence/QC (1994)	NS	F	62	ΣClordanes	Cord Blood	Mean (95%CI)	29.6 (27.6-31.7)	µg/k
	Coastal residence/QC (1995)	NS	F	82	ΣClordanes	Cord Blood	Mean (95%CI)	28.6 (26.9-30.4)	µg/k
	Coastal residence/QC (1996)	NS	F	71	ΣClordanes	Cord Blood	Mean (95%CI)	28.1 (26.4-30.0)	µg/k

First Authors (Year)	Population	Age	Sex	N	Chemical Types	Biological Sample	Measure	Concentration (units) As reported	
Dellaire et al. (2002)	Coastal residence/QC (1997)	NS	F	50	ΣClordanes	Cord Blood	Mean (95%CI)	25.9 (24.0-28.0)	µg/k
	Coastal residence/QC (2000)	NS	F	65	ΣClordanes	Cord Blood	Mean (95%CI)	25.8 (24.1-27.6)	µg/k
	Coastal residence/QC (Caucasians)	NS	F	224	ΣClordanes	Cord Blood	Mean (95%CI)	2.2 (0.6-3.8)	µg/k
	Coastal residence/QC (Natives)	NS	F	168	ΣClordanes	Cord Blood	Mean (95%CI)	4.1 (2.3-5.8)	µg/k
	Coastal residence/QC (All)	NS	F	392	ΣClordanes	Cord Blood	Mean (95%CI)	3.1 (1.9-4.3)	µg/k

Note: M (Males); F (Females); M & F (Male and Female); NS (Not specified); NA (Not applicable); Mean (arithmetic mean); GM (geometric mean); SD (standard deviation); ND (Non-detectable); µmol/L (micro-mole per litre); µg/dl (micro-gram per deciliter)

4.12 Uranium (U)

Uranium has been measured in urine and feces (Table 4.4) with the objective of measuring U uptake from dietary intake. None of the subpopulations of interest was addressed in these studies which were done to examine absorption factors from dietary media (food and water). The number of participants was small (N=50) but representative of high and low water U intake. Half of the participants in low U water areas received more than 95% of U intake from food in low U water areas, while only half the participants from a high U water area received more than 18% of their intake from food. No background levels in body tissues were provided (Zamora et al. 2002).

Population levels for U-urine are available from the US Third National Report on Human Exposure to Environmental Chemicals. July 2005. (NCEH No. 05-0570).

4.13. Emerging compounds

PFOS/PFOA/PFOSA have been measured in envrionmental samples in Canada (Hites et al. 2004; Ryan et al. 2002), and in blood. Not enough information was provided to make abstraction of values possible to to make any inferences about levels in Canadian populations.

4.14 Other chemicals of interest

Chemicals of interest to note that have not been the subject of any published human biomonitoring studies in Canada are: phthalates and polybrominated diphenyl ethers (PBDEs). This is of particular interest because recent studies have shown that phthalates are found in American urine samples (Ryan et al. 2002) and may have health effects. Moreover, PBDEs have been shown to be doubling in North American breast milk, blood and tissue every five years (Hites et al. 2004). The authors are aware of PBDE data for Canadian breast milk (Ryan J. personal communication 2006). However, these data are not included in the database because they are not yet available in the published literature.

4.15 Geographic Locations of Study Populations

Surveys were conducted across Canada (Mes, 1990; Mes et al., 1993; Mes, 1994; Wheatley and Paradis, 1995; Wheatley and Paradis, 1996; Newsome et al., 1996; Newsome et al., 1995; Crann et al. 1993, and Ryan et al. 1998) included coverage of all provinces in Canada. Wheatley and Paradis (1995; 1996) studies also include coverage of the three territories. The vast majority of the Canadian biomonitoring studies were conducted in Quebec, followed by Ontario. A significant number of studies conducted in the province of Quebec focus on northern Aboriginal communities. Seveal publications focus on specific cotaminants in Nova Scotia (As, Pb), Alberta (Pb), New Brunswick (Pb) and the Yukon Territories (OCs). Newfoundland and Labrador, Prince Edward Island, Manitoba and the Yukon Territories are underrepresented and were covered primarily in the cross-Canada studies, mentioned above.

4.16 Study Design of Biomonitoring Studies in Canada

The majority of the biomonitoring studies conducted in Canada were cross sectional in design, a common design for surveys of general and specific populations. Only a few were cohort studies or case control studies, where biological measures of contaminants were used as a measure of exposure to explore relationships (***e.g.***, breast cancer and OCs in breast milk or breast tissue) or longitudinal exposure trends.

4.17 Studies that link contaminant biomonitoring to health outcomes

Often biomonitoring studies will be used as exposure measures for the purpose of relating health effects in a given population. Some examples are the study of methyl-mercury and children's development, the study of organochlorine contaminants in human follicular fluid and fertility (Jarrell 2005, Foster 2003), contaminant levels and time to pregnancy etc. The research on health arising out of biomonitoring for exposure levels ultimately informs policy on exposure intervention and prevention.

5.0 Gaps Identified, Strengths and Limitations of this Review

5.1 Gaps Identified

There was little to no information on what constitutes "normal" background or average exposure by systematic sampling of populations which are not identified as at special risk of exposure from what is known about pathways of exposure. While much information has been developed on contaminants such as Pb, As, Cd, Se, and U, there is little to no information of this kind for many other contaminants, expecially emerging ones of interest such as phthalates, perfluorinated compounds, and polybrominated diphenyl ethers (PBDEs). Some of this work may be done and presented at conferences, it is not yet in the published literature.

While there are several published studies of animal exposures and food source contamination with PBDEs, and some publications on PBDE levels in environmental media (dust) (Wilford et al. 2005), information on human exposures is lacking. Some of this work is done (i.e. breast milk) (Ryan J, personal communicaton, 2006) but not yet published. This contrasts to the US where a recent review on trends in humans has recently been published (Schechter et al. 2005).

Very few intervention studies are published to measure the effect of regulatory or other public health activities on measured human exposure burdens. Lead is an exception, but even for Pb, there were only three intervention studies published [British Columbia (Hilts et al., 2003, a clinical trial); Toronto (Langlois et al. 1996, an observational study) and Ontario (Wang et al. 1997, an ecological study)].

With regard to geographic representation of sampling, regardless of the contaminant, Newfoundland and Labrador, Manitoba, PEI, and the Yukon territories are underrepresented.

Very few studies linking contaminant levels to specific health impacts are evident. Studies by Aronson et al. (2000) and McCready et al.(2004) on organochlorine pesticides and breast cancer risk are exceptions. With respect to the study of potential mechanisms of action, there are some exceptions, recent studies by Dr. Bruce Wainman and Dr. Warren Foster on West Hudson Bay Cree examining reproductive cycle and organochlorine levels (personal communication, March 9, 2006). A review of this topic is recently published (Foster 2003).

While there are studies on female reproductive cycle, there appears to be little to no research publications on biomarkers of reproductive function in males.

Importantly, a systematic approach to the measurement of relevant and important environmental contaminants in Canadians as a whole is not evident. The use of this information impacts many spheres of activity, from surveillance, regulatory and health effects research. Some key informants identified population monitoring as important for comparisons of at risk groups with "background" or average exposures. Key informants also identified utility of population biomonitoring for tracking interventions in pathways as feedback to regulatory efforts, and for risk assessment.

5.2 Strengths and limitations of this review

As with any review of a large body of literature, this one faced some challenges in carrying it out. Below are highlights of strengths and limitations of this review.

5.2.1 Strengths of this review

Three strengths are identified: systematic approach to the literature search, a review of all the papers resulting to determine if information provided incuded biological measures in useful format, laboratory methods with limits of detection and quantification, sample size and representativeness of the population tested. These characteristics are important in the use of the results for comparisons with other Canadian populations.

The project also identified grey literature systematically through Internet searches and through key informants and professional contacts. This search was complemented by the project team's experience in the area of biological monitoring for environmental contaminants in Canada.

5.2.2 Limitations of this review

An important limitation identified is the short period of time to analyze the results of the

search, potentially missed grey literature and literature from conference presentation which is not yet published, and even published information which may not have been identified. Although multiple search strategies were used to identify relevant studies, some publications may have been missed .The authors are aware of several unreviewed studies the results of which were accessed. However, the studies examined are representative of the overall Canadian biomonitoring literature and missed studies are not likely to change any conclusions made.

6.0 Summary

This report searched systematically for studies of human biological monitoring for environmental contaminants in Canada in the years 1990 to January 2007. Information from 130 studies was abstracted into a word abstraction form and then electronically converted to an Excel database. Information included publication details, population examined (including pregnant and nursing women, children and aboriginals), geographic location, period of sampling, environmental contaminant tested and results of tests, biological tissue used, laboratory methods, limits of detection, study design, author conclusions and comments.

The list of contaminants in environmental exposure biomonitoring studies includes metals (Pb, Cd, Cu, Mn and Hg-MeHg), nutrients (Se and Zn), (PCBs), OCs and non-OC pesticides, dioxins and furans (PCDD/PCDF), PAHs, and related other contaminants. While there was abundant information on Pb, PCBs, Hg and MeHg, and organochlorine pesticides, no information was found on Canadian populations about emerging chemicals of concern (phthalates, perfluorinated compounds, and (PBDEs). It is possible that the reason for the lack of readily available published information on some emerging chemicals is the lag time from testing humans to publication. Tables of contaminant levels for each contaminant group are displayed in section 4.

Newfoundland and Labrador, PEI, Manitoba and the Yukon had little coverage with biomonitoring for environmental contaminants, while most studies were conducted in Quebec and Ontario, with a small representation from Alberta, British Columbia, Nova Scotia and New Brunswick.

Children, pregnant women and nursing women, especially aboriginals, were addressed by relevant studies of Pb and persistent organic bioaccumulative contaminants. However, there is little coverage on non-organochlorine pesticides for the general population, other than breas milk. Cadmium and cotinine values, used as markers of cigarette smoking, may be available from many studies, but not reported in the publication.

Especially absent are biomonitoring studies which focus on urban children (except for Pb), non-Aboriginal males, and background populations (males, females and children – those not considered *at risk*).

A Canadian Health Measures Survey (CHMS) is currently in progress (Personal communication. D. Haines and Paul Walters, Health Canada, November 2006). This is a national survey that will collect information from a sample of 5,200 Canadians, aged six to 79 years in Atlantic provinces, Quebec, Ontario, Prairie provinces (including Yellowknife) and British Columbia (including Whitehorse). Fifteen collection sites have been allocated by region in proportion to their populations: Atlantic (1), Quebec (4), Ontario (6), Prairies (2) and British Columbia (2). The survey will provide nationally representative blood and urine biomonitoring data that is linked with chronic and infectious diseases and risk factors. The list of contaminants to be tested include trace metals, phthalates, organic contaminants (including PBDEs), alkyl phosphates, phenoxyherbicides, perfluorinated compounds, cotinine and bisphenol-A. The results are expected to be available by 2009-10 fiscal year.

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Appendix 1: Glossary of Terms

Glossary and Acronyms used

AB	Alberta
As	Arsenic
AAS	Atomic Absorption Spectroscopy
ASV	Anodic stripping voltametry
AT	Adipose tissue
ATSDR	Agency for Toxic Substances and Disease Registry
B cells	Bone marrow derived lymphocytes
CVAAS	Cold vapor atomic absorption spectroscopy
C	Cohort study
CC	Case Control Study
CS	Cross sectional study
CT	Controlled Trial
DDE	Dichlorochlorophenylethylene
DW	drinking water
EROD	ethoxyresorufin-*O*-deethylase
GC ECD	gas chromatography with electron capture detection
GN	Grassy Narrows
GCMS	Gas Chromatography Mass Spectrometry
HC	Health Canada
HCB	Hexaclorobenzene
HRGC	High Resolution Gas Chromatography
ICPMS	Inductively coupled plasma mass spectrometry
MCPA	4-chloro-2-methylphenoxyacetic acid
MCPB	4(4-chloro-2-methylphenoxy)butyric acid
MCPP	Mecoprop
MCRL	Mid Canada Radar Line
Hg	Mercury
MeHg	Methylmercury
NB	New Brunswick
NHRDP	National Health Research Scholar Program
NIEHS	National Institute of Environmental Health Sciences (US)
NK cells	natural killer lymphocytes
NSERC	Natural Sciences and Engineering Research Council (of Canada)
NS	Nova Scotia
OC	Organochlorines (aldrin, alpha chlordane, gamma chlordane, cis-nonachlor, hexachlorobenzene (HCB), p,p'DDE, mirex, oxychlordane, trans-nonachlor, beta hexachlorocyclohexane
Pb	Lead
ON	Ontario
OXCH	heptachloroepoxide-oxychlordane
PEI	Prince Edward Island
PECOS	Prairie Ecosystem Program
PCB	polychlorinated biphenyls
PCBC	PCB congeners

T cells	Thymus derived lymphocytes
TCDD	Tetrachlorodioxin
TEQ	Toxic equivalents (an equivalency of dioxin congeners mix)
TSRI	Toxic Substance Release Inventory
WD	White Dog
QC	Quebec
2,4-D	2,4-dichlorophenoxyacetic acid
2,4-DP	dichlorprop
2,4-DB	4(2,4-dichlorolphenoxy)butyric acid

biological monitoring: Continuous or repeated measurement of potentially toxic substances, their metabolites or their biochemical effects in tissues, secreta, excreta, expired air or any combination of these. Its purpose is to evaluate occupational or environmental exposure and health risk by comparison with appropriate reference values based on knowledge of the probable relationship between ambient exposure and resultant adverse health effects.

biomarker:

1. Indicator signaling an event or condition in a biological system or sample and giving a measure of exposure, effect, or susceptibility. As related to biomonitoring, a biomarker is the presence of any substance, or a change in any biological structure or process that can be measured as a result of exposure. Many biomonitoring studies focus on chemical substances or their metabolites as biomarkers.[3]

2. Parameter that can be used to identify and effect in an individual organism and can be used in extrapolation between species for risk assessment.[4]

Appendix 2: Search Strategy

Search Strategy - Review of Human Biomonitoring Studies of Environmental Contaminants in Canada 1990-Jan 2007

Keyword Search

DATABASES	LIMITS	KEYWORDS/DESCRIPTORS
MEDLINE® EMBASE®	1990- Jan 2007	Canad$ OR Newfoundland OR Labrador OR Nova Scotia OR New Brunswick OR Prince Edward Island OR PEI OR Quebec OR Ontario OR Manitoba OR Saskatchewan OR Alberta OR British Columbia OR Yukon OR North West Territories OR Nunavut OR circumpolar *AND* Biomon$ OR biomarker$ OR biological monitoring OR urine OR blood OR hair OR nail OR plasma OR fat OR adipose$ OR plasma OR serum OR semen OR human milk OR breast milk OR cord blood OR Amniotic OR saliva *AND* Metal$ OR Arsen$ OR cadmium OR Cd OR Manganese OR mercury OR beryllium OR nickel OR selenium OR uranium OR selenium OR cesium OR phthalate$ OR persistent organic pollutants OR organophosphate OR phenoxy herbicide OR bisphenol OR cotinine OR perfluorin$ OR polycyclic aromatic hydrocarbons OR PAHs OR benz$ OR PCB OR Dioxin OR DDT OR methylmercury OR pesticides OR environmental contaminants Performed: January 11, 2006 Number of unique record: 458 MEDLINE®: 295 EMBASE®: 163
	Human	
	Human	

Note 1: Pb was not searched since these studies were to be located through the CHE blood Pb study database project. Some studies were included here as they were known to the project team or arose out of the general search and author search.

Keyword Search with Occupation Search (exploratory search)

DATABASES	LIMITS	KEYWORDS/DESCRIPTORS
MEDLINE® EMBASE®	1990- 2007	Canad$ OR Newfoundland OR Labrador OR Nova Scotia OR New Brunswick OR Prince Edward Island OR PEI OR Quebec OR Ontario OR Manitoba OR Saskatchewan OR Alberta OR British Columbia OR Yukon OR North West Territories OR Nunavut OR circumpolar *AND* Biomon$ OR biomarker$ OR biological monitoring OR urine OR blood OR hair OR nail OR plasma OR fat OR adipose$ OR plasma OR serum OR semen OR human milk OR breast milk OR cord blood OR Amniotic OR saliva *AND* Metal$ OR Arsen$ OR cadmium OR Cd OR Manganese OR mercury OR beryllium OR nickel OR selenium OR uranium OR selenium OR cesium OR phthalate$ OR persistent organic pollutants OR organophosphate OR phenoxy herbicide OR bisphenol OR cotinine OR perfluorin$ OR polycyclic aromatic hydrocarbons OR PAHs OR benz$ OR PCB OR Dioxin OR DDT OR methylmercury OR pesticides OR environmental contaminants *AND* Occupa$ OR Indus$ OR worker$ OR production OR printing OR dry clean$ OR manufacture OR Farm$ OR shipyard OR milling OR construction OR foundaries OR underground miners OR radiologists OR machinists OR engineers OR pulp OR paper OR forest OR electroplating OR rubber OR printing OR coal$ OR lubricant OR chimney OR firefighters Performed: January 11, 2006 Number of unique record: 160 MEDLINE®: 78 EMBASE®: 82
	Human	
	Human	
	Occupations	

Note 1: Pb was not searched since these studies were to be located through the CHE blood Pb study database project. Some studies were included here as they were known to the project team or arose out of the general search or author search.

Appendix 3: Data Abstraction Form

Data Abstraction Form (DAF):
BC Systematic Review of Biomonitoring Studies in Canada

ID:	**First Author:**
Year:	**Reviewer Initials:**

STUDY CHARACTERISTICS

Study Participants (*e.g.*, Children living in East-end Montreal):

Country/ Location: _____

Study setting (population, clinic): _____

Ethnicity (*e.g.* natives): _____

Other participant characteristics: _____

Study Design:

	(Check one)	Sampling Strategy
Cross-sectional:		
Cohort:		
Case-control:		
Other (specify):		

Data Collection and Analysis:

Period of data collection (*e.g.*, 1990-1995): _____

	Contaminant of Concern (*e.g.*,, Pb)	Method of analysis (*e.g.*, ICPMS)	Detection Limit
Chemical 1:			
Chemical 2:			
Chemical 3:			
Chemical 4:			

Comments:

_____

_____

For Administration Only: **Author searched ❑** **Back referencing ❑**

Study ID:

Age/age-group	Sex	No. of subjects	Contaminant (*e.g.*, Cd)	Biological specimen (*e.g.*, urine)	Measure (*e.g.*, mean/median)	Concentration	Unit (*e.g.*,ug/l)	Comments