

# Traditional Food Consumption and Other Determinants of Exposure for Lead, Cobalt, Manganese, and Hexachlorobenzene in Northern Canada

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TABLE S1. List of analytes and biological matrices for Old Crow biomonitoring project (Drysdale et al., 2021).

Class	Matrix	Parent compounds	Biomarkers
Metals	Hair	Mercury	Mercury
	Whole Blood and Urine	Aluminium Arsenic Barium Beryllium Cadmium Cesium <sup>a</sup> Chromium Cobalt Copper Gallium Iron <sup>b</sup> Lead Lithium Manganese Mercury Nickel Rubidium <sup>a</sup> Selenium Strontium Thallium Uranium Vanadium Zinc	Aluminum Total Arsenic Total Barium Total Beryllium Total Cadmium Total Cesium Total Chromium Total Cobalt Total Copper Total Gallium Total Iron Total Lead Total Lithium Total Manganese Total Mercury Total Nickel Total Rubidium Total Selenium Total Strontium Total Thallium Total Uranium Total Vanadium Total Zinc
POPs – Flame retardants	Plasma	Polybrominated diphenyl ethers (PBDE)	PBDE , IUPAC # 15 PBDE , IUPAC # 17 PBDE , IUPAC # 25 PBDE , IUPAC # 28 PBDE , IUPAC # 33 PBDE , IUPAC # 47 PBDE , IUPAC # 99 PBDE , IUPAC # 100 PBDE , IUPAC # 153
	Plasma	Polybrominated biphenyls (PBB)	PBB , IUPAC # 153
POPs – Pesticides	Plasma	Aldrin	Aldrin
		Chlordane	gamma-Chlordane alpha-Chlordane Oxychlordane cis-Nonachlor trans-Nonachlor
		Lindane	gamma-HCH beta-HCH

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TABLE S1. List of analytes and biological matrices for Old Crow biomonitoring project (Drysdale et al., 2021). – *continued*:

Class	Matrix	Parent compounds	Biomarkers
POPs – Pesticides	Plasma	Hexachlorobenzene	Hexachlorobenzene
		Mirex	Mirex
		DDT	p,p'-DDE p,p'-DDT
		Toxaphene	Parlar no. 26 Parlar no. 50
Lipids	Plasma	Fatty acids	Omega-3 (EPA + DHA) PUFAs N-3, N-6
POPs – Electrical and coolant fluids	Plasma	Polychlorinated biphenyls (PCB)	PCB , Aroclor 1260 PCB , IUPAC # 28 PCB , IUPAC # 52 PCB , IUPAC # 66 PCB , IUPAC # 74 PCB , IUPAC # 99 PCB , IUPAC # 101 PCB , IUPAC # 105 PCB , IUPAC # 118 PCB , IUPAC # 128 PCB , IUPAC # 138 PCB , IUPAC # 146 PCB , IUPAC # 153 PCB , IUPAC # 156 PCB , IUPAC # 163 PCB , IUPAC # 167 PCB , IUPAC # 170 PCB , IUPAC # 178 PCB , IUPAC # 180 PCB , IUPAC # 183 PCB , IUPAC # 187 PCB , IUPAC # 194 PCB , IUPAC # 201 PCB , IUPAC # 203 PCB , IUPAC # 206

<sup>a</sup> Only available in blood samples

<sup>b</sup> Only available in urine samples

PUFA: Polyunsaturated fatty acid

EPA: Eicosapentaenoic acid

DHA: Docosahexaenoic acid

HCH: Hexachlorocyclohexane

DDT: Dichlorodiphenyltrichloroethane

DDE: Dichlorodiphenyldichloroethylene

\* Other contaminants have been analyzed as part of this study and are not included in this report. These contaminants include perfluoroalkylated substances (Garcia-Barrios et al., 2021) in serum, and dioxins and furans in plasma.

TABLE S2. Determinants of exposure selected for inclusion in this analysis.

Determinant of exposure	Source	Data type	Key parameter	Criteria for inclusion
<i>Demographics</i>				
Sex	Biomonitoring clinic intake demographics	Binary (Male/Female)	Co, Mn, Pb, HCB	In other biomonitoring studies, Mn, Co, and HCB have been higher in women (Arrebola et al., 2009; Oulhote et al., 2014; Fort et al., 2015) and Pb is often higher in men (Muntner et al., 2005)
Age	Biomonitoring clinic intake demographics	Continuous	Co, Mn, Pb, HCB	In other biomonitoring studies, Mn and Co (Health Canada 2013; Oulhote et al., 2014) have been shown to decrease with age, while Pb and HCB often increase (Muntner et al., 2005; Arrebola et al., 2009)
<i>Lifestyle risk factors</i>				
Smoking Status	Risk factors survey (Old Crow), Biomonitoring clinic intake demographics (reference populations)	Binary (smoked in the previous 24 hours)	Co, Mn, Pb, HCB	Smoking cigarettes can increase exposure to metals and HCB, Co, Mn (Caruso et al., 2014; Pappas et al., 2014; Lackmann et al., 2000)
Drinking water source	Risk factors survey*	Binary (sometimes or often drinks untreated river water)	Co, Mn, Pb	Drinking water can be an exposure source for metals, including Co, Pb, Mn (Agency for Toxic Substances and Disease Registry, 1992; Brown et al., 2012; Iyare 2019)
Use of lead ammunition	Risk factors survey*	Binary (sometimes or often uses lead ammunition)	Pb	Eating food hunted using lead ammunition may be a source for Pb exposure (Tsuji et al., 2008)
Vitamin intake	Risk factors survey*	Binary (takes a daily multivitamin)	Co, Mn, Pb	Mn and Co (as part of B12) are components of many multivitamins. Pb absorption can be affected by Ca and Vitamin D status (Sorrell et al., 2013; Knoop et al., 2019)
<i>Traditional food consumption</i>				
Birds	Food frequency questionnaire	Binary (eats the food)	Co, Mn, Pb, HCB	All four parameters have been found at elevated levels in some game birds, and birds can also become contaminated by lead ammunition during hunting (Kuhnlein and Receveur, 2007; Tsuji et al., 2008; Chan et al., 2011)
Berries	Food frequency questionnaire	Binary (eats the food)	Co, Mn, Pb	Berries can contain high levels of metal nutrients (Mn, Co) and become contaminated on the surface by Pb-bearing soils (Manninen and Tankkanen, 1993; Chan et al., 2011)
Moose Organs	Food frequency questionnaire	Binary (eats the food)	Co, Mn, Pb, HCB	Concentrations of all four parameters can accumulate in moose organs (Osdjo and Bignert, 2002; Venalainen et al., 2005; Chan et al., 2011)
Caribou Organs	Food frequency questionnaire	Binary (eats the food)	Co, Mn, Pb, HCB	Concentrations of all four parameters can accumulate in caribou organs (Chan et al., 2011; O'Hara et al., 2005)
Whitefish	Food frequency questionnaire	Binary (eats the food)	Co, Mn, Pb, HCB	This food can be high in trace metals, and fatty tissue can accumulate HCB (Robillard et al., 2002; Kuhnlein and Receveur, 2007; Chan et al., 2011)
Chinook	Food frequency questionnaire	Binary (eats the food)	Co, Mn, Pb, HCB	This food can be high in trace metals, and fatty tissue can accumulate HCB (Kuhnlein and Receveur, 2007; Chan et al., 2011; Kelly et al., 2011)

TABLE S3. Levels of key biomarkers in Old Crow, Dehcho, and Sahtú populations (&gt; 18 Years).

	Old Crow (Drysdale et al., 2021)		Sahtú region (Laird et al., 2019)		Dehcho region (Laird et al., 2019)		CHMS (General Canadian population) <sup>1</sup>		FNBI (First Nations Biomonitoring Initiative (Assembly of First Nations, 2013)	
	GM <sup>2</sup>	95P <sup>3</sup>	GM <sup>2</sup>	95P <sup>3</sup>	GM <sup>2</sup>	95P <sup>3</sup>	GM <sup>2</sup>	95P <sup>3</sup>	GM <sup>2</sup>	95P <sup>3</sup>
Whole blood	54		123		122		4596-6070 <sup>1</sup>		473	
Co	µg/L	0.31 (0.28-0.33)	0.61 (0.51-0.84)	< LOD	< LOD	< LOD	0.23 (0.21-0.24)	0.40 (0.36-0.43)	NA	NA
Mn	µg/L	12 (11-13)	22 (19-24)	9.6 (9.1-10)	16 (15-21)	11 (10-12)	9.8 (9.5-10)	15 (14-16)	12 (12-13)	21 (20-22)
Pb	µg/L	24 (19-30)	98 (75-140)	26 (23-29)	85 (73-130)	12 (10-14)	8.1 (7.7-8.5)	24 (21-28)	12 (11-13)	33 (21-45)
Plasma	54		123		122		1665 <sup>1</sup>		471	
HCB	µg/L	0.10 (0.080-0.12)	0.43 (0.31-0.66)	0.097 (0.086-0.11)	0.37 (0.31-0.59)	0.053 (0.048-0.059)	0.13 (0.12-0.29)	0.17 (0.14-0.20)	< LOD	0.14 (0.11-0.16)
HCB	µg/g lipids	14 (12-17)	71 (40-76)	15 (14-17)	54 (47-78)	8.7 (8.0-9.6)	9.1 (8.0-10)	27 (20-33)	< LOD	18 (13-24)
Urine	44		100		78		6311		495	
Co	µg/L	0.37 (0.30-0.47)	1.7 (0.69-3.6)	0.30 (0.25-0.35)	1.1 (0.76-2.7)	0.37 (0.32-0.43)	1.5 (0.91-2.0)	0.97 (0.86-1.1)	NA	NA
Mn	µg/L	0.14 (0.11-0.18)	1.5 (0.25-2.5)	0.16 (0.13-0.17)	0.46 (0.35-0.79)	0.35 (0.31-0.40)	1.2 (0.62-1.2)	0.36 (0.32-0.4)	< LOD	0.59 (0.27-0.92)
Pb	µg/L	0.68 (0.49-0.91)	3.9 (2.1-4.1)	0.68 (0.51-0.90)	4.5 (3.1-7.0)	0.51 (0.42-0.64)	2.0 (1.7-1.1)	1.9 (1.7-2.0)	0.51 (0.43-0.60)	2.3 (1.5-3.1)
Co	µg/g creatinine	0.35 (0.30-0.43)	1.8 (0.56-3.3)	0.33 (0.32-0.42)	1.1 (0.87-2.0)	0.41 (0.35-0.48)	1.5 (0.93-2.3)	0.88 (0.79-0.97)	NA	NA
Mn	µg/g creatinine	0.13 (0.096-0.17)	1.7 (0.37-2.8)	0.17 (0.14-0.21)	0.77 (0.50-4.2)	0.39 (0.32-0.48)	1.2 (1.2-5.8)	0.61 (0.51-0.7)	< LOD	0.89 (0.66-1.1)
Pb	µg/g creatinine	0.64 (0.47-0.87)	3.1 (2.3-17)	0.83 (0.66-1.1)	5.7 (3.3-21)	0.57 (0.48-0.68)	2.4 (1.7-3.6)	1.6 (1.4-1.8)	0.56 (0.48-0.66)	2.2 (1.6-2.8)

<sup>1</sup> Results for blood and urinary cobalt and manganese, and urinary blood, cobalt, and lead are from Cycle 2 of the CHMS (n=6070) (Health Canada, 2013). Lead results are from Cycle 6 of the CHMS (n = 4596) (Health Canada, 2021). Plasma HCB results are from Cycle 1 of the CHMS (n=1665) (Health Canada, 2010).

<sup>2</sup> GM = Geometric mean.

<sup>3</sup> 95P = 95th percentile.

TABLE S4. Percent difference<sup>1</sup> in biomarker concentrations for determinants of exposure, controlling for age and sex in Old Crow (n = 44, 54)<sup>2</sup>.

Determinant of exposure	Blood Mn	Urinary Mn <sup>3</sup>	Blood Co	Urinary Co <sup>3</sup>	Blood Pb	Urinary Pb <sup>3</sup>	Plasma HCB <sup>4</sup>
Smokers (smoked cigarettes within last 24 hours)	-0.048	-6.7	-6.0	-35	29	18	32
Consumed a vitamin within last 24 hours	-13	-0.48	29*	29	-32	-56*	-0.41
Consumes untreated water sometimes to often	29*	7.9	-8.4	2.6	120**	110	5.7
Consumes food hunted using lead ammunition	12	1.4	-14	21	45	78	22
Consumers of the following traditional foods:							
Birds	-6.9	29	-47	-5.4	16	38	0.97
Berries	9.6	91	16	82	4.5	-10	5.9
Moose							
Bones in soup/stew	1.8	86*	15	25	14	38	35
Fat	-0.25	55	7.4	7.9	14	15	-6.5
Kidneys	-3.4	32	6.4	-8.6	35	86	35
Bone marrow	3.8	-2.7	5.2	6.7	35	62	8.4
Liver	-7.5	26	16	28	26	91	-3.2
Caribou / Porcupine							
Bones in soup/stew	7.2	45	12	16	35	9.6	26
Fat	18	35	2.8	4.5	9.4	-16	9.1
Kidneys	22*	5.7	9.6	-2.5	58*	29	29
Bone marrow	11	51	5.2	19	13	-11	38
Liver	6.9	-5.4	14	5.9	7.9	-38	-0.32
Fish							
Whitefish	-17	-4.9	28*	14	-51*	-79**	2
Chinook salmon	2	44	9.4	17	51	22	-4.1

\*  $p < 0.05$  and \*\*  $p < 0.01$ .

– Food was eaten by <15% or item not included in community surveys.

<sup>1</sup> A positive value indicates that the participants who ate the specified food, smoked, took a vitamin, or drank untreated water, as indicated, had higher average biomarker levels in the percentage indicated than those who did not. A negative value indicates that the participant who ate the specified food, smoked, took a vitamin, or drank untreated water, as indicated, had lower average biomarker levels in the percentage indicated than those who did not.

<sup>2</sup> n = 44 for urine samples, and n = 54 for blood and plasma samples.

<sup>3</sup> creatinine-adjusted.

<sup>4</sup> lipid-adjusted.

TABLE S5. Percent difference<sup>1</sup> in biomarker concentrations for determinants of exposure, controlling for age and sex in the Dehcho region (n = 78, 122)<sup>2</sup>.

Determinant of exposure	Blood Mn	Urinary Mn <sup>3</sup>	Blood Co	Urinary Co <sup>3</sup>	Blood Pb	Urinary Pb <sup>3</sup>	Plasma HCB <sup>4</sup>	
Smokers (smoked cigarettes within last 24 hours)	0.46	-332	-	-319	48**	21	5.9	
Consumers of the following traditional foods:								
Birds	-3.2	7.6	-	32	12	-6.2	19	
Berries	-3.6	24	-	0.21	-1.8	-32	0.69	
Moose								
	Bones in soup/stew	-3.4	32	-	-0.73	-32	12	11
	Fat	9.4	20	-	6.2	7.6	11	-2.9
	Kidneys	6.2	22	-	-15	19	32	32*
	Bone marrow	4	9.4	-	-5.6	12	23	4.2
	Liver	-3.2	-16	-	-11	3.5	9.6	9.4
Caribou / Woodland								
	Bone marrow	5.4	55	-	11	-16	14	17
	Liver	-15	55	-	22	-28	25	35
Fish								
	Whitefish	1.3	11	-	25	10	-49	-12
	Lake Trout	-5.8	-16	-	-22	-7.5	-34*	6.7

\*  $p < 0.05$  and \*\*  $p < 0.01$ .

- Food was eaten by <15% or item not included in community surveys.

<sup>1</sup> A positive value indicates that the participants who ate the specified food, smoked, took a vitamin, or drank untreated water, as indicated, had higher average biomarker levels in the percentage indicated than those who did not. A negative value indicates that the participant who ate the specified food, smoked, took a vitamin, or drank untreated water, as indicated, had lower average biomarker levels in the percentage indicated than those who did not.

<sup>2</sup> n = 78 for urine samples, and n = 122 for blood and plasma samples.

<sup>3</sup> creatinine-adjusted.

<sup>4</sup> lipid-adjusted.

TABLE S6. Percent difference<sup>1</sup> in biomarker concentrations for determinants of exposure, controlling for age and sex in the Sahtú region (n = 100, 123)<sup>2</sup>.

Determinant of exposure	Blood Mn	Urinary Mn <sup>3</sup>	Blood Co	Urinary Co <sup>3</sup>	Blood Pb	Urinary Pb <sup>3</sup>	Plasma HCB <sup>4</sup>	
Smokers (smoked cigarettes within last 24 hours)	1.4	9.5	–	11	15	110**	14	
Consumers of the following traditional foods:								
Birds	–15	–2.7	–	–24	62	32	48*	
Berries	–0.03	–42	–	–28	–6.7	–59*	19	
Moose								
	Bones in soup/stew	12	–12	–	29	32	134	4.5
	Fat	8.4	0.58	–	11	18	91	8.4
	Kidneys	13	–10	–	21	20	86	7.2
	Bone Marrow	13	–15	–	41	26	66	15
	Liver	16	–38	–	–28	45	51	–4.7
Caribou / Barren-Ground								
	Bones in soup/stew	4.0	–41	–	–1.1	55	41	16
	Fat	–1.4	–53*	–	–15	41	26	16
	Bone marrow	–5.6	4.7	–	32	13	62	9.6
Caribou / Woodland								
	Bones in soup/stew	–7.3	–32	–	–1.3	38	58	29
	Fat	–9.4	–28	–	–2.0	35	58	45*
	Kidneys	6.7	–0.89	–	29	51	220	22
	Bone marrow	2.0	29	–	48	48	230*	48**
Fish								
	Whitefish	–15	14	–	–8.6	58	–25	–10
	Lake Trout	–6.9	38	–	25	14	130	17

\*  $p < 0.05$  and \*\*  $p < 0.01$ .

– Food was eaten by <15% or item not included in community surveys.

<sup>1</sup> A positive value indicates that the participants who ate the specified food, smoked, took a vitamin, or drank untreated water, as indicated, had higher average biomarker levels in the percentage indicated than those who did not. A negative value indicates that the participant who ate the specified food, smoked, took a vitamin, or drank untreated water, as indicated, had lower average biomarker levels in the percentage indicated than those who did not.

<sup>2</sup> n = 100 for urine samples, and n = 123 for blood and plasma samples.

<sup>3</sup> creatinine-adjusted.

<sup>4</sup> lipid-adjusted.

TABLE S7. Percent difference<sup>1</sup> in biomarker concentrations for determinants of exposure, controlling for age and sex in pooled participating communities (n = 222, 229)<sup>2</sup>.

Determinant of exposure	Blood Mn	Urinary Mn <sup>3</sup>	Blood Co	Urinary Co <sup>3</sup>	Blood Pb	Urinary Pb <sup>3</sup>	Plasma HCB <sup>4</sup>
Smokers (smoked cigarettes within last 24 hours)	5.0	16	–	3.5	22*	51**	11
Consumers of the following traditional foods:							
Birds	3.0	24	–	–1.8	9.7	18	12
Berries	8.4	–5.8	–	–9.0	–2.3	–41*	3.5
Moose							
	Bones in soup/stew	1.5	26	–	14	35*	45
	Fat	5.9	35	–	7.9	11	26
	Kidneys	7.2	23	–	–2.5	14	55*
	Bone marrow	5.9	26	–	7.9	8.1	38
	Liver	0.74	11	–	–8.0	1.5	25
Caribou / Barren-Ground							
	Bones in soup/stew	5.9	–31*	–	–2.5	74**	18
	Fat	13	–38**	–	–8.6	58**	6.9
	Bone marrow	7.9	–22	–	2.2	51**	14
Caribou / Woodland							
	Bones in soup/stew	–12	–17	–	7.1	38*	35
	Fat	–13	–28	–	7.4	29	23
	Kidneys	–10	–8.6	–	17	29	70
	Bone marrow	–3.0	38	–	26	26	91*
Fish							
	Whitefish	–9.2	32	–	–0.89	–9.6	–52*
	Lake Trout	2.0	–2.1	–	17	51	22

\*  $p < 0.05$  and \*\*  $p < 0.01$ .

– Food was eaten by <15% or item not included in community surveys.

<sup>1</sup> A positive value indicates that the participants who ate the specified food, smoked, took a vitamin, or drank untreated water, as indicated, had higher average biomarker levels in the percentage indicated than those who did not. A negative value indicates that the participant who ate the specified food, smoked, took a vitamin, or drank untreated water, as indicated, had lower average biomarker levels in the percentage indicated than those who did not.

<sup>2</sup> n = 222 for urine samples, and n = 299 for blood and plasma samples.

<sup>3</sup> creatinine-adjusted.

<sup>4</sup> lipid-adjusted.