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Results Report

Contaminant Biomonitoring in the Northwest Territories Mackenzie Valley: Investigating the Links Between Contaminant Exposure, Nutritional Status, and Country Food Use

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Ethics approval and consent to participate

Participants provided a free consent. Ethics approval was obtained by the University of Waterloo Research Ethics Committee (#20173, #20950), the Stanton Territorial Health Authority for Human Research (29/12/2015), and the Aurora Research Institute (#15560, #15775, #15966, #15977, #16021). Health Canada ethics approval was also obtained regarding additional analysis of the biobanked samples (REB 2016-0022).

Availability of data and material

The current manuscript reports aggregate data. In respect to the disclosure agreement with communities and respect of anonymity of participants from small communities, the researchers cannot share any individual-level results. However, the aggregate of the results at the regional level collected will be shared upon request.

Funding

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Key messages

- Following consultation visits, leaders and community members expressed an interest in the research team conducting a biomonitoring project in Jean Marie River, K'atl'odeeche, West Point, Deh Gah Gotie, Ka'a'gee Tu, Sambaa K'e, Tulit'a, Déline and K'asho Got'ine.
- The biomonitoring project was run in these communities between January 2016 and March 2018. A total of 537 participants agreed to provide samples, representing about 18% of residents living in these communities, or 9% living in the Dehcho and Sahtú region.
- Country foods represented about 5.1% of the caloric intake of participants over the study period (January 2016, November 2016-January 2017, November 2017-March 2018).
- Levels of contaminants in the urine, blood and hair samples of participants were generally similar to those seen in other biomonitoring studies in Canada. Average lead levels in blood and urine appeared higher than other populations in Canada, but lower than levels associated with immediate health problems.
- Most participants were below the health guidance values for toxic metals. 3.6% of the participants had mercury, cadmium or lead levels above the guidance values and were offered a re-testing.
- The health risks posed by these contaminants to most project participants appeared low. Overall, these results reinforce that the health benefits of country foods generally outweigh contaminant risks.

1. INTRODUCTION

Country food consumption in First Nations peoples is associated with improved nutrition, food security, and lower rates of chronic diseases; however, these foods can also pose potential risks via exposure to contaminants such as mercury and cadmium. Elevated mercury concentrations in some fish species in some lakes in the Dehcho Region of the Mackenzie Valley (Northwest Territories) resulted in a series of food consumption advisories that suggested people limit their consumption of walleye, northern pike, and lake trout from specific lakes in the region (NWT, 2016). Therefore, a multi-year contaminant biomonitoring study has begun to investigate current levels of contaminant exposure in participating First Nations communities. The project is funded by the Northern Contaminants Program (NCP). This work involves human hair, urine, and blood sampling in communities, laboratory analysis of samples, the administration of two dietary surveys (a food frequency questionnaire (FFQ) and a 24-hour recall) and a health messages survey. Results will be returned to participating communities and individuals. This work will incorporate a risk-benefit approach to promote the use of country foods in order to improve nutrition and food security while lessening contaminant exposure among Dehcho and Sahtú First Nations communities. The results from the analysis of the data (aggregate results of Jean Marie River, K'atl'odeeche, West Point, Deh Gah Gotie, Ka'a'gee Tu, Sambaa K'e, Tulit'a, Déline and K'asho Got'ine) is presented in this report.

2. METHODS

2.1. Partnerships and preparation

Professor Brian Laird, from University of Waterloo, Ontario, first met with the Aboriginal Aquatic Resources & Ocean Management (AAROM) coordinator George Low, working under the Dehcho First Nations (DFN)' umbrella, to discuss the human biomonitoring research. Dr. Heidi Swanson also from University of Waterloo was involved in these talks as she was monitoring levels of mercury in the fish of this region and was working in collaboration with the DFN. These were the first steps in an ongoing process to strengthen relationships and to create a project relevant for the communities involved. Brian Laird was then contacted by the Sahtú Resources Renewable Board (Deborah Simmons) to expand the project in the Sahtú region. The resources coordinators of each community were tentatively consulted through email, phone calls and in person meetings. When the leadership wanted to see this project happening in the community, public meetings with community members were planned. Brian Laird and his team (Mylene Ratelle, Matthew Laird, Sara Packull-McCormick, Danielle Brandow, Leicester Fung, Kelly Skinner, Kelsey Speed, Sharon Mackintosh) introduced the project during public meetings in Jean Marie River, K'atl'odeeche, West Point, Deh Gah Gotie, Ka'a'gee Tu, Sambaa K'e, Tulit'a, Déline, K'asho Got'ine and the Metis Association of Hay River. After this, the research team worked with the local partner to refine a Community Research Agreement (CRA) that clarified the responsibilities and expectations of the research team and each participating community. The agreement also defined the scope of the work, expected benefits and outcomes, principles of informed consent, and the data management plan. In preparation for the project, the project team received ethics clearance from the University of Waterloo Research Ethics Committee, the Stanton Territorial Health Authority and obtained the necessary research license from the Aurora Research Institute.

2.2. Recruitment and consent form

The team coordinated with the band office for the rental of space in the community center for 2 to 9 days. Members of the research team traveled to the participating community to collect samples and data. One or two local research coordinators were hired in each community to facilitate the implementation of the project, assist with participant recruitment and survey completion. The local coordinators contacted potential participants, explained the objectives of the study, and described the informed consent process. All members aged 6 years and older were eligible to participate regardless of sex, family status, or other characteristics**.** Potential participants met with research team members and the project was explained in one-on-one sessions. Those that chose to participate signed an informed consent form and were asked to provide basic personal information (age, sex, smoking status).

2.3. The 24h recall survey

Participants were asked in detail what they had eaten over the previous 24 hours using a web-based survey of eating behaviors (Hanning *et al.*, 2009). The survey used a multi-pass technique to sequentially ask about foods consumed by meal occasion, food details (e.g., methods of preparation, portion sizes selected from six options and associated photographic images), and commonly missed additions to foods (e.g., cream added to coffee). Participants were then asked to review answers for completeness and accuracy. The survey included a bank of approximately 900 food and beverage options. For the proposed research, local country foods and locally-obtained photos of these foods, as prepared, were added to assist food selection and portion size estimation. The local coordinators and the members of the research team were available to help participants finish the food surveys. Participants had the choice to participate in this component of the study. In total, 199 participants completed the 24h recall.

2.4. Food Frequency Questionnaire (FFQ)

This survey was based on the questionnaire previously used in the Northwest Territories in the 1990's. Through a pilot research project, this questionnaire was tested and modified for use in the Dehcho region. Traditional knowledge was incorporated to make sure that the foods included in this questionnaire were relevant to the region and used names participants would recognize. The survey was built in QuickTapSurvey and was administered on iPads through the QuickTapSurvey app. This FFQ gathered information about the country foods participants had eaten over the past year. Survey questions asked about the country foods consumed, how often the foods were eaten, and how the foods were prepared. Participants completed the questionnaire on iPads with the assistance of a local research coordinator. Participants had the choice to participate in this component of the study. In total, 238 participants completed the FFQ.

2.5 Health Messages Survey

In addition to questions on food consumption, participants were invited to respond to a short survey on contaminants, including the awareness and understanding of current health messages on country foods and contaminants, questions on risk perception related to contaminants, perspectives on health and country foods and how they usually get their information on health, foods and/or contaminants. Questions were asked using the same iPad tool as the one used for the FFQ survey. Questions on message awareness and comprehension were specific to the regions, including current health advisories on mercury and cadmium. Risk perception questions were adapted from survey tools developed by Furgal and Boyd to assess risk perception in Nunavut and Nunavik. In total, 87 participants completed this questionnaire.

2.6. Biological Sampling

Hair, blood and/or urine samples were collected from each participant. Every participant had the choice to provide any of the above types of samples. For those who agreed to provide hair, a small bundle was collected by a team member with scissors. For those who agreed to provide urine, they were provided with a container for the sample. For those who agreed to provide a blood sample, a nurse collected 3 tubes of blood. Each type of sample provides different types of information regarding contaminant and nutrient levels. For the data collection, the local coordinators assisted with hair sampling, preparing samples for storage and shipment, and assisting participants during the informed consent process and questionnaires.

2.7. Chemical Analysis

Metal nutrients (e.g., zinc, selenium), toxic metals (e.g, cadmium, arsenic, mercury), and persistent organic pollutants (e.g., PCBs) were measured in blood, urine, and/or hair samples. In addition, blood lipids were measured. Each hair sample was analyzed for total mercury in the laboratory of Brian Branfireun at Western University. Analyses were completed using a Direct Mercury Analyzer. Furthermore, whole blood and urine samples were analyzed at the Université de Montréal by Inductively Coupled Plasma Mass Spectrometer in the laboratory of Michele Bouchard. Over 20 metals were quantified in hair, urine, and blood. These approaches allowed us to compare participants results to those generated from other biomonitoring programs, such as the First Nations Biomonitoring Initiative (FNBI) and the Canadian Health Measures Survey (CHMS) (AFN, 2013; Health Canada, 2010; 2013). In addition, analysis of persistent organic pollutants (POPs) in blood plasma were conducted in the laboratory of Alain Leblanc of the Centre de Toxicology du Québec (CTQ). The fatty acid composition of whole blood was determined by high throughput gas chromatography system by Ken Stark at the University of Waterloo. Also, for participants who chose to opt-in, aliquots of the urine and blood samples were stored within a biobank to allow for the measurement of chemicals not included within the original suite of contaminants described in this NCP proposal. These samples will be stored in the biobank for up to 10 years. From this biobank, we plan to measure other environmental contaminants and nutrition markers from urine/blood samples in the future. Once these results are available, the results for these contaminants will also be returned to individual participants and the community. These additional analyses are providing a more complete understanding of peoples' exposure to contaminants from foods, including from store-bought foods.

2.8 Biobanked analysis

To provide an understanding of the full suite of dietary chemical exposures in these First Nations communities, we requested additionnal funding from the Population Biomonitoring Section of Health Canada in order to analyze chemicals that fall outside of the NCP mandate to measure phthalates, polycyclic aromatic hydrocarbons (PAHs), cotinine, and arsenic species in urine from a subset of the study participants in the Northwest Territories. The inclusion of these additional chemicals also reflects feedback from northern partners who have indicated that they would like the project to include these additional chemicals. Phthalates are found in food packaging and therefore may be elevated in relatively remote communities with less access to fresh food. Also, as cadmium levels are associated with smoking, the measurement of cotinine, the predominant metabolite of nicotine, will provide important information regarding the sources of cadmium exposure among study participants. Elevated exposure to inorganic arsenic species may come from naturally-high soil arsenic levels reported in some parts of the Northwest Territories. Inorganic arsenic exposure is best measured through the measurement of methylated arsenic metabolites (e.g. MMA and DMA) in urine. Population can be exposed to PAHs by smoking or cooking, but also through and industrial processes and pollution by fossil fuel and mining activity. These analysis were conducted in the laboratory of Alain Leblanc of the Centre de Toxicology du Québec at the National Institute of Public Health of Québec (INSPQ).

2.9. Returning Results

Each study participant that provided a hair, urine, and/or blood sample received a confidential, plain-language letter detailing their contaminant exposure levels. The letters were written to provide sufficient context so that the results were meaningful without going into so much detail to make them overwhelming. The individual results follow-up letters, which were designed in consultation with representatives from the Government of the Northwest Territories Department of Health and Social Services (NTHSS), Health Canada, and the Regional Contaminants Committee emphasized the general healthfulness and importance of country foods.

3. RESULTS and DISCUSSION

3.1. Participation

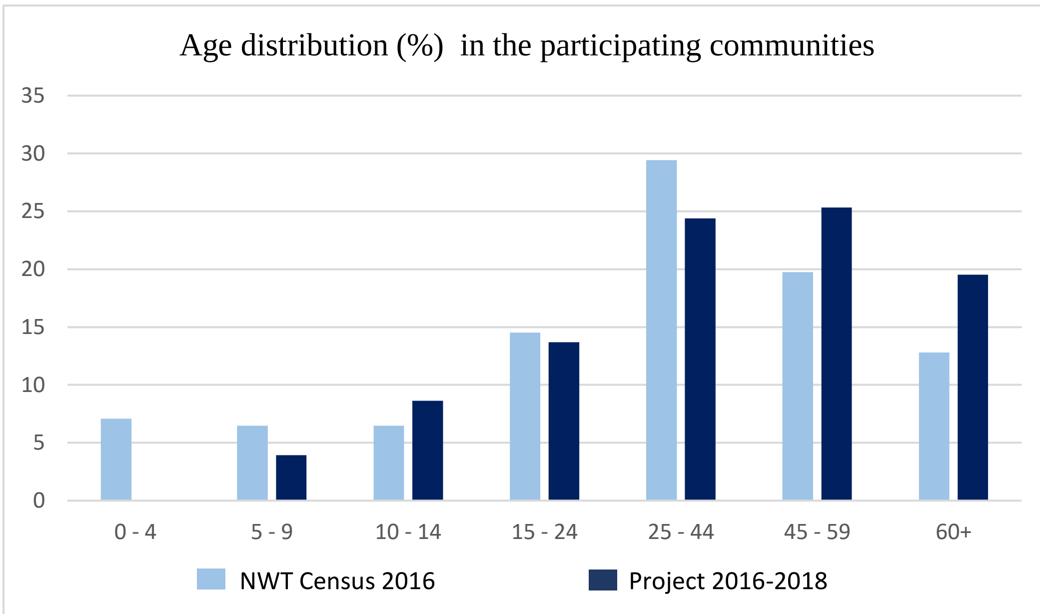
In winter time (January 2016, November 2016-January 2017, November 2017-March 2018), participants were recruited from 9 communities in the Dehcho and Sahtú for the biomonitoring project in order to provide biological samples and to complete two dietary surveys and one health messages questionnaire. About 18.2% (537 of 2951) of the residents from these communities agreed to take part. The participation rate for each community was between 12 and 40%. At the Dehcho and Sahtú level, it represents 8.9% of the residents (n=6018). Four participants chose to withdraw from the study, therefore, their characteristics and results will not be presented in this report. The research team spent up to 9 days in each community to run the biomonitoring project. A total of 917 samples were collected: 443 hair samples, 198 urine samples and 276 blood samples. Characteristics of participants, such as age, sex, smoking status, alcohol consumption and body mass index are found in Table 1. In total, 89 participants were under 18 years old.

Table 1. Characterization of participants (n=533)

Parameters	**Values**
Age	Range: 6 to 88 years old Mean: 40.8 years old Refusal: 4.5 %
Sex	Males: 49.5 % Females: 50.5 % Refusal: 0.0 %
Smoking status (in the last 24h)	Smokers: 39.8 % Not smokers: 59.3 % Refusal: 0.9 %
Alcohol consumption (in the last 24h)	Alcohol: 12.8 % No alcohol: 84.8 % Refusal: 2.4 %
Body mass index - for adults only (+18) Note: Below 19: Underweight, risk for health 19 to 25: Healthy weight Above 25: Overweight, risk for health	Range: 17.3 to 60.0 Mean: 27.8 Refusal: 17.5 %

Participating individuals were 50% men and 50% women. In relatively large communities (more than 100 residents), a random selection was done to actively contact potential participants. In both big and small communities, passive recruitment by posters, mouth to ear and radio interview was also done. Based on community feedback during the consultation stage, walk-in's were welcome to participate in order to make the project more inclusive. Overall, participants included children, adults, and elders of both sexes. As such, the results detailed in this report provide a reasonable snapshot across participating communities. The socio-demographics of the participating communities were similar to census estimates (Bureau of Statistics of the Northwest Territories for 2016). However, the current project does not include children under 6 years old, and is slightly over represented for older age groups (see figure 1).

Figure 1. Comparison of the distribution of age between the participants and the residents of these communities.



3.2. The 24h recall survey

A total of 199 participants completed the 24h recall survey. The participants were 49% male, 51% female, with an average age of 40 years old (range: 6 to 85 y.o.). Results showed that, on the day prior to sample/data collection in fall/winter time, an average for participants of 5.1 % (range 0 to 38%) of total calories consumed were from wild-harvested country foods. Approximately, one-in-three (31%) respondents reported consuming country food (e.g., caribou meat) in the previous 24 hours. Since this data collection took place between November – March of each sampling year, moose meat was the most often eaten country food from this food survey. Participants also reported eating bison, rabbit, hare, caribou, whitefish, bass fish, catfish, fish duck, wild chicken, spruce grouse, lake trout, beaver, blueberries and garden vegetables harvested in the community. The average calories consumed in the previous 24h was 1980 kcal (range: 10 to 10596 kcal) with 37 % of those calories being from fat. The average number of Canada Food Guide servings for Vegetables/Fruits, Grains, Dairy products, and Meats consumed are reported in Table 2. Fruit/vegetable consumption tended to be lower than recommended by the Canadian Food Guide for Indigenous populations. The Table 3 reports the nutrients intake estimated by the questionnaire. The median intake of vitamins C, D, folate, calcium and potassium seem to be below the Estimated Average Requirement (EAR). The EAR values are established for age/sex categories (Health Canada, 2010).

Table 2. Main food groups portions consumed

Group	Mean (min-max)	Recommended by the Canada's Food Guide - First Nations, Inuit and Métis
Vegetables and Fruits	2.9 (0- 18.6)	7-10
Grain Products	4.9 (0-23.8)	6-8
Dairy Products	1.3 (0-7.9)	2-3
Meat and Alternatives	3.2 (0-16.0)	2-3
Other	8.1 (0-37)	-

Table 3. Intake of nutrients

Nutrients		Average	Median	95th percentile
Fatty acids	Total Fatty Acids (g)	2.10	0.96	5.60
	Omega 3 (DHA+EPA) (g)	0.30	0.04	1.86
Vitamins	Vitamin A (RAE, µg)	513	442	1206
	Vitamin B1/Thiamin (mg)	1.5	1.3	3.6
	Vitamin B2/Riboflavin (mg)	2.2	1.8	5.0
	Vitamin B3/ Niacin (NE, mg)	39	37	79
	Vitamin B6 (mg)	9.5	1.3	3.4
	Vitamin B12 (µg)	7.2	4.9	21.9
	Vitamin C (mg)	80	36	263
	Vitamin D (µg)	4.6	3.2	15.3
	Folate (DFE, µg)	317	291	702
	Retinol (RE)	320	265	789
Macro-elements	Calcium (mg)	651	546	1368
	Potassium (mg)	2497	2139	5017
	Sodium (mg)	2959	2417	6549
Micro-elements	Selenium (µg)	117	105	240
	Iron (mg)	14	13	30
	Zinc (mg)	13	10	33

3.3. Food Frequency Questionnaire

A total of 237 participants completed the FFQ. The participants were 49% male, 51% female, with an average age of 42 years old (range: 6 to 79 y.o.). The most eaten country foods are reported in Table 4. Moose (93%), Whitefish (84%), and Lake Trout (61%) were consumed by the largest number of participants. Canada goose (55%) was the most commonly consumed game bird followed by mallard (40%). Of the most commonly consumed land mammal foods, 5 of 8 came from moose. These foods include moose meat, smoked moose meat, moose ribs, moose bone marrow, and moose tongue. The most commonly consumed berries were wild raspberries (42%), wild strawberries (32%) and low grey blueberries (32%). Berries and plants that were reported to be more occasionally consumed included: high black blueberries, high bush cranberries, Saskatoon berries, spruce gum, bog cranberries, blackberries, rat root, Labrador tea, red currants, wild rhubarb, wild peppermint, wild mushrooms, rosehips, wild onions, purple goose berries, and cloud berries.

Table 4. The country food the most consumed and the average frequency by week over one year within the respondents from the Mackenzie Project.

	Country Food Consumed	**Percent Consuming (%)**	**Average Frequency (days/week)**
1	Moose	93	1.9
2	Whitefish	84	1.5
3	Lake Trout	61	1.2
4/5	Woodland Caribou	55	1.7
	Canada Goose	55	1.1
6	Moose (Smoked)	54	1.5
7	Rabbit	51	1.2
8	Moose (Ribs)	47	1.4
9	Whitefish (Smoked)	44	1.2
10	Northern Pike	43	1.1
11	Wild Raspberries	42	1.1
12/13	Mallard	40	1.1
	Moose (Bone Marrow)	40	1.0
14	Moose (Tongue)	38	1.1
15	Beaver	36	0.94

[a]This percentage includes the participants who reported eating the food and gave the frequency of the food consumption (days/week)
[b]This is for consumers only (those who did not report consumption are not represented in this value)

When fish, land mammals, and game birds were harvested, participants reported eating the meat as well as most, if not all, organs and other parts of the animal. For example, when land mammals were harvested, participants reported eating the meat, ribs, bone marrow, head, tongue, liver, heart, kidney, bones (in soup/broth), fat, guts/tripe, brain, and blood. This was also true for birds (meat, gizzard, kidney, heart, liver, eggs, and fat) and for fish (meat, head, eggs, fish-pipe, sperm, and liver). A range of preparation methods were documented (cooked, pan fried/deep fried, grilled/roasted/baked, smoked, raw, boiled/soup/stew, smoked/fully dried, smoked/half dried, campfire). The respondent consuming the different parts and the frequency of the consumption for these individuals are reported in Table 5.

A comparison with a project done in the 90s in the Dene communities of the Dehcho and Sahtú (CINE, 1996) using a similar survey (adults only), suggest some changes in country food usage over the past 20 years. Whitefish is still the most consumed fish in these regions. However, adults appeared to eat more whitefish (% consumers and frequency) in this project than more than 20 years ago. Smaller game like muskrat, rabbit and beaver are more consumed. The majority of the birds and the berries and plants are also more consumed nowadays.

Great Slave Lake, the Mackenzie River, and Great Bear Lake were the main waterbodies from which fish were obtained. However, participants reported eating fish from a number of other waterbodies including: Colville Lake, Willow Lake, Trout Lake, and Kakisa Lake.

The majority of participants reported eating fish only from waterbodies that did not have a Government of the Northwest Territories consumption notice for that fish species (http://www.hss.gov.nt.ca/). However, approximately 17% of participants reported consuming Lake Trout from a waterbody with a consumption notice for Lake Trout. As well, approximately 13% of participants reported consuming Northern Pike from a waterbody with a consumption notice for Northern Pike and approximately 16% of participants reported eating Walleye from a waterbody with a consumption notice for Walleye. Only approximately 3% of participants reported consuming Loche (Burbot) from a waterbody with a consumption notice for Loche. Overall, approximately 29% of participants reported eating at least one fish species from a specific lake for which a consumption notice for mercury was issued for that species.

Table 5. Part consumed by participants and average frequency of consumption per week by consumer.

			Mackenzie Valley			
			All respondents (n=237)		**Adult respondents only (n=197)**	
			Consumers (%)	Frequency per week	Consumers (%)	Frequency per week
FISH	**Whitefish**	Meat: Cooked	86	1.5	89	1.6
		Meat: Smoked	45	1.2	48	1.2
		Head	16	0.8	19	0.8
		Eggs	26	1.1	31	1.1
		Fish-pipe	28	1.2	34	1.2
		OTHER:	Liver, Lungs, Guts, Tail			
	Inconnu (Coney)	Meat: Cooked	28	1.1	32	1.1
		Meat: Smoked	10	1.0	11	1.0
		Head	5	0.7	6	0.7
		Eggs	5	0.8	7	0.8
		Fish-pipe	5	0.8	6	0.8
		OTHER:	Lungs, Guts			
	Cisco	Meat: Cooked	6	1.1	6	1.0
		Meat: Smoked	2	0.9	2	1.0
		Head	2	0.5	2	0.5
		Eggs	2	1.6	2	1.6
		Fish-pipe	2	1.2	3	1.2
		OTHER:				
	Lake Trout	Meat: Cooked	61	1.2	65	1.2
		Meat: Smoked	20	1.1	21	1.0
		Head	17	1.3	19	1.3
		Eggs	8	1.4	9	1.5
		Fish-pipe	14	1.2	17	1.2
		Auxiliary Process	2	2.3	2	2.3
		OTHER:	Eyes, Guts, Fins			
	Loche (Burbot)	Meat: Cooked	17	1.0	19	1.0
		Meat: Smoked	1	0.5	1	0.5
		Head	3	0.6	4	0.6
		Eggs	4	0.7	5	0.7
		Fish-pipe	3	0.6	4	0.6
		Sperm	0.6	1.5	0.7	1.5
		Liver	8	0.7	14	0.7
		OTHER:	Guts			

	Northern Pike (Jackfish)	Meat: Cooked	43	1.1	44	1.2
		Meat: Smoked	11	1.4	10	1.4
		Head	3	0.6	3	0.7
		Eggs	6	0.9	8	0.9
		Fish-pipe	8	0.8	10	0.8
		OTHER:	Liver, Stomach, Guts			
	Grayling (Bluefish)	Meat: Cooked	22	0.9	25	0.8
		Meat: Smoked	5	0.8	6	0.9
		Head	2	1.3	2	1.3
		Eggs	2	0.5	2	0.5
		Fish-pipe	3	1.0	3	1.0
		OTHER:				
	Walleye (Pickerel)	Meat: Cooked	33	1.1	35	1.2
		Meat: Smoked	4	0.7	4	0.6
		Head	2	0.8	2	0.8
		Eggs	2	1.0	2	1.2
		Fish-pipe	3	1.1	3	1.2
		OTHER:	Liver, Guts, Cheeks			
	Longnose sucker (Red sucker)	Meat: Cooked	17	0.9	17	0.9
		Meat: Smoked	8	0.8	9	0.9
		Head	7	1.0	8	0.8
		Eggs	4	0.8	5	0.8
		Fish-pipe	3	0.6	4	0.6
		OTHER:	Air bladder, Guts			
Land animals	**Woodland Caribou**	Meat: Cooked	56	1.7	58	1.7
		Meat: Smoked	30	1.3	32	1.2
		Ribs	27	1.4	28	1.4
		Head	13	1.1	16	1.1
		Heart	21	0.8	23	0.8
		Tongue	22	1.0	23	1.1
		Liver	13	0.9	14	0.8
		Blood	6	0.9	7	0.9
		Stomach	9	1.1	10	1.1
		Kidney	15	0.8	18	0.8
		Bone Marrow	21	1.0	21	1.0
		Bones in soup	19	1.2	21	1.1
		Fat	18	1.0	18	0.9
		Brain	3	0.6	4	0.6
		OTHER:	Guts			
	Barrenland Caribou	Meat: Cooked	18	1.3	20	1.3

	Meat: Smoked	11	0.7	13	0.7
	Ribs	10	1.3	12	1.3
	Head	5	0.8	7	0.8
	Heart	9	1.0	11	1.0
	Tongue	7	0.9	9	0.9
	Liver	5	0.9	6	0.9
	Blood	3	1.1	3	1.1
	Stomach	4	1.3	5	1.3
	Kidney	5	0.8	7	0.8
	Bone Marrow	8	0.9	9	0.9
	Bones in soup	8	0.8	10	0.8
	Fat	5	0.7	7	0.7
	Brain	2	0.5	2	0.5
			Feet		
	OTHER:				
Bison	Meat: Cooked	20	0.8	22	0.8
	Meat: Smoked	7	0.8	8	0.7
	Ribs	4	1.1	5	1.1
	Head	0	0.5	1	0.5
	Heart	3	0.8	4	0.8
	Tongue	3	0.9	4	0.9
	Liver	3	0.8	4	0.8
	Blood	0	0.5	1	0.5
	Stomach	0	0.5	1	0.5
	Kidney	3	0.8	4	0.8
	Bone Marrow	3	0.8	3	0.7
	Bones in soup	3	0.8	3	0.7
	Fat	3	0.7	3	0.5
	Brain	0	-	0	-
	OTHER:				
Moose	Meat: Cooked	94	1.9	94	2.0
	Meat: Smoked	55	1.5	56	1.5
	Ribs	47	1.4	53	1.4
	Head	26	0.9	29	0.9
	Tongue	38	1.1	42	1.1
	Heart	30	0.9	35	0.9
	Liver	23	0.7	26	0.8
	Kidney	29	0.8	34	0.8
	Blood	8	0.7	10	0.7
	Bone Marrow	40	1.0	44	1.0
	Bones in soup	30	1.4	35	1.4
	Fat	35	1.1	38	1.1
	Brain	4	0.7	4	0.6
	Tripe	8	0.7	10	0.7

	Intestines	17	0.9	20	0.9
	OTHER:	Nose			
Elk	Meat: Cooked	3	1.0	4	0.9
	Meat: Smoked	1	0.5	1	0.5
	Ribs	0	-	1	-
	Head	0	-	1	-
	Heart	0	-	0	-
	Tongue	0	-	1	-
	Liver	0	-	0	-
	Blood	0	-	0	-
	Stomach	0	-	0	-
	Kidney	0	-	0	-
	Bone Marrow	0	-	0	-
	Bones in soup	0	-	0	-
	Fat	0	-	0	-
	Brain	0	-	0	-
	OTHER:				
Whitetailed deer	Meat: Cooked	3	0.8	4	0.8
	Meat: Smoked	0	-	0	-
	Ribs	0	1.5	1	1.5
	Head	0	-	0	-
	Tongue	0	1.5	1	1.5
	Heart	0	1.5	1	1.5
	Liver	0	0.5	1	0.5
	Kidney	0	1.5	1	1.5
	Blood	0	0.5	1	0.5
	Stomach	0	-	0	-
	Bone Marrow	0	-	0	-
	Bones in soup	0	-	0	-
	Fat	0	-	0	-
	Brain	0	-	0	-
	OTHER:				
Rabbit	Meat: Cooked	55	1.2	57	1.2
	Meat: Smoked	2	0.7	3	0.7
	Head	12	1.2	14	1.1
	Liver	8	0.9	10	0.9
	Blood	3	0.7	3	0.7
	Brain	10	1.3	11	1.3
	OTHER:	Ribs, Kidney, Heart			
Beaver	Meat: Cooked	36	0.9	37	1.0
	Meat: Smoked	5	1.0	6	1.0
	Tail and Feet	16	0.8	16	0.8
	Liver	5	0.8	6	0.8

		Blood	0	0.5	1	0.5
		Brain	0	-	0	-
		OTHER:		Kidney		
	Muskrat	Meat: Cooked	6	0.6	6	0.6
		Meat: Smoked	0	0.5	1	0.5
		Tail	2	0.9	3	0.9
		Liver	1	1.0	1	1.0
		Blood	0	0.5	1	0.5
		Brain	0	-	0	-
		OTHER:				
	Lynx	Meat: Cooked	9	1.0	11	1.0
		Meat: Smoked	0	-	0	-
		Head	0	-	0	-
		Liver	1	1.2	2	1.2
		Blood	0	1.5	1	1.5
		Brain	0	-	0	-
		OTHER:		Ribs		
	Porcupine	Meat: Cooked	6	0.6	6	0.6
		Meat: Smoked	0	-	0	-
		Liver	1	1.0	1	1.0
		Blood	0	-	0	-
		Brain	0	-	0	-
		OTHER:		Kidney		
	Dall Sheep	Meat: Cooked	5	0.8	5	0.8
		Meat: Smoked	0	-	0	-
		Liver	0	-	0	-
		Blood	0	-	0	-
		Brain	0	-	0	-
		OTHER:				
	Bear	Meat: Cooked	1	1.0	1	1.5
		Meat: Smoked	0	-	0	-
		Fat	1	1.0	1	1.5
		Blood	0	0.5	1	0.5
		Brain	0	-	0	-
		OTHER:				
BIRDS	**Spruce Grouse**	Meat: Cooked	28	1.0	29	0.9
		Meat: Smoked	1	1.5	1	1.5
		Gizzard	8	0.8	10	0.8
		Kidney	5	1.0	6	1.0
		Heart	6	0.6	8	0.6
		Liver	4	0.6	5	0.6
		Eggs	0	0.5	1	0.5
		OTHER:				

Sharp-tailed Grouse	Meat: Cooked	24	1.0	27	1.0
	Meat: Smoked	0	-	1	-
	Gizzard	5	1.2	6	1.2
	Kidney	3	0.7	3	0.7
	Heart	5	0.7	6	0.7
	Liver	3	0.8	4	0.8
	Eggs	0	0.5	1	0.5
	OTHER:				
Ptarmigan	Meat: Cooked	25	0.8	27	0.8
	Meat: Smoked	1	0.5	1	0.5
	Gizzard	5	0.7	6	0.7
	Kidney	3	0.8	3	0.8
	Heart	6	0.6	7	0.6
	Liver	3	0.8	4	0.8
	OTHER:				
Black Duck	Meat: Cooked	29	0.9	31	0.8
	Meat: Smoked	2	1.6	2	1.6
	Gizzard	4	0.6	5	0.6
	Kidney	1	0.5	2	0.5
	Heart	4	0.6	5	0.6
	Liver	2	0.5	3	0.5
	Eggs	0	0.5	1	0.5
	OTHER:	Head, Lungs			
Mallard	Meat: Cooked	43	1.1	44	1.1
	Meat: Smoked	1	0.5	1	0.5
	Gizzard	8	1.0	9	1.0
	Kidney	4	0.8	5	0.8
	Heart	8	1.1	9	1.1
	Liver	5	0.8	6	0.8
	Eggs	3	0.8	4	0.8
	OTHER:	Head			
Fish Duck	Meat: Cooked	1	0.5	1	0.5
	Meat: Smoked	0	-	0	-
	Gizzard	0	-	0	-
	Kidney	0	-	0	-
	Heart	0	-	0	-
	Liver	0	-	0	-
	Eggs	0	-	0	-
	OTHER:				
Oldsquaw	Meat: Cooked	3	0.5	4	0.5
	Meat: Smoked	0	-	0	-
	Gizzard	2	0.5	2	0.5
	Kidney	0	-	0	-

	Heart	2	0.5	2	0.5
	Liver	0	0.5	1	0.5
	Eggs	0	-	0	-
	OTHER:	Lungs			
Wigeon	Meat: Cooked	6	1.1	7	1.2
	Meat: Smoked	1	0.5	1	0.5
	Gizzard	3	1.3	3	1.3
	Kidney	2	1.0	2	1.0
	Heart	2	1.6	3	1.6
	Liver	2	0.8	2	0.8
	Eggs	1	0.8	2	0.8
	OTHER:	Head, Guts			
Canvasback	Meat: Cooked	5	0.9	6	0.9
	Meat: Smoked	0	0.5	1	0.5
	Gizzard	2	1.2	3	1.2
	Kidney	0	0.5	1	0.5
	Heart	2	1.4	2	1.4
	Liver	1	0.5	1	0.5
	Eggs	0	0.5	1	0.5
	OTHER:				
Canada Goose	Meat: Cooked	57	1.1	59	1.0
	Meat: Smoked	8	1.1	9	0.9
	Gizzard	12	0.8	15	0.8
	Kidney	8	0.7	10	0.7
	Heart	12	0.8	15	0.8
	Liver	7	0.8	8	0.8
	Fat	11	0.8	13	0.8
	Eggs	3	0.8	3	0.8
	OTHER:	Head, Neck			
Snow Goose	Meat: Cooked	19	0.8	22	0.8
	Meat: Smoked	3	0.5	4	0.5
	Gizzard	6	0.8	7	0.8
	Kidney	3	0.5	4	0.5
	Heart	4	0.6	5	0.6
	Liver	3	0.5	3	0.5
	Eggs	0	0.5	1	0.5
	OTHER:	Head			
Pintail	Meat: Cooked	13	0.7	14	0.6
	Meat: Smoked	1	0.5	1	0.5
	Gizzard	4	0.6	5	0.6
	Kidney	2	0.5	3	0.5
	Heart	3	0.6	4	0.6
	Liver	1	0.5	2	0.5
	Eggs	1	0.5	2	0.5

		OTHER:	Head			
	Swan	Meat: Cooked	19	0.8	21	0.8
		Meat: Smoked	4	0.8	4	0.8
		Gizzard	6	0.6	7	0.6
		Kidney	4	0.7	5	0.7
		Heart	6	0.7	7	0.7
		Liver	4	0.6	5	0.6
		Eggs	1	0.5	1	0.5
		OTHER:				
PLANTS and BERRIES	**Low Grey Blueberries**		33	1.1	35	1.1
	High Black Blueberries		21	1.4	20	1.2
	Bog Cranberries		24	0.8	26	0.8
	High Bush Cranberry Parts		20	0.8	18	0.8
	Green Gooseberries		3	0.6	4	0.6
	Purple Gooseberries		4	0.6	4	0.6
	Blackberries		11	0.9	9	0.7
	Wild Raspberries		42	1.1	41	1.1
	Wild Strawberries		32	1.3	30	1.1
	Cloud Berries		11	1.0	11	0.7
	Red Currants		1	0.5	2	0.5
	Black Currants		2	0.9	2	0.8
	Saskatoon Berries		24	1.3	25	1.3
	Rosehips		9	0.8	9	0.8
	Labrador Tea		16	1.1	18	1.1
	Wild Peppermint		8	0.8	9	0.7
	Wild Mushrooms		4	0.6	4	0.6
	Wild Greens		1	0.5	1	0.5
	Wild Onions		7	0.8	7	0.8
	Wild Rhubarb		1	0.5	1	0.5
	Rat Root		19	1.1	20	1.1
	Spruce Gum		24	1.3	25	1.2
		OTHER:	Partridgeberry, frog berries, crowberries, other gooseberries, salmonberries			

3.4. Health Messages Survey

A total of 87 participants completed the Health Messages Questionnaire. The participants were 44% male, 56% female, with an average age of 41 years old (range: 12 to 77 y.o.). Results of the Health Messages Survey in the Mackenzie Valley showed that 99% of respondents consume country foods, and that 38% would prefer to solely eat country foods (rather than store-bought or a mix of both country and store foods). Results are found in Tables 6-14. Few participants indicated their preference for store bought foods, rather than country foods. This result underlines the importance of country foods, and indicates how country foods are favoured in the diets of the Mackenzie Valley residents. Participants not only preferred country foods, but indicated they were aware of the many nutritional and health benefits of eating country foods. For example, 90% of respondents indicated that they had heard or seen the message that "country foods can provide a significant variety and amount of nutrients". Over 65% of respondents also indicated hearing or seeing the message that "eating country foods can lower the risk of diabetes" and "heart disease".

The survey also assessed which health messages about country foods participants remembered hearing. Nearly 70% of project respondents indicated that they have heard or seen messages about fish that had high levels of mercury. Most of these individuals reported that they had been informed of these messages by researcher or scientists (51%), by the radio (48%), or by a friend (46%). Relatively few (i.e., less than a third of the respondents) said they heard the information from poster or pamphlet in public spaces, newspaper, social media, or on a website. The least frequent was by a Doctor (8%) or a nurse (12%). When asked about specific lakes being affected, 57% said that they had heard/seen contaminant messages about fish from one or more of: Ekali Lake (Kelly Lake), Trout Lake, Ste Therese Lake, McGill Lake, Cli Lake, Deep Lake, and Fisk Lake. More than the quarter of the participant reported they heard the message for other lakes, such as Kakisa Lake, Great Bear Lake, Great Slave Lake and Melville Lake in Labrador, Churchill River, Ashuanipi River, Sanguez Lake and Hareskin River. Since hearing these various messages, respondents reported that they: decreased the amount of fish they ate (34%), changed the location where they usually fish (20%), and changed the way they prepared fish (15%).

Since hearing these messages, 42% of respondents reported that they were more concerned about the fish that they eat, and the quality of the country foods they consume. Although mercury was the leading contaminant of concern among participants, chlorine in drinking water, lead, indoor air quality, antibiotics in meat, asbestos, uranium, radon, PCBs, pesticides, and other heavy metals were also of concern for participants. It is important to note that 21% felt they did not know enough about contaminants in country foods to protect their own health and their family's health. Participants were less familiar with the messages related to moose with high levels of cadmium. A total of 21% indicated having heard or seen these messages about moose with high levels of cadmium, and over half of them (56%) heard or seen messages that they should limit their consumption of moose kidneys and livers from the Mackenzie Mountains.

Respondents were also asked about communication preferences and how they are able to access information. Most participants (50%-70%) had access to the internet, a landline phone, a cell phone, an e-mail account and a Facebook account. The most frequently sources of information were local radio, national radio, local TV, with over half of the participants checking these modes daily. When participants were asked about trust when receiving information about contaminants in the environment and country foods, Doctors were trusted the most (over half of the respondents trust them a lot), followed by Elders, family and friends and University Researchers and nurse (40-50%). Federal government and social media were the least trusted information sources with respectively 8% and 9% or respondents reporting no trusting at all. In line with these results, most of the respondents reported receiving their health information from friends or relatives (62%), Doctors (53%), and other health workers (e.g. nurses) (56%). Although reported to be less well trusted, participants also reported receiving health information via social media (44%) and from the Federal government (21%).

Table 6: Knowledge of country food and advisories

Country foods and advisories (n=61-87)	YES (%)	NO (%)
Do you eat country foods?	99	1
Do you prefer country foods over store foods or a mix of both?	38	62
Do you prefer store foods over country foods or a mix of both?	3	38
Have you heard any advisories or messages about fish that had high levels of mercury?	70	30
Did you hear about a specific lake or area that was affected?	57	43
Have you heard any advisories or messages about moose with high levels of cadmium?	21	79

Table 7: Awareness of the lakes having specific mercury advisories

Awareness of the lakes having advisories about fish with high levels of mercury (n=35)	(%)
Ekali Lake (Kelly Lake)	51
Ste Therese Lake	29
Trout Lake	17
Cli Lake	14
McGill Lake	14
Deep Lake	11
Fish Lake	9
Other	29
Don't know	14

Table 8: Consequences of the fish messages awareness

Consequences of hearing the messages about fish and mercury (n=59)	Agree or Strongly Agree (%)	Disagree or strongly disagree (%)	Neither Disagree nor Agree (%)
In general, I have increased the amount of fish I eat	12	64	22
In general, I have decreased the amount of fish I eat	34	51	15
I have reduced my consumption of only some kinds of fish (e.g. whitefish, trout) that I eat	24	59	14
I have changed the way I prepare fish	15	68	14
I eat smaller fish	15	71	10
I eat less predatory fish (examples of predatory fish are walleye, lake trout or northern pike)	8	69	17
I have changed the location where I usually fish	20	63	14

I am more concerned about the fish I eat	42	42	12
I am less concerned about the fish I eat	14	69	15

Table 9: Awareness of the moose consumption messages

Awareness of the messages associated with contaminants and moose (n=13-18)	YES (%)	NO (%)	Don't know (%)
Moose from Mackenzie Valley have low levels of cadmium.	56	33	11
Moose from Liard Valley have low levels of cadmium.	28	50	22
Moose from Mackenzie Mountains have high levels of cadmium.	39	22	39
You should reduce your consumption of moose kidneys from the Mackenzie Mountains.	56	33	11
You should reduce your consumption of moose liver from the Mackenzie Mountains.	56	17	28
Moose meat from Mackenzie and Liard Valleys is a healthy food choice.	33	22	44
The most effective lifestyle choice you can make to reduce cadmium in your body is to eliminate your exposure to cigarette smoke.	46	23	31

Table 10: Consequences of the moose messages awareness

Awareness of the messages about moose and cadmium (n=12-13)	Agree or Strongly agree (%)	Disagree or strongly disagree (%)	Neither Disagree nor Agree (%)
I have decreased the amount of moose meat I eat	17	58	25
I have reduced the amount of moose kidney I eat from Mackenzie Mountains	25	42	33
I have reduced the amount of moose liver I eat from Mackenzie Mountains	39	30	31
I have increased the amount of moose meat I eat	17	50	33
I have changed the way I prepare the moose meat I eat	25	50	25
I have changed the way I prepare the moose organs I eat	25	50	25
I am more concerned about the moose meat I eat	46	30	23
I am more concerned about the moose organs I eat	42	25	33
I am less concerned about the moose meat I eat	33	33	33
I am less concerned about the moose organs I eat	25	42	33

Table 11: Awareness of the country food messages

Awareness of messages associated with contaminants and country foods (n=87)	YES (%)	NO (%)	Don't know (%)
Eating fish contributes to a healthy, nutritious diet.	83	10	7
Fish is an excellent source of good omega-3 fatty acids.	78	11	10
In general, regular fish consumption by pregnant women and nursing mothers is beneficial for healthy prenatal and early childhood development.	52	30	18
Pregnant women should avoid eating lake trout and northern pike that are larger than 60cm.	32	33	34
Children under the age of 12 should avoid eating lake trout and northern pike that are larger than 60cm.	24	54	22
Country foods can provide a significant variety and amount of nutrients.	90	6	5
Eating country foods can lower the risk of getting diabetes.	68	15	17
Eating country foods can lower the risk of getting heart disease.	66	23	11

Table 12: Perception of country food messages

Agreement with statements about foods and contaminants (n=87)	Agree or Strongly Agree (%)	Disagree or strongly disagree (%)	Neither Disagree nor Agree (%)
Most First Nations and Métis adults in the Northwest Territories do not need to be concerned about contaminant-related effects from country food consumption	16	46	38
Most First Nations and Métis adults who live in this community do not need to be concerned about contaminant-related effects from country food consumption	18	22	60
I have concerns about the quality or safety of the country foods I eat	60	9	31
I have concerns about the quality or safety of the store-bought foods I eat	72	7	21
I think that I know enough about contaminants (like lead and mercury) in country food to protect me and my family's health	41	22	37

Table 13: Perception of contaminants exposure factors

Perception of the exposure factor: (n=87)	YES (%)	NO (%)	Don't know (%)
Do you think cigarette smoke (through smoking cigarettes and second-hand smoke) may impact the amount of contaminants you are exposed to?	80	8	11
Do you think eating store bought foods may impact the amount of contaminants you are exposed to?	46	6	48
Do you think eating fish may impact the amount of contaminants you are exposed to?	48	24	28
Do you think eating moose meat may impact the amount of contaminants you are exposed to?	31	39	30
Do you think eating moose organs, like liver or kidneys, may impact the amount of contaminants you are exposed to?	38	33	29
Do you think eating other country foods may impact the amount of contaminants you are exposed to?	41	30	29
Are there other items which you think may impact the amount of contaminants you are exposed to?	25	29	46

Table 14. Information sources

10 main sources of information on messages related to Fish and mercury (%) (n=35)	
Researcher or scientist	51
Radio	48
Friends	46
Television	34
Family	34
Poster or pamphlet in public spaces	33
Social media, like Facebook or Twitter	33
Newspaper	33
On a website	31
Community Chief	18
Access to mean of communication at home (%) (n=87)	
Internet	68
Cell phone	61
Landline phone	61
Email address	56
Facebook account	52
Instagram account	16
Twitter account	10

10 main sources of information (%) (n=87)	
Friends or Relatives	62
Other health workers (nurses, etc)	56
Doctor	53
Local Radio	46
Social media	44
NWT Government	43
Local Newspaper	39
Teachers or Schools	38
National TV	34
National Radio	32
Access to different sources of information daily or weekly (%) (n=46)	
Local Radio	87
National Radio	74
National TV	74
Local Newspapers	74
Local TV	70
Social Media	57
Websites	50
National Newspapers	46
10 main sources of information trusted 'a lot' about contaminants in the environment and country foods (%) (n=87)	
Doctors	51
Friends or Relatives	45
Elders	44
Other Health Workers (nurses, etc)	43
University Researchers	43
Community Chief	25
Local Radio	23
Non-Profit Organization	21
NWT Government	20
Local Government	18

3.5. Biological Samples Analysis

A total of 917 biological samples were collected. These included 443 hair samples, 198 urine samples and 276 blood samples. For each contaminant and nutrient measured, the detection rate (%), the geometric mean (GM) and the 95th percentile (95P) amongst participants are presented. The 95th percentile is an indicator of the upper-limit of typical exposures, excluding the most extreme values that are less representative of the distribution as a whole. The 95th percentiles from this project can be compared to those from biomonitoring projects, such as the Canadian Health Measure Survey (CHMS) and the First Nations Biomonitoring Initiative (FNBI). None of these projects recruited participants from the communities of the Northwest Territories. However, it is important to remember that such comparisons do not describe risk but only whether levels were in the normal range. The vast majority of the contaminant and nutrient markers in the current study can be compared against the normal range found in the CHMS and FNBI projects.

Relatively few contaminants, on the other hand, have health-based guidance values that can describe whether the observed exposures have exceeded generally safe levels. At the time of this project, such guidance values were available for: total mercury (blood, hair, urine), lead (blood, urine) and cadmium (blood, urine). These values are found in annexe. Other guidance values exist, such as those used in the workplace. However, these workplace limits are not meant to be used within a general population for lifelong exposures. Instead, these work place limits describe the maximum level that adults should be exposed to for 40h per week over several years. The research team has selected the best available guidance values for the contaminants being studied in this research. Regardless of whether the contaminants currently have established guidance values, results from these types of biomonitoring studies can provide a useful point of comparison for future projects, helping community-based researchers to monitor changes in levels over time. Additional health-based guidance values may come available in the future as more is learned about other contaminants and their risks for health.

3.5.1. Hair

A total of 443 participants provided a hair sample. The participants were 50% male, 50% female, with an average age of 41.6 years old (range: 6 to 88 y.o.). Mercury was measured in hair. It represents the cumulative mercury exposures from 2 months prior to hair sampling. Table 15 presents the level of mercury in hair. These hair levels suggest that the risks posed by mercury to participants are low. Participants who had hair samples long enough will have additional segments analyzed. This will help us learn more about how exposures changed over a year. These results will be returned to participating communities as soon as they are available.

A project done in Tulit'a, Northwest Territories, in 2010 (Delormier, 2012) recruited 67 participants for the measurement of hair mercury. Mercury concentrations for all children and women of childbearing age were below the health-based guidance values requiring follow-up (2 µg/g hair). Also, 97% of participants had hair mercury levels below the 5 µg/g guidance value (for adult men and women over 45 years). However, from the earlier project in Tulit'a, 3% of participants had hair mercury levels towards the low-end of the increasing risk (5-25 µg/g hair) category. Similarly, 2% of participants of Mackenzie Valley project described herein had hair mercury levels above these health guidance values.

3.5.2. Urine

A total of 198 participants provided an urine sample. The participants were 52% male, 48% female, with an average age of 46.7 years old (range: 6 to 88 y.o.). Several metals, including some toxic metals (e.g. cadmium, lead) and some metal nutrients were measured in urine (Tables 16 and 17). Some participants had relatively high levels of several metal nutrients (such as manganese and selenium) in urine samples. Vanadium was also elevated. These levels appeared higher than those usually observed in the Canadian general population and those seen in other First Nations communities. Cadmium and mercury are toxic metals and seem to be similar or lower than other studies done in Canada. However, lead level seems higher than both the general Canadian population and the First Nations Biomonitoring Initiative.

3.5.3. Blood

A total of 276 participants provided a blood sample. The participants were 49% male, 51% female, with an average age of 43.3 years old (range: 8 to 88 y.o.). Several metals, including some toxic metals (e.g. cadmium, lead) and some metal nutrients, persistent organic pollutants, and fatty acids were measured in whole blood or blood plasma. Table 18 presents levels of metals in blood samples. Lead levels in blood samples from the Mackenzie Valley appear to be higher than the Canadian population and the First Nations Biomonitoring Initiative. Cadmium and mercury level appear to be similar or lower than other projects.

Table 15. The levels of mercury quantified in hair (ug/g)

HAIR	**Detection (%)**	**Project**		**Canadian population**	**First Nations Biomonitoring Initiative**
		GM [a]	P95 [b]	P95 [b]	P95 [b]
Mercury	99.1	0.47	2.8	NA	NA

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95th percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
NA. Not available. No data available for the Canadian population.

Table 16. The levels of metals quantified in urine (µg/L)

URINE	Project			Canadian population	First Nations Biomonitoring Initiative
	Detection (%)[e]	**GM [a, d]**	**P95 [b]**	**P95 [b, c]**	**P95 [b]**
Aluminum	100	14	40	NA	NA
Arsenic	100	5.5	34	77	39
Barium	99.5	1.4	7.2	NA	NA
Beryllium	96.2	0.014	0.11	NA	NA
Cadmium	100	0.32	1.3	1.9	2.1
Cesium[e]	100	4.2	7.1	NA	NA
Chromium*	96.0	0.47	5.4	NA	NA
Cobalt*	100	0.34	1.4	0.97	NA
Copper*	100	8.8	26	28	43
Gallium	100	0.081	0.35	NA	NA
Iron*	99.5	11	39	NA	NA
Lead	99.0	0.59	4.0	1.9	2.3
Lithium	100	17	49	NA	NA
Manganese*	100	0.21	0.66	0.36	0.59
Mercury	59.9	0.38	1.8	NA	2.0[f]
Nickel*	98.5	1.0	4.3	4.8	4.6
Rubidium[e]	100	1500	2800	NA	NA
Selenium*	100	54	180	130	160
Strontium	100	99	360	NA	NA
Thallium	95.5	0.12	0.39	0.62	NA
Uranium	66.7	0.0058	0.020	0.020	<LOD
Vanadium	98.5	0.15	0.55	0.13	0.19
Zinc*	100	330	1200	1200	1400

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95th percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] From the Canadian Health Measure Survey cycle 2 (Health Canada, 2013)
[d] Not presented if detection rate was below 50%
[e] The analytical method was modified in Summer 2016 and Cesium and Rubidium were removed from the analysis, therefore these results are reported for a small size sample (n=10).
[f] Inorganic mercury only.
NA. Not available. No data available for the Canadian population.
*Essential for good health
<LOD: Not detected/ Under the limit of detection. (LOD Uranium: 0.01 µg/L)

Table 17. The levels of metals quantified in urine (µg/g of creatinine)

URINE	Project			Canadian population	First Nations Biomonitoring Initiative
	Detection (%)[e]	GM [a, d]	P95 [b]	P95 [b, c]	P95 [b]
Aluminum	100	16	54	NA	NA
Arsenic	100	6.3	27	77	38
Barium	99.5	1.6	6.3	NA	NA
Beryllium	96.2	0.016	0.29	NA	NA
Cadmium	100	0.36	1.3	1.4	1.6
Cesium[e]	100	5.5	9.4	NA	NA
Chromium*	96.0	0.54	10	NA	NA
Cobalt*	100	0.40	1.3	0.88	NA
Copper*	100	10	19	19	33
Gallium	100	0.093	0.32	NA	NA
Iron*	99.5	13	49	NA	NA
Lead	99.0	0.69	3.8	1.6	2.2
Lithium	100	20	48	NA	NA
Manganese*	100	0.24	1.5	0.61	0.89
Mercury	59.9	0.45	1.7	NA	1.8[f]
Nickel*	98.5	1.2	5.6	4.0	3.8
Rubidium[e]	100	2000	2400	NA	NA
Selenium*	100	62	140	96	130
Strontium	100	110	270	NA	NA
Thallium	95.5	0.13	0.37	0.55	NA
Uranium	66.7	0.0066	0.034	0.024	<LOD
Vanadium	98.5	0.17	0.59	0.24	0.35
Zinc*	100	380	900	770	1200

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95th percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] From the Canadian Health Measure Survey cycle 2 (Health Canada, 2013)
[d] Not presented if detection rate was below 50%
[e] The analytical method was modified in Summer 2016 and Cesium and Rubidium were removed from the analysis, therefore these results are reported for a small size sample (n=10).
[f] Inorganic mercury only.
NA. Not available. No data available for the Canadian population.
*Essential for good health
<LOD. Not detected/ Under the limit of detection. (LOD Uranium: 0.01 µg/L)

Table 18. The levels of metals quantified in whole blood (ug/L)

BLOOD	Project			Canadian population	First Nations Biomonitoring Initiative
	Detection (%)[e]	GM [a, e]	P95 [b, f]	P95 [b, c]	P95 [b]
Aluminum	14.9		44	NA	NA
Arsenic	22.5		0.58	4.1[d]	3.3
Barium	44.2		1.5	NA	NA
Beryllium	51.7	0.036	0.30	NA	NA
Cadmium	88.8	0.35	3.2	2.6	4.7
Cesium[g]	27.1		3.7	NA	NA
Chromium*	44.9		1.3	NA	NA
Cobalt*	5.1		0.12	0.40	NA
Copper*	100.0	980	1300	1200	1200
Gallium	18.8		0.058	NA	NA
Lead	100.0	16	70	32	33
Lithium	33.0		5.7	NA	NA
Manganese*	100.0	10	19	15	21
Mercury	38.4		4.7	5.6	9.3
Nickel*	7.6		0.45	1.1	1.1
Rubidium[g]	100.0	1900	2600	NA	NA
Selenium*	100.0	170	230	240	230
Silver[h]	0.0		<LOD	0.27	NA
Strontium	100.0	17	29	NA	NA
Thallium	0.0		<LOD	NA	NA
Uranium	1.1		<LOD	<LOD	<LOD
Vanadium[h]	2.3		<LOD	NA	NA
Zinc*	100.0	5600	7100	7300	6900

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95th percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] From the Canadian Health Measure Survey cycle 2 (Health Canada, 2013)
[d] From the Canadian Health Measure Survey cycle 1 (Health Canada, 2010)
[e] Not presented if detection rate was below 50%
[f] Not presented if detection rate was below 5%
[g] Test done in only 144 samples, due to a modification in the analytical method.
[h] Test done in only 44 samples, due to a modification in the analytical method.
<LOD. Not detected. Below the limit of detection of the method.
NA. Not available. No data available for the Canadian population.
*Essential for good health

Many fatty acids are also essential for good health. One such type of healthy fats are the omega-3's (which can be calculated from the sum of EPA and DHA). These level of omega-3's in participants were on average 80 mg/L (95^{th} percentile: 151 mg/L). Also, average levels of omega-3 fatty acids (as a ratio on total fatty acids) were between 0.51 % and 5.5 % with an average of 2.1 %, similar to what was observed in previous studies in Canada (1.5-2.4) (Stark et al., 2016).

Any metal, whether it is a toxic metal or a metal nutrient, can pose health risks if its intake is too high. In the case of metal nutrients, which perform important functions in the body, health risks can also result from low levels. These current levels of urine manganese and selenium seem slightly higher than the normal range. The levels of these essential metals do not appear high enough to pose health concerns, and contribute to the health status.

Like toxic metals, persistent organic pollutants (which include several pesticides and industrial chemicals) hold no positive biological functions. Tables 19-20 present the levels of POPs and their break-down products (i.e. metabolites) in the blood plasma of participants. Several POPs, especially those from organochlorine pesticides markers,appeared to be at levels above those seen in the Canadian general population biomonitoring studies (CHMS) and First Nations across the 10 provinces (FNBI). POPs can travel very long distances through the atmosphere and, because they last a long time in the environment, can be detected many years after their release in the environment. The majority of the POPs listed in Tables 19-20 have not been used or produced in North America for decades. Also, many of these POPs were banned globally in 2001 through an agreement known as the Stockholm Convention. The levels reported here in Tables 19-20 will enable future studies to monitor the extent to which POP exposures decrease over time as a result of the Stockholm Convention.

Table 19. The levels of persistent organic pollutants (POPs) in blood plasma (ug/L).

BLOOD [1]	Project			Canadian population[d]	First Nations Biomonitoring Initiative
	Detection (%)	GM [a,c]	P95 [b]	P95 [b]	P95 [b]
PCB , Aroclor 1260	87.9	0.58	5.8	4.2	6.3
PCB74	3.7		<LOD	0.10	0.09
PCB99	7.4		0.050	0.07	0.07
PCB105	14.7		0.022	0.02	0.04
PCB118	51.8	0.013	0.12	0.12	0.19
PCB138	79.4	0.033	0.33	0.28	0.37
PCB146	49.3		0.11	0.06	0.13
PCB153	90.4	0.077	0.85	0.54	0.81
PCB156	43.8		0.073	0.07	0.10
PCB163	53.7	0.015	0.12	0.10	0.12
PCB167	18.8		0.026	0.02	0.04
PCB170	61.0	0.020	0.19	0.14	0.26
PCB178	31.3		0.053	0.03	0.06
PCB180	79.8	0.054	0.70	0.49	0.86
PCB183	36.0		0.057	0.04	0.09
PCB187	67.3	0.024	0.28	0.13	0.29
PCB194	54.0	0.016	0.17	0.10	0.20
PCB201	53.7	0.016	0.16	0.09	0.22
PCB203	46.3		0.10	0.07	0.15
PCB206	36.0		0.058	0.03	0.08
PBDE28	2.2		<LOD	<LOD	<LOD
PBDE33	0.4		<LOD	<LOD	<LOD
PBDE47	57.4	0.035	0.16	0.41	<LOD
PBDE99	21.7		0.10	0.08	0.05
PBDE100	16.9		0.10	0.09	0.05
PBDE153	33.8		0.10	0.22	0.15
PBB153	1.8		<LOD	<LOD	NR
gamma-Chlordane	7.7		0.0060	<LOD	<LOD
cis-Nonachlor	57.4	0.0083	0.19	0.02	0.03
trans-Nonachlor	80.9	0.036	0.49	0.14	0.19
beta-HCH	37.5		0.029	0.54	0.06
Hexachlorobenzene	97.1	0.066	0.30	0.17	0.14
Mirex	49.6		0.17	0.05	0.21
Oxychlordane	78.3	0.014	0.16	0.09	0.10
p,p'-DDE	100.0	0.30	1.7	6.5	4.18
Toxaphene Parlar #26	38.2		0.083	0.01	0.01
Toxaphene Parlar #50	46.3		0.18	0.01	0.01

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95th percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] Not presented if detection was below 50%
[d] From the Canadian Health Measure Survey cycle 1 (Health Canada, 2010)
[1] Results were not listed for pollutants that were not detected in any of the samples. These included: Aldrin, PCB28, PCB52, PCB66, , PCB101, PCB128, PBDE15, PBDE17, PBDE25, alpha-Chlordane, gamma-HCH, p,p'-DDT.
<LOD: Not detected. Below the limit of detection of the method.
NR. Not reported because considered unreliable.

Table 20. The levels of persistent organic pollutants (POPs) in blood plasma (ug/kg lipids).

BLOOD [1]	Project			Canadian population[d]	First Nations Biomonitoring Initiative
	Detection (%)	GM [a,c]	P95 [b]	P95 [b]	P95 [b]
PCB , Aroclor 1260	87.9	100	1000	680	1000
PCB74	3.7		<LOD	16	15
PCB99	7.4		10	11	14
PCB105	14.7		3.0	3.6	4.9
PCB118	51.8	2.2	17	20	NR
PCB138	79.4	5.5	45	45	62
PCB146	49.3		16	9.2	22
PCB153	90.4	13	140	86	140
PCB156	43.8		12	11	13
PCB163	53.7	2.4	19	16	22
PCB167	18.8		3.8	3.4	5.9
PCB170	61.0	3.3	29	23	39
PCB178	31.3		8.2	4.6	8.0
PCB180	79.8	9.1	110	77	120
PCB183	36.0		9.1	6.6	13
PCB187	67.3	4.0	41	20	49
PCB194	54.0	2.7	25	16	28
PCB201	53.7	2.6	24	14	32
PCB203	46.3		15	11	22
PCB206	36.0		8.3	5.5	14
PBDE28	2.2		<LOD	<LOD	<LOD
PBDE33	0.4		<LOD	<LOD	<LOD
PBDE47	57.4	5.8	31	67	<LOD
PBDE99	21.7		17	13	8.1
PBDE100	16.9		18	15	6.7
PBDE153	33.8		17	35	20
PBB153	1.8		<LOD	<LOD	2.9
gamma-Chlordane	7.7		1.0	<LOD	<LOD
cis-Nonachlor	57.4	1.4	32	3.1	5.1
trans-Nonachlor	80.9	5.9	76	23	25
beta-HCH	37.5		4.3	90	9.3
Hexachlorobenzene	97.1	11	46	27	18
Mirex	49.6		22	9.1	28
Oxychlordane	78.3	2.4	28	14	14
p,p'-DDE	100.0	50	250	1000	690
Toxaphene Parlar #26	38.2		14	1.6	1.5
Toxaphene Parlar #50	46.3		27	2.4	2.2

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95^{th} percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] Not presented if detection was below 50%.
[d] From the Canadian Health Measure Survey cycle 1 (Health Canada, 2010)
[1] Results were not listed for pollutants that were not detected in any of the samples. These included: Aldrin, PCB28, PCB52, PCB66, , PCB101, PCB128, PBDE15, PBDE17, PBDE25, PBDE33, alpha-Chlordane, gamma-HCH, p,p'-DDT.
<LOD: Not detected. Below the limit of detection of the method.
NR. Not reported because considered unreliable.

The majority of the participants showed cadmium, lead and mercury exposure levels in blood, hair and urine below their health guidance values. However, 3.6% of all the participants had levels above these thresholds. For example, blood mercury concentrations below 8 ug/L (women less than 46 years of age; children) or below 20 ug/L (adult men; women over 45 years of age) are thought to pose little to no risk (Environment Canada, 2010), equivalent to 5 μg/g in hair (women less than 46 years of age; children) or 2 μg/g in hair (adult men; women over 45 years of age). Similarly, the current Health Canada guidance value for blood lead is 100 μg/L (Health Canada, 2013b). Lastly, cadmium levels above 5 ug/L in blood and 7.3 ug/L in urine may indicate an increased risk to health that would warrant follow up (Haines *et al.*, 2011). In summary, few participants who provided a sample are above the guidance value for blood lead (2.2%), hair mercury (1.8%), blood cadmium (1.0%), urinary lead (0.5%) and urinary cadmium (0.4%).Uranium also does not have a health-based guidance value for the general population. Overall, uranium levels for participants in the Mackenzie valley appear lower than seen in other studies. In addition, an occupational guideline of 15 ug/L of urine was set by the Nuclear Regulatory Commission (NRC, 2014) and uranium levels are far below those that are known to pose health risks. Furthermore, it is known that:

- Treated drinking water is regularly tested for many chemicals, including uranium. Treated drinking water is safe to drink.
- Uranium has been measured in several country foods, including moose and caribou. The uranium levels in the country foods that have been measured are low.

The research team is committed to working with the community alongside officials from the Government of the Northwest Territories to follow-up on these results at the community level and individual participants. These results will be presented to the public presentation in 2018-2019 (See Section 4.3 Next steps of the project).

3.6. Biobanked Samples Analysis

A total of 26 of urine samples exclusively from the Dehcho only underwent chemical analysis for this supplemental analysis for arsenic species and phthalates. As reported in Tables 21-22, the levels of arsenic seems low. The high levels of arsenic naturally present in the environment but also released by the Giant mine around Yellowknife do not seems to affect the Dehcho region. For the phthalates levels (Tables 23-24), the levels appeared higher than observed in the CHMS for one phthalates metabolites (MBzP, MiNP). No arsenic species were higher than those observed in the CHMS. It is notable, however, that some differences between the participants of this study and those of the CHMS were no longer observable after adjusting for creatinine levels.

Table 21. The levels of Arsenic species quantified in urine (ug/L). (n=26)

URINE[1,2]	Project			Canadian population
	Detection (%)	GM [a, c]	P95 [b]	P95 [b, d]
Dimethylarsinic acid	100.0	4.8	10	30
Monomethylarsonic acid	100.0	0.53	1.2	3.0
Arsenocholine+Arsenobetaine	96.2	0.94	16	110
AsIII (arsenite)	80.8	0.37	2.0	4.5
AsV (arsenate)	34.6		0.33	<LOD

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95[th] percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] Results were not reported for compounds that were detected in in less than 50% of the samples.
[d] From the Second Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex 3–79 years (HC, 2013).
<LOD. Not detected/under the limit of detection.

Table 22. The levels of Arsenic species quantified in urine (ug/g of creatinine). (n=26)

URINE[1,2]	Project			Canadian population
	Detection (%)	GM[a, c]	P95 [b]	P95 [b,d]
Dimethylarsinic acid	100.0	4.6	9.7	29
Monomethylarsonic acid	100.0	0.51	1.4	3.4
Arsenocholine+Arsenobetaine	96.2	0.90	10	110
AsIII (arsenite)	80.8	0.36	1.5	4.5
AsV (arsenate)	34.6		0.23	<LOD

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95[th] percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] Results were not reported for compounds that were detected in in less than 50% of the samples.
[d] From the Second Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex 3–79 years (HC, 2013).
<LOD. Not detected/under the limit of detection.

Table 23. The levels of Phthalates quantified in urine (ug/L). (n=26)

URINE[1,2]	Project			Canadian population
	Detection (%)	GM [a,c]	P95 [b]	P95 [b,d]
Mono-benzyl phthalate (MBzP)	100.0	20	84	61
Mono-cyclohexyl phthalate (MCHP)	19.2		0.95	0.45
Mono-3-carboxypropyl phthalate (MCPP)	96.2	0.80	3.9	12
Mono(2-ethyl-5-carboxypentyl) phthalate (MECPP)	100.0	8.4	24	NA
Mono-(2-ethyl-5-hydroxyhexyl) phthalate (MEHHP)	100.0	7.5	20	59
Mono-2-ethylhexyl phthalate (MEHP)	96.2	1.3	6.7	9.3
Mono-(2-ethyl-5-oxyhexyl) phthalate (MEOHP)	100.0	4.3	11	34
Mono-ethyl phthalate (MEP)	100.0	19	115	460
Mono-isobutyl phthalate (MiBP)	100.0	9.6	28	64
Mono-isononyl phthalate (MiNP)	53.8	0.39	1.0	<LOD
mono-methyl phthalate (MMP)	100.0	2.3	7.0	17
Mono-n-butyl phthalate (MnBP)	100.0	15	37	90
Mono-*n*-octyl phthalate (MnOP/MOP)	0.0			<LOD

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95th percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] Results were not reported for compounds that were detected in in less than 50% of the samples.
[d] From the Second Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex 3–79 years (HC, 2013).
<LOD. Not detected/under the limit of detection.

Table 24. The levels of Phthalates quantified in urine (ug/g of creatinine). (n=26)

URINE[1,2]	Project			Canadian population
	Detection (%)	GM [a,c]	P95 [b]	P95 [b,d]
Mono-benzyl phthalate (MBzP)	100.0	20	160	43
Mono-cyclohexyl phthalate (MCHP)	19.2		0.95	0.44
Mono-3-carboxypropyl phthalate (MCPP)	96.2	0.77	2.7	9.9
Mono(2-ethyl-5-carboxypentyl) phthalate (MECPP)	100.0	8.1	36	NA
Mono-(2-ethyl-5-hydroxyhexyl) phthalate (MEHHP)	100.0	7.2	26	48
Mono-2-ethylhexyl phthalate (MEHP)	96.2	1.3	6.3	8.3
Mono-(2-ethyl-5-oxyhexyl) phthalate (MEOHP)	100.0	4.1	13	27
Mono-ethyl phthalate (MEP)	100.0	19	210	NA
Mono-isobutyl phthalate (MiBP)	100.0	9.3	20	48
Mono-isononyl phthalate (MiNP)	53.8	0.38	1.9	<LOD
mono-methyl phthalate (MMP)	100.0	2.3	4.8	16
Mono-n-butyl phthalate (MnBP)	100.0	14	47	72
Mono-*n*-octyl phthalate (MnOP/MOP)	0.0			<LOD

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95th percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] Results were not reported for compounds that were detected in in less than 50% of the samples.
[d] From the Second Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex 3–79 years (HC, 2013).
<LOD. Not detected/under the limit of detection.

Cotinine and polycyclic aromatic hydrocarbons (PAHs) were analysed in 97 samples. Cotinine levels appeared similar to those seen in Canada (Tables 25-26). It is important to note that 41% of the subset of the Mackenzie study participants were smokers. Smoking rate for the CHMS is believed to be approximately the national rate in 2013 of 19% (Statistics Canada, 2013). Cotinine is a biomarker of smoking and smoking rate will have an impact on the cotinine level in the region. At the individual level, 50 ug/L can be used as the threshold to separate smoking/non smoking status (Wong et al., 2012).

In contrast, several polycyclic aromatic hydrocarbons (PAHs) metabolites appear higher than usually observed (Tables 27-28). However, the levels generally fell below those known to cause health problems. In fact, four biomarkers are above both the GM and the 95th percentile in urine concentration (ug/L) but also in excretion rate (ug/g of creatinine). These metabolites (2-hydroxyfluorene, 2-naphtol, 9-hydroxyfluorene and 9-hydroxyphenanthrene) are breakdown compounds from naphthalene, fluorene and phenanthrene.

Biomarkers of phenanthrene are below what was measured in workers and in the people living in industrial areas (Angerer et al., 1997; Gundel et al., 1996). No association between phenanthrene metabolites and biomarkers of effect (e.g. DNA adducts; 8-oxodGuo) have been observed in workplace studies at such levels (Pesch et al., 2007). This suggests that, even if the levels are higner than observed in the CHMS, there is no evidence that the current levels are high enough to bring about adverse effects. It is not yet known why the levels of several of these PAHs biomarkers appeared higher than usually observed in nationally-representative studies in Canada. Source apportionment for PAHs can be particularly challenging as there are numerous potential dietary and non-dietary sources of exposure. The research team will work with community leaders and the Governement of the Northwest Territories to implement a follow-up plan based on these results.

Table 25. The levels of the cotinine quantified in urine (ug/L). (n=97)

URINE	Project			Canadian population
	Detection (%)	**GM** [a,d]	P95 [b]	**P95** [b, c]
Cotinine- smokers	100	540	2100	2600
Cotinine- non smokers	30.9	NR[d]	1000	NA
Cotinine-All	72.2	39	1800	NA

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95th percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] From the Third Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex (HC, 2015). The CHMS did not report the 95th percentile for non-smokers because the data was considered as too unreliable to report.
[d] Results were not reported for compounds that were detected in in less than 50% of the samples
NA. Not available.

Table 26. The levels of the cotinine quantified in urine (ug/g of creatinine). (n=97)

URINE	Project			Canadian population
	Detection (%)	**GM** [a,d]	P95 [b]	**P95** [b, c]
Cotinine- smokers	100	620	3200	3800
Cotinine- non smokers	30.9	NR[d]	2200	NA
Cotinine-All	72.2	48	3000	NA

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95th percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] From the Third Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex (HC, 2015). The CHMS did not report the 95th percentile for non-smokers because the data was considered as too unreliable to report.
[d] Results were not reported for compounds that were detected in in less than 50% of the samples
NA. Not available.

Table 27. The levels of the polycyclic aromatic hydrocarbons (PAHs) quantified in urine (ug/L). (n=97)

URINE	Project			Canadian population[d]
	Detection (%)	GM [a, c]	P95 [b]	P95 [b]
1-Hydroxybenz(a)anthracene	0.0			NA
1-Hydroxyphenanthrene	100	0.10	0.60	0.70
1-Hydroxypyrene	98.9	0.087	0.49	0.51
1-Naphtol	100	1.3	16	13
2-Hydroxychrysene	0.0			<LOD
2-Hydroxyfluorene	100	0.35	3.0	2.3
2-Hydroxyphenanthrene	100	0.054	0.32	0.26
2-Naphtol	100	5.8	30	27
3-Hydroxybenz(a)anthracene	0.0			NA
3-Hydroxybenzo(a)pyrene	0.0			<LOD
3-Hydroxychrysene	0.0			<LOD
3-Hydroxyfluoranthene	2.1		<LOD	<LOD
3-Hydroxyfluorene	100	0.13	1.5	1.3
3-Hydroxyphenanthrene	100	0.068	0.52	0.43
4-Hydroxychrysene	0.0			<LOD
4-Hydroxyphenanthrene	92.6	0.021	0.20	0.12
6-Hydroxychrysene	0.0			<LOD
9-Hydroxyfluorene	100	0.21	0.83	0.72
9-Hydroxyphenanthrene	99.0	0.048	0.41	0.33

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95th percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] Results were not reported for compounds that were detected in in less than 50% of the samples.
[d] From the Fourth Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex 3–79 years (HC, 2017),
NA. Not available (not measured).
<LOD. Not detected/under the limit of detection.

Table 28. The levels of the polycyclic aromatic hydrocarbons (PAHs) quantified in urine (ug/g of creatinine). (n=97)

URINE	Project			Canadian population[d]
	Detection (%)	GM [a,c]	P95 [b]	P95 [b]
1-Hydroxybenz(a)anthracene	0.0			NA
1-Hydroxyphenanthrene	100	0.13	0.31	0.49
1-Hydroxypyrene	98.9	0.11	0.35	0.34
1-Naphtol	100	1.6	9.9	11
2-Hydroxychrysene	0.0			<LOD
2-Hydroxyfluorene	100	0.44	2.3	1.9
2-Hydroxyphenanthrene	100	0.068	0.18	0.20
2-Naphtol	100	7.3	23	17
3-Hydroxybenz(a)anthracene	0.0			NA
3-Hydroxybenzo(a)pyrene	0.0			<LOD
3-Hydroxychrysene	0.0			<LOD
3-Hydroxyfluoranthene	2.1		<LOD	<LOD
3-Hydroxyfluorene	100	0.17	1.0	1.0
3-Hydroxyphenanthrene	100	0.085	0.30	0.32
4-Hydroxychrysene	0.0			<LOD
4-Hydroxyphenanthrene	92.6	0.026	0.12	0.099
6-Hydroxychrysene	0.0			<LOD
9-Hydroxyfluorene	100	0.25	0.99	0.67
9-Hydroxyphenanthrene	99.0	0.060	0.33	0.29

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] 95th percentile: Represents the upper margin of exposure. It approximates the highest, commonly observed value.
[c] Results were not reported for compounds that were detected in in less than 50% of the samples.
[d] From the Fourth Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex 3–79 years (HC, 2017),
NA. Not available (not measured).
<LOD. Not detected/under the limit of detection.

3.7. Differences between Dehcho and Sahtú regions

The participants recruited in the Sahtú region are slightly older that in the Dehcho region (average 43 vs 39 years old). The ratio female to male is similar (50 vs 49% male). However, the smoking rate reported in higher in the Sahtú than in the Dehcho (48 vs 32%), as well as the alcohol consumption in the last 24h (16 vs 10%). The Body mass index (BMI) is lower in the Sahtú (27 vs 29) but a there was a higher rate of refusal to provide the weight and height (19 vs 13%).

Both regions eat country foods and are aware of their benefits. Slight differences were observed. The Sahtú participants seem to eat more country foods in terms of calories intake (winter daily average of 6.1 vs 4.9%). While caribou is the second most consumed country food in the Sahtú with 77% of the participants eating caribou, it is eaten by only 44% of the respondents from the Dehcho. Lake Trout is also more frequently consumed in the Sahtú. In fact, almost half of the respondents in the Sahtú (49%) reported they would prefer to solely eat country foods while it is the case for the quarter of the respondent in the Dehcho (27%). While 16% of the Sahtú respondent heard on seen advisories on Cadmium in moose organ, it is the case of 25% in the Dehcho. It makes sense, as the consumption notice are more restrictive for the Moose from the southern part of the mountains. The socio-demographics and behavioral differences between the Dehcho and Sahtú regions are reported in Table 29.

Table 29. Socio-demographics and behavioral differences between the Dehcho and Sahtú regions

Characteristics	Dehcho	Sahtú
Sex (%)- Male; Female	48.7; 51.3	50.4; 49.6
Age -average (min-max)	39 (6-79)	43 (6-88)
Smoking rate (%)	32	48
Body mass index (BMI)- average (min-max)	28.7 (18-60)	26.8 (17-47)
Energy from country food consumption (%) (min-max)	4.9 (0-38)	6.1 (0-25)
Caribou consumption (%)	44	77
Moose consumption (%)	92	95
Whitefish consumption (%)	89	76
Lake Trout consumption (%)	53	76
Aware of message on Fish and mercury (%)	68	72
Aware of message on Moose and cadmium (%)	25	16
Participants with levels higher than the guideline for Mercury in blood (%)[a]	0.7	0
Participants with levels higher than the guideline for Lead in blood (%)[b]	0	3.6

[a] Health Canada recommend limit levels of mercury in blood (20 ug/L or 8 ug/L for children or woman of 45 years old and below)
[b] Health Canada recommend limit levels of lead in blood (100 ug/L or 50 ug/L for children or woman of 45 years old and below)

The biological levels are also overall similar. For mercury, the Sahtú participants had GM and 95th percentile in hair higher than the Dehcho. However, it is not the case in urine and blood, in which Dehcho participants have higher levels. In the Dehcho, the essential element selenium, manganese and zinc were higher, while toxic metal lead was also lower. The main difference in biological levels are related to the persistent organic pollutants. Patterns in organochlorine pesticide exposure are very different between regions and consistently higher in the Sahtú than in the Dehcho. It is the case for the biomarkers of toxaphene, mirex and chlordane. The omega-3 concentrations are similar, with 71 mg/L plasma in the Dehcho and 73 mg/L in the Sahtú. The biological results are presented in Tables 30-33.

Table 30. Comparison of the levels of metals in the Dehcho and the Sahtú

Type of sample	Contaminant	Dehcho		Sahtú		Canadian population[d]
		Detection (%)	GM[a,b]	Detection (%)	GM[a,b]	GM
HAIR (ug/g)	Mercury	99.6	0.39	98.6	0.59	
URINE (μg/L)	Aluminum	100	14	100	14	
	Arsenic	100	5.7	100	5.4	9.2
	Barium	100	1.5	99.1	1.3	
	Beryllium	100	0.029	92.0	0.0063	
	Cadmium	100	0.31	100	0.32	0.40
	Cesium	100	4.2			4.9
	Chromium	96.5	1.3	95.6	0.21	
	Cobalt	100	0.38	100	0.32	0.23
	Copper	100	9.6	100	8.3	11
	Gallium	100	0.089	100	0.076	
	Iron	98.8	13	100	10	
	Lead	100	0.50	98.2	0.67	0.52
	Lithium	100	21	100	14	
	Manganese	100	0.35	100	0.14	
	Mercury	55.1	0.46	63.3	0.34	
	Nickel	100	1.6	97.3	0.71	1.3
	Rubidium[c]	100	1500	NA	NA	
	Selenium	100	66	100	47	51
	Strontium	100	100	100	96	
	Thallium	89.4	0.11	100	0.13	0.23
	Uranium	97.6	0.0057	43.4	0.0059	
	Vanadium	96.5	0.16	100	0.14	
	Zinc	100	380	100	290	320
BLOOD (μg/L)	Aluminum	13.2	0.74	16.4	0.79	
	Arsenic	31.6	0.015	13.6	0.0076	
	Barium	26.5	0.15	61.4	0.27	
	Beryllium	35.0	0.021	66.4	0.058	
	Cadmium	98.5	0.53	79.3	0.23	0.31
	Cesium	23.5	0.024	44.0	0.058	
	Chromium	33.8	0.039	55.7	0.080	
	Cobalt	10.3	0.083	0	0.074	0.23
	Copper	100	1000	100	930	900
	Gallium	18.4	0.00079	19.3	0.00087	
	Lead	100	11	100	23	13
	Lithium	34.6	0.17	31.4	0.12	
	Manganese	100	11	100	9.8	9.8
	Mercury	44.1	0.13	32.9	0.065	0.72

	Nickel	10.3	0.12	5.0	0.12	0.48
	Rubidium	100	1900	100	1900	
	Selenium	100	180	100	160	190
	Strontium	100	18	100	15	
	Thallium	0	0.050	0	0.052	
	Uranium	2.2	0.0032	0	0.0030	
	Zinc	100	5800	100	5400	6000

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] Not presented if detection rate was below 50%
[c] Test done in only 144 samples, due to a modification in the analytical method, and only in the Dehcho.
[d] From the Second Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex (HC, 2015),

Table 31. Comparison of the levels of persistent organic pollutants (POPs) in the Dehcho and the Sahtú

Type of sample	Contaminant	Dehcho (n=279)		Sahtú (n=254)		Canadian population[c]
		Detection (%)	GM	Detection (%)	GM	GM
PLASMA (µg/L)	PCB , Aroclor 1260	82.2	0.42	93.4	0.80	0.90
	PCB28	0		0		
	PCB52	0		0		
	PCB66	0		0		
	PCB74	3.7		3.6		
	PCB99	3.0		11.7		
	PCB101	0		0		
	PCB105	5.2		24.1		
	PCB118	45.2		58.4	0.017	0.03
	PCB128	0		0		
	PCB138	74.1	0.025	84.7	0.043	0.06
	PCB146	45.2		53.3	0.016	0.01
	PCB153	85.2	0.055	95.6	0.11	0.11
	PCB156	40.0	0.010	47.4	0.012	0.02
	PCB163	50.4	0.012	56.9	0.018	0.02
	PCB167	13.3		24.1		
	PCB170	60.0	0.018	62.0	0.022	
	PCB178	18.5		43.8		0.03
	PCB180	77.8	0.047	81.8	0.063	0.09
	PCB183	30.4		41.6		
	PCB187	63.7	0.019	70.8	0.031	0.02
	PCB194	54.1	0.015	54.0	0.018	0.02
	PCB201	52.6	0.014	54.7	0.018	0.02
	PCB203	43.7		48.9		0.01
	PCB206	34.1		38.0		
	PBDE15	0		0		
	PBDE17	0		0		
	PBDE25	0		0		
	PBDE28	1.5		2.9		
	PBDE33	0		0.7		
	PBDE47	51.9	0.031	62.8	0.039	0.06
	PBDE99	13.3		29.9		
	PBDE100	9.6		24.1		
	PBDE153	27.4		40.1		
	PBB153	0.7		2.9		
	Aldrin	0		0		
	gamma-Chlordane	15.6		0		
	Alpha-Chlordane	0		0		

	cis-Nonachlor	38.5		75.9	0.017	
	trans-Nonachlor	73.3	0.020	88.3	0.063	0.04
	gamma-HCH	0		0		
	beta-HCH	36.3		38.7		0.04
	Hexachlorobenzene	95.6	0.049	98.5	0.089	0.05
	Mirex	43.7		55.5	0.019	
	Oxychlordane	73.3	0.011	83.2	0.019	0.03
	p,p'-DDE	100	0.27	100	0.33	0.91
	p,p'-DDT	0		0		
	Toxaphene Parlar #26	25.9		50.4	0.0059	
	Toxaphene Parlar #50	24.4		67.9	0.013	

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] Not presented if detection rate was below 50%
[c] From the First Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex 3–79 years (HC, 2010)

Table 32. Comparison of the levels of polycyclic aromatic hydrocarbons (PAHs) in the Dehcho and the Sahtú

Type of sample	Contaminant	Dehcho		Sahtú		Canadian population[d]
		Detection (%)	GM	Detection (%)	GM	GM
URINE (µg/L)	1-Hydroxybenz(a)anthracene	0		0		
	1-Hydroxyphenanthrene	100	0.10	100	0.096	0.16
	1-Hydroxypyrene	98.3	0.091	100	0.080	0.096
	1-Naphtol	100	1.3	100	1.2	0.97
	2-Hydroxychrysene	0		0		
	2-Hydroxyfluorene	100	0.36	100	0.33	0.28
	2-Hydroxyphenanthrene	100	0.058	100	0.048	0.062
	2-Naphtol	100	6.9	100	4.1	4.6
	3-Hydroxybenz(a)anthracene	0		0		
	3-Hydroxybenzo(a)pyrene	0		0		
	3-Hydroxychrysene	0		0		
	3-Hydroxyfluoranthene	3.3		0		
	3-Hydroxyfluorene	100	0.14	100	0.12	0.10
	3-Hydroxyphenanthrene	100	0.072	100	0.059	0.089
	4-Hydroxychrysene	0		0		
	4-Hydroxyphenanthrene	91.9	0.022	93.8	0.020	0.023
	6-Hydroxychrysene	0		0		
	9-Hydroxyfluorene	100	0.21	100	0.20	0.15
	9-Hydroxyphenanthrene	98.4	0.043	100	0.057	0.045

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] Not presented if detection rate was below 50%
[c] From the Fourth Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex (HC, 2017)

Table 33. Comparison of the levels of cotinine in the Dehcho and the Sahtú

Type of sample	Contaminant	Dehcho		Sahtú		Canadian population[c]
		Detection (%)	GM	Detection (%)	GM	GM
URINE (µg/L)	Cotinine- smokers	100	510	100	580	490
	Cotinine- non smokers	61.0	11	31.3	1.4	
	Cotinine-All	75.4	45	63.6	29	

[a] Geometric mean: A type of average that describes the central tendency of a set of values
[b] Not presented if detection rate was below 50%
[c] From the Third Report on Human Biomonitoring of Environmental Chemicals in Canada for both sex 12–79 years (HC, 2017)

4. CONCLUSION

4.1. Biomonitoring levels and guidelines

The biomonitoring results in the region show that participants' mercury, lead and cadmium exposures were generally low. For example, almost all participants' levels fell below the health guidance values for these metals. It's worth noting though that lead from urine samples looked slightly higher than other projects done in Canada. Through the ongoing project, we reported the results to the participating communities, based on the dataset we had so we could get all participants results back quickly. Single community results and partial dataset might not report the same messages of the whole project. Overall, the main finding is the results for participants were lower than those known to pose health risks.

These results are especially important since some country foods, are sometimes found to have higher levels of mercury and cadmium. For example, mercury levels in northern pike, walleye, and lake trout resulted in the release of several consumption notices from the Government of the Northwest Territories Department of Health and Social Services. Additionally, a consumption notice was issued in 2017 to inform communities about cadmium levels in the kidneys/liver of moose from the southern Mackenzie Mountains. Overall, the biomonitoring results have shown that although country foods in the Northwest Territories sometimes show elevated contaminant levels, that peoples' exposures in the territory have typically remained low. These results reinforce the important message that the **benefits of country food consumption generally outweigh contaminant risks.**

For more information on the consumption notices issued by the Government of the Northwest Territories Department of Health and Social Services:

http://www.hss.gov.nt.ca/en/services/environmental-contaminants

Mercury exposure is often due to the consumption of fish that eat other fish (such as jackfish, lake trout, and walleye). Lake trout, one of the most consumed fish, can have high levels of mercury, but also a high level of good fats. Smaller fish or fish low in the food chain (whitefish, cisco, grayling, suckers, and inconnu) have generally very low mercury levels. Whitefish, the most consumed fish by participants, has very low mercury levels.

4.2. Balancing Risks and benefits of country foods

Country foods provide the people of the Northwest Territories many benefits. These include nutritional, economic, social, and cultural benefits. It is, therefore, important that messages about contaminants and country foods are carefully crafted in a way that balances benefits and risks. We know the health benefit of fish consumption, the fact that is it a reliable food and its important cultural value. Our current project integrates a risk-benefit approach and reports the nutrients mainly associated with fish and country food consumption (e.g. omega-3, selenium), part of a healthy diet.

Although different levels of mercury, lead and cadmium were detected among participants, some biomarkers for metal nutrients were relatively high (copper and manganese). Average levels of omega-3 fatty acids is similar to what was observed in previous studies in Canada. Higher levels of omega-3's may help protect peoples' health against heart disease and other health problems. Eating fish is one of the best ways to increase levels of omega-3's and some country foods (Lake Whitefish, Cisco) are particularly rich in these important nutrients. Lake whitefish and cisco are also very low in mercury and can be eaten without restriction. Lake trout is also rich in these healthy fats, but can sometimes have higher levels of mercury. The General Fish Consumption Guidelines for the Northwest Territories offers useful advice on how people can access the nutritional benefits of eating fish while protecting themselves from contaminants like mercury:

http://www.hss.gov.nt.ca/en/services/fish-consumption-guidance

4.3. Sharing the knowledge

The health messages survey results informed on the priorities and concerns among study participants as well as the ways by which researchers can effectively share information with community members in the Mackenzie Valley, Northwest Territories. Over the next year, we will work with local, regional, territorial, and federal partners to return the messages from the communities in the Northwest Territories Mackenzie Valley (Dehcho and Sahtú regions). The priority for this communication strategy will be the use of information from this project to promote country foods in a way that helps people lower their contaminant exposures while encouraging health and wellness.

4.4. Next steps of the project

The research team will share these results in 2019. This report, which provides a written record of the overall/aggregate results, can be useful as a reference document as it contains baseline levels of contaminants among the people of these communities. In this way, this research may form the foundation for future community-based monitoring projects designed to track changes in exposures over time.

We will continue working to better understand the:

- Typical contaminant exposure ranges across Indigenous communities in the Northwest Territories Mackenzie Valley;
- Profound importance of country foods to participating communities;
- Main sources and drivers of contaminant exposure in participating communities, and
- Complex relationships between food use, contaminant exposures, and nutritional status.

This information will help us work with communities and territorial partners to ensure that messages regarding contaminants (and the importance of country foods) are communicated throughout the Dehcho and Sahtú regions. We look forward to working with community leaders to make sure that these messages are brought back in ways that are useful and meaningful to the people of the Mackenzie Valley.

Although the average exposures were low, a few participants had higher than usual levels of mercury, cadmium and lead. One of the best ways to protect against contaminants exposure in general is to have a healthy, balanced diet and reduce smoking. The best way to lower mercury is to choose smaller fish and none predatory fish over big fish or predatory fish when possible. Lead can be found in natural well, in old paint or dust, but one of the frequent dietary source is intentionally via the contaminated game meat hunted with lead bullets. Therefore it is preferable to use steel ammunition. Participants with toxic metals levels higher than the guidance value were invited to provide additional samples to see whether the exposures have remained high.

Going forward, the research team will continue working with community and territorial representatives to:

1. Make sure that any follow-up monitoring addresses community concerns.
2. Identify contaminants exposure sources.

3. Identify individual action which have an impact on level of contaminants
4. Help find additional ways for people can lower their exposure levels.Investigate more the relation between country foods concumption and health

As described earlier (see Section 2.6. Chemical Analysis), every participant who took part in the research had the opportunity to opt-in to the "biobank". By opting into the biobank, participants allowed us to store their samples for up to 10 years so that we can measure additional contaminants as funds become available. No genetic or drug testing will ever be done on these biobanked samples. If we have results for other contaminants, we will return them to the community as well.

4.5. Future Research

There is still work to do to complement this project. Table 34 lists off the main data gaps that existed at the start of the project, and which data gaps remain.

Table 34. List of the main data gaps

√	Northwest Territories population levels
√	Recent characterization of country food consumption for Dene/Metis communities
#	Exposure determinants and groups of people with elevated contaminant exposure
√	Perception and awareness of country foods and contaminants
#	Communication strategy to share environmental health information
>	Country foods with less contaminants and the most nutrients for health
>	Main sources of contaminants exposure

√ Improved Knowledge through this project
Ongoing work
> Next steps

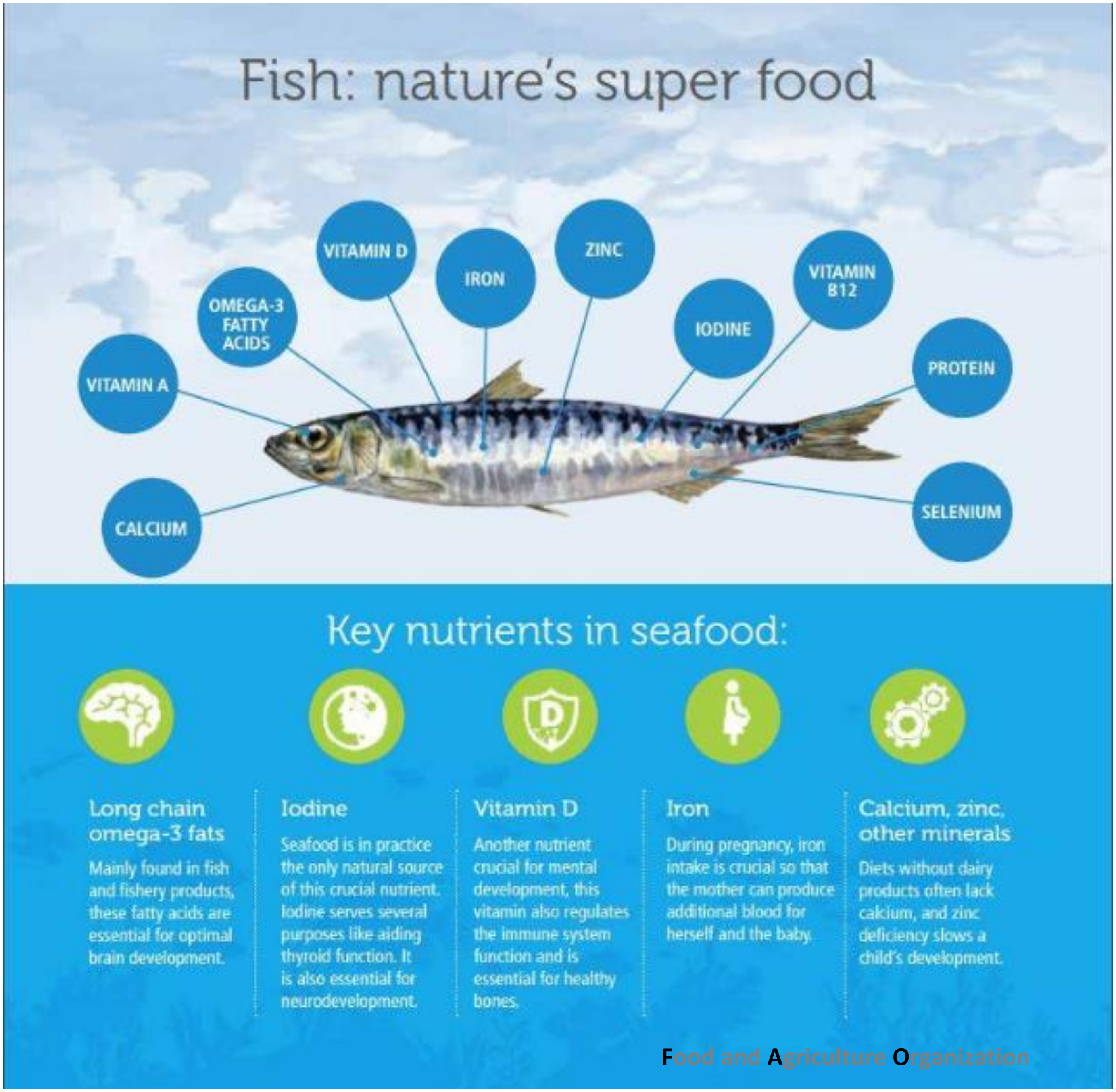
Our existing dataset helped to answer several of the main knowledge gaps but there are still few remaining gaps. Some of them will require follow-up research. To better assess the benefits and risk from country foods, the research team will continue to work with the local partners to investigate:

- Country food content, water quality, and dietary intake;
- Differences between regions and potential contaminant sources;

- Nutrition status and vitamins deficiency for these communities;
- Food security and country food access and consumption;
- Wellbeing related to country foods and the land;
- Relationship between awareness and perception, and
- Social media and the health messages communication.

4.6. Final message

Almost all participants' exposure levels fell below the biomonitoring guidance values established for mercury, cadmium and lead. Most of the contaminants measured in this project do not have guidelines to distinguish whether the participants' levels have exceeded those that are known to be safe. But, the levels observed for these contaminants were generally similar to the levels seen in other biomonitoring studies in Canada. Therefore, the health risks posed by these contaminants to participants appears to be low. The levels of some metal nutrients appeared higher than usually seen in other biomonitoring studies in Canada. Overall, these results reinforce that the health benefits of country foods generally outweigh contaminant risks.



Food and **A**griculture **O**rganization

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Glossary

- **24h recall:** Survey on all the food during the previous day (24h).
- **Biobank:** Storage of a sample of hair, blood or urine.
- **Biomarker:** Markers from biomonitoring.
- **Biomonitoring:** Biological measurement of chemicals
- **Contaminant:** Polluting substance found in the environment, animals, or people. It can be natural (e.g. mercury) or human made (e.g. pesticide).
- **Cotinine:** marker of smoking, derived from nicotine.
- **Creatinine:** Waste product from the body, filtered through the kidneys and eliminated in urine.
- **Essential trace element**: A type of nutrient the body needs to be healthy. Examples include copper, iron, manganese, and zinc.
- **FFQ (Food Frequency Questionnaire)**: Survey on country food consumption (frequency, preparation, parts/organs).
- **Guidelines:** Maximal levels of contaminants not associated with adverse impact on health
- **Heavy metal**: Metal and metal-like substances that can be harmful to human health. Examples include arsenic, cadmium, lead and mercury.
- **Metal**: Chemical elements naturally present in the environment. Examples include essential trace elements, and heavy metals, like mercury.
- **Nutrient:** Substances that the body needs to be healthy. Examples include vitamins, essential trace elements, and omega-3 fatty acids.
- **Omega-3 fatty acids**: Healthy fats present in some country foods and some store-bought foods. They are needed for proper brain development in children and good heart health in adults. Fish and seafood are some of the best sources of these healthy fats.
- **PAHs (Polycyclic Aromatic Hydrocarbons):** Chemicals released from burning coal , oil, gasoline , tobacco, and wood.
- **POPs (Persistent Organic Pollutants):** Man-made chemicals that can harm human and environmental health. Many of these chemicals are decreasing in the environment since their global ban in 2001. Examples include pesticides like DDT and industrial chemicals like PCBs.

Publications from the project

Manuscripts: published

Ratelle M, Laird M, Majowicz S, Skinner K, Swanson H, Laird B, 2018. Design of a human biomonitoring community-based project in the Northwest Territories Mackenzie Valley, Canada, to investigate the links between nutrition, contaminants and country foods. Int J Circumpolar Health, 77(1): 1510714.

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Napenas J, et al. Risk assessment of mercury in segmental hair of indigenous communities of the Dehcho Region, Northwest Territories, Canada: Characterizing chronological exposure, season variability and modeling.

Ratelle M, et al. Polycyclic aromatic hydrocarbons (PAHs) levels in urine samples collected in subarctic region in the Northwest Territories, Canada.

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Skinner K et al. Health Communication preferencee and the role of social media for Dene Communities.

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Thesis completed:

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Laird B, Swanson H, Skinner K (2017). Contaminant and Nutrient Biomonitoring in the Northwest Territories, Canada: Shedding Light on the Risks and Benefits of Food Choices. International Symposium on Biological Monitoring, Italy (Seminar).

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Ratelle M, Packull-McCormick S, Laird M, Laird B (2017). Balance Between Mercury Risks and Nutrient Benefits from Fresh Water Fish Consumption in the Northwest Territories, Canada: Preliminary Results from a First Nations Biomonitoring Study. International Conference on Mercury as a Global Pollutant, USA (Poster).

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Appendices

Guidance values used in the Mackenzie Valley Project

Contaminant	Sample	Regular Follow-up	Early Notification
Mercury	Hair	>5 µg/g[1] (2 µg/g)[1]	> 25 µg/g[1] (10 µg/g)[1]
Mercury	Blood	>20 µg/L[3] (8 µg/L)[3, 5]	>100 µg/L[3, 4, 5] (40 µg/L)[3]
Mercury	Urine	>25 µg/L[8]	
Cadmium	Blood	> 5 µg/L[2, 4, 6]	
Cadmium	Urine	> 7.3 µg/L[2]	
Lead	Blood	>100 µg/L[4, 7] (50 µg/L)	>200 µg/L[2, 4, 7] (100 µg/L)[2, 4]
Lead	Urine	>7 µg/L[2]	
Uranium	Urine		>15 µg/L[9]

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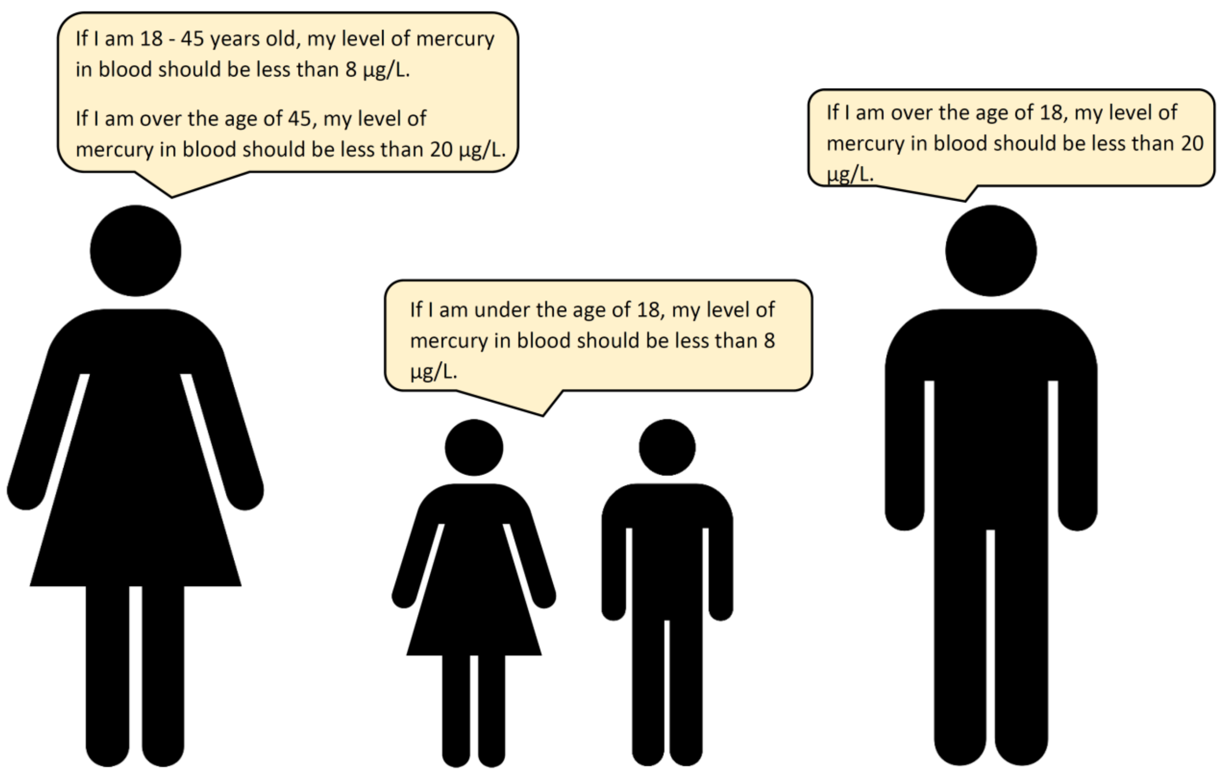
Additional information to interpret results

Contaminants and Health Guidelines

A **health guideline** is the maximum value of exposure thought to have no health effects. These health guidelines are set by regulatory agencies like the World Health Organization and Health Canada.

Guidelines used in the interpretation of the results may be different between participants. This is because some health guidelines are based on age and sex. Contaminants can have different effects on people of different ages. Also, contaminants can have different effects on women than men.

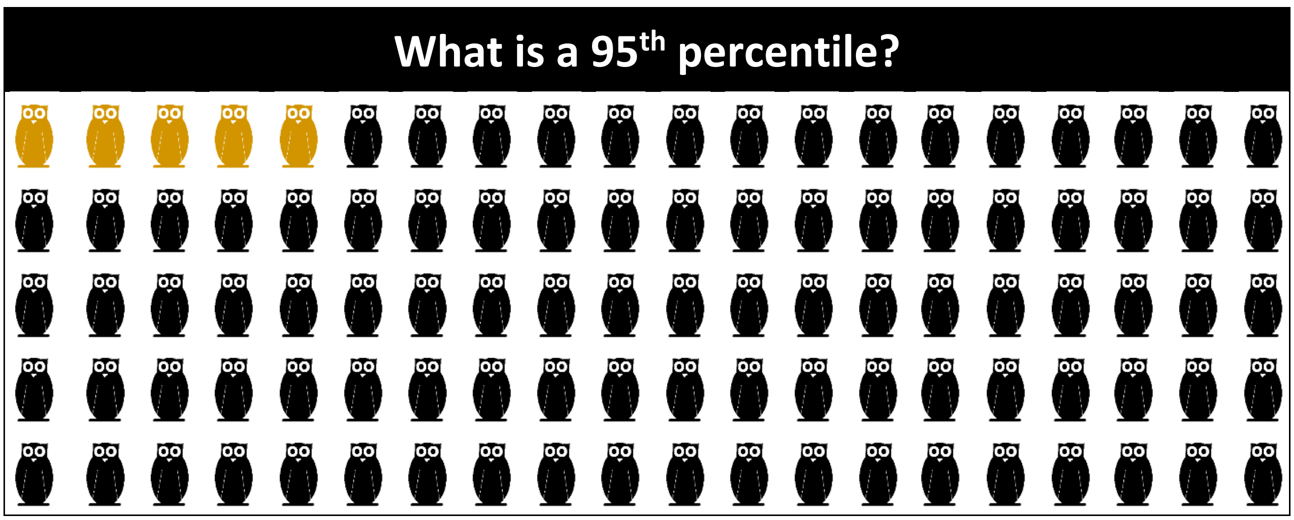
For example, the guidelines for mercury are different based on your age and sex. Children have a lower guideline for mercury because mercury can negatively affect the developing brain. Also, women between 18 - 45 years have a lower health guideline since this is childbearing age. Mercury exposure in pregnant women can harm the developing fetus. Adult men and women over 45 years can be exposed to higher mercury levels and not be affected. This is why the health guideline for mercury in the blood of adult men and women over 45 years is a higher level.



What if there is no guideline?

For most contaminants, no health guidelines are available. For those contaminants, we can check to see if your level is in the normal range seen in Canada. Whenever possible, we compared your results to normal levels measured in the Canadian general population as well as other First Nations communities in Canada. These normal ranges are published in the Canadian Health Measures Survey (CHMS) and the First Nations Biomonitoring Initiative (FNBI).

This normal range of each contaminant is set from the **95th percentile of exposures** from the CHMS and/or FNBI. This means that 95 out of 100 people had levels at or below the 95th percentile of exposure. For example, if the 95th percentile of arsenic is 39 µg/L, only 5% of people had levels higher than this value.



How to lower contaminant levels

Some of the contaminant/nutrient levels may have been higher than we usually see in the general population of Canada. ***This does not mean that your health is at risk***. But, we have included some information describing what you could do to try to lower your levels:

Cadmium

Is it harmful? Exposure to cadmium from food can cause kidney problems. Breathing in cadmium can cause lung damage and cancer.

How are people exposed? For smokers, breathing in tobacco smoke is the primary source of cadmium exposure. Second-hand smoke can also be a source of cadmium exposure. For non-smokers, diet is the major source of cadmium exposure.

What can I do? Eating a healthy diet rich in zinc, iron, and calcium can help reduce cadmium levels over time. To reduce cadmium exposure, we recommend reducing your exposure to tobacco smoke (from smoking and second hand smoke). Some organs (liver/kidney) of moose from the southern Mackenzie Mountains might also contain high cadmium levels. Eating less liver/kidney from the moose in these regions could also help lower your exposure. Moose meat is a safe and healthy alternative.

Lead

Is it harmful? Long-term exposure to low levels of lead can be harmful to the brain, kidneys, and heart. Children, infants, and the developing fetus are most at risk to harmful effects caused by lead.

How are people exposed? People can be exposed to lead from many sources (food, water, soil, dust). In houses built before the 1980's, lead exposure can also come from lead paint or pipes. You can also be exposed to lead if you eat wild game and birds harvested with lead ammunition.

What can I do? Eating a healthy diet rich in iron, vitamin D, zinc, and calcium can help lower lead levels over time. Using lead-free ammunition can also help lower your lead exposure.

Mercury

Is it harmful? Long-term exposure to low levels of mercury can harm the brain, immune system, and heart. Children, infants, and the developing fetus are most at risk to mercury's harmful effects.

How are people exposed? Eating fish and seafood that contains high levels of mercury is usually how most people are exposed. Dental amalgam (silver fillings for cavities) can also cause people to be exposed.

What can I do? Fish contain a number of important nutrients and Health Canada recommends eating at least two servings of fish a week; however, different types of fish from different areas have different levels of mercury. If you are going to eat a lot of fish it is important to choose fish that are low in mercury. In general, if you want to lower your mercury exposure, we recommend you eat less predatory fish (such as jackfish, lake trout, and walleye). When you do eat predatory fish, it is best to eat the smaller fish. Whitefish, cisco, grayling, suckers, and inconnu generally have very low mercury levels. If you eat a lot of fish, these are the best fish to choose to keep your mercury levels low. Recommendations on fish consumption can be found on the Government of Northwest Territories' website: http://www.hss.gov.nt.ca/

Uranium

Is it harmful? Exposure to the type of uranium normally found in the environment can cause kidney problems. However, there are different types of uranium which can have different health effects. We cannot assess what these levels mean for your health without doing a further analysis of your samples.

How are people exposed? There are many ways by which people can be exposed to uranium. The most common ways people are exposed to high levels of uranium are from contaminated soil, dust, or drinking water.

What can I do? We will continue to work with you and your community to identify the source of this uranium so that we can better help to lower your exposure. Municipal drinking water is tested regularly for several chemicals, including uranium, and is safe to drink.

Manganese

Is it harmful? Manganese is a mineral that is required for good health. It is important to have enough manganese in your diet. However, taking in too much manganese may harm the brain.

How are people exposed? The main source of manganese for Canadians is from their diet. Some multi-vitamins may also contain manganese.

What can I do? Eating a healthy, balanced diet provides your body with all the manganese it needs. If you are taking a multi-vitamin and your level was higher than usual, you may want to talk to your doctor about your choice of multi-vitamin.

Arsenic

Is it harmful? There are different types of arsenic. Some types are more harmful than others. Each type of arsenic causes different types of effects. Long term exposure to the most harmful types of arsenic can cause cancer of the bladder, lungs, and skin.

How are people exposed? Everyone is exposed to low levels of arsenic. There are many ways by which people can be exposed to arsenic, including from contaminated soil, house dust, and harvesting berries from near contaminated sites. Many parts of the Northwest Territories have naturally-high levels of arsenic.

What can I do? To better understand what these levels mean and how to help lower your levels, we need to study which forms of arsenic people in your community/region have been exposed to. This work will begin very soon. We will return the results to you and your community as soon as we have more information.

Nutrients

Is it harmful? Cobalt, copper, nickel, selenium, and zinc are essential elements required for good health. It is important to have enough of these nutrients in your diet. However, being exposed to too much of these nutrients can cause health problems.

How are people exposed? The main source of these nutrients is food. Many multi-vitamins also contain one or more of these nutrients.

What can I do? Eating a healthy, balanced diet usually provides the right levels of these nutrients for the body. If you are taking a multi-vitamin and your level was higher than usual, you may want to talk to your doctor about your choice of multi-vitamin.

PCB and DDT (Persistent Organic Pollutants)

Are they harmful? Excessive exposure to PCB and DDT can damage to the nervous system and liver. PCB and DDT are pesticides that were banned in North America in the 1980's due to environmental and human health concerns. In 2001, they were banned worldwide.

How are people exposed? Levels of Persistent Organic Pollutants in the environment have decreased greatly since they were banned. The foods with the highest Persistent Organic Pollutants levels tend to be fish, shellfish, and fatty foods. Results were not presented for pollutants with no detection in the community (Aldrin, PCB28, PCB52, PCB66, PCB99, PCB101, PCB105, PCB128, PBDE15, PBDE17, PBDE25, PBDE28, PBDE33, PBDE100, PBB153, alpha-Chlordane, gamma-Chlordane, gamma-HCH, p,p'-DDT).

What can I do? Because persistent organic pollutants can remain in the body for an extended period, the levels in body may have been from exposures that occurred a long time ago. Because they were banned many years ago, levels in people should continue to decrease with time.

General Fish Consumption Guidelines for the NWT

Why eat fish?

Eating fish contributes to a healthy, nutritious diet. Fish is an excellent source of protein, calcium, minerals, and omega-3 fatty acids which help maintain your health!

How much fish should I eat each week?

Canada's Food Guide recommends at least two servings (equal to 150 grams, 5 ounces or 1/3 of a pound) of fish each week as a part of a healthy, balanced diet.

Can fish be contaminated by chemicals in the environment?

Fish, like other foods, can contain varying levels of chemical contaminants such as mercury. An environmental contaminant is any chemical in a food that would not normally be present. Environmental contaminants can result from human releases of contaminants to the environment, or from natural activities which allow contaminants to enter the food chain.

Are these contaminants harmful?

The mere presence of a contaminant may not always be harmful. Small amounts of mercury can also be found in fish bought in the supermarket or caught in the wild.

Do some fish contain more contaminants than others?

Predatory fish that feed on other fish and reach a large size – like walleye, lake trout and northern pike – may contain levels of mercury in excess of consumption guidelines. Other fish species – like whitefish, cisco, suckers, grayling, Arctic Char, and inconnu – generally have very low levels of mercury, even in larger fish.

Should pregnant women eat fish?

Regular fish consumption by pregnant women and nursing mothers is overall beneficial for healthy prenatal and early childhood development.

Fetuses, infants and young children are particularly sensitive to the effects of mercury. Unless there are specific fish consumption guidelines for a particular lake, women who are pregnant (or maybe pregnant), nursing mothers, and children under 12 are advised to limit their predatory fish consumption of lake trout and northern pike that are less than 60 cm (or 24 inches), and walleye that are less than 45 cm (18 inches), to a single serving per week. These groups are also advised to avoid lake trout and northern pike larger than 60 cm (or 24 inches) and walleye larger than 45 cm (or 18 inches).

Non-predatory fish are a good choice for women of child bearing age and children in terms of mercury exposure. Consuming fish contributes to a healthy, nutritious lifestyle. Women who eat fish are encouraged to continue breastfeeding to provide infants the best start to a healthy life.

For specific fish consumption guidelines on NWT lakes that have been tested for contaminants please visit the GNWT Department of Health and Social Services website at http://www.hss.gov.nt.ca/health/environmental-health/mercury-levels-fish.

For more information on fish species and regulations, consult the 2015/2016 NWT Sport Fishing Guide at
http://www.enr.gov.nt.ca/sites/default/files/nwt_sport_fishing_guide_2015-2016.pdf.

Moose Organ Consumption Notice

April 2017 | www.hss.gov.nt.ca

The Chief Public Health Officer recommends that the consumption of liver and kidneys from moose harvested in the southern Mackenzie Mountains within the Dehcho region should be limited due to high cadmium levels. However, moose harvested in the Mackenzie and Liard valleys, and from the Sahtu region have lower levels of cadmium such that recommended guidelines therefore allow for more consumption of moose organs from these areas than for moose organs harvested from the southern Mackenzie Mountains.

Moose liver and kidney had previously been collected from the southern Mackenzie Mountains and the Mackenzie and Liard valleys as part of a wildlife monitoring program. Some animals were found to have elevated levels of cadmium and a public health advisory was issued (February 10, 2009). Moose from the same regions were recently re-tested and also included an additional region (Sahtu). Updated recommended guidelines for consumption are now being provided based on the new data.

There was a significant difference in cadmium levels between the moose sampled in the mountains and those collected from the other regions. The following Recommended Maximum Monthly Intakes were provided based on the Provisional Tolerable Monthly Intake for cadmium of 25 µg/kg bw/month (Health Canada).

Region + Organ Type (average cadmium concentration)	Recommended Maximum Monthly Intakes
Southern Mackenzie Mountain Moose Liver (30.9 µg/g*)	¾ serving per month* (56 g)
Southern Mackenzie Mountain Moose Kidney (47 µg/g)	½ serving per month (37 g)
Mackenzie and Liard Valley Moose Liver (2.7 µg/g)	8-9 servings per month (650 g)
Mackenzie and Liard Valley Moose Kidney (14 µg/g)	1-2 servings per month (125 g)
Sahtu Moose Liver (2.3 µg/g)	10 servings per month (739 g)
Sahtu Moose Kidney (14.6 µg/g)	1-2 servings per month (117 g)

1 serving = 75 grams = 1 pack of cards

* based on previous data due to only 1 liver sample being provided in the more recent data.

Moose Organ Consumption Notice

April 2017 | www.hss.gov.nt.ca

Levels of cadmium in the meat of moose are very low, and moose meat remains a very healthy food choice. Moose is a nutritious food source and is good for us when following recommended consumption guidelines.

Moose meat, liver, kidney and blood are all excellent sources of protein and iron. Protein is needed to build and repair all parts of the body. Iron is used to make healthy blood. The meat and liver are also excellent sources of B vitamins, which help our bodies use energy from foods and are important for healthy skin, hair, nerves and muscles as well as healthy growth and development.

According to the World Health Organization, **smoking tobacco remains the most important source of exposure to cadmium, and the daily intake will exceed that from food in the case of heavy smokers**. The most effective way to minimize exposure to cadmium is to stop smoking and to avoid second hand smoke.