Northern Saskatchewan Prenatal Biomonitoring Study Technical Summary Report

Ministry of Health, Government of Saskatchewan, 2019

Saskatchewan Health Authority

Saskatchewan

Northern Saskatchewan Prenatal Biomonitoring Study

Summary Report

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For more information contact:

Environmental Health
Population Health Branch
Miinistry of Health
3475 Albert Street,
Regina, SK, Canada, S4S 6X6

Telephone: 306-787-8847

Website: https://publications.saskatchewan.ca:443/api/v1/products/101374/formats/112048/download

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EXECUTIVE SUMMARY

What was the study about?

Humans are surrounded by chemicals—some are essential to life (e.g., oxygen, iron, selenium), while some may cause harm under certain circumstances or at certain doses. Environmental chemicals describe those man-made or naturally occurring chemicals that we are exposed to in our daily lives. People interact with a variety of chemicals every day. Some may be eaten or drank, breathed in, or absorbed through the skin in consumer products, water, soil, food, or air.

The biomonitoring study looked at various environmental chemicals found in the blood of pregnant women in northern Saskatchewan.

What is biomonitoring and what is the purpose of biomonitoring?

Biomonitoring measures chemicals in humans through analyzing blood, urine, hair or breast milk. At this time, it is the most accurate means we have to determine the amount of a given chemical or element a person is exposed to in the environment. It gives us a snapshot in time and allows us to know the quantity of a given chemical in the body, but does not tell us information on the source, duration, or route exposure. The risk to human health is determined by the complex interplay between the type of chemical, the amount of the chemical, what kind of exposure, how often the exposure took place and the person exposed.

Information from biomonitoring can:

- enable the public and communities to become more aware of and take steps to reduce their exposure to environmental chemicals;
- enable comparisons between populations and, over time, assist with government, environment and health agencies to assess risks and take public health or environmental actions; and
- assist in the prioritization of further research.

How was the study done?

The study involved the co-operation of pregnant women living in the Northern Administrative District of Saskatchewan between April 2011 and April 2013. These pregnant women allowed any blood remaining after their routine prenatal blood tests were completed to be included in the study. Pooling of the residual blood from 855 serum samples was done to ensure there was enough specimen for testing of over 280 environmental chemicals.

There were six different pools of specimens based on the area of northern Saskatchewan in which the women resided. This allowed for comparisons across the north as well as comparisons with results from a previously completed prenatal biomonitoring study in Alberta. Some comparisons were possible with other biomonitoring studies; however, for some chemicals, only baseline results are available.

Who are the agencies involved?

The study was done in partnership between the Saskatchewan Ministry of Health, northern Health Authorities and Alberta Health.

A Steering Committee was engaged to assist with overall direction of the project. This included representatives from the Ministries of Health and Environment, northern health authorities, First Nations health authorities, and the First Nations Inuit Health Branch of Health Canada.

Feedback and support for the project was provided by the Northern Saskatchewan Environmental Quality Committee, the Boards of the Athabasca Health Authority, the Keewatin Yatthé and the Mamawetan Churchill River Health Regions, the Northern Intertribal Health Authority Board of Chiefs and Executive Council, the Prince Albert Grand Council Chiefs and the Meadow Lake Tribal Council Health and Social Services group.

Information was provided to northern health professionals involved in the care of prenatal women, including public health nurses and physicians. Community awareness was enhanced through the use of radio messaging in Cree, Dene and English. Pamphlets were available at all health centers and through prenatal education. Posters or bulletin boards were used at health centers and other community centers.

What environmental chemicals were tested?

The chemicals selected were based on other Canadian biomonitoring projects as well as chemicals that may be of concern in Alberta and Saskatchewan including:

- industrial and agricultural by-products,
- those used in the manufacture of consumer goods (furniture, building materials, clothing, cosmetics, etc), and
- those that naturally exist in the environment.

A variety of mineral micronutrients (required for good health) and trace metals, a wide variety of chemicals classified as pesticides, PCBs, flame retardants, phlalates, dioxians and furans were tested. Commercial tobacco contains many chemicals of concern which be can be elevated in people exposed to tobacco smoke, so continine which is a break-down product of nicotine, was also measured.

What did the study show?

Finding a chemical in the body through testing does not necessarily mean that this poses a health risk or causes a health problem. Some chemicals (e.g minerals) are required for good health, but too much could increase the chance of health problems.

Some highlights include:

- Some specific chemicals in the categories such as polybrominated diphenyl ethers (flame retardants), perfluorochemicals, most pesticides tested, dioxins and furans, were either lower than Alberta levels or were undetectable. Uranium, nonylphenol and bisphenol A were also not detectable or were below the level that could be accurately measured.

- Selenium and molybdenum were slightly lower than the average levels in Alberta. Iron levels were also slightly lower in Saskatchewan than Alberta women but cobalt was higher. Both iron and cobalt help prevent anemia (weak blood from low iron or vitamin B12).

- The levels of lead, a heavy metal, were higher than the average levels seen in Alberta. People may be exposed to lead through lead-based paints (in older homes), drinking water coming in contact with old lead plumbing, consumer products, or the ingestion of lead shot or lead bullet fragments in country foods. Smokers or those exposed to second hand smoke tend to have higher levels.

- Mercury levels were comparable to those in Alberta; however, the levels in the far northern area of Saskatchewan were higher. Methylmercury levels tend to be higher in those who consume a lot of fish especially large predatory fish.

- Continine levels, a breakdown product of nicotine, were higher in northern Saskatchewan women indicating higher exposures to tobacco smoke either through smoking or passive smoke exposure. Exposure to tobacco smoke increases exposure to many other environmental chemicals as well.

OVERALL, MOST OF THE ENVIRONMENTAL CHEMICAL TESTING FOR NORTHERN SASKATCHEWAN REVEALED LEVELS LOWER THAN OR COMPARABLE TO LEVELS IN PREGNANT WOMEN IN THE ALBERTA STUDY.

INTRODUCTION

Humans are immersed in chemicals. Some of these chemicals, such as oxygen and hydrogen, are essential to life. On the other hand, some chemicals may cause harm under certain circumstances. **Environmental chemicals** are those chemical substances we are exposed to in our daily lives; some are human-made while others are naturally occurring; as with all chemicals, they may be helpful, harmful or neither.

This biomonitoring study should be seen as foundational work for developing a better understanding of the people of Saskatchewan's exposures to environment chemicals of interest or potential concern. Biomonitoring is a tool that allows for a population level understanding of what chemicals people are being exposed to and to some degree, how much.

STUDY RATIONALE

The biomonitoring study was intended to establish typical human exposures to environmental chemicals during pregnancy for women living in northern Saskatchewan. This purpose arose from several streams of thought:

- Saskatchewan has never systematically performed population level biomonitoring. In Canada, there is information available for overall Canadian biomonitoring results, but Saskatchewan was not included in the sampling for the Canadian Health Measures Survey until its fourth cycle in 2014/15. There is also biomonitoring information available for northern Canada (north of 60) there are biomonitoring projects involving some Canadian First Nations communities, including some in Saskatchewan. The data collected from a systematic biomonitoring program could inform governments, researchers and health practitioners in a variety of ways.
- The Alberta Ministry of Health is a key partner. They have a similar biomonitoring program. Periodically they collect information; however, they were also interested in establishing a comparator similar to their population prior to industrial particularly oil and gas development. Parts of northern Saskatchewan are relatively untouched by oil and gas developments and so this population was considered a reasonable comparitor.
- New environmental chemicals continue to be developed with the potential for human health exposure. Biomonitoring has potential to inform further action.
- Pregnant women are of particular concern in terms of potentially adverse exposures due to the sensitive nature of the fetus, and as it is routine for these women to have blood studies done

BIOMONITORING AS THE TOOL OF CHOICE

Biomonitoring is the measurement of chemicals or their metabolites (break down products) in humans. It is done by measuring these chemicals in a **biological matrix** such as blood, urine, hair or breast milk.[1] At this time, it is the most accurate means we have to determine the amount of a given chemical or element a person is exposed to in the environment. This information can then be used to inform decisions about health risks.

All persons interact with a variety of chemicals on any given day. Some may be eaten, inhaled or absorbed through the skin (termed the 'route' of exposure) in any or all consumer products, water, soil, food or air. The risk to human health is determined by the complex interplay between the chemical in question, the dose (amount) of the chemical, the route[a] and frequency of exposure, and the person exposed.[2]

The **internal dose** is the measurable amount of a chemical that exists in a biological matrix. It depends on both the **pharmacokinetics** (what the body does to the chemical) and the **pharmacodynamics** (what the chemical does to the body) of a particular chemical in an individual. It is also affected by the same factors that are considered in human health risk assessments (chemical characteristics, route of exposure, duration of exposure, frequency of exposure and receptor).

Biomonitoring gives us a snapshot in time. It allows us to determine the internal dose, but only for a specific point in time. It does not provide us with information on the source, duration or route of exposure, all of which are fundamental in developing a complete understanding of exposure. **Periodic biomonitoring**, where biomonitoring is repeated in a given population at a certain frequency, still cannot account for source, duration or route, but it does allow for comparison over time.

Even with its limitations, biomonitoring has proven valuable in understanding population exposures to environmental chemicals. In Canada, in addition to the Alberta program, the Canadian Health Measures Survey[10] (CHMS), the Maternal-Infant Research on Environmental Chemicals (MIREC), the First Nations Biomonitoring Initiative[29], and the Northern Contaminants Program (in Nunavut, Northwest Territories and the Yukon) all used biomonitoring as a tool to identify and monitor population exposures to environmental chemicals.

The data provided from biomonitoring has the capacity to inform governments, researchers and health practitioners by[152]:

1. Establishing baseline levels of chemicals in the Canadian population.
2. Allowing for comparison of exposure to environmental chemicals among different populations.
3. Identification of chemicals for which further action should be taken to protect the public's health.
4. Supporting future research on potential links between exposure to certain chemicals and specific health effects.
5. Contributing to international monitoring programs.

[a] Ingestion, inhalation, injection or dermal absorption

Biomonitoring is a novel tool with great promise, but there are limitations on what can be drawn from the information collected using this methodology. These limitations will be explored further in the "Limitations" sections of this document and should be considered seriously in interpreting the findings of this study.

STAKEHOLDER ANALYSIS

ALBERTA'S BIOMONITORING PROGRAM

The Alberta Biomonitoring Program began with Phase I in 2005 and focussed on pregnant women.[3] The second phase included a study of Southern Alberta children in 2006.[4] Phase III of this program is underway.

Alberta's program was implemented after the development of the oil sands in Northern Alberta and therefore, a baseline level of population exposure to chemicals of potential concern was not obtained prior to establishment of the industry.

Northern Saskatchewan was deemed a suitable population to act as a proxy baseline. Subsequently, Saskatchewan was offered the opportunity to undergo its own biomonitoring initiative which, along with providing comparison values for Alberta, can provide some valuable information on Northern Saskatchewan's exposures.

ENGAGEMENT WITH NORTHERN COMMUNITIES

At the outset, a steering committee for the study was engaged to assist with overall direction of the project. Representatives included: the Saskatchewan Ministries of Health and Environment, northern health authorities and northern health regions, First Nations Health Authorities, and the First Nations Inuit Health Branch of Health Canada.

The goals, principles, design, and purpose were shared with a variety of northern leadership, health and/or environmental groups who provided feedback and support for the project including Northern Saskatchewan Environmental Quality Committee, the Boards of the Athabasca Health Authority, the Keewatin Yatthé and the Mamawetan Churchill River Health Regions, the Northern Intertribal Health Authority Board of Chiefs and Executive Council, the Prince Albert Grand Council Chiefs and the Meadow Lake Tribal Council Health and Social Services group.

Further information was provided to northern health professionals involved with the care of prenatal women including public health nurses and physicians. Community awareness was enhanced through the use of radio messaging in Cree, Dene and English as well as pamphlets available at all health centers and through prenatal education, and posters used at health centers and other community centers or bulletin boards

GLOSSARY

Aliquot	A small portion of the total sample.
Arithmetic mean	The average set of numbers, calculated by adding them together and dividing by the number of terms in the set.
Background concentration of chemicals	A subjective term normally used to describe the baseline concentration of a chemical in humans or the environment where there has been no occupational or accidental exposure to high concentrations.
Bioaccumulation	Accumulation of substances in an organism (plant, animal or human) above what is in the environment (e.g. water, air, food).
Biological matrix	Body fluid or tissue (e.g. blood, urine, breast milk, expelled air, hair, nails, etc.)
Biomonitoring	The measurement of chemicals in human bodies. These measurements are often made by analzying blood, urine or other body tissues such as hair or nails.
Blood serum	The clear yellowish liquid part of whole blood. It is obtained by clotting the whole blood, and then by separating the liquid from the solids.
Congener	Chemicals that are related to each other by origin, structure, or function.
Descriptive statistics	Statistical analysis that describes or summarizes the data in a meaningful way.
Environnmental chemicals	The chemicals that can be found in the world around humans - both in nature and in the man-made environment.
Fungicide	A chemical that destroys fungus.
Geometric mean	A type of mean or average that uses the product of a set of numbers (the nth root of the product of n numbers).
Internal dose	The amount of an agent/compound that enters the body by crossing an exposure surface that acts like an absorption barrier such as the skin, or gastrointestinal lining. The same as "absorbed dose".
Isomer	Each of two or more compounds with the same chemical formula that have different arrangements of atoms leading to different properties.
Limit of detection (LOD)	The lowest concentration at which chemical can be measured.

Limit of quantification (LOQ)	The limit of quantitation (LOQ) is set at a higher value than the limit of detection and is the concentration at which concentrations of an analyte can be reported with confidence.
Lipid	Synonym of fat or oils.
Lipid serum weight	This is the concentration of a lipophilic chemical presented in reference to the amount of lipid in the serum sample.
Lipophilic	"Fat loving" – describes compounds that can be easily dissolved or stored in lipids.
Man-made chemicals	Chemicals that are produced by human activities, either intentionally or unintentionally, and are not normally found in the environment. Also referred to as synthetic chemicals or anthropomorphic (human-made) chemicals.
Metabolite	A substance produced from another precursor substance through metabolic transformation by enzymes or microorganisms in our bodies.
Naturally occurring chemicals	Chemicals that are present or produced naturally in the environment. Some man-made chemicals are also naturally occurring.
Opt-in consent	Participants volunteer to take part in the research.
Opt-out consent	Participants are contacted without volunteering to take part in the research and are excluded when they declare they are unwilling to participate.
Periodic biomonitoring	Repeated biomonitoring over more than one time point.
Persistent	Resistant to degradation processes in our bodies or in the environment.
Pesticide	A substance used to destroy insects or other organisms that may cause harm to crops or animals.
Pharmacodynamics	An area of study in pharmacology that explores the effects of substances on the human body.
Pharmacokinetics	An area of study in pharmacology that explores how the body responds to the presence of a substance.

METHODOLOGY

For details on the methodology please refer to the detailed technical document entitled "Northern Saskatchewan Biomonitoring Survey Report, 2019".
See: https://publications.saskatchewan.ca:443/api/v1/products/101375/formats/112049/download

SCOPE

The scope of this survey was to establish blood serum levels of various chemicals in women who were pregnant and resided in the Northern Administrative District of Saskatchewan between April 2011 and April 2013.

1. Geographic: only residents in the Northern Administrative District of Saskatchewan from the former Keewatin Yatthé, Mamawetan Churchhill River, and Athabasca Health Authorities plus the Village of Cumberland House and Cumberland House First Nation were included;
2. Only females who were pregnant and had testing done during their pregnancy were selected;
3. Consent to use the sample was provided (direct or implied); and
4. Pregnancy testing had to be done between April 2011 and April 2013.

SAMPLE SELECTION

Pregnant women were selected for several reasons. The first is the known susceptibility of a developing fetus. There are several chemicals known to have adverse effects on fetal development at relatively high maternal body doses, but the effects on the fetus of new and emerging chemicals and low levels of some long standing chemicals are less clearly defined. Second, targeting pregnant women was practical as there are routine blood tests performed at the initial prenatal assessment. The serum specimens analyzed for biomonitoring were derived from these blood draws - once the prenatal studies were completed if there was more than 1 ml of residual serum, the sample was then eligible to be included for study.

- 1233 samples were collected
- 1086 consented to participate
- 841 samples were eligible for the study.

In total, the Roy Romanow Provincial Laboratory (formerly the Saskatchewan Disease Control Laboratory) received 1,233 serum samples between April 1, 2011 and April 8, 2013. Of these, 1,096 specimens were consented for study inclusion; of those, 841 had a residual volume of 1mL and could be used for analysis. About 68% of the total numbers of specimens from pregnant women in northern Saskatchewan were included in the pool. This is relatively comparable to the Alberta sampling at 64% (28,484 samples drawn from 44,584 specimens collected).

The 841 samples were then grouped by geographic area into pools of at least 120 samples. This results in six distinct collections of pooled serum samples.

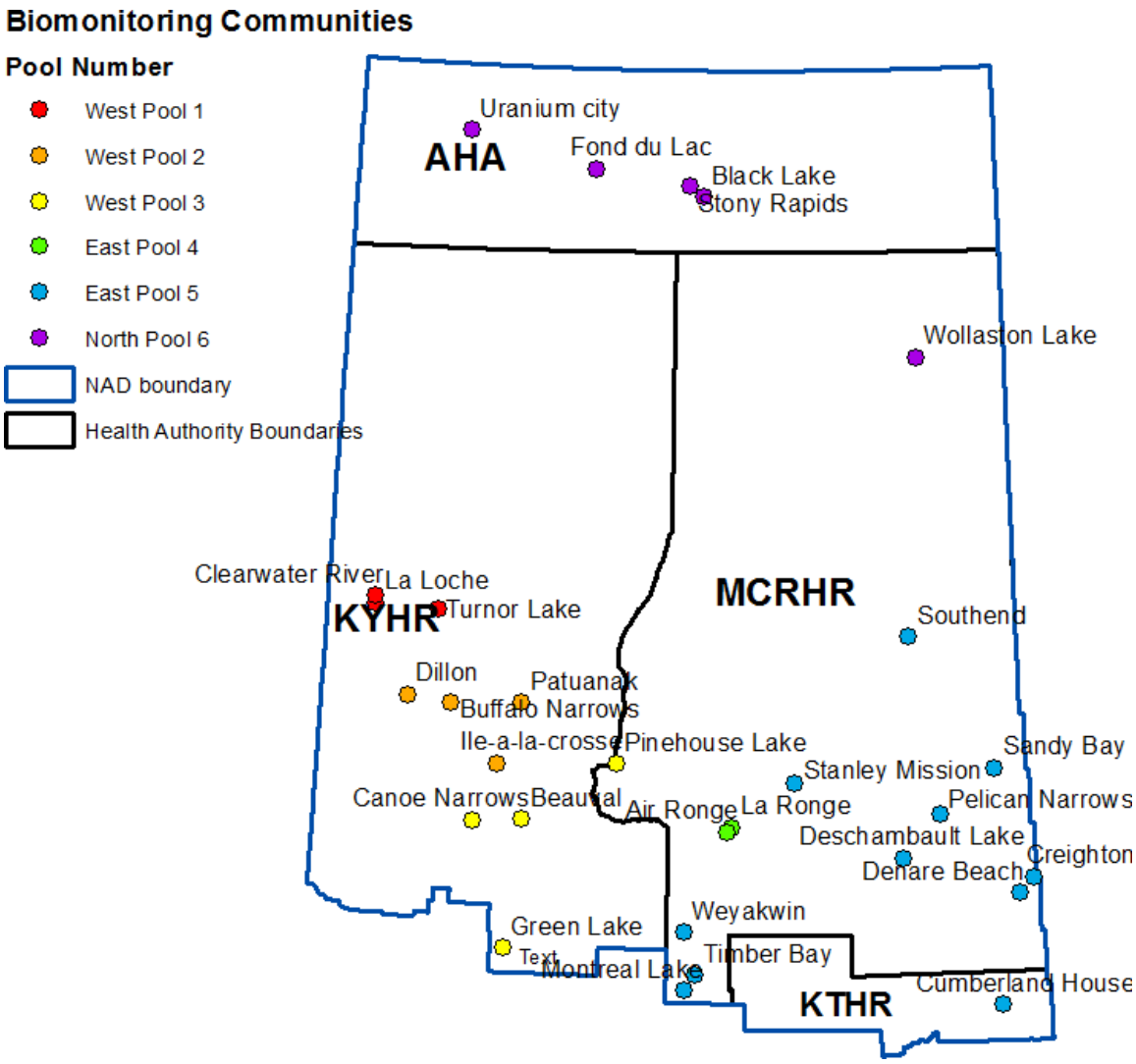


Figure 1: Biomonitoring communities and the resulting pools. Pool 1, 2, 3 = NW; Pool 4,5 = NE; Pool 6 = FarN; AHA = Athabasca Health Authority, KYHR = Keewatin Yatthé Health Region, MCRRHA = Mamawetan Churchill River Health Region, KTHR = Kelsey Trail Health Region

Information on specific individuals is not available and results cannot be linked to an individual, a specific community (other than the pool area of groups of communities) or to a specific age group.

RECRUITMENT AND CONSENT

There were two phases of recruitment for this study over a two-year period. The first phase ran from April 1, 2011 to July 31, 2011. It included 189 specimens from northern pregnant women already at the Provincial Lab. Letters to provide consent for the use of their residual blood specimen were mailed to the ordering physician to distibute to the pregnant woman. Seventy-one (71/189) forms were returned and of those fifty-two (52) consented, six declined and 13 forms were incomplete.

The second phase from August 1, 2011 to April 8, 2013 followed an extensive community awareness campaign with the option for women to opt out. There were no refusals during this stage of the study.

Table 1: Sampling over two years

	Phase One	Phase Two
Date	April 1, 2011 to July 31, 2011 (121 days)	August 1, 2011 to April 8, 2013 (616 days)
Sample Source	Specimens already at the provincial lab (189)	Pregnant women
Consent	Letters sent to ordering physicians to provide to women	Opt out at time of test (nil opted out)
Sample Size	52 Of the 189 samples - 71 forms returned - 52 consented - 6 declined - 13 incomplete	1044
Samples with adequate serum (> 1 ml) and included in study pools	841 samples included across 6 pools	

All of northern Saskatchewan was not sampled to the same extent. Some geographic areas were under sampled compared to others. For example, those served by the Flin Flon Hospital have samples processed in Manitoba and were not available for the study. In the first year, areas served by LaRonge Health Centre laboratory were not included in the study samples, but were full participants in the subsequent year.

CHEMICAL SELECTION

Chemicals were selected by reviewing data from similar biomonitoring studies, using criteria outlined in the CHMS[89], and consulting experts in the field.

Chemical Selection Approach:

1) **Using criteria outlined in the CHMS[89]:**
   - known or suspected health effects related to the substance;
   - need for public health actions related to the substance;
   - level of public concern about exposures and possible health effects related to the substance;
   - evidence of exposure of the Canadian population to the substance;
   - feasibility of collecting biological specimens in a [national] survey and associated burden on survey respondents;
   - availability and efficiency of laboratory analytical methods; costs of performing the test; and,
   - parity of selected chemicals with other national and international surveys and studies.
2) **Reviewing data from similar population biomonitoring studies;**
3) **Expert opinion.**

The chemicals selected could be described as[b]:

- Industrial and agricultural by-products;
- Used in the manufacture of consumer goods;
- Contaminants of potential concern either by The Stockholm Convention or in Federal regulations;
- "Emerging" contaminants such as bisphenol A, parabens and phthalates (few studies available);
- Naturally occurring in the environment though they may be found in different concentrations in different geographical areas. Some occur naturally in foods and some are required for the maintenance of good health, but can cause health concerns if people are exposed to large amounts.

[b] A similar set of chemicals were tested in Alberta as part of the Alberta Biomonitoring Study though the Saskatchewan study did include some additional chemicals not included in the first phases of the Alberta study. A most recent Alberta study (Phase 3) included similar chemicals.

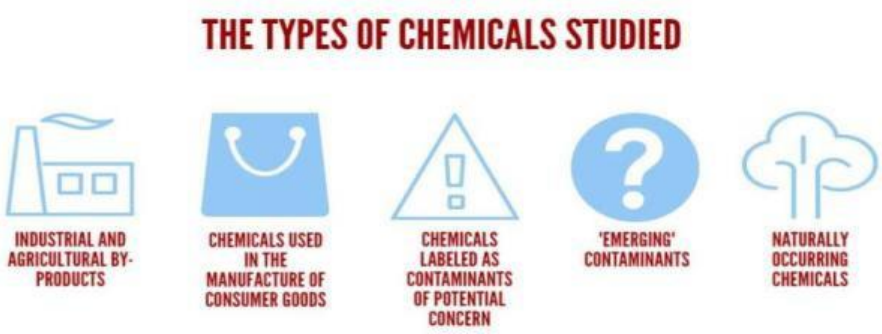


Figure 2: Type of chemicals studied

SELECTION OF BIOMONITORING MATRIX

There are advantages and disadvantages to using each biological matrix (such as urine, whole blood or serum). In addition to these considerations, there are varying resource costs for collection and laboratory analysis of chemicals in biological samples. In population level biomonitoring studies, choosing one matrix is considered to be most cost-effective. Blood is typically considered a good reflection of the amount of the chemical that has accumulated in the body or the internal body burden[5]. Thus, although blood serum may not be ideal for all chemicals analyzed, it was the matrix selected for this study.

The chemical's properities determine where the chemical will be found in the blood serum. Lipophilic (fat-loving) chemicals are mostly found in the lipid rich portion of serum and are often described in reference to the lipid weight of a serum sample. Some metals, such as mercury, prefer the blood cells and are not well measured in the serum (which lacks blood cells). Therefore, it is necessary to consider the results found here with the realization that blood serum was the matrix of choice (and not *whole* or *lipid adjusted blood serum*).

LABORATORY ANALYSIS

Several chemicals were analyzed at the Alberta Centre for Toxicology (Calgary, AB) including cotinine, phytoestrogens and metals. Polybrominated diphenyl ethers (PBDEs) were analyzed in Prague, Czech Republic by ALS Laboratory Group, while methylmercury was analyzed by ALS Laboratory Group in Sweden. The remaining substances were evaluated in Edmonton, AB at the ALS Laboratory Group.

For the details of the analytical method for each chemical of interest, please refer to the full technical report.

The analysis of all Saskatchewan samples was provided by Alberta Health.

STATISTICAL ANALYSIS

ANALYSIS AND LIMITATIONS

The blood serum samples collected for this study were physically combined before analysis in a process called "pooling". The blood samples were pooled into six groups based on region (northeast, northwest and far north). The pooling of blood samples has many advantages; however, it limits the information that can be derived from the samples.

When individual blood samples are pooled together, the measured chemical concentration is a close estimate of the **arithmetic mean** (average) of the concentrations that would have been in the blood of each individual.[6] That is to say, the concentrations for each pool are arithmetic averages of the pregnant women from a defined geographic area.

In reality, most blood concentrations of chemicals across any given population tend to follow what is known as a log-normal distribution.[6] This is important because the best way to describe the "average" of such a population is actually the **geometric mean**. [7]

Standard deviation and standard error are important values that help add robustness to the information an average, or mean, can provide. These were calculated and presented with all mean values. Both the standard deviation and standard error provide an indication of the extent of the variability between the samples or the range of results.

Pooling is important to increase the likelihood of detecting a concentration that is above either the **limit of detection (LOD)** or the **limit of quantification (LOQ).** A challenge for assessing environmental chemicals in human biomonitoring is that the concentrations of some chemicals are often so small that current techniques cannot measure them. This is known as being below the **limit of detection** or the **limit of quantification**. When this occurs, the presence of a particular chemical is unknown. When you pool together various samples you increase the likelihood of measuring a substance if it is indeed there.

For the purposes of this study, the average across all six pools was determined only if at least five pools had concentrations above the LOD or LOQ. 136 out of the approximately 283 chemicals met these criteria.

Unfortunately, due to the lack of randomization in the study design, we cannot generalize the findings of this study to all pregnant women in northern Saskatchewan with certainty.

All analyses were conducted using Microsoft Excel (2003) with graphs generated using SigmaPlot (v12.5).

WEIGHTING OF CONCENTRATIONS

In order to compare the pools to each other and to pools in Alberta, statistical weighting was necessary. Some pools had more individual samples than others, and to allow comparisons between these differing pools a weighting factor was necessary. The detected concentration in a pool was multiplied by the number of its samples. The sum of these products was divided by the sum of the number of samples (total participants), resulting in a weighted overall mean. In this report, the combined northern values (weighted-arithmetic means) will be identified as "mean" values.

ETHICAL CONSIDERATIONS

Biomonitoring provides valuable information, but the interpretation and application of that information should be done ethically.

Formal ethical approval for this study was obtained from the University of Saskatchewan's Research Ethics Board (May 9, 2011 – Bio-RED-11-109). As well, approval was obtained from all four northern health authorities (Athabasca Health Authority, Keewatin-Yatthé, Mamawetan Churchill River and Kelsey Trail Health Regions); and the Northern Intertribal Health Authority (representing Prince Albert Grand Council, Meadow Lake Tribal Council, Lac La Ronge Indian Band and the Peter Ballantyne Cree Nation).

RESULTS

PREAMBLE

Biomonitoring is an important tool for understanding exposure to chemicals in the environment, but it is a tool with limitations. These limitations are important to consider in the interpretation of the results. The "Limitations" section of this document explores some of these in detail, but two key considerations include understanding the ability to compare and the ability to interpret these results through a health lens.

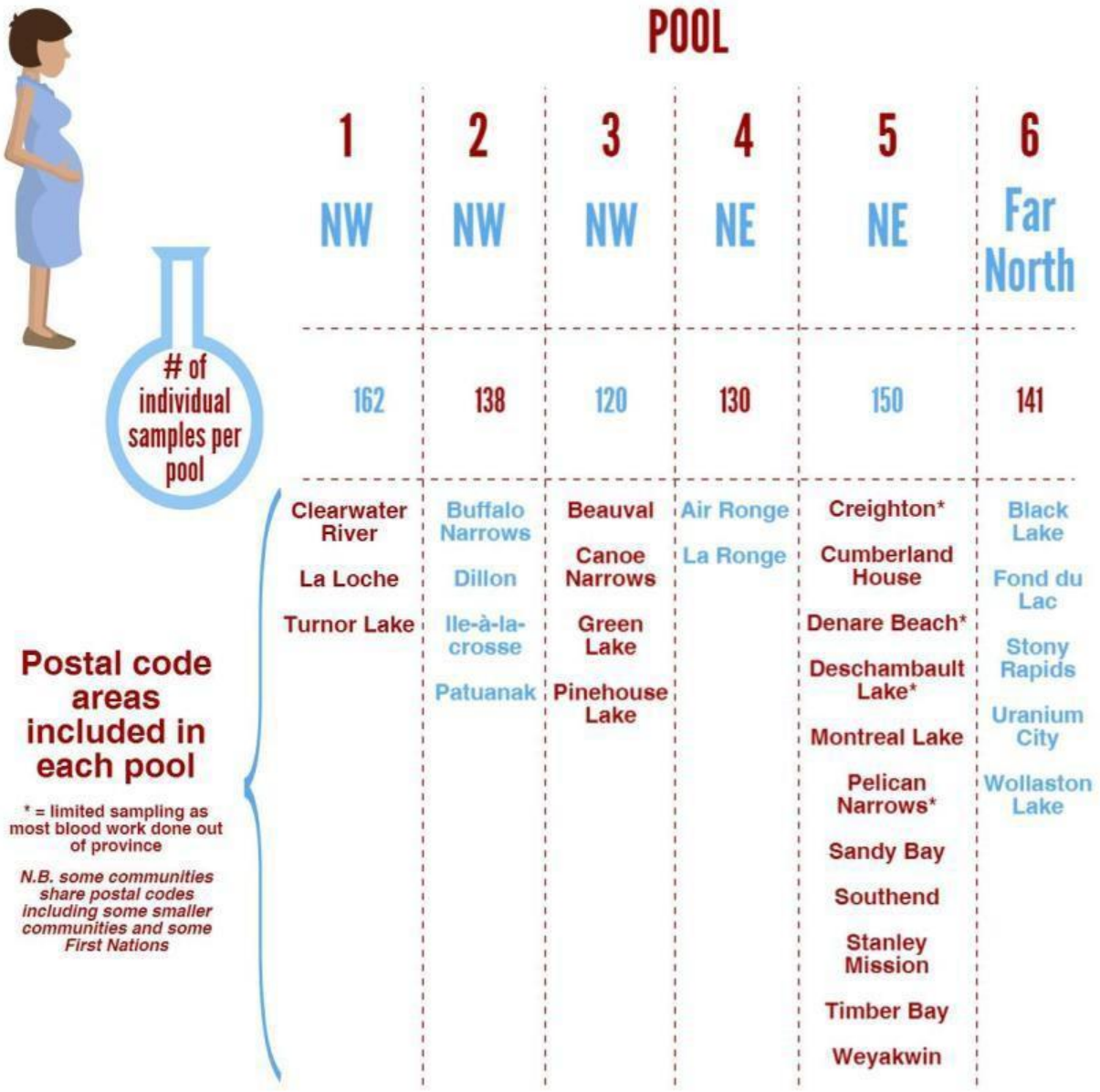
Comparing Studies: The precision and accuracy of analytical instruments continue to improve with time. We now can measure chemicals at very low concentrations, lower than ever before. As a result, the detection of a chemical in one study and not in another may be the result of the changes in detection limits and may not reflect an actual difference in exposure.

Chemicals and Health: For most chemicals or metals there are thresholds above which measurable health effects are known to occur. Some substances are required for normal physiological functioning and thus too low amounts can have detrimental effects. For other substances, chiefly carcinogens, but also some heavy metals such as lead, there is no level of exposure below which health risk is considered zero. Some newer substances (such as bisphenol-A) are still being studied and the health effects, if any, are unknown or unclear.

POOLED SAMPLES

Six pooled samples were prepared based on the individual samples available. (Figure 3)

Figure 3: Infographic of how samples were assigned to geographic pools



***** = limited sampling as most blood work done out of province

COMPARISONS TO OTHER STUDIES

A result is difficult to interpret without context to put value to that number. A challenge within the field of biomonitoring is that due to the limited number of large scale biomonitoring projects and the constantly changing technologies, this context is not always possible.

In this case, there are two key comparison studies from which comparisons are appropriate. The first is the Alberta Biomonitoring Program[3] and the second is the CHMS[10]. The Alberta Biomonitoring Program utilized serum samples and the CHMS utilized whole blood, serum or urine. The comparison with the CHMS is possible when serum samples were used. In cases where these two are not valid comparators, other sources will be presented.

There are circumstances, due to a variety of reasons (novel chemical, unique methodology, etc.), where no comparison can be made.

SERUM CHEMICAL LEVELS IN NORTHERN SASKATCHEWAN

Of the estimated 283 different chemicals that were studied, only 136 chemicals had at least five pools with concentrations above the limit of detection or limit of quanitification. These chemicals met the criteria for further statistical analysis. Where results were below the limit or detection or quantification, the concentrations for that substance were either plotted without providing an overall mean value or were not reported at all.

RESULTS BY CHEMICAL CLASS

ORGANIC CHEMICALS

COTININE

Background

Cotinine is a breakdown product of nicotine, a chemical found in all tobacco products. Cotinine can be used to estimate the exposure to tobacco smoke.

Individuals who are non-smokers are known to have serum cotinine concentrations less than 1-5 ng/mL (range reflects variations across studies).[11,12] Those who are heavily exposed to second-hand smoke have cotinine levels in the range of 1-10 ng/mL, while active smokers have levels higher than 10 ng/mL. Any value above 10 ng/mL strongly suggests regular tobacco smoking.

Notably, exposure to tobacco smoke is known to be associated with exposure to a wide variety of chemicals, many measured in this study. The section "Smoking – An Important Source of Exposure and Risk" further explores how this can influence the interpretation of some findings.

How can you be exposed to cotinine?

Tobacco smoke is the primary source of exposure to cotinine. Exposure can be via direct exposure to tobacco smoke, but also as a consequence of second-hand smoke. Around 70% of the nicotine absorbed into the body via exposure to tobacco is converted into cotinine.

What health effects have been linked to cotinine?

The health effects of cotinine are not of concern, but the health effects of tobacco smoke exposure are well understood. These include a variety of life limiting and disabling diseases of the heart and respiratory tract. Cancers of the lung, larynx and mouth are also known consequences of tobacco use. [13]

Tobacco exposure during pregnancy has been associated with disruption in fetal development, pre-term birth and adverse birth outcomes, and has also been linked with sudden infant death syndrome (SIDS).[14,15] Babies born to smoking mothers are known to be smaller than normal at the time of delivery.[16]

Result

Overall, serum cotinine concentrations measured among pregnant women in all pooled samples ranged from 46.8 ng/mL to 66.4 ng/mL (mean ± 95% confidence interval = 58.0 ng/mL ± 5.6 ng/mL). Non-smokers are normally defined as having serum cotinine concentrations below 10 ng/mL, although often have concentrations below 1 ng/mL.[11,12] Therefore, the concentrations of cotinine measured here indicate that many of the study participants were smoking or exposed to significant amounts of second-hand smoke at the time of their blood sample collection.

How do these values compare?

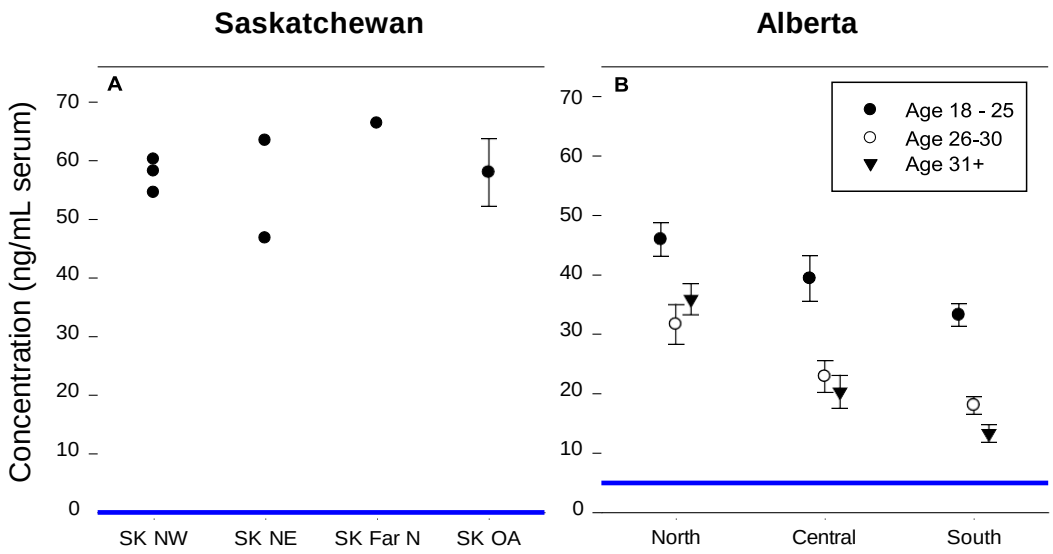


Figure 4: Concentrations of cotinine in the blood serum of pregnant women in Saskatchewan (A) and Alberta (B). The blue lines represent the limit of detection used in laboratory analysis. Estimates provided represent a 95% confidence interval around the mean. SK OA = mean of the pooled samples from Northern Saskatchewan.

Nearly all pools from Saskatchewan were higher than the concentrations of cotinine identified in the Alberta study. This suggests that smoking rates and overall tobacco exposure is markedly higher among the Saskatchewan participants than those from Alberta.

PHYTOESTROGENS

Background

Phytoestrogens are naturally occurring compounds in plants and are consumed by humans in their diet. These chemicals emulate estrogen and have been heralded as potentially protective against some medical conditions.[17–19] There are three major groups of phytoestrogens; **isoflavones**, **lignans** and **coumestans**.

How can you be exposed to phytoestrogens?

Common sources of isoflavones are legumes and soybean products, while lignans can be found in flaxseed, citrus fruit, wheat, fennel, celery, and nuts.[19] On average, Canadians consume less than 1 mg/day of isoflavones though this may be higher in Asian populations.[20]

What health effects have been linked to phytoestrogens?

Scientific studies suggest that isoflavone products may reduce severe and frequent menopausal symptoms, as well as lowered risk of osteoporosis, heart disease and some cancers.[21,22] As isoflavones do act like estrogen in the human body there is concern that some of them theoretically could lead to cancers associated with estrogen, but at this time the scientific evidence does not support a need for concern.[19,21]

Result

Two isoflavones (daidzein and genistein) were measured in blood serum samples of pregnant northern Saskatchewan women. Overall, the concentrations for daidzein ranged from 0.9 ng/mL to 2.0 ng/mL, while genistein ranged from 3.0 ng/mL to 5.3 ng/mL. Pool 6 (far N) had the lowest blood serum concentration of both daidzein and genistein whereas pool 2 (NW) had the highest.

How do these values compare?

Only the concentrations of daidzein in the Saskatchewan pools could be compared to the Alberta study. In general, concentrations in Saskatchewan were comparable to those in Alberta and do not present any concerns.

DIOXINS AND FURANS

Background

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), commonly known as **dioxins** and **furans**, are relatively toxic and persistent environmental chemicals.

These compounds are not commercially manufactured or imported, but are produced as unintentional by-products of several industrial processes (e.g. incineration, pulp bleaching, pesticide production), burning of municipal and medical waste, backyard burning of household waste, wood burning and electrical power generation. Tobacco smoke is also an exposure source for dioxins and furans. Dioxins and furans can also be naturally released during forest fires and volcanic eruptions.

Dioxins and furans, once released into the air, can travel long distances before settling. This results in exposures occurring far from the source.

How can you be exposed to dioxins and furans?

Most humans are exposed to dioxins and furans through diet or occupational exposures, with an estimated 90% of total human exposure coming from food product of animal origin.[23] Being that these classes of chemicals are so widespread in the environment, all people have background concentrations in their body. As well, these compounds accumulate in the human body and can take a long time to be excreted. These internal stores can then be passed from mother to fetus during pregnancy or to an infant during breastfeeding.

What health effects have been linked to dioxins and furans?

Dioxins and furans are known to cause adverse health effects in humans. How likely or how severe depends on a variety of factors including the chemical composition, dose, route of exposure, duration of exposure and timing of exposure.

Some dioxins and furans have been clearly identified as a cause for cancer such as 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) which has been classified as a Group 1 carcinogen (carcinogen to humans) by the International Agency for Research on Cancer (IARC), while others have not.

At high doses over short periods of time, such as what may occur in an occupational setting, dioxins and furans may cause skin, liver and neurological problems, psychological effects, and impairment of the immune or endocrine systems.[24]

Result

Out of 17 different dioxins and furans tested only OCDD and 1,2,3,4,6,7,8 – HpCDD were detected in all pools.

How do these values compare?

In general, OCDD concentrations were slightly lower than Alberta phase one values (2008). The same applied to 1,2,3,4,6,7,8 HPCDD. The remaining congeners could not be compared because of the number of Saskatchewan pools below the limit of detection.

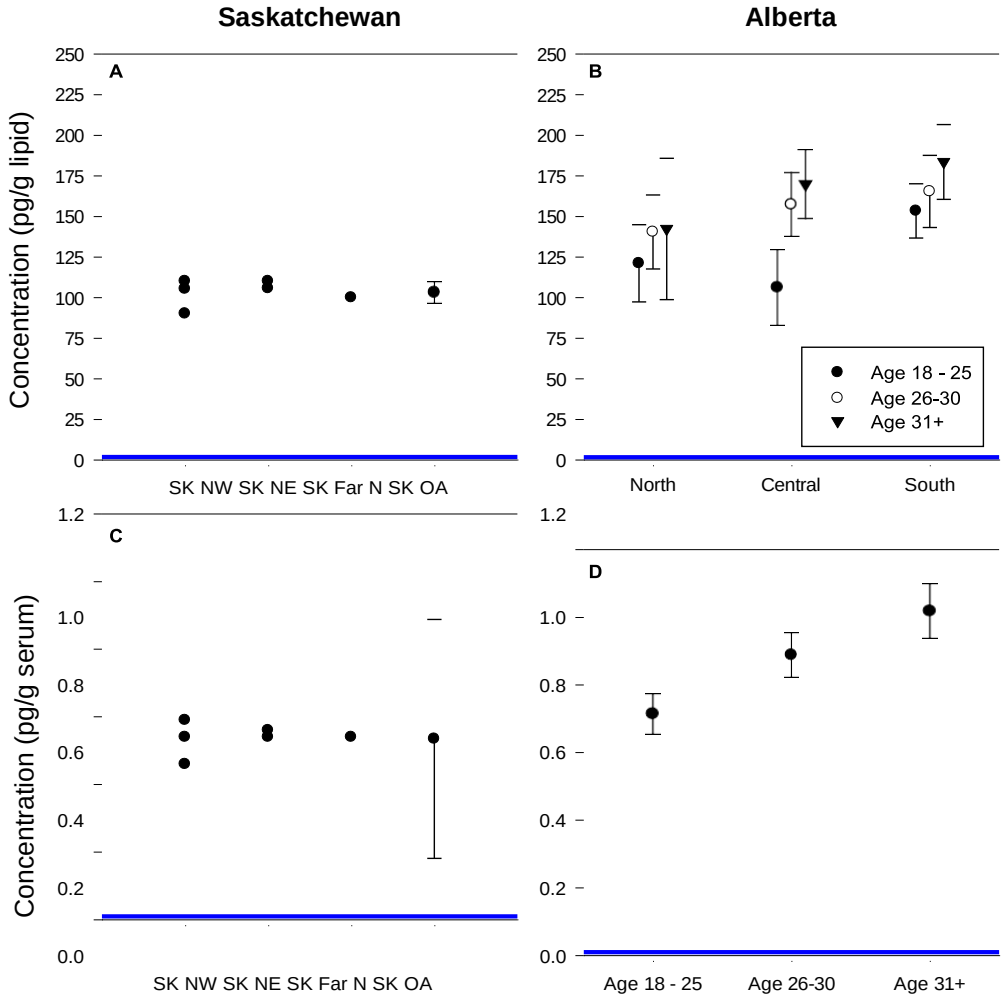


Figure 5: Concentrations of OCDD in blood serum of pregnant women in Saskatchewan and Alberta as determined by lipid weight (A, B) and by total concentration in serum (C and D). The blue lines represent the limit of detection used in laboratory analysis. Estimates provided represent a 95% confidence interval around the mean.

POLYCHLORINATED BIPHENYLS (PCBS)

Background

Polychlorinated biphenyls (PCBs) are human-made chemicals used for many decades as dielectric fluids in transformers and capacitors in heat-exchange systems, as lubricants, plasticizers, and adhesives, as well as an additive in sealants, plastics, paint, fire retardants, hydraulic oil, and pesticide extenders.[25] Although PCB manufacturing no longer occurs, PCBs were released into the environment during their manufacture, use and disposal.

How can you be exposed to PCBs?

As PCBs do not degrade, they continue to exist in the environment long after manufacturing has ceased. Most people continue to be exposed through their diet as oceans, freshwater bodies, pastures and agricultural soils around the world contain low concentrations of PCBs. Once ingested, these compounds accumulate in the human body and can take a long time to be excreted. Of particular concern is the transfer of these internal stores from mother to fetus during pregnancy or to an infant during lactation.

Like dioxins and furans, PCBs are widespread and thus most people do have measurable concentrations.

What health effects have been linked to PCBs?

In terms of the health effects of being exposed to PCBs, the International Agency for Research on Cancer (IARC) has determined that some of these chemicals are a Group 2A "probable carcinogen," but at unknown exposure levels over long periods of time. From studies on acute high level exposures (usually occupational) skin changes, nail changes, limb swelling and neurological effects have all been identified.

PCBs have been somewhat evaluated in children of mothers who were exposed to remarkably high levels of PCBs. The studies concluded that the children were at risk of several adverse health effects including low-birth weight, immune system abnormalities, depressed motor skills and a decrease in short-term memory.[26,27]

Result

Of the 178 congeners of PCBs that were evaluated, 81 met the criteria for reporting (a sufficient number of pools were above the limit of detection).

Overall mean concentrations of PCBs ranged from below the limit of detection to 249 ng/g.

Pool 1 most often had the highest concentration of PCB congeners compared to the other pools, particularly for those congeners where the molecular size was smaller and had less chlorine in its molecular makeup. But, among those PCBs with larger molecular sizes, the highest concentrations were seen more so in pools 4-6. Pool 6 had the greatest concentration of the PCBs with the highest molecular weight. The penta- to hexa-chlorobiphenyl isomers[c] were primarily detected in pools 3-5.

[c] These isomers (molecules with the same atoms, but configured differently) have 60% or higher chlorination (chlorine atoms per molecule)

How do these values compare?

There were 8 PCB congeners detected and analyzed in both Saskatchewan and Alberta studies (PCBs 156, 158/129, 146, 170, 183, 187, 180, 199). Seven of these had similar levels between the two groups and for the PCB 158/129, the mean concentration was lower in the Saskatchewan sample (mean ± 95% confidence interval: 0.25 ± 0.13 ng/g lipid) than in the Alberta sample (mean ± 95% confidence interval: 0.62 ± 0.13 ng/g lipid).

Three other major studies in North American looked at PCBs; the Center for Disease Control and Prevention's (CDC) Fourth National Report on Human Exposure to Environmental Chemicals[28], the First Nations Biomonitoring Initiaitive[29] (FNBI) and the CHMS[10]. The following graphic briefly describes the variation between the concentrations of various PCBs examined in this study against the findings of these three previous studies. These studies used geometric means and the FNBI and CHMS studies used plasma versus serum so caution is needed in these comparisons.

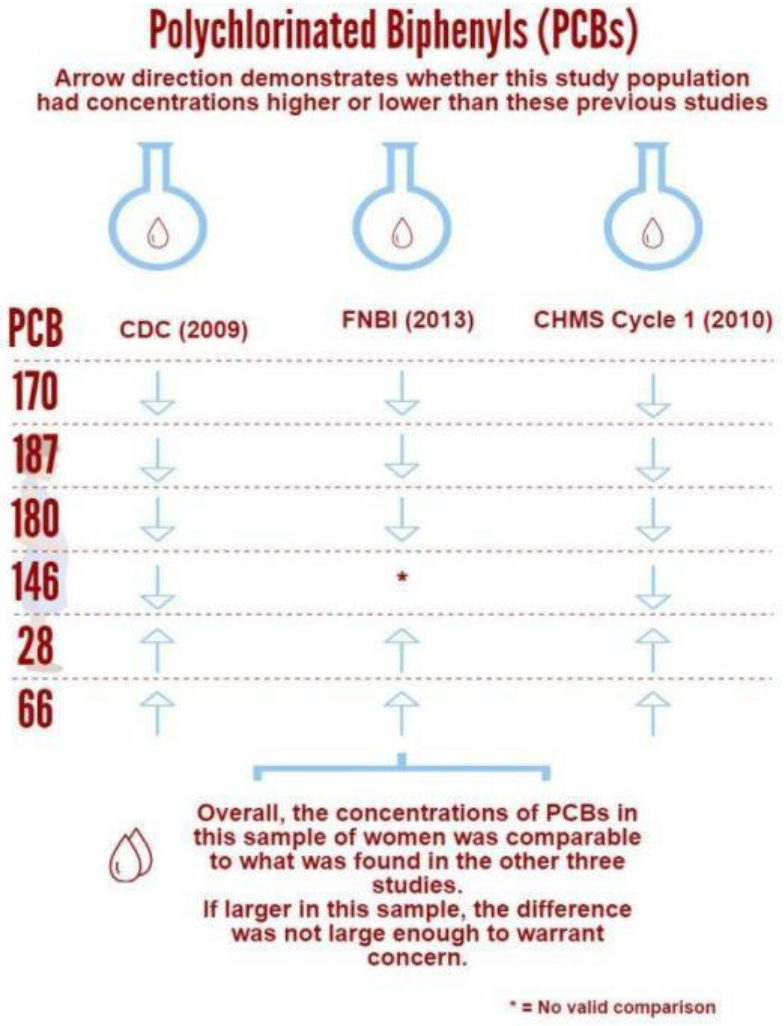


Figure 6: Graphical comparison of the concentration of PCBs found in the Saskatchewan study against various large scale biomonitoring initiatives

ORGANOCHLORINE PESTICIDES

Background

Organochlorine (OC) pesticides are synthetic chlorinated hydrocarbons. Historically they have been used as insecticides and fungicides. Now they are mostly strictly controlled by international agreements on persistent organic pollutants (POPs) as they are known to persist in the environment, travel long distances and bioaccumulate through the food chain.

How can you be exposed to OC pesticides?

Most humans are exposed to OCs through diet as most are now stored in the world's soils and these chemicals bioaccumulate through food sources. Less commonly, people are exposed to OCs through contaminated water or air.

Once ingested, these compounds accumulate in the fat stores in the human body and can take a long time to be excreted. Of particular concern is the transfer of these internal stores from mother to fetus during pregnancy or to an infant during lactation.

Result

In the present study, the following OC pesticides were tested for in blood serum samples of pregnant women in northern Saskatchewan (bolded chemicals were detected in some of the pools):

alpha-BHC	Oxychlordane	Endosulfan	2,4'-DDT
beta-BHC	Aldrin	4,4'-DDD	Trans-nonachlor
delta-BHC	Heptachlor Epoxide	**4,4'-DDT**	Mirex
gamma-BHC (Lindane)	Dieldrin	Methoxychlor	
Octachlorostyrene	**4,4'-DDE**	alpha-Chlordane	
Heptachlor	**Endrin**	gamma-Chlordane	
Hexachlorobenzene			

Only endrin, 4,4-DDE, 4,4'-DDT, beta-BHC and hexachlorobenzene were detected in blood serum samples and not in all pools, and only 4,4-DDE and hexachorobenzene were detected above detection limit in 5 pools and met the statistical inclusion criteria of this report. Of the 22 pesticides tested only 4,4-DDE have levels detected in all pools.

DDT AND RELATED COMPOUNDS

Background

DDT is a broad-spectrum insecticide and has been used historically in Canada to control insects known to transmit human disease such as mosquitoes. Over time, it became apparent that the breakdown products of DDT (**4,4'-DDE** and **4,4'-DDD**) were highly persistent in the environment.[30] As a result, DDT cannot be used in Canada, although it continues to be used in parts of the world as an affordable form of mosquito control.

DDT has the ability to travel long distances, leading to contamination in areas of the world where DDT was never actively used, such as Canada's far north.[31] DDT and its breakdown products accumulate on soil and aquatic sediments with bioaccumulation up through the food chain.

How can you be exposed to DDT and related compounds?

Humans are generally exposed to DDT through dietary consumption of contaminated foods. Once ingested, these compounds accumulate in the body. Of particular concern is the transfer of these internal stores from mother to fetus during pregnancy or to an infant during breast feeding.[30]

What health effects have been linked to DDT and related compounds?

Both the hepatic and nervous systems are known to be adversely affected by exposure to DDT in adults.[31] The effects on children and the developing fetus remain unknown.[30]

DDE is known to persist longer in the human body and, as such DDE is recognized as a better indicator of historical exposures.[32] DDE at background concentrations is not known to cause adverse health effects in humans, but at very high doses (e.g. accidental chemical releases) it can cause respiratory problems, impairment of the immune system, neurotoxicity, birth defects and reproductive toxicity. [33–36]

Result

Blood serum concentrations of 4,4'-DDE ranged from 19 ng/g lipid to 138 ng/g lipid across the pools. Pool 2 (NW) had the greatest concentration at 138 ng/g lipid, followed by pool 4 (NE) at 68 ng/g lipid. Pool 1 was below the limit of detection. Pool 3 (NW) measured 19 ng/g lipid, pool 5 (NE) 26 ng/g of lipid and pool 6 (FarN) had a concentration of 51 ng/g lipid.

How do these values compare?

The overall mean serum lipid concentration from the Saskatchewan participants is comparable to all age groupings from northern Alberta and 18-25 year olds in central Alberta. Otherwise, the overall Saskatchewan mean was lower than mean concentrations determined in the other Alberta groups. (see Figure 7) Also, the highest mean concentration in AB was higher than the pool with the highest concentration in Saskatchewan.

The overall mean lipid concentration from the Saskatchewan study is comparable to women above the age of 31 in Northern Alberta (mean ± 95% confidence interval: 55.94 ± 19.33 ng/g). Women in Southern Alberta have serum blood concentrations of 4'4 DDE higher than that of women in Saskatchewan.

In the U.S. National Health and Nutrition Examination Survey (NHANES, 2003-2004 Fourth Report) (CDC, 2009), the geometric mean of serum DDE concentrations in females were 241 ng/g of lipid and 1.5 ng/g of serum, and the 50th percentile was reported as 207 ng/g lipid. The Saskatchewan study mean is not a geometric mean thus direct comparison is not possible, but this value does help suggest a range.

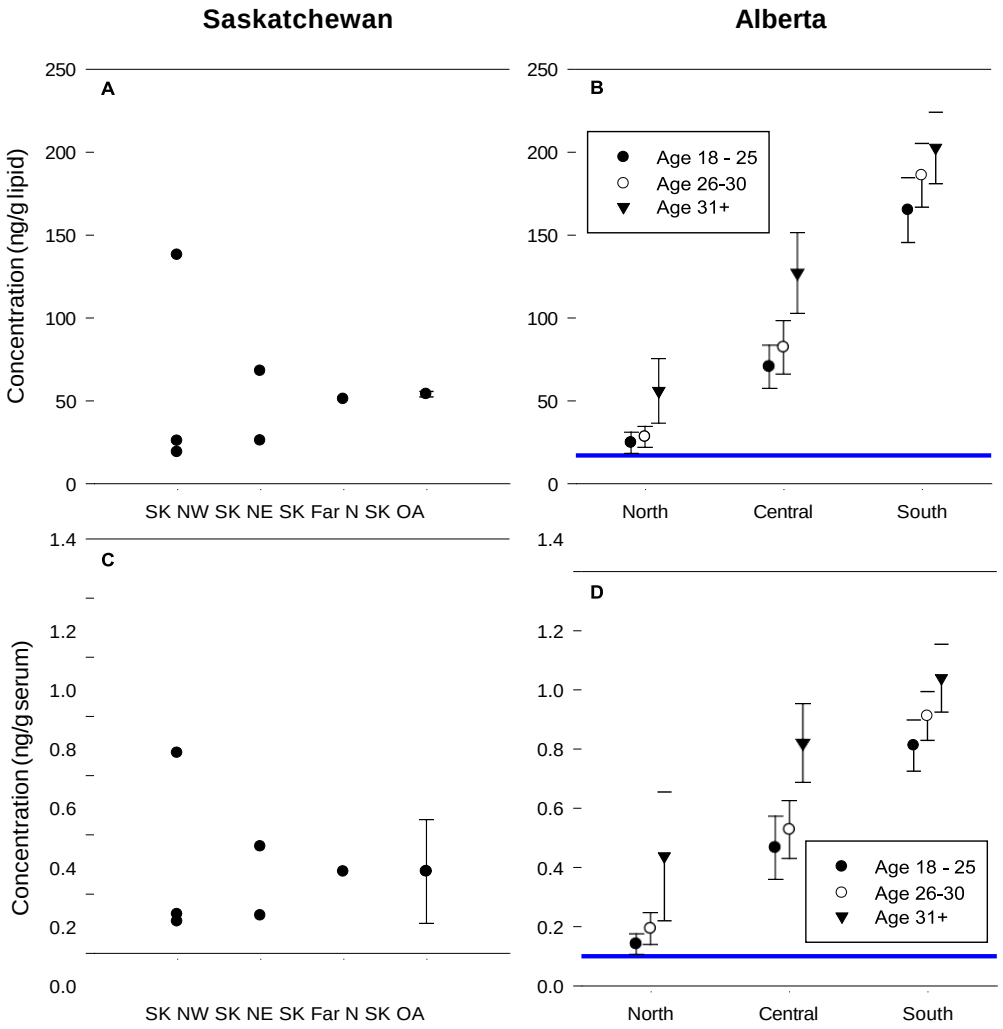


Figure 7: Concentrations of 4,4'-DDE in blood serum of pregnant women in Saskatchewan and Alberta as determined by lipid weight (A, B) and by total concentration in serum (C and D). The blue lines represent the limit of detection used in laboratory analysis. Estimates provided represent a 95% confidence interval around the mean. For the Saskatchewan study, the LOD varied by pool.

HEXACHLOROBENZENE

Background

Hexachlorobenzene (HCB), also known as pentachlorophenyl chloride, was formerly (until the 1960s) widely used as a synthetic fungicide. It had various other uses through history including fireworks, ammunition, synthetic rubber, wood preservative and dialectic fluids.[37]

Today HCB is still released into the environment in small amounts as a byproduct of manufacturing, the use of chlorinated solvents and pesticides, emissions from incinerators, and through long range transport in air and water from other countries.[37]

Hexachlorobenzene is resistant to degradation and is able to persist in the environment for long periods of time. Although it binds strongly to soil, it can leach over time, reintroducing the chemical into the environment long after use has been stopped. It is known to bioaccumulate through aquatic species.

How can you be exposed to HCB?

Most people are exposed to HCB through diet. Once in the body, HCB accumulates in fatty tissue and is barely broken down by the body's metabolism. This chemical can cross the placenta and be excreted in breast milk.

What health effects have been linked to HCB?

Studies of HCB have found that background concentrations of the chemical are not associated with known adverse health effects in humans. Nonetheless, high doses whether accidental or otherwise can cause severe health effects including liver disease, neurotoxicity, immunotoxicity and skin lesions.[37]

Result

All pools except pool 5 (NE), did have measurable amounts of HCB ranging between 0.042 ng/g and 0.35 ng/g (lipid serum weight: 7.5 ng/g to 71 ng/g). Pool 2 was higher than the rest with a concentration (lipid weighted) of 71 ng/g whereas the remaining pools had concentrations between 7.5 ng/g lipid weight and 27 ng/g lipid weight.

How do these values compare?

The overall means of the Saskatchewan study were comparable to that of the Alberta study. Pool 2 (NW) was notably elevated both compared to other Saskatchewan pools and Alberta mean study concentration. (Figure 8)

NHANES 2003-2004 Fourth Report reported a geometric mean for females of 15.8 ng/g lipid, which is slightly lower than the overall mean for the Saskatchewan study. The Saskatchewan study mean is not a geometric mean thus direct comparison is not possible, but this value does help suggest a range.

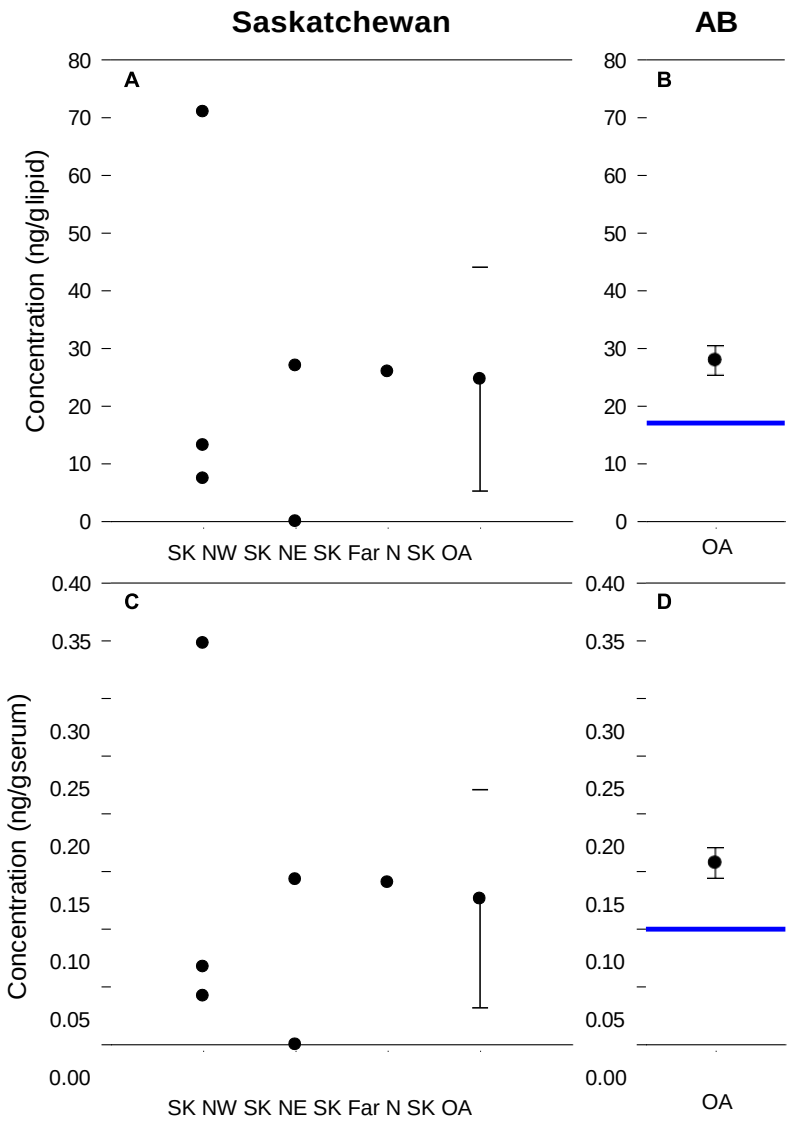


Figure 8: Concentrations of hexachlorobenzene in blood serum of pregnant women in Saskatchewan and Alberta as determined by lipid weight (A, B) and by total concentration in serum (C and D). The blue lines represent the limit of detection used in laboratory analysis in the Alberta data. The limit of detection varied by pool in the Saskatchewan data. Estimates provided represent a 95% confidence interval around the mean.

POLYBROMINATED DIPHENYL ETHERS

Background

Polybrominated diphenyl ethers (PBDEs) are flame retardants that have been used for decades in commercial products. Three main types of manufactured commercial mixtures have been classically produced; penta-BDE, octa-BDE and deca-BDE (names based on the average bromine content). Overall, there are 209 possible congeners. Currently, commercial mixtures of penta-BDE and octa-BDE cannot be manufactured, sold or imported in Canada.

PBDEs can be released into the environment from the products in which they are used. They are persistent chemicals that can travel long distances.

How can you be exposed to PBDEs?

Humans are exposed to PBDEs primarily through dust at home and in workplaces, as the chemicals are released from manufactured commercial products.[38] It is possible to be exposed through diet, particularly from meat, dairy, fish and eggs.[39] PBDEs can be passed to the fetus or to infants by crossing the placenta or through breast milk.[40] Those PBDE congeners that are smaller (1-5 bromine atoms per molecule) are better absorbed by the body, stay longer in the body and are more toxic compared to larger ones.[41]

What health effects have been linked to PBDEs?

There are no definitive links between PBDEs and negative health outcomes in people. Research on rats and mice demonstrated that PBDEs can affect thyroid and liver function, and high concentrations may affect neurological function and the immune system. Based on animal studies, decabromodiphenyl ether (PBDE 209) has been classified as a possible human carcinogens.[42]

Result

The following twelve PBDEs were tested for in the blood serum samples of pregnant women in northern Saskatchewan with two of them not being detected (not bolded in figure below) in any of the northern Saskatchewan pools (those bolded were detected):

2,4,4'-tribromodiphenyl ether (BDE 28)	**2,2',4,4'-tetrabromodiphenyl ether (BDE 47)**
2,3',4,4'-tetrabromodiphenyl ether (BDE 66)	3,3',4,4'-tetrabromodiphenyl ether (BDE 77)
2,2',3,4,4'-pentabromodiphenyl ether (BDE 85)	**2,2',4,4',5-pentabromodiphenyl ether (BDE 99)**
2,2',4,4',6-pentabromodiphenyl ether (BDE 100)	**2,3,3',4,4',5'- hexabromodiphenyl ether (BDE 138)**
2,2',4,4',5,5'-hexabromodiphenyl ether (BDE 153)	**2,2',4,4',5,6'-hexabromodiphenyl ether (BDE 154)**
2,2',3,4,4',5',6-heptabromodiphenyl ether (BDE 183)	Decabromodiphenyl ether (BDE 209)

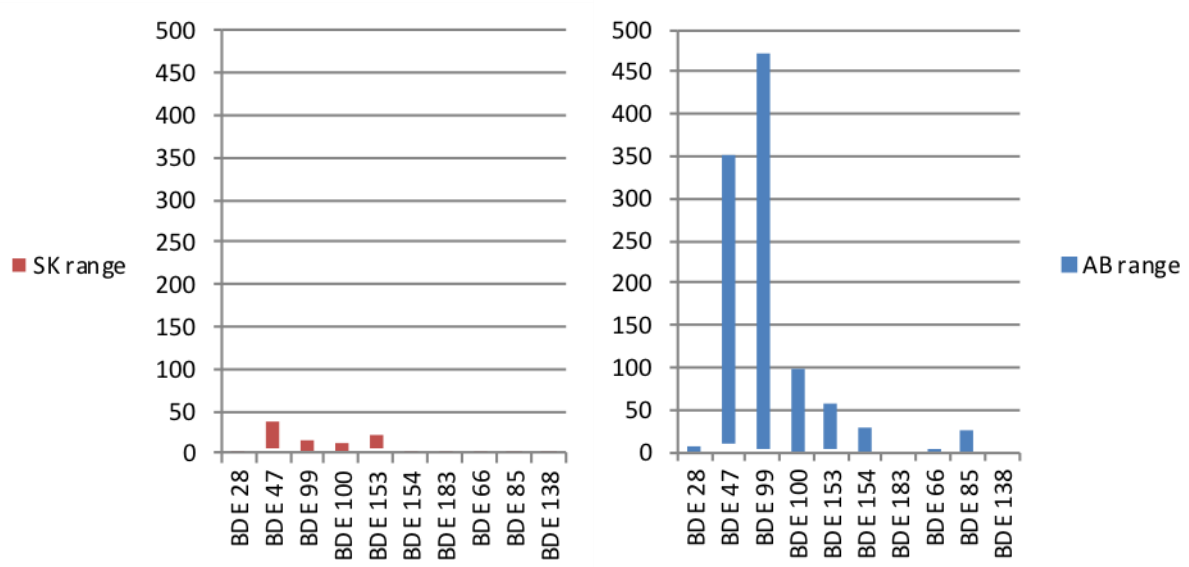


Figure 9: Contrasting the range of PBDE concentrations in the Saskatchewan study to the range of values for the same in the Alberta study

Of the 12 congeners evaluated, there is no distinct overarching geographic trend in northern Saskatchewan. In general, pools 2-4 (NW, NW, NE) generally had the highest concentrations of PBDEs.

How do these values compare?

The Saskatchewan pools had a lower range of concentrations of PBDEs compared to the Alberta study values. BDE 99 and BDE 47 were about three times higher in the Alberta study.

PERFLUOROCHEMICALS

Background

Perfluorochemicals (PFCs) are also referred to as perfluroalkyls or perfluorinated chemicals and have been used for decades in industrial processes and commercial products. PFCs have primarily been used for stain repellent formulations for textiles, paints, waxes, polishes, electronics, adhesives and food packaging.[43]

Perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are the two most commonly detected isomers of PFCs. PFCs are found across the globe as they are able to travel long-distances and thus can be found in areas where PFCs were not used (remote regions of the far north). PFCs are widely found in wildlife and human blood due to long half-lives.[44] They, like many other chemicals, are able to cross the placenta.[45]

How can you be exposed to PFCs?

Humans are exposed by the dust in homes and workplaces, and through diet (mainly fish and food products of animal origin, and from food packaging leaching).[43]

What health effects have been linked to PFCs?

PFCs have not been linked to human health effects, although there are a limited number of studies. Studies on animals indicate that high doses of PFCs can affect development, reproduction and liver function.[46,47] Recent studies suggest that there may be an association between the concentrations of PFOS or PFOA in pregnant women and infant birth weight.[48,49]

Result

The following eight PFCs were tested for in this study:

Perfluoroalkyl sulfonates	**Perfluoroalkyl carboxylates**
Perfluorohexane sulfonate (PFHxS)*	**Perfluorooctanoate (PFOA)**
Perfluorooctane sulfonate (PFOS)	Perfluorononanoate (PFNA)
Perfluorodecane sulfonate (PFDS)*	Perfluorodecanoate (PFDA)
	Perfluoroundecanoate (PFUA)
	Perfluorododecanoate (PFDoA)*

Bold = detected in all pools *= not detected in any pool

Only PFOS and PFOA were above the level of detection in all pools. Levels for all pools were lower than Alberta levels Overall, there was no distinct trend across the pools for these chemicals, although pool 6 (Far N) had the highest concentration for five of the eight isomers. Three of the eight isomers were not detected in any pool.

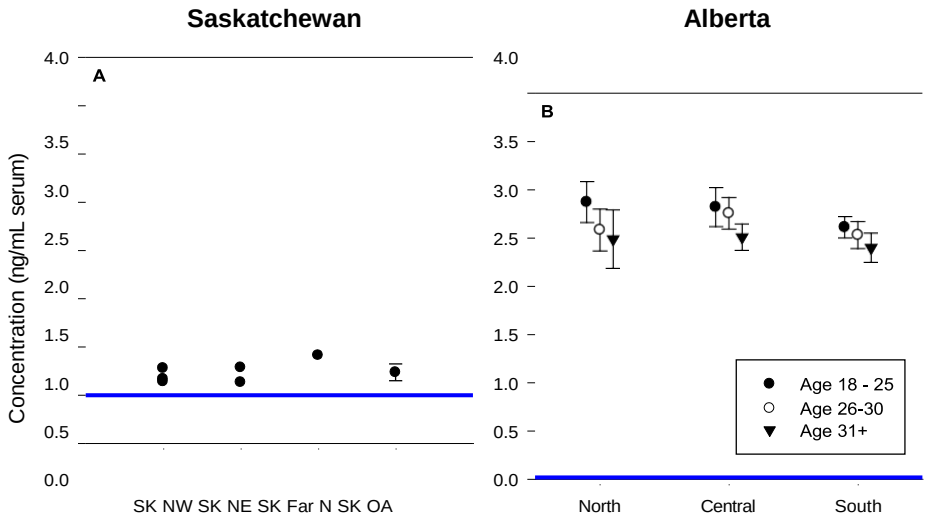


Figure 10: Concentrations of Perfluorooctanoate (PFOA) in the blood serum of pregnant women in Saskatchewan (A) and Alberta (B). Saskatchewan data is presented for each of the six pooled samples, and for an overall (OA) weighted arithmetic mean of the six pools. Alberta data is presented by mean concentrations stratified by both age and region. The blue lines represent the limit of detection used in laboratory analysis. Estimates provided represent a 95% confidence interval around the mean.

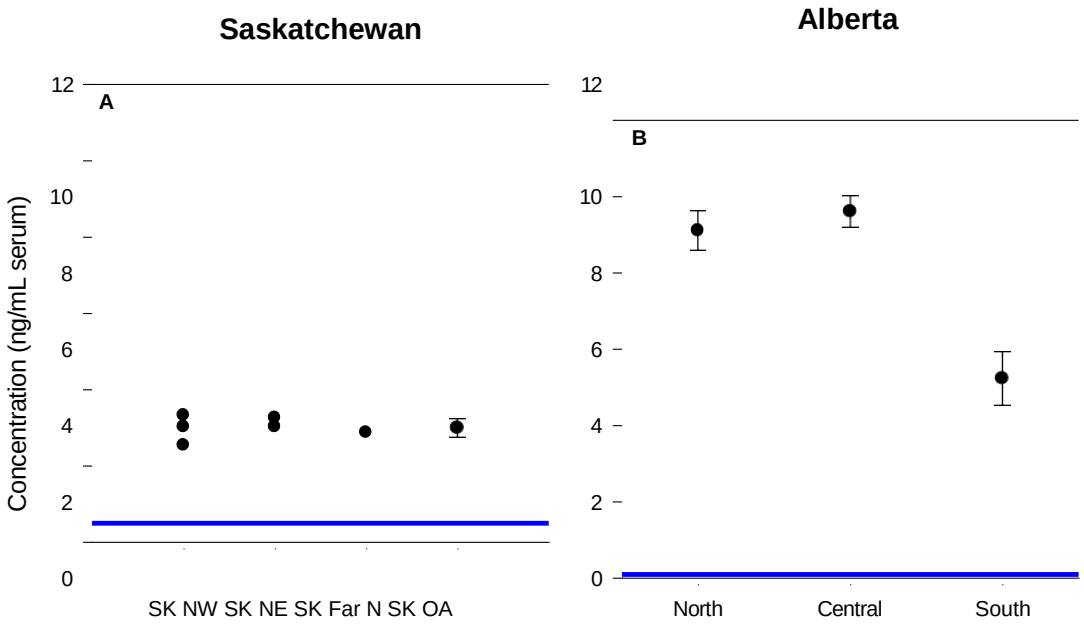


Figure 11: Concentrations of Perfluorooctane sulfonate (PFOS) in the blood serum of pregnant women in Saskatchewan (A) and Alberta (B). Saskatchewan data is presented for each of the six pooled samples, and for an overall (OA) weighted arithmetic mean of the six pools. Alberta data is presented by region with mean of all the pools that were analyzed from each region. The blue lines represent the limit of detection used in laboratory analysis. Estimates provided represent a 95% confidence interval around the mean.

How do these values compare?

Only PFOS and PFOA had enough pools with concentrations above the limit of detection to allow for a mean to be determined in the Saskatchewan study. In contrast, in Alberta 8 of the 9 assessed isomers reached this threshold. In the case of these two identified isomers, the weighted arthimetic mean of the study pools in Saskatchewan was lower than all Alberta mean values (study groups were stratified by age and geographic location).

In the CHMS Cycle 2[10] the geometric means of female participants aged 20-79 was 2.0 (1.8 to 2.2) µg/L plasma for PFOA and 5.7 (4.9 to 6.6) µg/L plasma for PFOS (units are equivalent to our study) and Health Canada indicated that these levels were not a concern for human health. The northern Saskatchewan weighted arithmetic means were lower than these values for PFOS and PFOA. The CDC's NHANES Fourth Report PFOS reported a geometric mean of 18.4 µg/L plasma of PFOS in the general female population 12 years of age and older.[28]

BISPHENOL-A

Background

Bisphenol-A (BPA) is a synthetic chemical used in the manufacturing of plastics and resins that are found in food and beverage bottles, medical devices, dental fillings and sealants and thermal paper products. Health Canada has concluded that current dietary exposure to BPA through food packaging uses is not expected to pose a health risk including to newborns and young infants. However, Health Canada, as a precautionary measure, is working with industry to reduce BPA in food packaging especially for infants and newborns. [50]

How can you be exposed to BPAs?

Most humans are exposed to BPAs as the chemical leaches from these plastics and resins, contaminating foods and beverages.[51] There is also evidence emerging that BPAs can leach from landfills and enter into the surrounding environment.[52] Once BPA is in the body, it is able to cross the placenta[53] and accumulate in breast milk.[54]

What health effects have been linked to BPAs?

The potential health effects of BPA on humans have yet to be determined due to it being a relatively new substance and few human studies.[55] Results of animal studies suggest that BPA may act like the human hormone estrogen and may be linked to developmental and reproductive issues, neurotoxicity, ovarian dysfunction and recurrent miscarriages in animals.

Result

Bisphenol-A was not detected in any of the northern Saskatchewan pools.

How do these values compare?

Bisphenol A was detected in over 25% of the pools in the Alberta study, whereas bisphenol-A was not detected in any of the Saskatchewan pools.

Notably, the test for bisphenol A performed in Alberta differed from that in the Saskatchewan study. This difference resulted in a higher limit of detection in the Saskatchewan study (a 20-fold difference), which meant all pools with concentrations below 0.20 ng/mL were considered non-detectable (conversely this threshold was ~0.01 ng/mL for the Alberta pools). It is important to note that the Alberta samples were collected before the prohibition of BPA in baby bottles and similar plastic products, while the Saskatchewan samples were collected after this change in regulation. Therefore it is possible that women in Saskatchewan were exposed to a smaller amount of BPA due to regulatory changes.

A single study performed in the Eastern Townships in Canada found a mean serum concentration of 3.83 ng/mL across the women in their study.[56] The Canadian Health Measures Survey and the First Nations Biomonitoring Initiative measured BPA levels in urine.

OCTYLPHENOL

Background

Octylphenol (OP) refers to a group of chemicals used for surfactant manufacturing. In Canada these are used in the development of detergents, industrial cleaners, paints, textile mills and the pulp and paper industry.

How can you be exposed to octylphenol?

Humans are primarily exposed through diet (these chemicals can bioaccumulate through the food chain) and exposure to the trace amounts of OPs in water and air.[57,58] OPs can cross the placenta and be passed on through breast milk.

What health effects have been linked to octylphenol?

The health effects of octylphenol from background exposures are unknown. Concerns exist due to the potential estrogenic effects, but at this time research into these effects continues.[59]

Result

Octylphenol was detected in all pools with concentrations ranging from 13.7 ng/mL to 19 ng/mL.

Table 2: Concentrations of serum octylphenol by pool

	Wet weight (ng/mL)	Pool 1 NW N=162	Pool 2 NW N=138	Pool 3 NW N=120	Pool 4 NE N= 130	Pool 5 NE N=150	Pool 6 FarN N=141	*Mean (95% CI)*
Octylphenol		19	15	18.7	13.7	18.7	18.2	17.3 (15.5-19.1)

How do these values compare?

There is presently no comparable value for serum from the Alberta study.

Two small studies can be used - the first of women between 55 and 75 years of age in Wisconsin and another of maternal serum samples of women in the Yantze River Delta region. The first reported a median (of detectable values) of 1.78 ng/mL[60] and the second a median or 470 (Interquartile range = 280-660) ng/mL.[61] The Saskatchewan values fall well below the Chinese study, but all pools do measure above the Wisconsin study. Unfortunately, there are no large scale studies against which to compare.

METHYLMERCURY

Background

Mercury is a widespread, naturally occurring metal that is found across the globe. It exists in three forms; elemental, inorganic and organic. Elemental and inorganic forms of mercury are released into the air and water through a variety of human processes including burning of fossil fuels, mining, smelting, and other industrial practices. It is also released through natural processes such as erosion, volcanoes and forest fires.[62] It is discussed in the Inorganic Chemicals section.

Methylmercury (MeHg, CH3Hg, "organic mercury") is of particular concern as it is the most toxic form of mercury to humans and its ability to adversely affect health is well understood. Of all the forms of mercury, it has the greatest ability to cross the blood brain barrier and enter the brain - the nervous system is very sensitive to mercury.[63] It is also able to cross the placenta.[64]

How can you be exposed to methylmercury?

Methylmercury (MeHg) is often produced from other forms of mercury through natural biological processes by bacteria in aquatic sediments. It efficiently bioaccumulates through the aquatic food chain.The greatest source for humans is through dietary consumption of certain fish and seafood.

Large predatory fish such as shark, large tuna, swordfish, marlin and king mackerel have been identified as being of particular concern.[66] Fish and seafood are good sources of protein, omega-3 fatty acids, minerals and vitamins (including vitamin D) that promote healthy hearts, healthy growth and brain and eye development of infants and children. Health Canada recommends that all Canadians, including pregnant women and children, eat at least two servings of fish per week to benefit from the nutrients found in fish and seafood but to limit the consumption of fish known to have higher mercury levels.[67]

In order to minimize mercury exposure, Health Canada has guidelines advising Canadians to limit their consumption of those higher mercury fish to a maximum of 150 grams per week. Pregnant women and children have more stringent guidelines. Most importantly Health Canada promotes consuming a wide variety of fish and seafood.[68] Saskatchewan has additional consumption guidelines available for sports fish based on the lake, the type and size of the fish recommendations and whether it is for the general population or for women of child bearing age and for children.[69]

What health effects have been linked to methylmercury?

Methylmercury is a known neurotoxin. At moderate to high doses (such as in the case of a poisoning) MeHg is known to cause adverse effects to both the motor and sensory nervous systems. If pregnant women are exposed to high amounts, then there is risk of fetal abnormalities and neurotoxicity.[64]

At moderate to low doses, there are more subtle neurodevelopment effects that can result from MeHg exposure, including memory loss, attention deficits, language issues and visual-motor skill problems in childhood.[64]

Result

Methymercury was detected in four of the six pools. Pool six had the highest concentration of methymercury at 0.3 ng/g. The detectable concentrations ranged from 0.1 ng/g to 0.3 ng/g.

How do these values compare?

Of the pools that were above the LOD, pools 1 (NW), 2(NW) and 4(NE) had values comparable to the detected range in Alberta. Pool 6 (far N) had a concentration higher than the mean concentrations determined in the Alberta study (where groups were defined by age and geographic region) (Figure 12). Although Health Canada has set guidelines for methylmercury in whole blood, it is difficult to interpret the present results in this context because serum is known to contain only a small fraction (5%) of total methylmercury.

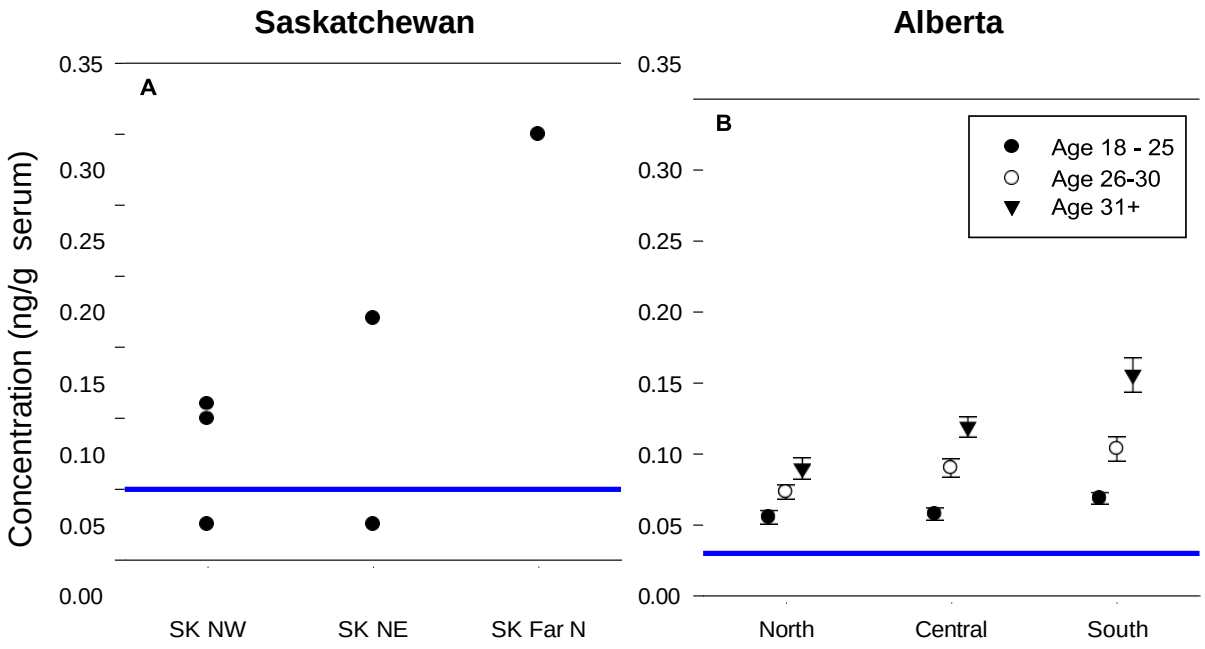


Figure 12: Concentrations of methylmercury in the blood serum of pregnant women in Saskatchewan (A) and Alberta (B). The blue lines represent the limit of detection used in laboratory analysis. Estimates provided represent a 95% confidence interval around the mean.

The recent First Nations Food, Nutrition and Environment Survey in Saskatchewan reported on mercury exposures as measured in hair samples and calculated through dietary estimates, to be low and not a health concern for Saskatchewan First Nations generally; however, there were some exceedances of Health Canada guidelines among women of childbearing age living in the Boreal Shield ecozone of the province.[65]

PHTHALATES

Background

Phthalates are a class of industrial chemicals used in plastics to make them more flexible and harder to break.[70] It is estimated that nearly 18 billion pounds of phthalates are produced and used each year for a variety of purposes including PVC flooring, printing inks, personal care products and medical equipment.[71]

How can you be exposed to phthalates?

Exposure usually occurs by eating or drinking foods stored in containers that were made using phthalates. There is also the possibility of being exposed by inhaling dust that contains phthalate particles (more common in children).[70] Phthalates can be passed through breast milk to the infant.[72]

What health effects have been linked to phthalates?

Phthalates are considered endocrine disruptors or hormonally active agents (HAAs) because of their ability to interfere with the body's natural hormones. At this time, most of the studies of phthalates have been on animals and there is evidence to suggest these chemicals can cause developmental abnormalities such as cleft palates and malformations of the genital tract (particularly in males).[72]

At this time there is more research needed into the effects of background environmental exposure to humans.

Result

Ten phthalate metabolites were tested for in the blood serum samples of select pregnant women in northern Saskatchewan. Only four were detected as bolded below:

Monomethyl phthalate	**Mono-(2-ethylhexyl) phthalate**
Monoethyl phthalate	Mono-n-octyl phthalate
Monoisobutyl phthalate	Mono-(2-ethyl-5-oxohexyl) phthalate
Monocyclohexyl phthalate	Monoisononyl phthalate
Monobenzyl phthalate	Mono-(2-ethyl-5-hydroxyhexyl) phthalate

Mono-(2-ethylhexyl) phthalate (MEHP) was detected, but upon review it was discovered that sample containers used for storage and analysis were plastic which resulted in falsely elevated values. As a consequence, MEHP was removed from the final analysis.

There are no distinct geographic trends across the metabolites.

Table 3: Concentration of detected pthalate metabolites by pool

Pthalate	ng/mL	Pool 1 NW N=162	Pool 2 NW N=138	Pool 3 NW N=120	Pool 4 NE N= 130	Pool 5 NE N=150	Pool 6 FarN N=141	*Mean (95% CI)*
Monoethyl phthalate	Serum	6	4.3	6.1	5.3	4.2	2.5	4.7 (3.6-5.8)
Monoisobutyl phthalate	Serum	15	13.6	16.9	13.4	13.9	12.8	14.2 (13.1-15.3)
Monobenzyl phthalate	Serum	1.4	0.9	1.8	1.5	2.1	1.2	1.5 (1.2-1.8)

How do these values compare?

There is presently no comparable value for serum or blood from the Alberta study or from other data sources.

PARABENS

Background

Parabens are widely used preservatives in cosmetics and personal care products. All commercial parabens are man-made, although parabens do occur naturally in certain fruits.[73]

How can you be exposed to parabens?

Most people are exposed to parabens through the use of personal care products, consumer foods or pharmaceuticals that contain parabens.

What health effects have been linked to parabens?

In animal studies, parabens have been found to weakly behave like estrogen. There is a known link between estrogen and some cancers (breast), and there is a theoretical concern with chemicals that act like estrogen. Several expert reviews[73,74] have demonstrated that parabens are safe at the concentrations currently found in cosmetics.

Result

The following five paraben isomers were tested for in the blood serum samples of select pregnant women in northern Saskatchewan. Those bolded were detected:

Methyl Paraben	Butyl Paraben
Ethyl Paraben	Benzyl Paraben
Propyl Paraben	

Three of the five tested paraben isomers were detected (Table 4). Pool 4 (NE) consistently had the lowest concentration of the detected isomers.

Table 4: Concentrations of paraben isomers by pool

Paraben	**ng/mL**	**Pool 1 NW N=162**	**Pool 2 NW N=138**	**Pool 3 NW N=120**	**Pool 4 NE N= 130**	**Pool 5 NE N=150**	**Pool 6 FarN N=141**	***Mean (95% CI)***
Methyl Paraben	Serum	12	14	9.7	4.5	7.6	8.2	9.4 (6.7-12.1)
Ethyl Paraben	Serum	2.6	<LOD	<LOD	<LOD	1.6	1.7	N/A
Propyl Paraben	Serum	1.9	2.4	1.48	0.9	1.5	1.4	1.6 (1.2-2.0)

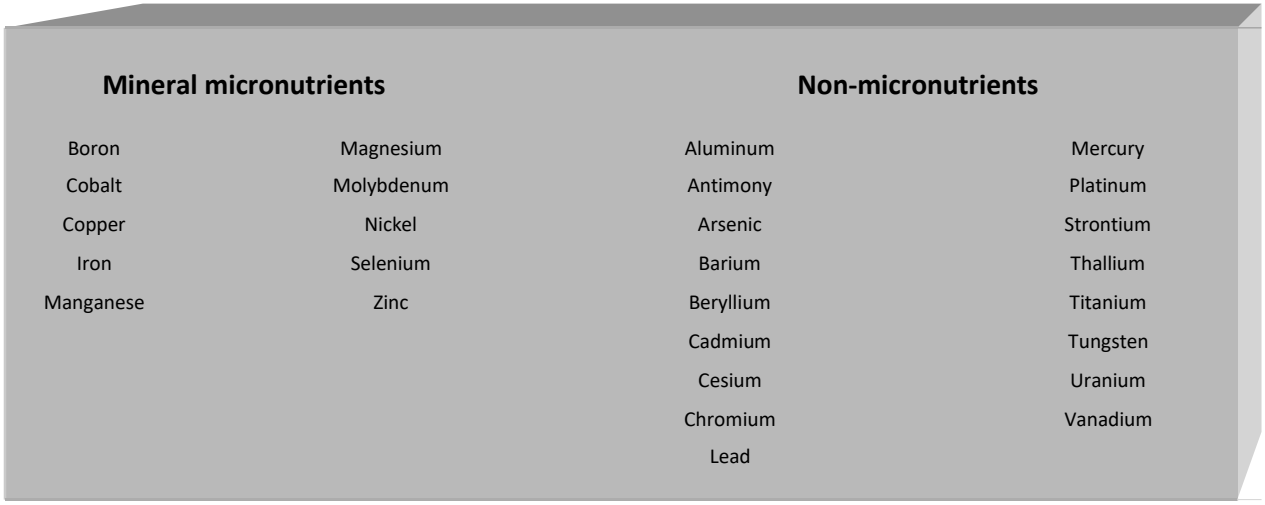
where LOD = limit of detection

How do these values compare?

There is no value presently to compare in the Alberta study and no other comparable source is available for serum or blood.

TRACE METALS AND MINERALS

The following trace metals were analyzed in the participant blood serum samples:



Mineral micronutrients are those metals and minerals that are required in small amounts to maintain the health of a living organism.

TRACE METALS (NON-MICRONUTRIENTS)

The results of this study indicated that the following trace elements had more than 1 pool below detection limits: Uranium, thallium, tungsten, cadmium, arsenic, chromium, vanadium, titanium, beryllium and boron. As such, no aggregate statistics were performed on these trace metals and findings are not be presented here for all of these.

ALUMINUM (AL)

Background

Aluminum is the third most abundant chemical element in mineral rocks and is widespread in the environment.[75] It has ideal chemical and physical properties and is used in many products such as automobiles, wiring, electrical devices, paints, antiperspirants, cooking accessories, as well as additives in pharmaceuticals and food. [76] Aluminum sulphate is also commonly used in water treatment.

How can you be exposed to aluminum?

Aluminum can be released into our environment (air, water and soil) through the use or disposal of aluminum containing products, as well as through various industrial processes. Most people are exposed to background concentrations of aluminum in food, water or soil, or inhalation of air or dust containing trace amounts of the metal. [75]

What health effects have been linked to aluminum?

Background concentrations of aluminum have been recognized as having no ill effects on humans. Most ingested aluminum is not absorbed and is excreted in the feces, and that which is absorbed is excreted in the urine. [75]

At high doses (such as in the case of accidental releases or unusual occupational exposures) aluminum is a known neurotoxin, renal toxin and may causes respiratory problems, vomiting and/or rash.[75]

Result

Concentrations of aluminum ranged from 6.4 µg/L to 15 µg/L across all pools. (Figure).

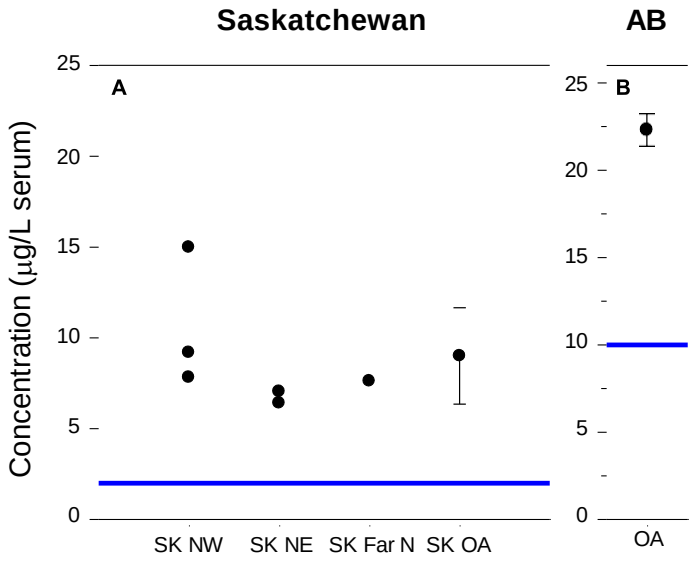


Figure 13: Concentrations of aluminum in the blood serum of pregnant women in Saskatchewan (A) and Alberta (B). The blue lines represent the limit of quantification used in laboratory analysis. Estimates provided represent a 95% confidence interval around the mean.

How do these values compare?

The overall mean serum concentration (± 95% confidence interval) measured was 22.3 ± 0.9 µg/L in the Alberta study, thus all Saskatchewan pools were lower than this value. Although, the detection limit was quite different between the two studies which can reduce the ability to reliably compare the two studies.

ANTIMONY (SB)

Background

Antimony is a naturally occurring metal. It can be released from the weathering of rocks and minerals and exists naturally as various compounds used for a variety of alloys.[75] It can be used to manufacture ceramics, glass, pigments, flame retardants, paints, semi-conductors, fireworks, batteries and some plastics.[76]

Antimony is released into the environment through disposal of these products or through a variety of mining and industrial processes. It can also enter the water system naturally through soil erosion [77]

How can you be exposed to antimony?

Exposure to antimony can occur through ingestion of food, and less so through inhalation or dermal contact with substances containing antimony (including drinking water).[79] People may be exposed to higher antimony concentrations in occupational settings.[77]

What health effects have been linked to antimony?

Background exposures to antimony are not known to cause any ill health effects in humans.[77] In cases where doses are high such as in unusual occupational exposures or accidental releases, antimony may cause adverse health effects of the respiratory, cardiac or digestive systems.[77]

Result

Overall, mean concentrations for antimony ranged from 3.3 µg/L to 3.8 µg/L (mean ± 95% confidence interval: 3.5 µg/L ± 0.2 µg/L). There was no apparent difference between regions.

How do these values compare?

Mean concentrations in the Alberta study are comparable to the mean concentration of the Saskatchewan study. No single Saskatchewan pool varied from the ranges of mean values in the Alberta study.

ARSENIC (AS)

Background

Arsenic is a naturally occurring element widely found in the earth's crust. In nature arsenic can combine with other elements to form inorganic arsenic compounds, or it can combine with carbon and hydrogen to form organic arsenic compounds.[80] There are trace amounts of arsenic in all living matter.

Inorganic arsenic is often used to make pressure-treated lumber (in the form of copper chromated arsenic (CCA)) for use in industrial applications but is no longer used in residential lumber. Some arsenic compounds are used as pesticides, but uses are restricted. Some organic forms of arsenic are used in poultry feed as a form of disease protection. There is a role for some elemental metalloids in ammunition, solders and lead-acid storage battery grids.[81]

How can you be exposed to arsenic?

Background exposure can occur from a variety of pathways. For most Canadians, the primary source of exposure to arsenic is food, followed by drinking water, soil and air. Geographical variation in naturally occurring soil concentrations of arsenic can result in variations in population exposure.

In the Canadian Total Diet Survey, marine fish, fresh water fish, and canned fish contribute most to the total arsenic intake from food.[82] Individuals with higher fish and seafood consumption will have higher exposures to

total arsenic; however, fish and other seafood contain mostly organic forms of arsenic which is essentially non-toxic.

Human exposure to inorganic arsenic can also be from smoking tobacco.[83]

What health effects have been linked to arsenic?

Inorganic arsenic is well absorbed by the gastrointestinal tract, and to a lesser degree through inhalation. It is poorly absorbed through skin.[81]

Inorganic arsenic can contribute to human cancers (gastrointestinal tract, kidneys, liver, lungs and skin) in cases of long-term high level exposures. Short term exposures of very high levels of inorganic arsenic are also known to cause ill health by disturbing the gastrointestinal, neurologic and dermal systems.[84]

Organic forms of arsenic are not known to cause ill health in humans.

Result

Serum arsenic concentrations were above the limit of detection in pools 1 (NW), 4 (NE) and 6 (Far N). The concentrations ranged from 0.07 µg/L to 0.15 µg/L. Pool 6 had the highest concentration and pool 1 the minimum detected (Figure 14). The results represent the total amount of arsenic and do not describe the quantity of inorganic versus organic forms of the metal found in these blood serum samples. Higher levels in the Far N pool may be a result of the essentially non-toxic organic form common in fish.

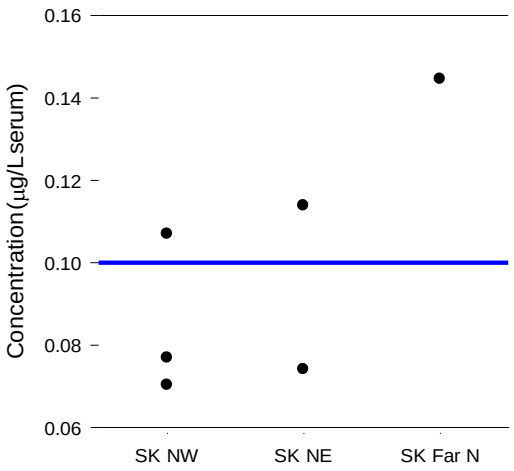


Figure 14: Serum concentration of arsenic in pregnant women in Saskatchewan. The blue line represents the analytical limit of quantification.

How do these values compare?

There is no value to compare in the Alberta study and no other comparable source is available for serum values. The First Nations Biomonitoring Initiative measured arsenic in blood (not serum) and urine so comparison is not possible.[29]

BARIUM (BA)

Background

Barium is a naturally occurring element found often in sedimentary and igneous rocks. It is most often found in compounds (such as salts) rather than in its free elemental state.[85] No known barite deposits occur in Saskatchewan or Alberta.

Barium compounds are used or found in many products including drilling mud, bricks, glass, rubber, florescent lamps and are used forimaging-ray diagnosis of the digestive tract. [86]

How can you be exposed to barium?

Background exposure to barium in the general population occurs through absorption, ingestion and inhalation of food, water, soil and/or air containing trace amounts of barium. Barium is released into the environment by using or disposing of products that contain barium as well as mining, burning coal and fossil fuels and other industrial processes.[86] Barium sulfate which is used as a benign aid to x-ray diagnosis, is not absorbed into the blood and is non-toxic to humans.

Some foods have higher amounts of barium - milk, flour, potatoes and some cereals and nuts. Nonetheless, most foods contain less than 0.0002 mg/g of barium.[85] It is estimated that the average person consumes about 0.03 mg/day of barium. [87]

Barium may be excreted in breast milk.

What health effects have been linked to barium?

Background concentrations of barium in humans are not known to cause ill health effects.[86]

The absorption of barium into the body via the gastrointestinal tract and lungs depends on the type of barium compound, contents within the gastrointestinal tract and age of person.[85,86] Barium salts, such as barium sulphate, that are less water soluble cause fewer negative health effects. Soluble barium salts are extremely toxic at high doses causing arteries to constrict, seizures, paralysis and in some cases death.[85] Other symptoms of acute barium toxicity include gastrointestinal issues.[85]

Result

Pool concentrations for barium ranged from 2.6 µg/L to 3.5 µg/L (mean ± 95% confidence interval: 3.2 µg/L ± 0.3 µg/L). There was not much variation between pools.

How do these values compare?

Saskatchewan pool concentrations were all lower than those detected in Alberta (Alberta was stratified by geographic region and age).

CADMIUM (CD)

Background

Cadmium is a soft metal, often a by-product of refining metals such as zinc, copper, or lead. Cadmium is used in electroplating, as well as the manufacture of plastics and pigments and, to a lesser extent, fungicides, nuclear reactors, television, batteries, motor oils and in rubber production. [88]

Cadmium can enter the food chain through the soil into plants.[89] It can also enter into water sources through industrial and municipal wastes, and leaching from soldering, and black or galvanized pipes.[88]

How can you be exposed to cadmium?

In non-smokers, cadmium exposure often occurs through ingestion of foods containing cadmium. It can accumulate in aquatic species and agricultural crops. Leafy greens, vegetables, potatoes, grains and peanuts are primary food sources of cadmium, although individuals who consume shellfish and organ meats (kidney and liver) regularly may have elevated exposures.[88,89]

An important source of cadmium is through inhalation of tobacco smoke;[90] a single cigarette contains about 1 to 2 µg of cadmium. Those who smoke have kidney levels of cadmium twice that of non-smokers.[88]

Indigenous smoking rates are approximately double that of the general non-Indigenous population in Canada.[91] As a consequence, cadmium exposure is higher in this group. As well, cadmium is taken up by lichens and other plants such as willow, thereby accumulating in the organs (kidney and livers) of herbivorous animals that are then consumed by Indigenous populations.[92] Several studies of Canadian First Nations show that cadmium levels were associated with the number of cigarettes smoked by humans in the area, but not associated with traditional food consumption.[92,93] A study revealed cadmium levels in moose liver in northern Saskatchewan[94,95] were lower than levels found in southern Saskatchewan, Ontario[96], Yukon[97], northern British Columbia[98], Manitoba[99] and Alaska[100].

What health effects have been linked to cadmium?

Cadmium when entering the body is deposited in all major organs, but the liver and kidney are the most common sites. Cadmium can stay in the body for years. As a consequence, chronic low-level exposures can lead to a build-up of cadmium in the body, and kidney damage can result. Long-terms exposures have also been linked to skeletal changes, lumbar pain and myalgias.[88]

Cadmium has been determined to be a human carcinogen by the International Agency for Research on Cancer.[89]

Result

All pools were below the limit of quantification of 0.05 ug/L.

How do these values compare?

There is no value to compare in the Alberta study and no other comparable source is available for serum values. It is not possible to compare the Saskatchewan data directly with the blood cadmium levels determined in the Canadian Health Measures Survey, the Canadian survey found that cadmium levels were strongly associated with smoking, while the impact of diet was modest to small

CESIUM (CS)

Background

Cesium is naturally occurring and enters the environment from natural processes such as weathering of rocks and minerals.[101] In the environment, cesium exists as either the stable isotope form of cesium (^{134}Cs) or as a compound (hydroxides, carbonates, iodides and bromides).

Cesium compounds are used in a variety of products including alkaline storage batteries, photoelectric cells, optical instruments, glasses and atomic clocks.[101] Cesium is mined in southeastern Manitoba for the production of a biodegradable lubricant fluid used in oil drilling.[102] Use or disposal of cesium containing products, as well as mining and some other industrial processes can release cesium into the environment (air, water and soil).

How can you be exposed to cesium?

Background exposure to cesium is primarily through ingestion or inhalation of food, water, soil and air containing trace amounts of cesium. Tea and coffee contributes to the largest consumption of cesium by the average Canadian adult. Yeast, herbs and spices have high concentrations of cesium but these are generally only consumed in small amounts.[82] Lichens are also high in cesium which is a major dietary source for caribou. Studies in lichen and caribou in the Northwest Territories[103] and Saskatchewan show relatively high levels of stable cesium.[104] Cesium chloride is sold as an oral alternative cancer therapy though there is no evidence of effectiveness and this high dose use can cause serious heart rhythm problems.[105]

What health effects have been linked to cesium?

Background concentrations of cesium are not known to cause any ill health effects in humans, but long term exposure studies of cesium are limited.[101] High doses of cesium chloride as an alternative cancer therapy can cause heart arrhythmias.

Result

The cesium analyzed in this study represents the amount of cesium 133 (stable or non-radioactive cesium) and is not a measure of total cesium as other isotopes were not analyzed.

Overall, mean concentrations of cesium in the six pools ranged from 0.3 µg/L to 3.5 µg/L (mean ± 95% confidence interval: 0.9 µg/L ± 1.0 µg/L). Pool 6 (Far N) had the highest concentration of cesium (3.46 µg/L).

The reasoning behind the elevated concentration of cesium in the far north (Pool 6) at this time is unclear. There are behavioural variations in this area that include more subsistence hunting and consumption of country foods and possible geological crustal variations, however, the concentrations measured here only indicate body burden, so sources of exposure can only be speculative at this time.

How do these values compare?

Cesium levels in pools 1-5 were very similar both with Saskatchewan and when compared to the Alberta mean concentrations (grouped by geography and age). Pool 6 when compared against all mean cesium concentrations in Alberta is orders of magnitude greater (Figure 15).

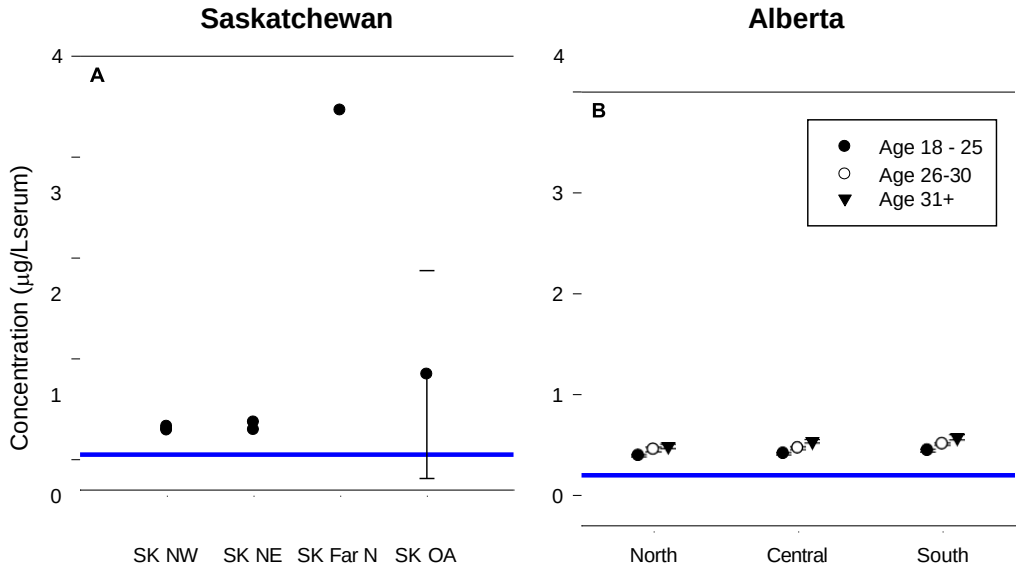


Figure 15: Concentrations of cesium in the blood serum of pregnant women in Saskatchewan (A) and Alberta (B). Saskatchewan data is presented for each of the six pooled samples, and for an overall (OA) mean of the six pools. Mean concentrations stratified by both age and region are presented for Alberta. The blue lines represent the limit of quantification used in laboratory analysis.

CHROMIUM (CR)

Background

Chromium occurs naturally in the environment and released by weathering of rocks and minerals, and volcanic eruptions. Naturally occurring chromium has three states; metallic (Cr(0)), trivalent (Cr(III)) or hexavalentCr(VI). Hexavalent chromium is most commonly found in surface waters and aerobic soil environments. Trivalent chromium is usually in sediments and wetlands. Hexavalent chromium salts are more able than trivalent chromium to be mobile due to being more soluble.[107]

Chromium compounds are used as wood preservatives, in metal plating, for leather tanning, as a catalyst, and in pigments, paints and fertilizers. Chromium is naturally released into environment from volcanoes, forest fires and marine aerosols.[108]

Chromium is released into water by effluent of tanneries, pulp and paper mills, and cement and fertilizer plants and other industrial sources.[109] It is released into the air by aerosol.[110] Chromium is not known to bioaccumulate in aquatic environments.[108]

How can you be exposed to chromium?

The general population is most likely to be exposed to trace levels of chromium in food. Low levels of the non-toxic form of chromium (chromium III) occur naturally in a variety of foods, such as fruits, vegetables, nuts, and meats. However, the general population is exposed to the more toxic forms of chromium (Cr VI) most often by ingestion of contaminated foods, but also through tobacco smoking and contact with older forms of pressure treated lumber (with chromated copper arsensate).[109]

What health effects have been linked to chromium?

Health effects of chromium depend on the dose, the length and timing of exposure, the environment, the species of chromium and other physiological factors. Chromium (III) is an essential micro-nutrient, while chromium (VI) can be toxic.

Background concentrations of hexavalent Cr is not known to cause any adverse health effects.[109] Long-term exposure of high doses of hexavalent chromium may cause health effects such as eye, skin, mucous membrane and nose irritation as well as digestive system problems.[109] Cr (VI) can accumulate in tissues such as the lymph nodes, liver, spleen, kidneys and lungs as it can, unlike Cr (III), cross into cells.

Result

Concentrations for all pools were below the limit of quantification (0.5 µg/L).

How do these values compare?

The mean concentration of blood serum chromium in the Alberta study was 1.5 ± 0.7 µg/L.

Studies have found that serum and whole blood sampling cannot be compared due to chromium's interaction with red blood cells, and thus no other comparable studies are available.[111]

LEAD (PB)

Background

Lead is a ubiquitous, naturally occurring heavy metal used in both industrial and commercial products (paints, gasoline, plumbing fixtures, storage batteries, leaded glass, leaded crystal, radiation shielding, bullets, shot, and fishing weights).[112] Lead is released into homes and environments with the use or disposal of such products, as well as a consequence of mining and other industrial processes.

Lead can enter into the environment through air plumes from smelters and emission stacks or mobilization in the soil (under the right circumstances) and contamination of ground and surface water. Lead can also enter into the water system through the leaching of lead containing pipes.[112,113]

How can you be exposed to lead?

Humans can be exposed to lead in a variety of ways. Lead containing dust can be found in homes and workplaces, particularly older homes where lead-based paints were used. Drinking water that is delivered through older water pipes containing lead is a known source of lead exposure.[114]

Tobacco smoking is an important source of lead exposure among smokers.[115] Lead shot shells and bullets used in hunting have been identified as a source of exposure for those who consume game animals and birds. Indigenous populations may be particularly vulnerable due to the higher degree of consumption of game animals and birds.[116–122]

Lead can be detected in breast milk and may cross the placenta as early as 12 weeks into gestation[112]; infants and fetal exposure can occur from either of these methods.

What health effects have been linked to lead?

Lead is rapidly absorbed by the body, both by ingestion and inhalation. Toxic effects are dependent on dose, exposure length and timing.

At low levels, lead exposure has been linked with spontaneous abortion, premature delivery and neurotoxic effects in the developing fetus.[112] The developing fetus may also be affected by anemia, motor or sensory system disturbances, immune system disruption and reproductive system problems.[113]

In humans, lead in higher concentrations can cause anemia, impaired kidney function, abdominal pain and nervous system disturbances. It is a known neurotoxin that can cause hallucinations, headaches, dullness, muscle tremors, poor attention span and loss of memory.[112,113]

The International Agency for Research on Cancer (IARC) has declared that inorganic lead compounds are a probable human carcinogen, while organic lead compounds are not yet classifiable as to their carcinogenicity.[112]

Result

Overall, mean concentrations of lead ranged from 0.3 µg/L to 0.6 µg/L (mean ± 95% confidence interval: 0.5 µg/L ± 0.1 µg/L). All pools were above the level of quantification.

How do these values compare?

The overall mean of the six Saskatchewan pools was larger than the three geographic means measured in Alberta. As well, many of the Alberta pools were below the level of quantification (< 0.2 µg/L)[d] (Figure 16). There are no other studies available using serum levels for comparison.

[d] For lead the level of quantification for Saskatchewan (0.1 µg/L) did differ from that in Alberta (0.2 µg/L)

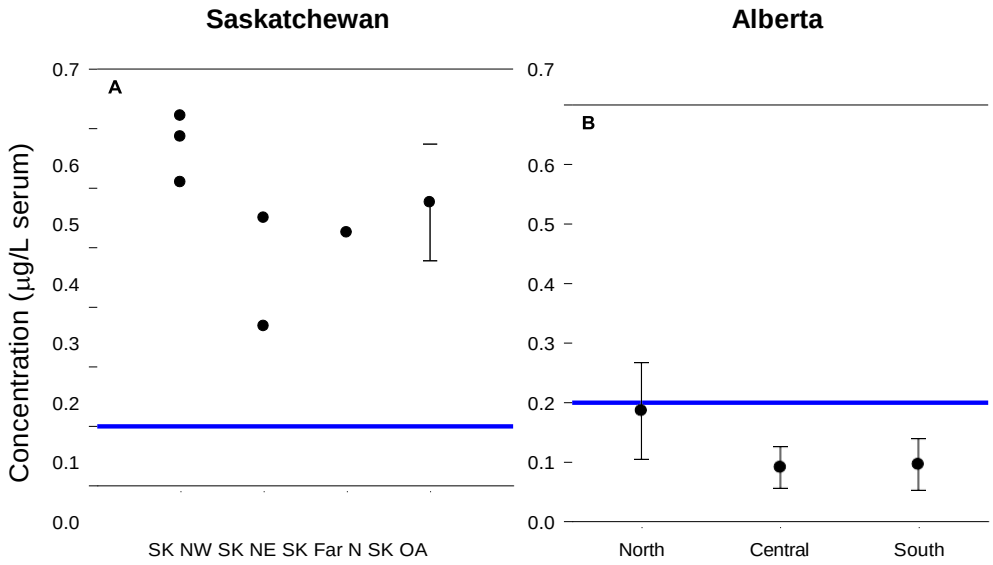


Figure 16: Concentrations of lead in the blood serum of pregnant women in Saskatchewan (A) and Alberta by geographic region (B). The blue lines represent the limit of quantification used in laboratory analysis. Estimates provided represent a 95% confidence interval around the mean.

The recent First Nations Food, Nutrition and Environment Survey in Saskatchewan identified samples such as wild birds and game meat with higher concentrations of lead, likely as a result of contamination from lead-containing ammunition.[65] They recommended the use of nonlead ammunition when hunting and if hunting with lead-containing ammunition, they recommended cutting away the portion of meat surrounding the entry are to decrease the risk of lead exposure.

MERCURY (HG)

Background

This section relates primarily to elemental and inorganic mercury. Methylmercury is addressed in the Organic Chemicals section of this report.

Mercury is naturally occurring and is introduced into the environment by the weathering of rocks and minerals, as well as volcanic activities. It is the only metal that exists in liquid form at room temperature. It exists naturally in elemental, inorganic and organic forms.[123] High levels have been detected in the Arctic due to global atmospheric circulation.

Elemental and inorganic mercury compounds are used in a wide variety of industrial, commercial and medicinal products, including electrical instruments, thermometers, lamps and lights, batteries, cosmetics, dental amalgams and antiseptics,[123] although it is being phased out of most products.[124]

How can you be exposed to mercury?

Mercury can be released into the air, water or soil by the use or disposal of mercury containing products, burning of coal, and through mining and other industrial processes.

What health effects have been linked to mercury?

Background concentrations of elemental and inorganic mercury are not known to cause any ill health effects in humans.

In exceptional scenarios where exposures are high (such as in accidental releases or unusual occupational exposures) elemental and inorganic mercury may cause serious health effects, such as neurological, renal and digestive system dysfunction, rash and eye irritation.[63]

Result

Mean concentrations of mercury ranged from 0.2 µg/L to 0.7 µg/L (mean ± 95% confidence interval: 0.4 µg/L ± 0.1 µg/L). There is no clear geographic trend, but the highest concentration was detected in pool 6 (Far N).

How do these values compare?

The mean concentrations from the Alberta study (by age group) were values that fell within the lower range of the Saskatchewan pools, with concentrations in the two NW pools in Saskatchewan approximating the pool average concentration of those women 18 to 25 years. (Figure 17)

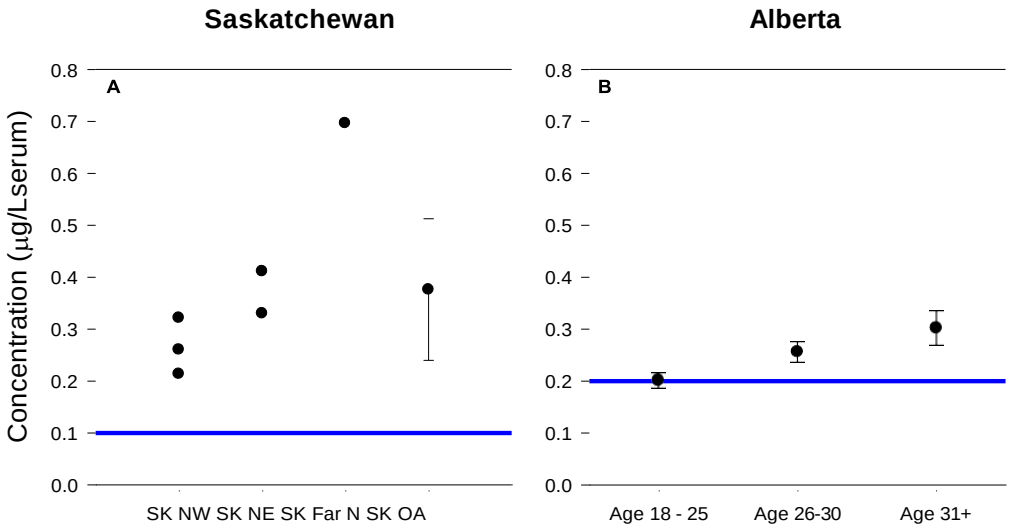


Figure 17: Concentrations of inorganic mercury in the blood serum of pregnant women in Saskatchewan (A) and Alberta by age (B). The blue lines represent the limit of quantification used in laboratory analysis. Estimates provided represent a 95% confidence interval around the mean.

Walker et al. completed a study in Arctic Canada (Northwest Territories and Nunavut) that included measuring concentrations of inorganic mercury. Unfortunately, the results cannot be compared against the Saskatchewan or Alberta values as the methodologies differed. This study does nonetheless point to elevated inorganic mercury values in those who self-identify as Inuit compared to those who identify as either Dene, Métis or Caucasian. This suggests that variations in country food consumption may explain variations in inorganic mercury levels[126] and may help to understand the variability seen between the geographic pools in Saskatchewan.

STRONTIUM (SR)

Background

Strontium is a hard, white metal commonly found in nature that turns yellow when exposed to air. Rocks, soil, dust, coal, oil, air, plants and animals all contain strontium. It exists in four stable isotopes and two radioactive isotopes. Strontium compounds are used to make ceramics, glass products, pyrotechnics, paint pigments, other products.[127]

Strontium-90 (one of the radioactive isotopes) was widely dispersed in the 1950s and 1960s in the United States as fallout from nuclear weapons testing. Since that time, this isotope has been slowly decaying (half-life of 29.1 years).[127] This study measured the non-radioactive form of strontium.

How can you be exposed to strontium?

Strontium naturally occurs in food and water however, additional strontium can be deposited into soil with the disposal of coal ash, incinerator ash and industrial wastes. Depending on whether strontium in soil is soluble or insoluble will determine whether it is likely to then migrate further into the ground and into groundwater.

Both stable and radioactive strontium background exposure occurs most often by breathing air, eating food or drinking water that contains strontium. Food and drinking water are the most important sources, particularly grains, leafy vegetables and dairy products.[127]

When strontium enters the body it either resides in the lungs (after inhaling strontium) or the bone, and the length of time it remains in the body depends on the solubility of the compound. Excretion of strontium can happen quickly through urine, feces or sweat or the metal may stay in the body for an extended period of time. Strontium behaves similarly to calcium and can, in some cases, be built into bone matrix, depending on the age of the person at the time of exposure.[127]

What health effects have been linked to strontium?

There is no negative human health effects linked to stable strontium.

Result

Overall, mean concentrations of strontium 88, a non-radioactive form of strontrium, ranged from 20.5 µg/L to 39.1 µg/L (mean ± 95% confidence interval: 26.9 µg/L ± 5.5 µg/L). There was no distinct geographic trend identified across the pools.

Radioactive strontium was not evaluted in this study.

How do these values compare?

There is no value to compare in the Alberta study.

Two comparably small scale studies evaluated strontium levels in child-bearing age women can be used for comparison. A Brazilian study of women aged 18 to 60 identified a mean plasma concentration of strontium to be 15.4 µg/L (standard deviation 4.2 µg/L).[128] This value falls below the range of Saskatchewan pool concentrations

determined. While a Chinese study of non-pregnant, non-smoking women determined a median serum strontium concentration of 57.59 (interquartile range 51.33-68.14) µg/L.[129] The median value determined from China exceeded both the Brazilian study and all Saskatchewan pools.

URANIUM (U)

Background

Uranium is a naturally occurring element that is widespread in nature and found in rock, soil and water. Distribution in the environment is based on existing geology and climatic processes.

Uranium is a weakly radioactive substance that exists as three isotopes in the environment: ^{238}U, ^{235}U and ^{234}U. All three naturally occurring isotopes are radioactive. It is usually found in an oxide form.[130]

Canada is the world's second largest producer of uranium. Northern Saskatchewan, the source of Canadian uranium, has some of the world's most abundant and high grade deposits.[131]

Uranium is used as fuel for commercial nuclear power plants with industrial uses in ceramics, electron microscopy, photography, as well as some military applications (e.g., armour plating, armour piercing ammunition).[132]

How can you be exposed to uranium?

The general population is most often exposed to uranium through diet, particularly root vegetables, and drinking water especially from ground waters which naturally contain uranium in varying amounts.[130] It is estimated that an average person takes in between 0.07 to 1.1 µg of uranium through food each day.[132]

What health effects have been linked to uranium?

The health effects of background exposure to uranium are not known and the radiation risk from exposure to natural uranium is very low. At high levels of exposure, uranium is known to cause kidney damange due to chemical toxicity.[130]

Result

All pool concentrations were below the limit of quantification at 0.05 ug/L.

How do these values compare?

There is no value against which to compare in the Alberta study and no other source is available for comparison of serum values. CHMS and the First Nations Biomonitoring Initiative demonstrated a high proportion of results for whole blood and urine were below detection limits.

MINERAL MICRONUTRIENTS

The following substances are required by humans for normal physiological function. These are also known as *trace elements* as they are only required in very small quantities. Given they are necessary to life, the following ten substances can be linked to potential health effects in cases of either deficiency or excess.

BORON (B)

Background

Boron occurs naturally in soil, water and food. It is required for normal development of plants and is "probably essential", as per the World Health Organization, in humans. Consumer products that contain boron or boron compounds include laundry detergent, pesticides, facial creams and cleansers, plant foods and household cleaners.[133]

How can you be exposed to boron?

Exposure to boron primarily occurs through consumption of food and water. The general public is not likely to be exposed through air, although some occupational exposures are through inhalation.

What health effects have been linked to boron?

There have been studies in animals and humans that suggests that boron may play a role in reducing the risk of osteoporosis but this has not been confirmed.[134] Deficiency, though exceedingly rare and unknown in North America, has been linked to adverse effects on embryonic development, brain function and cognitive performance. Boron supplementation in people who are not deficient will not likely provide benefit.[135]

Very high exposures (over 30 g of boric acid) over a very short period of time can result in detrimental health effects.

Result

The Saskatchewan pools had boron concentrations ranging from 13 µg/L to 24 µg/L (mean ± 95% confidence interval: 17 ± 3.1 µg/L). There was no notable geographic variation.

How do these values compare?

Blood serum concentrations of boron in pregnant women in Alberta had mean concentrations ranging from 13.2 µg/L to 34.4 µg/L, with no trends between regions or across age groups. The Saskatchewan pools were quite comparable to those in Alberta.

COBALT (CO)

Background

Cobalt is found in rocks, water, soil, plants and animals. It is usually combined with other elements such as oxygen, sulphur and arsenic. Cobalt is naturally released into the environment through leaching from soil, airborne dust, sea spray, volcanic eruptions and forest fires. The burning of fossil fuels, sewage, sludge, phosphate fertilizers, mining and smelting of cobalt-containing ores and industrial processes that use cobalt compounds are all human-made sources of cobalt in the environment. Cobalt can exist in two important radioactive forms; isotopes cobalt-60 and cobalt-57.[136] This study measured the stable form of cobalt.

How can you be exposed to cobalt?

For most people, the vast majority of cobalt intake is from food including coffee and through vitamin B12 found in meat and dairy products. In people who have a joint prosthesis made of cobalt alloys, exposure can be from the prosthesis.

What health effects have been linked to cobalt?

Cobalt is a key component of vitamin B-12 (cobalamin) which is an essential nutrient for good health. Low levels of vitamin B-12 can lead to anemia and neurological troubles. Exposure to cobalt levels normally found in the environment is not harmful to humans.

Result

Overall, mean concentrations of cobalt ranged from 0.4 µg/L to 0.5 µg/L (mean ± 95% confidence interval: 0.5 µg/L ± 0.03 µg/L). All six pools had comparable concentrations and there was no distinct geographic pattern.

How do these values compare?

All Saskatchewan pools were higher than the overall mean serum concentration of the Alberta (mean ± 95% confidence interval: 0.29 ± 0.05 µg/L) (Figure 18).

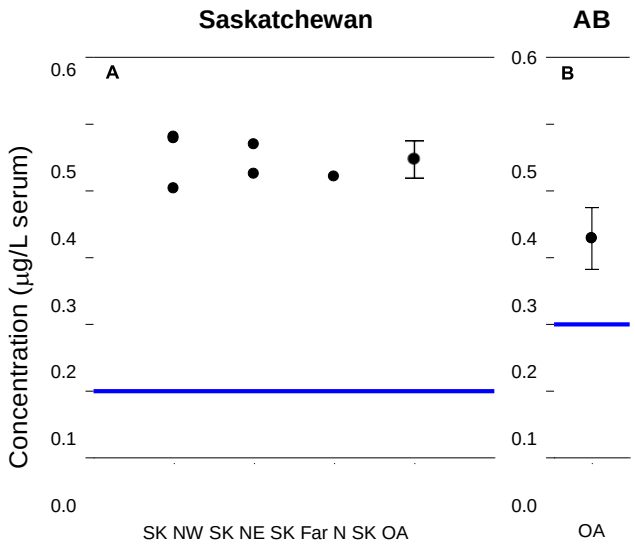


Figure 18: Concentrations of cobalt in the blood serum of pregnant women in Saskatchewan (A) and Alberta (B). Saskatchewan data is presented for each of the six pooled samples, and for an overall (OA) weighted arithmetic mean of the six pools. An overall mean concentration (OA) is provided for Alberta. The blue lines represent the limit of quantification used in laboratory analysis. Estimates provided represent a 95% confidence interval around the mean.

COPPER (CU)

Background

Copper has been mined and used by humans for over 5,000 years. Copper is used extensively for plumbing pipes, particularly in domestic water systems. It is also used for electroplating, the production of alloys, as a fungicide, as an antimicrobial agent and a variety of other industrial and commercial uses.[137]

Copper is an essential nutrient in mammals as it is required for normal enzyme function.

How can you be exposed to copper?

For the general population, copper is ingested in food. Less commonly exposure can result from inhalation of dust particles containing copper or ingestion of drinking water.[138]

What health effects have been linked to copper?

Copper deficiency (less than 2 mg/day) can result in anemia, although exceedingly rare.

Copper, while generally considered to be non-toxic, can cause ill health effects in high doses (more than 15 mg/day).[137] In these cases copper will build up in the liver and kidneys and cause harm to these organs.[139]

Result

The overall mean concentration of copper ranged from 1.81 x 10^3 µg/L to 2.13 x 10^3 µg/L (mean ± 95% confidence interval: 1.96 x 10^3 ± 1.11 x 10^2 µg/L). There was little variation between the 6 pools.

How do these values compare?

The Saskatchewan pools approximated the Alberta mean concentrations which were grouped by age and geographic region of Alberta.

IRON (FE)

Background

Iron is the fourth most common element that makes up the Earth's crust. It has been used for many centuries in the making of materials for tools and for construction. It is mined, smelted and is used in the manufacture of steel. Iron is critical to human physiology, as many enzymes require it for normal functioning. Most iron in the body is present in hemoglobin, the enzyme in red blood cells that carries oxygen to tissues. Women require more iron than men, and pregnant women require increasing amounts of iron as the fetus develops through the pregnancy.

How can you be exposed to iron?

Iron is present in many foods and so the most common exposure route is through diet. Red meat, fish and poultry contain the most easily absorbed iron. Intake through drinking water is also possible, but comparably much lower. Health Canada recommends prenatal women take vitamin supplements including iron and folic acid. In workplace settings, welders can be exposed to iron through welding fumes.

What health effects have been linked to iron?

Not enough iron in adults most often results in anemia, which causes fatigue and limited stamina.

Not enough iron in pregnant women can cause fatigue, heart stress, lower immunity and maternal anemia. It also has consequences for the growing fetus including increased risk of premature delivery, low birth weight and increased risk of perinatal infant mortality.[140]

Not enough iron in children can result in delayed motor or mental development.

Very high doses of iron can cause problems with the lining of the gastrointestinal tract, neurologic disturbances and liver failure.[141] This usually occurs through the accidental overdose of iron pills.

Result

Overall, mean concentrations for iron in the six pools of pregnant women sampled ranged from 967 µg/L to 1.23 x 10^3 µg/L (mean ± 95% confidence interval: 1.07 x 10^3 ± 82.4 µg/L). There was little inter-pool variation.

How do these values compare?

In the Saskatchewan study the mean concentration of iron ($1.07 \times 10^3 \pm 82.4$ ug/L) was slightly lower than the mean concentration of iron measured in the Alberta study ($1.2 \times 10^3 \pm 24$ ug/L).

MANGANESE (MN)

Background

Manganese is found in rocks and soils naturally, but it does not occur in nature as a pure metal but rather in combination with oxygen sulphur or chlorine. It is often used in steel production, fireworks, dry cell batteries, paints, for medical imaging and in cosmetics.[142]

How can you be exposed to manganese?

Most people are exposed to manganese through food, water, air and consumer products that contain manganese. Grains, nuts, legumes and fruit have higher concentrations of the element compared to most other foods.[142]

Manganese is required for normal function of many enzymes in the human body. It is required for normal bone formation, protection of cells and in the metabolism of amino acids, cholesterol and carbohydrates.[142]

What health effects have been linked to manganese?

Manganese deficiency is very rare, but when it does occur neurological effects may result.

High doses of ingested manganese can result in lung damage. High doses of inhaled manganese can result in a condition known as *manganism* – tremors, difficultly walking and facial spasms.[142]

Result

Overall, mean concentrations of manganese ranged from 2.6 µg/L to 4.2 µg/L (mean ± 95% confidence interval: 3.5 µg/L ± 0.4 µg/L). All six pools had comparable levels of manganese.

How do these values compare?

The Alberta pooled mean is slightly lower than the Saskchewan pooled mean, but this difference is not statistically significant.

MAGNESIUM (MG)

Background

Magnesium is the eighth most common natural element. Magnesium alloys are used to make beverage cans, pressure die-cast products, electrical equipment, portable tools, sports equipment, and many other products. It is used in both the steel and chemical industries extensively. It is also found naturally in many foods.[143]

Magnesium is required for over 300 known enzyme reactions in the body.

How can you be exposed to magnesium?

Magnesium is found in many foods and food products. Green leafy vegetables, unpolished grains and nuts are all rich in magnesium.[144]

What health effects have been linked to magnesium?

Magnesium deficiencies are exceptionally rare, but when they do occur they negatively affect heart, kidney, muscle and nerve function. The most common effect of too much magnesium is its ability to act as a laxative, although the human body can quickly adapt and resolve this issue in many cases. More seriously, high levels of magnesium can result in changes in heartbeat, and at very high levels (plasma concentrations above 180,000 µg/L) paralysis, respiratory depression, coma or even death may occur.[143]

Result

Overall, mean concentrations of magnesium ranged from 1.70 x 10^4 to 1.97 x 10^4 µg/L (1.86 x 10^4 µg/L ± 685 µg/L). There was no notable variation between pools.

How do these values compare?

There is no value to compare in the Alberta study and no other similar studies available for comparison. Although reference values may differ between laboratories, the magnesium reference value for Mayo Clinic Laboratories is between 1.7 and 2.3 X 10^4 ug/L.[167]

MOLYBDENUM (MO)

Background

Molybdenum naturally occurs in the Earth's crust and is found in combination with other elements. It is naturally found in rocks, soil, sediment, surface water, groundwater, plants, animals and humans. Both natural and man-made processes can release it into the environment, including weathering, combustion of coal, sewage sludge and mining. Fertilizer use is an important source of aquatic species exposure.[145]

Molybdenum is required for three types of enzymes to work properly in the human body: sulphite oxidase, aldehyde dehydrogenase, and xanthine oxidase.[146]

How can you be exposed to molybdenum?

Diet is the primary source of molybdenum.

What health effects have been linked to molybdenum?

Human health effects from low levels of molybdenum are unknown. In circumstances of long-term exposures to very high levels (10-15 mg/day), gout-like symptoms can occur.[146]

Result

Overall, mean concentrations of molybdenum (Mo) ranged from 1.1 µg/L to 1.3 µg/L (1.2 µg/L ± 0.06 µg/L). There is not a distinct pattern across pools.

How do these values compare?

Compared to the range of blood serum concentrations in pregnant women in Alberta (1.06 µg/L to 4.29 µg/L), northern Saskatchewan presented with slightly lower overall concentrations (1.2 ± 0.060 µg/L).

NICKEL (NI)

Background

Nickel is hard, silvery-white metal that is commonly combined with other metals to form alloys. It is used to make steel, nickel plate, battery production and as a catalyst. Alloys are used in coins and jewelry. Human activities such as mining, industry, oil-burning, coal-burning and trash incineration can release nickel into the environment.[147]

How can you be exposed to nickel?

Exposure to nickel is primarily through food. Foods naturally high in nickel include chocolate, soybeans, nuts and oatmeal. Wearing nickel containing jewelry or using consumer products contain nickel are less important sources.[147]

What health effects have been linked to nickel?

The most common health effect of nickel exposure is an allergic reaction. Yet, this reaction is mostly in cases of skin exposure and the result is most commonly a rash.[147]

Result

Overall, mean concentrations of nickel ranged from 0.4 µg/L to 2.08 µg/L (mean ± 95% confidence interval = 0.8 µg/L ± 0.6 µg/L).

How do these values compare?

The mean concentration of the Saskatchewan pools combined was statistically comparable to that found in the Alberta study (0.9 ± 0.09 µg/L). The range of the Alberta results were from 0.386 to 5.58 ug/L.

SELENIUM (SE)

Background

Selenium is a naturally occurring substance found distributed in the Earth's crust, with some geographic areas known to contain more selenium than others.[148] Selenium and selenium compounds can be used in plastics, rubber, agriculture, paints, ceramics and glass, electronic materials, drug products, natural health products, lubricants and metallurgical applications.[149] Mining and burning of fossil fuels also can release selenium into the environment.

Selenium can also be released into the environment through natural processes such as volcanic activity and weathering of soils and rocks.[149]

Selenium is necessary for human functioning as antioxidant enzymes, enzymes that protect the body from tissue damage, require it. It is also required for normal growth and metabolism.[148]

Fish consumption recommendations are in place for Beaverlodge and Martin Lakes in the Eastern Athabascan Region of Saskatchewan since 2003 due to high concentrations of selenium in fish associated with historical uranium mining in the area. These advisories provide recommendations of the maximum number of fish that it is advisable to eat from these lakes (Personal communication: Dr. James Irvine).

How can you be exposed to selenium?

People are exposed to low levels of selenium on a daily basis through food, water and air, with most coming from dietary sources. Food that are grown (e.g. grains) or fed (animal products) with feed grown in areas known to be higher in selenium will contain more selenium.[148] Selenium is an ingredient in some vitamin pills, including some prenatal vitamins.

What health effects have been linked to selenium?

Selenium is a necessary substance for normal physiological functioning, but too high levels have been shown to cause harm.

Not consuming enough selenium is hazardous to health as it makes the body more susceptible to illness caused by other nutritional, biochemical or infectious stresses.[148]

Selenosis is a well described health outcome of consuming elevated levels of selenium (above 800 µg/day) over an extended period of time. Selenosis is characterized by brittle hair and deformed nails and/or tooth decay. The most extreme cases present with loss of feeling and control of the arms and legs.[148]

Result

Overall, concentrations of selenium ranged from 107.9 µg/L to 124.1 µg/L (118 µg/L ± 4.8 µg/L). There is no apparent trend between pools.

How do these values compare?

The blood serum pools in Saskatchewan (means of 118 ± 4.77 µg/L) were slightly lower than the overall mean serum concentration in Alberta of 154 ± 2.84 µg/L. (Figure 19)

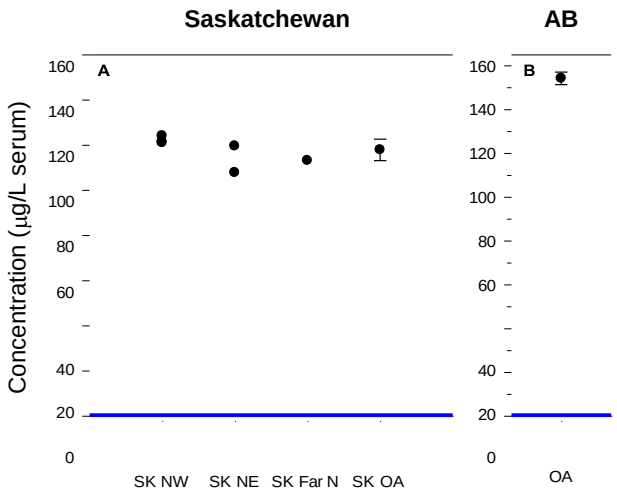


Figure 19: Concentrations of selenium in the blood serum of pregnant women in Saskatchewan (A) and Alberta (B). The blue lines represent the limit of quantification used in laboratory analysis. Estimates provided represent a 95% confidence interval around the mean.

ZINC (ZN)

Background

Zinc is an essential micronutrient for microorganisms, plants and animals. Nearly 100 known enzymes depend on zinc as a catalyst.

How can you be exposed to zinc?

Food is the common source of zinc for humans. Water that has either been stored or passed through containers or pipes that are coated with zinc to reduce rust could also contain zinc.[150]

What health effects have been linked to zinc?

Too little zinc can cause varying degrees of severity of a wide range of ill health effects, depending on the degree of deficiency. Growth retardation, hair loss, diarrhea, delayed sexual maturation, impotence, eye and skin problems and impaired appetite have all been associated with zinc deficiencies.[151] Severe zinc deficiency is very rare.

Maternal zinc deficiency may lead to poor birth outcomes and compromise infant growth and development. Too little zinc during pregnancy may also result in pre-term birth.[152]

Consuming too much zinc in a short period of time (such as poisoning) can produce adverse health effects such as stomach cramps, nausea and vomiting. Ingesting high levels of zinc for several months can cause anemia, damage to the pancreas, and decreased levels of HDL (high density lipoprotein or “good”) cholesterol.[150]

Result

Overall, concentrations of zinc ranged from 1303.86 µg/L to 1528.70 µg/L (mean ± 95% confidence interval: 1409.39 µg/L ± 66.40 µg/L). There were no meaningful differences between pools.

How do these values compare?

The mean concentration in Saskatchewan (1409.39 ± 66.40 µg/L) overlaps with the overall mean concentrations in women in Northern, Central and Southern Alberta based on the Alberta study.

STUDY LIMITATIONS

BIOMONITORING

As technology advances and biomonitoring continues to evolve the ability to measure chemicals in a biological matrix, such as blood serum, continues to improve. The ability to interpret the data in regards to risk to health remains limited. Further research in a variety of fields is required before biomonitoring data can be used to meaningfully and reliably determine risk. [153]

STUDY DESIGN AND IMPLEMENTATION

The desire for knowledge was weighed against feasibility in this study, as is the case in many studies. Choices that were made in regards to the study design resulted in several limitations.

MISSING DEMOGRAPHIC INFORMATION

In this study only the postal code of participants was collected and no other demographic information was included. As a result, we cannot further evaluate these findings by particular sub-categories such as age of mother, gestational age, etc.

POOLED SAMPLE DESIGN

The choice to use a pooled sample design over individual samples had the benefit of being more economical and less likely to have a high number of concentrations below the limit of detection (this can complicate statistical analysis). However, with pooled samples it becomes impossible to know individual level information about participants.

Without knowing individual level data, it is impossible to answer queries such as whether all the participants have approximately the same blood serum concentrations or if one person had a really high level and everyone else had very low concentrations. Pooling makes it impossible to know the difference between the two.

MISSING PEOPLE

Women whose prenatal blood screen was sent through Flin Flon Hospital laboratory were not included in the study, and some of the prenatal blood specimens from LaRonge Health Center at the very beginning of specimen collection were not included. It is estimated that pools 1, 2, 3, 4 and 6 included most of the pregnant women from those regions, but pool 5 is likely less reflective. Therefore, all pools save pool 5 are likely able to represent what is happening to most women in their respective geographies. Pool 5 does not represent women from those communities where the blood work was sent through the Flin Flon Hospital (e.g. Creighton, Denare Beach, Pelican Narrows and Deschambault).

LIMITED BIOLOGICAL MATRIX SELECTION

This study analyzed all substances from the blood serum of participants. Although this simplifies the study and made it economical, it limits some of the conclusions that can be derived from the information. For example, some substances are better measured in another matrix (whole blood including blood cells, urine etc.).

LIMITED OPTIONS FOR COMPARISON

Comparisons to other biomonitoring studies (such as CHMS or First Nations Biomonitoring Initiative) were often not possible due to either differences in analytical methods or due to selection of another biological matrix. The Saskatchewan study was designed to allow for comparison with the Alberta study. Even then comparisons between the two studies were not always possible due to:

- Inclusion of some substances in the Saskatchewan study that were not in the Alberta study.
- Variations in how the pools were determined (e.g. geographically versus by age).
- Variation in analytical techniques and resulting difference in the limit of detection

Without comparison it can be difficult to understand what a particular concentration may mean.

DISCUSSION

CROSS-JURISDICTION COLLABORATION

Cross-jurisdictional projects are challenging for a variety of reasons. In the case of this study the legal, organization, ethical and cultural milieus of each jurisdiction (Alberta and Saskatchewan) varied sufficiently that certain modifications in study design were necessary. The efficient negotiation of these realities is a valuable lesson learned from this study.

The structure of the team behind this biomonitoring initiative was a laudable example of cross-boundary cooperation and collaboration.

Europe and the U.S. are leaders in large scale biomonitoring initiatives and have independently developed approaches to improve cross-border biomonitoring initiatives. The CDC introduced (2009) the State Biomonitoring Cooperative Agreement that supports the capability and capacity of states to conduct biomonitoring and state population-based biomonitoring surveillance.[154] In Europe the trans-national challenge was met by support from European Union affiliated organizations acting as leads and from that a cohesive project was produced.[155] The Alberta-Saskatchewan biomonitoring initiative, was a collaborative and receptive process that demonstrates how provincial governments can partner on large scale projects. Fundamentally, environmental contaminants do not abide by boundaries and this must be considered when developing sound biomonitoring surveillance programs.

Without the mentoring, leadership and fiscal support from Alberta, biomonitoring in Saskatchewan would not have occurred. At the time of the project there was little expertise and capacity around human biomonitoring provincially and, as a result, no momentum for developing human biomonitoring as a surveillance tool in Saskatchewan existed.

The area of biomonitoring is emerging as an important tool in environment and public health surveillance. Alberta has opened the door with this study on Saskatchewan's northern population, but there is an opportunity to go further and develop human biomonitoring surveillance across the province.

SMOKING - AN IMPORTANT SOURCE OF EXPOSURE AND RISK

The World Health Organization describes tobacco as "the most widely available harmful product on the market." Tobacco smoking is known to increase the risk of disability, disease and death, in particular due to cancer and cardiovascular disease. Cigarettes contain over 4,000 chemicals, 50 of which are known carcinogens.[156] In 2002, 37,209 Canadians died from tobacco use and tobacco use was attributed to 2,210,155 days in hospital.[157]

Tobacco smoke is known to cause elevated levels of heavy metals, including arsenic[81], cadmium[88] and lead[115], among various other chemicals.[158] Measured lead levels in this study were higher than the Alberta study values (Figure 16). There are many other chemicals also known to be statistically significantly different (often higher) in smokers than in non-smokers including dioxins and furans, polyaromatic hydrocarbon and volatile organic compounds (Table 5).

Table 5: Chemicals found to be statistically significantly different for smokers and non-smokers in biomonitoring studies in the United States. From the National Health and Nutritional Examination Survey (NHANES) 2011-2012 for males and females combined 20 years of age or over.

Chemical	Geometric Mean Concentrations (urine) (95% Confidence Intervals)		Fold Difference
	Smokers	Non-Smokers	
Metals and Arsenic Species			
Cadmium (ug/g)	0.366 (0.295 – 0.383)	0.199 (0.163-0.216)	1.8
Lead (ug/g)	0.518 (0.465-0.576)	0.417 (0.386-0.451)	1.24
Molybdenum	35.6 (33.7 – 37.7)	40.4 (38.7 – 42.2)	0.88
Uranium	0.008 (0.007 - 0.009)	0.006 (0.005 – 0.007)	1.4
Thiocyanate			
Thiocyanate (mg/g)	4.53 (4.02-5.10)	0.933 (0.881-0.988)	4.86
Metabolites of Polyaromatic hydrocarbons (PAHs)			
2-Hydroxyfluorene (ng/g)	1260 (1140-1400)	190 (176-203)	6.63
3-Hydroxyfluorene (ng/g)	662 (595-738)	66.9 (62.0-72.1)	9.9
9-Hydroxyfluorene (ng/g)	666 (592-751)	240 (220-261)	2.8
1-Hydroxyphenanthrene	216 (200 – 234)	134 (123 – 145)	1.6
2-Hydroxyphenanthrene	123 (114 – 133)	62.4 (57.9 – 67.3)	2.0
3-Hydroxyphenanthrene	153 (144 – 163)	56.6 (52.3 – 61.3)	2.7
4-Hydroxyphenanthrene	41.6 (37.5 – 46.1)	20.4 (19.1 – 21.9)	2.0
1-Hydroxypyrene	266 (246 - 269)	96.8 (90.8 – 103)	2.7
1-Hydroxynapthalene	10.5 (9.06 – 12.1)	1.37 (1.25 – 1.51)	7.7
2-Hydroxynapthalene	13.5 (12.3 – 14.8)	3.69 (3.46 – 3.93)	3.7
Metabolites of Volatile Organic Compounds (VOCs)			
N-Acetyl-S-(2-carbamoyl-2-hydroxyethyl)-L-cysteine	31.1 (28.0 – 34.6)	15.0 (14.1 – 15.9)	2.1
N-Acetyl-S-(2-carbamoylethyl)-L-cysteine	121 (110 – 134)	42.4 (39.9 – 44. 9)	2.9
N-Acetyl-S-(2-carboxyethyl)-L-cysteine	250 (224 – 278)	93.6 (87.6 – 100)	2.7

N-Acetyl-S-(3-hydroxypropyl)-L-cysteine	1090 (968 – 1230)	224 (208 – 241)	4.9
N-Acetyl-S-(2-cyanoethyl)-L-cysteine	134 (118 – 151)	1.75 (1.57 – 1.94)	76.6
N-Acetyl-S-(N-methylcarbamoyl)-L-cysteine	455 (390 – 531)	126 (119 – 134)	3.6
N-Acetyl-S-(3,4-dihydroxybutyl)-L-cysteine	365 (340 – 392)	269 (257 – 281)	1.4
N-Acetyl-S-(4-hydroxy-2-butenyl)-L-cysteine	63.1 (55.1 – 72.2)	8.12 (7.41 – 8.89)	7.8
N-Acetyl-S-(2-hydroxypropyl)-L-cysteine	115 (99.4 – 134)	61.0 (54.8 – 67.9)	1.9
N-Acetyl-S-(3-hydroxypropyl-1-methyl)-L-cysteine	1969 (1720 – 2240)	388 (362 – 416)	5.1
t,t-Muconic acid	132 (117 – 150)	73.8 (67.1 – 81.1)	1.8
Mandelic acid	311 (280 – 345)	150 (141 – 160)	2.1
2-Methylhippuric acid	109 (96.5 – 123)	30.1 (27.0 – 33.6)	3.6
3-and 4-Methylhippuric acid	732 (647 -828)	201 (187 – 215)	3.6
Phenylglyoxylic acid	338 (306 – 374)	186 (172 – 200)	1.8

*where applicable, creatine corrected levels provided, +highlighted chemicals were assessed in this study

Cotinine, a substance measured in this study, is a primary nicotine metabolite and is a recognized marker of smoking. Non-smokers typically have serum cotinine levels below 5 ng/mL.[12,13] The mean cotinine level of the 6 pools was 58.03 ng/mL (95% CI 52.40-63.66 ng/mL), suggesting that a sizeable number of participants either smoked themselves or were exposed to second-hand smoke at the time of their blood sample collection.

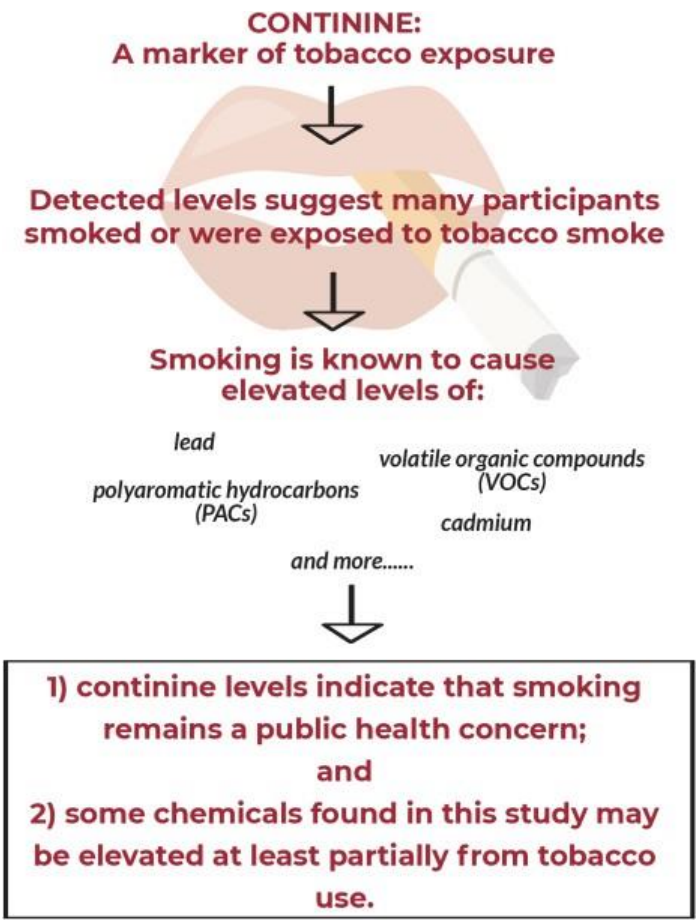


Figure 20: Tobacco impact on biomonitoring

In 2013, 17.6% of people smoked in Saskatchewan, while the national rate was only 14.6%.[158] In 2010, those living in northern Saskatchewan were smoking at nearly twice the provincial rate. Almost half of the population of northern Saskatchewan lives in First Nations communities and it is estimated that 59% of on-reserve persons smoke tobacco.

A questionnaire administered to women postpartum in Saskatchewan (2007-2011) revealed that about 54.2% of the northern population did smoke during pregnancy, compared to 24.2% of the general Saskatchewan population.[160] The Athabasca Health Authority, Keewatin Yatthé and Mamawetan Churchill River Health Regions reported 73%, 54.5% and 49% of women who smoked while pregnant, respectively. [91]

This is to say that the cotinine levels detected align with epidemiologic evidence – that smoking in northern Saskatchewan remains a priority public health concern.

The Saskatchewan Ministry of Health is responsible for developing and amending *The Tobacco Control Act* and *The Tobacco Control Regulations*. The goal of this legislation is to reduce youth access to tobacco products and protect Saskatchewan residents from the harms associated with environmental tobacco smoke. The Act was put into place in 2002 and has since been amended. Laws within *The Tobacco Control Act* include a ban on smoking in

enclosed public places, in cars with children under the age of 16 present, around doorways, windows and air intakes of public buildings, a ban on tobacco use on school grounds, and a number of restrictions on the sale and advertising of tobacco products. As of October 1, 2010, amendments to *The Tobacco Control Act* further reduce youth access to tobacco products and continue to protect Saskatchewan people from the harms of environmental tobacco smoke. On April 1, 2011, the provision of *The Tobacco Control Act* banning the sale of tobacco and tobacco-related products in pharmacies came into effect. The Federal government has instituted *Tobacco Reporting Regulations* which ensures that tobacco manufacturers provide annual reports to Health Canada with their product ingredients, sale numbers, promotional activities and toxic constituents.[161]

The cotinine levels from this study, beyond putting some of the other chemical findings in context, can be used as a benchmark to follow future trends in tobacco use and the effectiveness of current and future tobacco control strategies in the region.

SPECIAL CONSIDERATION IN INTERPRETATION

BIOLOGICAL

The findings in this study are of a specific set of chemicals in the blood serum of a select number of people over a given time. The amount of chemical present at the time of blood draw depends on a wide variety of factors including time of exposure, length of exposure, the chemical properties of the substance itself and the physiology of the participant. Nonetheless, the detected amount of chemical provides valuable baseline information on which to build.

PSYCHOLOGICAL

The interpretation of results in a biomonitoring study can be challenging - environmental research is complex, and consequentially scientific controversies and uncertainties are expected.[8] As well, the assessment of human health risks associated with chemicals is complex since some chemicals may not cause any health concerns at low levels and that levels of concern (threshold levels) are not known for all chemicals. An individual or a community may feel anxiety due to being made aware of the presence of a given substance in a biomonitoring study, but may be left with uncertainty as to what to do with that information.

Given the improvements in laboratory testing, many substances can be detected at minute quantities, so, as in the case of this study, a region can be told that they are being exposed to chemicals or exposed at a higher level compared to another region without an understanding of their health risk. To address these concerns where possible, further explanation will be provided to put the value in context. For some levels, individual action may reduce exposures, whereas other exposures may require broader societal changes. For many levels, there may not be any known health effect; but the value will be important for future assessments to determine if exposures are increasing.

SOCIAL

The findings of this study focus on human exposure to various chemicals, but the presence or absence of chemicals in the participants reflects to some degree the physical and social environments in which they exist. The social

determinants of health such as physical and social environments, are well known to influence the health of populations.[162]

Communities in northern Saskatchewan have specific physical and social environment concerns.[91] Housing conditions, access to fresh and clean water and indoor air quality are other important elements of the physical environment that affect health and can be sources of exposure to a variety of substances.[163] In particular, smoking rates are higher in this area compared to the rest of the province (smoking is a major contributor to indoor air quality), and these elevated rates of smoking influence some of the findings in this study.

Those living in northern Saskatchewan tend to draw on traditional food sources (such as hunting and fishing) to meet their foods needs. Thus, exploring country foods as a source of exposure for some substances has value. Studies that have explored the relationship between traditional diets and chemical expsoures such as methylmercury in northern Canada, including northern Saskatchewan, have identified that a good understanding of possible exposure balanced against the environmental, societal and individual values of consuming country foods is important.[164,165]

BALANCING RISK – BREAST FEEDING IS BETTER

Various substances that have been discussed in this study, particularly a subset of the organic chemicals, are known to, or considered to possibly be, passed on through breast milk when a mother is breastfeeding.

It is well understood that the benefits of breastfeeding outweigh the risks of potential introduction of some of these substances to a newborn or infant. Breastfeeding is the best food to help a newborn grow and develop healthfully. It has been linked to improved cognitive skills. It is often also the most practical and affordable option.

As with all risk considerations, both the risk of exposure and the risk of the actions taken to avoid the exposure should be thoroughly weighed. Although in some cases that can be complex, in the case of breastfeeding the benefits of continuing to breastfeed far outweigh the possible risk of exposure to some chemicals. Breastfeeding is better.

RISK ASSESSMENTS – THE ROLE OF BIOMONITORING

A human health risk assessment (HHRA) is a process wherein the risk to human health and wellbeing is estimated based on exposure. Often the exposure is chemical. A HHRA attempts to answer questions around what health effects could result from exposure to a particular chemical or set of chemicals over a period of time.

A biomonitoring study does not provide sufficient evidence to complete a risk assessment. The information found by biomonitoring can be used to inform a complete human health risk assessment. Biomonitoring does not provide information about how or to what degree a specific exposure occurred. For most substances biomonitoring just gives a snap shot in time and does not allow for a complete understanding of how much a person is exposed to a certain substance over time. Detailed dose and exposure assessments are necessary elements of a HHRA.

The findings of this study can provide insight into whether a thorough HHRA is a reasonable next step, but can also be a resource for any future HHRAs in the region.

CONCLUSIONS

The study provides information on serum levels of a wide range of environmental chemical levels in pregnant women from various geographic areas in northern Saskatchewan. This information is useful as baseline information for monitoring in the future as well as for public policy and preventive health approaches. For some of the environmental chemicals, one is able to make direct comparisons with levels in pregnant women in other areas such as in Alberta.

Overall, most of the environmental chemical testing for northern Saskatchewan revealed levels lower than or comparable to levels in pregnant women in Alberta. Some highlights include:

- Some specific chemicals in the categories such as polybrominated diphenyl ethers (flame retardants), perfluorochemicals, most pesticides tested, dioxins and furans, were either lower than Alberta levels or were undetectable. Uranium, nonylphenol and bisphenol A were also not detectable or were below the level that could be accurately measured.

- Selenium and molybdenum were slightly lower than the average levels in Alberta. Iron levels were also slightly lower in Saskatchewan than Alberta women but cobalt was higher. Both iron and cobalt help prevent anemia (weak blood from low iron or vitamin B12).

- The levels of lead, a heavy metal, were higher than the average levels seen in Alberta. People may be exposed to lead through lead-based paints (in older homes), drinking water coming in contact with old lead plumbing, consumer products, or the ingestion of lead shot or lead bullet fragments in country foods. Smokers or those exposed to second hand smoke tend to have higher levels.

- Mercury levels were comparable to those in Alberta; however, the levels in the far northern area of Saskatchewan were higher. Methylmercury levels tend to be higher in those who consume a lot of fish especially large predatory fish.

- Continine levels, a breakdown product of nicotine, were higher in northern Saskatchewan women indicating higher exposures to tobacco smoke either through smoking or passive smoke exposure. Exposure to tobacco smoke increases exposure to many other environmental chemicals as well.

A factsheet has been prepared called “Reducing My Exposure to Environmental Chemicals” which is available at: https://publications.saskatchewan.ca:443/api/v1/products/101376/formats/112050/download

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The technical report and this summary report were prepared by:

Dr. James Irvine	Saskatchewan Ministry of Health & SK Health Authority
Megan Reichert	Alberta Health
Briana Yee	Saskatchewan Ministry of Health (summer student)
Dr. Jasmine Hasselbach	Public Health & Preventive Medicine Resident, SK Ministry of Health

With contributions from:

Technical Working Group:

Tim Macaulay	Saskatchewan Ministry of Health
Dr. Jennifer Graydon	Alberta Health
Dr. Valerie Mann	Saskatchewan Ministry of Health
Nicole Maserek	Saskatchewan Ministry of Health
Fred Ackah	Alberta Health
Dr. Weiping Zhang	Alberta Health
Dr. David Kinniburgh	Alberta Centre for Toxicology
Dr. Amy MacDonald	Alberta Centre for Toxicology
Maureen Anderson	Public Health Agency of Canada Placement – SK Ministry of Health
Haoer Ying	Saskatchewan Ministry of Health (summer student)
Sheila Kelly	Saskatchewan Ministry of Health

Other contributors:

Penni Edwards	Alberta Centre for Toxicology
Patricia Parmentier	Alberta Centre for Toxicology
Xu Zhang	Alberta Centre for Toxicology
Dr. Stephan Gabos	Environmental Health Consultant, University of Alberta
Dr. Don Schopflocher	Consultant
Sylvia Tiu	Contractor, Alberta Centre for Toxicology
Dr. Greg Horsman	Roy Romanow Provincial Laboratory
Dr. Paul Levitt	Roy Romanow Provincial Laboratory
Jim Putz	Roy Romanow Provincial Laboratory

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Rolf Puchtinger	Saskatchewan Ministry of Health

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Cindy Rogers	Saskatchewan Ministry of Health