

Human Biomonitoring: Levels, Determinants and Sources of Polychlorinated Biphenyl Exposure in
the Northwest Territories and Yukon

by

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

This thesis presents the work of Victoria Gevaert in direct collaboration with her supervisor Dr. Brian Laird, with comments and feedback from Dr. Joel Dubin and Dr. Ken Froese.

The methods, including the implementation, collection, and initial analysis of the human biomonitoring projects, for this thesis, were informed by Dr. Brian Laird and Dr. Mylène Ratelle. Dr. Laird was the primary investigator of the Contaminant Biomonitoring Study in the Northwest Territories Mackenzie Valley and in the Yukon and was involved with all aspects of the section writing of this thesis. Dr. Mylène Ratelle assisted through chemical analysis, oversight, and database creation. Biomonitoring clinics were coordinated and implemented by other members of the research team including Dr. Mylène Ratelle. Sections 2,3,4, and 5 of this thesis were written intended for publication.

Abstract

Background: Human biomonitoring is a useful tool to assess contaminant exposure levels in human populations. Several human biomonitoring projects have been established in Canada to measure and report analyte exposure levels. However, these projects often do not include participants from Arctic and subarctic Indigenous communities in the Northwest Territories and Yukon. Thus, to fill a data gap in Canada, biomonitoring projects in the Dehcho and Sahtú regions of the Northwest Territories as well as Old Crow, Yukon were established between 2016 and 2019 to assess contaminant and nutrient exposure status as well as report information related to traditional food diets. Data on traditional food diets is also useful to collect as these diets provide several benefits related to health and well-being. Importantly, identifying exposure levels is the first step in identifying potential sources of exposure, which often include diet for many classes of contaminants. Polychlorinated biphenyl's (PCB) were among the dozens of analytes measured in these projects. These man-made chemicals are an important chemical to monitor due to their persistent nature and their potential for adverse human health effects. Although production of PCBs has been banned in North America since 1979 and worldwide since 2001, levels of PCBs are still detected in human biological samples. This research aims to report levels of PCB exposure in participating regions of the biomonitoring project described above as well as identify potential determinants and sources of these chemicals.

Methods Biomonitoring clinics were set up in communities within the Dehcho and Sahtú regions of the Northwest Territories and in the community of Old Crow, Yukon. At these clinics, select biological samples were collected, including plasma for POP analysis. Surveys and questionnaires were also administered to collect demographic and dietary data. Using the analytical and survey data collected from these biomonitoring projects, statistical analyses were completed to determine if PCB exposure levels were within a normal range, what potential determinants were associated with exposure levels, and if traditional food consumption was a potential source of PCB concentration level. Plasma samples (n=328) collected from these biomonitoring projects were used to develop simple linear regression models to identify potential determinants of PCBs between log-normalized PCB exposure levels and BMI, omega-3 fatty acid level and age. Independent samples T-tests were used to determine associations between PCB concentration level and binary variables including sex and smoking status. ANOVA multiple comparisons were used to assess if levels appeared elevated between the study regions. To determine if levels were within a normal range, comparisons were completed between

exposure levels reported in the First Nation Biomonitoring Initiative (FNBI) and the Canadian Health Measures Survey (CHMS). Food frequency questionnaire (FFQ) data were used to report consumption patterns in participating regions. To identify if traditional food was associated with PCB biomarkers, multiple linear regression models were developed using FFQ data and PCB exposure levels, while adjusting for age and sex.

Results: Among those participants below the age of 60 in all the study regions, all PCB biomarkers were within the normal range observed in Canada (i.e., below or similar to the CHMS or FNBI levels). As well, in Old Crow, those participants over 60 also had all PCB levels within the normal range. In contrast, for participants over 60 years in the Dehcho and Sahtú, levels began to appear outside of the normal range. For example, in the Dehcho, PCB187 and PCB201 appeared elevated compared to CHMS levels for those over 60 years. In the Sahtú, Arochlor 1260, PCB146, PCB153, PCB163, PCB170, PCB178, PCB180, PCB183, PCB187, PCB194, PCB201 and PCB203 appeared elevated compared to CHMS levels for those over 60 years. As well in the Sahtú, Arochlor 1260 was observed at an elevated level compared to the FNBI. When results were stratified by sex, PCB levels were largely observed within the normal range. The main exception was for male participants in the Sahtú, for whom PCB187 was elevated compared to the CHMS but not the FNBI.

Biomarkers of PCBs were all strongly correlated ($p < 0.05$) with one another. As well, age and PCB exposure level were strongly correlated ($p < 0.05$) in all PCB congeners and regions. Omega-3 fatty acids were also correlated ($p < 0.05$) with PCB congeners, but less so compared to age. Sahtú PCB levels appeared highest compared to the Dehcho and Old Crow regions, with geometric mean differences ranging between 1.5 (PCB163) to 2.9-fold (PCB153) among the study regions. In the Dehcho, men had higher PCB levels (up to 1.98-fold) compared to women for Arochlor 1260, PCB138, PCB153, PCB170, PCB180 and $\sum \text{PCB}_{138,153,180}$. Some associations ($p < 0.05$) were found between BMI and higher PCB exposure levels in Old Crow and Sahtú, but not for the Dehcho region. In the Dehcho and Sahtú regions, those who reported smoking in the last 24 hours had lower GM PCB levels compared to those who had not reported smoking. In contrast, Old Crow participants who reported smoking had generally higher PCB levels than those that did not. When PCB biomarkers were pooled across regions, some traditional foods were associated with higher PCB exposure levels. For example, among the traditional foods that were included in the multiple linear regression models, controlling for age and sex, lake trout ($\beta = 0.152$), fish eating waterfowl including black duck, fish duck, long-tailed duck, pintail, swan, canvasback, white-winged scoter, and mallard ($\beta = 0.136$), as well as game birds including spruce

grouse, sharp-tailed grouse, ptarmigan, black duck, mallard, fish duck, oldsquaw (long-tailed duck), wigeon, speckle belly goose, canvasback, Canada goose, snow goose, pintail, white-winged scoter, and swan ($\beta=0.159$) were associated ($p<0.05$) with increased PCB exposure levels of $\sum\text{PCB}_{138,153,180}$.

Conclusions: These results provide baseline PCB exposure levels in the Dehcho and Sahtú regions of the Northwest Territories and Old Crow, Yukon. PCB levels were similar if not lower to the CHMS and FNBI in younger participants but, for older participants, especially in the Sahtú region, PCB levels appeared elevated to the CHMS. As well, some demographic (e.g., age, sex, region), lifestyle (e.g., smoking status) and dietary variables (e.g., lake trout and bird consumption) were identified as determinants and potential sources of PCBs; but the strength of those links varied by region. On a broad scale, these results are important in identifying temporal trends of contaminants, as several initiatives were established to protect environmental and human health from several contaminants. On a small scale, these results offer guidance for further localized monitoring efforts related to environmental exposure sources or pathways including traditional diet, for these communities. Further work is required to draw more conclusions about traditional food consumption and PCB exposure levels.

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List of Abbreviations

AMAP	Arctic Monitoring and Assessment Program
ANSES	Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail
BE	Biomonitoring Equivalent
CHMS	Canadian Health Measures Survey
CI	Confidence Interval
CRA	Community Research Agreement
EDC	Endocrine Disrupting Chemicals
FFQ	Food Frequency Questionnaire
FNBI	First Nation Biomonitoring Initiative
GM	Geometric Mean
ISR	Inuvialuit Settlement Area
LOD	Limit of detection/detection limit
MIREC	Maternal Infant Research on Environmental Levels
MRL	Minimum Risk Level
NHANES	National Health and Nutrition Examination Survey
PCB	Polychlorinated Biphenyls
POP	Persistent Organic Pollutant
RV95	Reference Values 95 th Percentile
SSA	Sahtú Settlement Area
$t_{1/2}$	Half Life
TEF	Toxic Equivalency Factor

1. Literature Review

1.1 Study Regions and Traditional Foods

1.1.1 The Sahtú Region

The Sahtú region, became a settled land claim in 1993 under the Sahtú Dene and Metis Comprehensive Land Claim Agreement (Figure 1.1) (1). In this agreement, the Dene and Metis received title to 41437 km² and the agreement has outlined several topics related to harvesting and wildlife management and self-governance, among other resource agreements throughout the Sahtú Settlement Area (SSA) (1). The Sahtú includes five communities: Déline, Tulita, Norman Wells, Fort Good Hope, and Colville Lake. Its land is robust in forests, waterways, and mountains. For example, the Mackenzie River Valley portion of the boreal forest is located in the center of the SSA and the tundra is situated to the northeast of Great Bear Lake (2). Great Bear Lake is the largest lake located within the region and its west basin and east arm have been used as sampling sites for environmental monitoring (3). The most recent total population count of the SSA was 2669 and the populations among the communities within the SSA varied. The largest community population within the SSA was Norman Wells (704) followed by Déline (633), then Fort Good Hope (628), then Tulita (543) and lastly, Colville Lake (161). Among the organized regions of the Northwest Territories, the SSA makes up 5.83% of the territory's population (4). The Dene, Metis and Inuit make up over 70% of the population within the SSA (4).

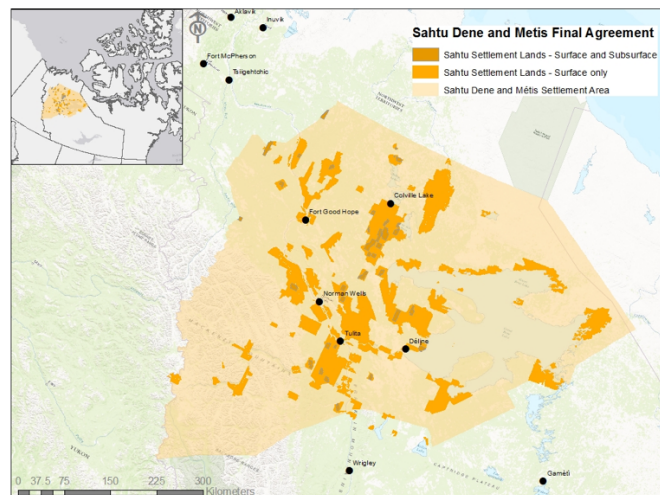


Figure 1.1 Map of Sahtú settlement area. Figure taken from the Government of Northwest Territories.

1.1.2 The Dehcho Region

The Dehcho region is situated to the west of Great Slave Lake and covers approximately 215000km² of the Northwest Territories (Figure 1.2) (5). Land claim negotiations began in 1999 and are ongoing (5,6). The total population of the Dehcho region is 3,316 as of July 1st 2022 and has 9 communities located within it, including Fort Liard with a population of 523, Fort Providence with a population of 711, Fort Simpson with a population of 1230, Hay River Dene Reserve with a population of 341, Jean Marie River with a population of 92, Kakisa with a population of 36, Nahanni Butte with a population of 101, Sambaa K'e with a population of 97 and Wrigley with a population of 126 (4). Indigenous peoples make up approximately 84% of the population of the Dehcho region and include the Metis, Dene and Inuit (4). The land boasts many geographic features including the Nahanni River, The Edézhíe National Wildlife Area, the high mountain cordillera located to the west, and the low interior plains in the eastern area of the Dehcho region (5,7,8). Its population size is comparable to other regions in the area including the Tłı̨chǫ Region which has a population of 3027.

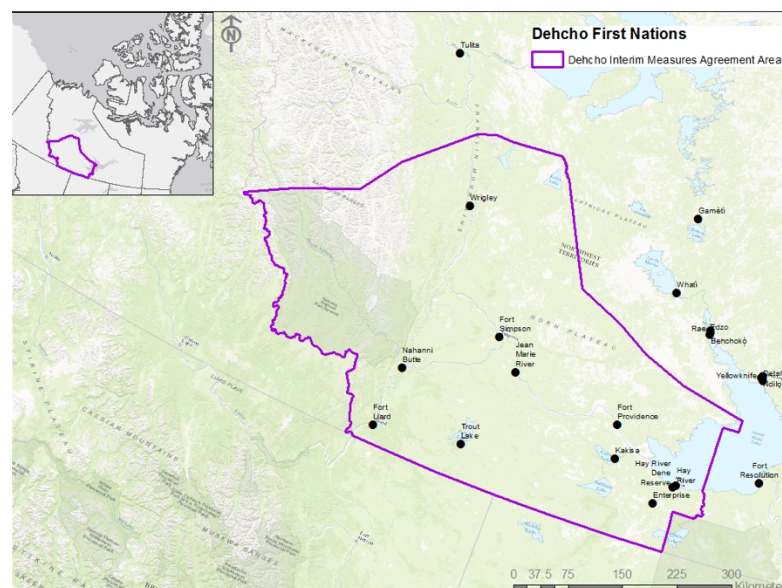


Figure 1.2 Map of the Dehcho interim agreement settlement area. Figure taken from the government of Northwest Territories.

1.1.3 Old Crow, Yukon

Old Crow is a community located in the northern part of the Yukon Territory and is home to the Vuntut Gwitchin First Nation- People of the Lakes (Figure 1.3) (9). The community has a total population of 249 as of June 2022 and 81.3% of its population identify as Indigenous. The final Vuntut Gwitchin First Nation Final & Self-Government Agreement was signed in 1993 which includes a land claim of 55,000 km² in traditional territory and 7744.06 km² in settlement land. This community has no road access; therefore, the community can only be reached by boat, plane or snow machine depending on time of year. The Vuntut Gwitchin nation is comprised of 19 communities across the Yukon and Northwest Territories, Canada and Alaska, USA (10). Old Crow is located on Porcupine River and is located near the Old Crow flats. These flats are comprised of many small lakes and span an area of 12,116 km². Notably, Old Crow is situated in the migration routes of many animals such as the porcupine caribou and fish including Chinook Salmon and importantly, traditional food systems have been centered around these migratory species (11). It is thought that Old Crow may have been one of the earliest known communities for human occupation in North America (9).

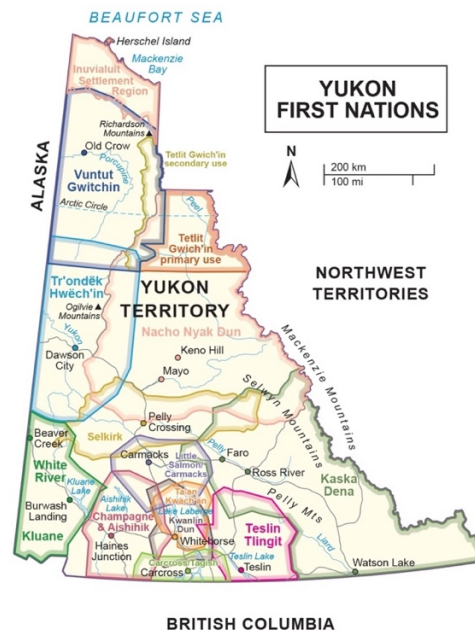


Figure 1.3 Map of Yukon First Nations including the Vuntut Gwitchin in Old Crow. Figure taken from Castillo VE, et al., 2020.

1.1.4 Traditional Food Diets

Traditional food diets, also known as country food diets, are an important and significant part of life in many northern Indigenous communities. Traditional foods are foods that are harvested locally from the environment (e.g., land or water) and include those foods that hold value and meaning within a community (e.g., sociocultural meaning). These diets provide several health benefits and add to overall wellbeing (12). Several Indigenous communities in Canada have reported eating traditional foods as a relevant part of their diet (13–16). Other health benefits include providing essential nutrients, macronutrients (e.g., protein), vitamins, fatty acids and energy for maintaining human health (17,18). One study identified a decrease in intake of ultra-processed foods with increasing traditional food intake, in the Eeyou Istchee (Cree) of northern Quebec (19). Several positive lifestyle benefits also exist while maintaining a traditional food diet including providing physical activity during hunting activities and increased self-identification (20).

1.1.5 Contaminant Concerns in the Study Region

Historically, there has been concern that some northern communities may face increased exposure levels of contaminants (21,22). For instance, mining was a large part of the Yukon and NWT history, and several mining sites that had used products containing PCBs as well as other contaminants, were established decades ago. (23). Other contaminants of concern include mercury, lead, PCBs, and other POPs. For the purposes of this thesis, PCBs will be exclusively focused on. Other studies within the research team have characterized other contaminants. Long-range atmospheric and ocean transport from the south of PCBs contribute to PCB exposures in the Canadian Arctic and subarctic (24). Consequently, environmental monitoring programs were established (25). For example, local to the study regions, long-running monitoring studies reported PCB levels in biota from lakes across the Dehcho and Sahtú regions (26,27). In addition to long-range transport, contaminated sites may have also contributed to PCB exposures in the north. For example, abandoned DEW line stations contained elevated PCB levels in soil and sediment (28). Notably, due to the “halo effect¹”, the influence that these Arctic radar sites have on elevated levels in matrices extend into the surrounding environment (28). Other potential point sources include mining sites located within the Arctic regions of the NWT. Since then, some mining sites have been shut down and remediation efforts began (23). To my

¹ Halo effect describes a distance that contaminant point sources may extend to within environmental media.

knowledge, the closest point sources of PCBs were sites identified before remediation efforts took place in the Inuvialuit Settlement Region (ISR) which is located north of the study regions (23). However, these sites are not expected to contribute significantly to PCB levels in participating regions, as they are far from each of the Dehcho, Sahtú and Old Crow, Yukon. There are few federal contaminated sites within the Northwest Territories with PCB contaminated environmental media. The main exception to this appears to be site 00024148 (near Echo Bay, Great Bear Lake) in the Federal Contaminated Sites Inventory on Great Bear Lake. This inventory noted PCBs and dioxins were measured in sediment, and this site undergoes periodic monitoring, but has not yet appeared to be remediated (29). The Federal Contaminated Sites Inventory only includes those under the custodianship of federal department agencies, and consolidated Crown corporations, It does not include sites under the control of private citizens, firms, or other levels of government (30). Investigations of contaminant exposure levels, including PCB concentrations in certain traditional foods, have been implemented (31,32) to address concerns surrounding traditional food consumption. Previous studies have identified some traditional foods (e.g., fish, marine mammals, birds) associated with PCB contaminant exposure levels in Arctic and subarctic Indigenous populations (33–35).

1.2 Overview of Polychlorinated Biphenyls (PCBs)

1.2.1 Structure and Properties

PCBs are a group of persistent organic pollutant (POP) that include 209 different congeners with a common general structure (i.e., two benzene rings attached to one another) and varying alternating chlorine substituents (e.g., $C_{12}H_{10-n}Cl_n$ where $n=1, 2 \dots 10$, etc.) (Figure 1.4) (36,37). Congeners are differentiated based on their molecular structure, specifically the number of chlorines and their position(s) on the benzene rings. For example, PCB56 has a structure of 2,3,3',4', whereas PCB 201 has a structure of 2,2',3,3',4',5,5',6 (Figure 1.5). Note the congeners that have fewer chlorine substituents result in a smaller PCB number whereas higher chlorinated congeners have larger PCB numbers (38,39). At any rate, because of their different chemical make-up, metabolism, human uptake, toxicity and environmental concentrations can differ by PCB congener (39,40). For example, all congeners are considered lipophilic but those congeners with a higher degree of chlorination (e.g., PCB206 versus PCB54) show a higher degree of lipophilicity and may accumulate in certain media (e.g., fatty tissue), compared to other congeners (37,39). Other properties that differ based on degree of chlorination include solubility and ability to volatilize. PCBs that are less chlorinated are more water soluble and

more volatile (37,41). In general, PCBs are more likely to be found in sediment, biota, living organisms, animals, and humans rather than water. PCBs are odorless, tasteless, can range from non-viscous to heavier liquids or solids and their colour can appear as colourless, yellow or black depending on chemical properties such as the amount of chlorine in the chemical (37,42,43). Commercial mixtures of PCBs, such as Arochlors, (e.g., Arochlor 1260, Arochlor 1254, Arochlor 1242) were also manufactured for several uses due to their physicochemical properties such as their stability, and persistence (40). Nomenclature is assigned based on the composition of the mixture. For example, Arochlor 1260 contains the biphenyl structure (i.e., 2 benzene rings) with around 60% chlorine (37,40). Understanding the properties and make-up of these chemicals is useful when reporting concentrations, determinants and sources to identify exposure pathways.

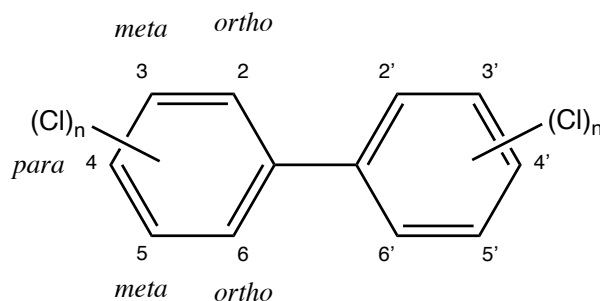


Figure 1.4 General chemical structure of PCBs

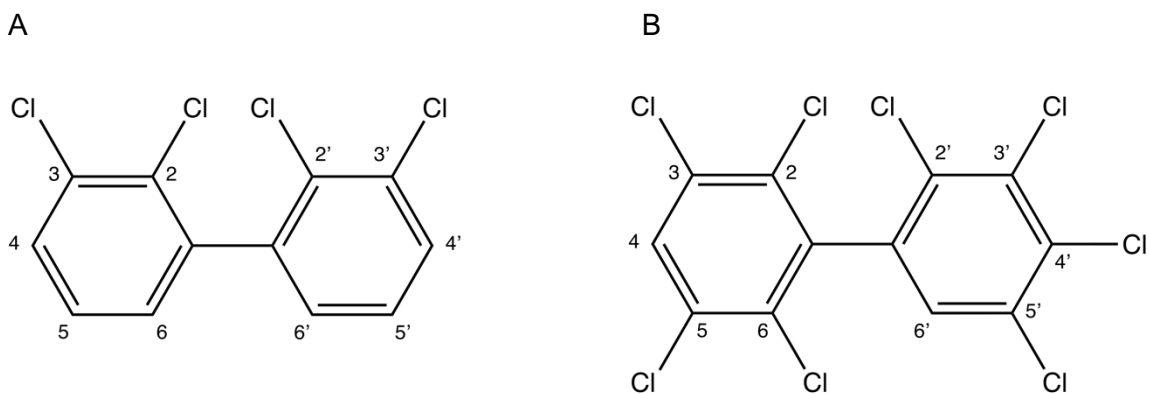


Figure 1.5 Chemical structures of (A) PCB56 and (B) PCB206

1.2.2 History

In the mid-1900s, global production of PCBs began, and since then, approximately 1,324,131 tonnes of PCBs were produced across several countries, including those from North America, Europe and Asia (44). Environmental monitoring studies have reported PCBs in soil and other environmental media internationally since the late 20th century (45–47). Environmental levels are being reported in parts of Canada within the latter part of the last two decades in some soil and water monitoring studies (48–51). PCBs were once produced for their uses in several industrial and commercial settings due to their persistent and stable properties. Some products that contained PCBs included plasticizers, paints, sprays, adhesives, dyes, electrical and hydraulic equipment, and transformers (37). Although never manufactured in Canada, they were used in Canada and undergo global transport. Therefore, PCBs are commonly detected in environmental samples in Canada (52,53).

Due to their potential toxicity and reported adverse health effects, PCB production was discontinued globally in 2001. Several toxicological, epidemiological, and occupational exposure studies were completed in the last 20 years documenting exposure levels and the environmental and human health effects of PCB exposure (37). PCB containing products can be found in some household items if they were manufactured before the ban of PCB production, such as paints, televisions, and other electrical equipment (43). These chemicals are considered legacy contaminants as levels are still being detected in environmental media, animals, and humans even after their discontinuation (54). Even though these chemicals are no longer being produced and used intentionally, most large-scale biomonitoring studies in North America still include PCBs in their list of contaminants to monitor (55–58).

1.2.3 Human Health Effects of PCB Exposure

Over the last several decades, epidemiological, occupational, toxicological, and animal studies have documented potential adverse health effects of human PCB exposure (37,40). Importantly, the amount of exposure, duration of exposure and route of exposure are all factors to consider when determining toxicity of PCB exposure. For example, short-term high level exposure may present different health outcomes (e.g., chloracne) compared to long-term low level exposure health outcomes (e.g., developmental issues) (59,60). Some adverse health outcomes may affect human endocrine, immune, neurological, and developmental systems and exposure is considered cancerous and these health effects are described below.

Endocrine and Immune

PCBs are classified as endocrine disrupting chemicals (EDCs) and their endocrine effects can lead to a cascade of other health issues within the body (37,61). EDCs alter or mimic hormone responses which can lead to adverse health effects. For example, disruption of certain enzymes (e.g., cytochrome P450) can induce changes in liver size which alters metabolism of substances that enter the body. Normal liver function may be compromised and lead to negative responses in the body such as reduction in the thymus gland, altering immune system responses in the body (62). Organochlorines including PCBs are also thought to disturb the HPA axis, which is regulated by hormones such as total thyroxine and thyroid-stimulating hormone. One effect biomarker study using the National Health and Nutrition Examination Survey (NHANES) data and found links between levels of total thyroxine and PCB and toxic equivalent quotients in certain demographics. Specifically, results suggested older adults may be more at risk of hormone disruption from organochlorines, including PCBs, compared to younger populations (63). Other endocrine and immune adverse health issues are thought to be related to EDCs (e.g., PCBs) including immunotoxicity, neurotoxicity, diabetes, thyroid disorders, and issues related to reproductive health (37,64,65).

Neurological and Developmental

Neurological effects and developmental issues have been documented following PCB exposure (37,66–69). Observational studies also found evidence of neurological issues following PCB exposure. For example, children aged four to five who had been previously exposed to higher levels of PCBs, scored five points lower on a standardized cognitive development test compared to a control group whose exposure was closer to background levels (70). One cross-sectional study, reported chronic inhalation of select PCB congeners was associated with a change in emotional state, increase in tiredness and a slowness in activities (71). Overall, neurotoxicity can be an adverse health effect of PCB exposure, especially in children and infants, and such adverse health effects are dependent on the amount of PCB exposure that occurs.

Cancer

The International Agency for Research on Cancer has listed PCBs as a probable carcinogen (i.e., a group 1 carcinogen) (72). For example, one cohort study conducted using the Nurses' Health Study dataset study found an elevated risk of breast cancer in post-menopausal women who presented with at least one gene variant and PCB exposure levels in the highest tertile (0.67-1.99 µg/g) compared to those women in the lowest PCB tertile (0.13-0.47 µg/g) of 2.78 (95% CI 0.99-7.82) (73). The Carolina Breast

Cancer study found an increase (33-40%) in short-term breast cancer mortality risk from PCB exposure levels from PCB74, PCB99, PCB118 and total PCBs (74). In contrast, a prospective case control large-scale epidemiological study found no elevated risk of breast cancer from higher PCB exposures. The odd ratios for PCBs exposure levels that were in the upper most quartiles were higher, however, these results were not significant and thus no trends were found in the data (75). Other studies have shown contrasting results among clinic-based case-control studies, retrospective case-control studies, and nested case control studies (72).

1.2.4 Environmental Sources and Transport of PCBs

PCBs can be detected in air, water and soil following a variety of environmental releases (37,76–78). Thus, human exposure to PCBs can be attributed to local point sources and dispersed long-range transport. Point sources can include locations where PCBs were once known to have been manufactured, or in locations where products containing PCBs were used or distributed. Such point sources include leaks from equipment that use PCBs (e.g., emissions from electrical transformers), waste sites with poor infrastructure for containment of PCBs and disposing PCB containing products in landfills. Following these releases, subsequent adsorption into soil and volatilization of PCBs occurs (37). For instance, point sources of PCBs in the Arctic include 42 radar sites, where PCB containing products were used, that were built in the 1950s and spanned northern and mid-land. Elevated levels of PCBs were found in soil samples and since then, these sites have been decommissioned and remediation efforts were put in place (28). Local sources are thought to generally contribute less to PCB exposure in Canada, due in part to the remediation of many of these contaminated sites (79). Long-range transportation of chemicals occurs due to ocean and atmospheric trends transporting PCBs globally and arriving in Arctic and subarctic environmental media. Due in part to their persistence, PCBs can bio-magnify and are found in food chains (21).

1.2.5 Routes of Exposure

Contaminant exposure occurs from four main routes, including absorption, injection, inhalation, and ingestion. Once exposed, PCBs can be absorbed into the gastro-intestinal tract, or the blood stream and circulate throughout the body, depending on the exposure route. Inhalation allows PCBs to enter to the bloodstream and distribute throughout the body (37). PCBs may enter the body through any of these routes, however, since their ban, one of the most common routes of PCB exposure is diet (i.e., ingestion), including from foods that are typically fatty or exist in higher levels of the food chain (62).

Following ingestion, PCBs can be absorbed from the gastrointestinal tract into the blood stream and circulate throughout the body. Although a less significant route of exposure for most people, PCBs can also be absorbed into the bloodstream following inhalation and distributed throughout the body (37). Aside from diet, inhalation from indoor air exposure has also been identified as a potentially more common source of PCBs (62,80–82).

Exposure through Diets

It is well known that diet plays a key role in PCB exposure levels. In fact, some studies have shown fish and other food consumption is associated with elevated PCB exposure levels (83–86). Several meat and dairy products may also contribute to PCB exposure levels (87,88). Certain fatty fish species are thought to be a source of PCB exposure, as lipids tend to co-vary with PCB levels due to the lipophilicity of PCBs (37). Bottom feeder fish also tend to have higher PCB levels as they are located near sediments that may contain PCBs (89). On that note, higher trophic fish may also be a source of PCB exposure when consumed, as PCBs are able to biomagnify in food chains, and large or predatory fish may have higher tissue concentrations relative to smaller or non-predatory fish (90). Further, anglers or those who frequently consume fish may be exposed to PCBs through the consumption of sportfish (91). Also, the First Nations Food, Nutrition and Environment Study reported fish as the main contributor to PCB exposure (92). Thus, diet as an exposure source is a current topic being explored in northern Canadian communities, whose diet may consist of fish or other foods that are thought to be higher in PCB levels (33). However, the associations between dietary patterns and PCB blood levels have yet to be determined in certain arctic and subarctic regions in Canada.

Occupational Exposure

Occupational exposure of PCBs has been well-documented since the introduction of PCBs through to their discontinuation and onwards (93–98). For example, a biomonitoring study of workers from a manufacturing plant containing PCB products was conducted and although PCB levels were within acceptable values as determined by the American Conference of Government Industrial hygienists, PCB (Arochlor 1242 or 1016) concentrations between 2-22 $\mu\text{g}/\text{cm}^2$ were found on skin wipes of capacitor workers, internal levels ranged from 41 to 1319 $\mu\text{g}/\text{kg}$ in whole blood (99,100). More recently, an occupational exposure assessment documented that workers who spent six years or more in the electricity sector (where PCB containing items are still used) had significantly higher ($p=0.037$)

PCB blood plasma levels (94). Thus, it is important to consider occupational exposure to PCBs (e.g., as a covariable) when evaluating dietary sources of PCB exposures.

1.3 Human Biomonitoring

Human biomonitoring involves the collection of human biological samples to assess and report levels of contaminants, nutrients, metabolites, or macro-molecules in individuals (101). This collection of biomarkers of exposure is useful for determining chemical and nutrient information in individuals. Some examples of biomarkers of exposure include metals or elements such as lead or cadmium detected in blood or hair, or organic pollutants detected in whole blood or plasma. Nutrient biomarkers of exposure can also be assessed such as vitamins, or n-3 PUFAs in blood. Human biomonitoring is beneficial as it leaves little room for certain types of error that might occur from other subjective data collection methods (e.g., dietary assessments) and is a useful tool to map out an individual's exposure to chemicals and nutrients (101,102). Thus, biomonitoring is sometimes a preferred method for exposure assessments as well as risk- benefit analyses.

Human biomonitoring projects can occur on a large scale (national), or at a smaller scale (regional or community level) depending on the goal of the project. For risk assessment purposes, biomonitoring projects may be used for monitoring levels of POPs and other contaminants that may be toxic or harmful to individuals while also collecting nutrient exposure levels (102). One of the first large-scale human biomonitoring projects began in the 1970s, known as NHANES. Since then, several other national and international large-scale studies have been completed or are ongoing (103). Some regional studies also exist within countries that partner with local communities to address needs and concerns of community members (104–106).

1.3.1 National Biomonitoring Projects

Several national biomonitoring projects have been completed or are ongoing in Canada. These studies have contributed greatly to human biomonitoring efforts in Canada and have collected and reported human chemical exposure levels of several contaminants, including PCBs and other POPs, among the Canadian population. Several of the most notable national-level biomonitoring projects in Canada include the Canadian Health Measures Survey (CHMS), the First Nations Biomonitoring Initiative (FNBI) and the Maternal Infant Research on Environmental Chemicals (MIREC) study (56,57,107).

CHMS

The CHMS began in 2007 with the aim to gather health information from a nationally representative (approximately 5000 total participants) population of Canadians (107). One of the main components of the CHMS is the collection of biological tissues and fluids (e.g., hair, urine, plasma) for the measurement of contaminant levels, including PCBs, in human biological matrices. The CHMS is ongoing with six cycles completed, and a seventh cycle underway between the years 2022-2024. Each cycle consists of data collection over a two-three-year period and reports published present data tables summarizing exposure levels of different chemicals and contaminants. PCB exposure levels (through the measure of 24 congeners and Arochlor 1260) were measured during CHMS Cycle 1. Since then select congeners (e.g., dioxin-like PCB congeners, PCB74, PCB99, PCB138, PCB146, PCB153, PCB170, PCB180, PCB187, PCB194) in pooled samples were measured in Cycles 2 to 6 (108–113). In the first CHMS Cycle, plasma samples for PCB analysis were collected from participants aged 20-79 and reported as plasma concentration ($\mu\text{g L}^{-1}$) as well as lipid-adjusted plasma concentration ($\mu\text{g kg}^{-1}$), and the following cycles after that, plasma samples for PCB analysis were collected from participants aged 3-79 (108). This CHMS provides nationally representative data on PCB exposure levels that allow for international comparisons as well as RV for targeted biomonitoring studies. For example, PCB exposure levels in Canada are similar to those reported in the United States and lower than those reported in Europe (114). The CHMS provides a strong blueprint for protocol and methods for other Canadian biomonitoring studies measuring PCB exposure levels (55).

FNBI

To fill a gap in biomonitoring in Canada, the FNBI was established in 2008 to provide First Nations communities across the ten Canadian provinces information on baseline exposure levels of contaminants and other health data (115). The aim of this 5-year national health survey was to collect exposure levels of 97 analytes from participants aged 20 years or older, exclusively from First Nations living on reserve. Fifteen communities were selected to participate with just over 40 community members participating from each community. Along with contaminant exposure level data, the project collected demographic and anthropometric data along with questionnaires related to exposure sources within the household. The FNBI was completed in 2013 and results were returned to participants. A final report was created and was made available to the public and generally documents levels of PCBs being lower than or similar to the general Canadian population. This report included exposure levels for participating regions by age and region for each of the chemicals measured (57).

MIREC

Another important human biomonitoring project currently underway in Canada is MIREC, which began as a Canadian cohort following individuals during pregnancy, and has since expanded to follow cohorts including MIREC-Infant Development (2009-2012), MIREC-Child Development Plus (2013-2015), and MIREC-Endocrine Phase 1 (2018-2021), Phase 2 (2022-2024), and Phase 3 (2024-2027) (116). The MIREC- Infant Development cohort followed participants from birth to six months to report on environmental chemical exposures that might affect infant growth, development, and behaviour skills. The MIREC-Child Development Plus cohort, reported on growth, development and behaviour skills in children aged two to five from similar exposures, and the MIREC- Endocrine phases aims to follow children from seven to 15 years to explore links between environmental chemical exposures and health outcomes related to the endocrine system. Recruitment for the MIREC study began in 2008, with efforts to collect chemical exposure data from pregnant women across 10 Canadian cities. Over three years, blood, hair, urine and milk samples were collected from mothers, and cord blood and meconium was collected from infants, to assess exposure levels of several contaminants including, but not limited to, metals, pesticides and POPs including PCBs (56). Initial results have been shared from the MIREC cohort, and several scientific papers describing these results have been published. With respect to PCBs, the select congeners (e.g., PCB118, PCB138, PCB153, PCB180) were detected in participants and generally, exposure levels (e.g., PCB118) were lower in the MIREC cohort, compared to similar national and international biomonitoring studies (e.g., (INfancia y Medio Ambiente cohort in Spain, National Health and Nutrition Examination Survey in the United States) (56,117,118).

1.3.2 Targeted Biomonitoring Projects

In addition to the above national biomonitoring projects, several targeted biomonitoring studies have been implemented in Canada to address data gaps related to contaminant levels in specific subpopulations (119,120). Targeted biomonitoring projects may be implemented based on trends or patterns of exposure sources, or contaminant levels observed within a specific vulnerable subpopulation (e.g., mothers, children) or a certain location (e.g., rural, remote, urban centers). For example, some targeted biomonitoring have been justified according to elevated levels of some contaminants in particular traditional foods relied upon by Indigenous populations in Canada (119). Likewise, targeted biomonitoring projects usually include participants of a specific subpopulations or demographic (e.g., Indigenous peoples, provincial populations, community-level populations) and document more specific

aims and questions, that national biomonitoring projects would not be able to adequately address (120). For example, several community-based Indigenous studies including the Nituuchischaayihitaa Aschi (“Learn about ourselves and our earth”) Environment-and-Health Longitudinal Study in Eeyou Istchee, among others, were created with an objective of assessing environmental exposure to contaminants, along with assessing exposure sources related to traditional and store-bought foods in remote areas. Other examples of these initiatives across Canada include, but are not limited, to the Mackenzie Valley and Yukon biomonitoring projects, described within this MSc thesis and reported on previously in the literature (104,121). Other targeted biomonitoring projects have also included the 2004 and 2017 Qanuippitaa? Nunavik Inuit health Surveys, the 2007-2008 Inuvialuit Settlement Region, Nunavut and Nunatsiavut Inuit Health Survey, the Alberta Biomonitoring Project and the Newcomers project (105,121–125).

1.3.3 PCB Temporal Trends and International Monitoring and Regulations

Several international initiatives were created and implemented to monitor and control environmental releases of PCBs. For example, the Stockholm Convention, banned the production and use of several POPs, known as the “dirty dozen”. Since 2000, other contaminants that meet the persistent, bioaccumulative, and toxic criteria have been added under the convention (126). The Arctic Monitoring and Assessment Program (AMAP) is another major initiative that exists to monitor contaminant levels with efforts to decrease contaminant exposure levels, including PCBs, in the Arctic. Eight Arctic countries including Denmark, Iceland, Sweden, Norway, Finland, Russia, Canada, and the USA formed this program. AMAP was established in 1991 with goals of detecting gaps in data related to northern contaminant exposure. (25). Even prior to the Stockholm Convention, several regulations were implemented in North America control and ban the production and use of PCBs within the last 50 years (60). For example, Canada and the US began an agreement called the Great Lakes Water Quality Agreement to eliminate persistent toxic substances in the Great Lakes after PCB production stopped in 1970 (127).

Studies have shown that these initiatives may be working as PCB exposure levels are in decline in certain parts of Canada (79,128,129). For example, the MIREC study sampled human milk between 2008 and 2011 and noted levels were approximately one third of those observed 20 years earlier in Canada (130). Among the Inuit of Nunavik, declining PCB levels have been reported between the years 1992 and 2017. Specifically, PCB180 GM (geometric mean) was 90 (range: 34-150) µg/kg plasma

lipids among study participants in 1992, compared to a GM of 13 (range: 1.8-100) µg/kg plasma lipids in 2017 (33).

Similarly, PCBs reportedly declined in certain fish species air and biota in the Canadian arctic (3,79). For example, burbot liver Σ PCB concentrations showed declining trends as annual percent changes in the East Arm (-3.6%) and in the West Basin (-5.3%) of Great Slave Lake in the Northwest Territories. However, temporal trends in Canada have varied depending on species and location (3). In Canada, PCBs in Arctic air have generally been in decline, however that decline has slowed down as concentrations have been lower and reported half-lives ($t_{1/2}$) have become longer. For example, at a northern Canadian air sampling station, PCBs were detected in Arctic air between 2003 and 2012 where the $t_{1/2}$ for PCB180 was 17 compared to a $t_{1/2}$ of 3.6 between the years 1993 to 2003 (24). On a global scale, atmospheric PCBs have declined from the years 2005-2014 as reported from the global atmospheric passive air sampling network (131).

Trends and patterns of PCBs may also be affected by climate change. For example, climate change may exacerbate contaminant concentrations in sediment and biota as increasing temperatures may melt ice and snow containing contaminant concentrations (24,132). Northern Contaminants Program core monitoring and research programs have identified air, snow, sediment, seawater and biota as PCB containing environmental compartments in the Canadian Arctic beginning in 1991 (3,24). Researchers, have identified that several Arctic and subarctic communities in Canada may be disproportionately negatively affected by climate change in the context of environmental contaminant levels and human health (133). Thus, communities in the north and their traditional foods, may be subject to these changing contaminant pathways, therefore, research is underway to explore temporal trends in these regions to discover the potential role that climate change has in the remobilization of contaminants (134).

1.3.4 Interpreting Biomonitoring Data in the Context of Reporting PCB Exposure Levels

Congener Specific Measures

PCB exposure levels from human biomonitoring data may be presented in several ways. For example, exposures may be described according to the sum of congeners (describing cumulative exposures to related chemicals) or described as individual congeners. Several factors may be considered when selecting subsets of congeners to sum, including their abundance, environmental impact and occurrence

and toxicity (41). Previous literature has explored grouping PCB congeners based on chemical make-up (i.e., degree of chlorination) or their activity once taken up (i.e., patterns related to enzyme induction or endocrine-disrupting activity) (62). For example, congeners that are less chlorinated are likely to be more volatile compared to more-chlorinated congeners and are able to biodegrade more easily (135). Alternatively, PCB data can be aggregated across numerous congeners based on abundance. For example, a recent biomonitoring study following a group of pregnant women, used the sum of the 12 most abundant PCB congeners (i.e., PCB28, PCB11, PCB118, PCB101, PCB52, PCB153, PCB180, PCB149, PCB138, PCB84, PCB135, PCB95) that were detected in serum samples from the study population (136). Interestingly, PCB11 and PCB52 were among those congeners that were highly detected, despite their lower chlorination. Due to these observations, this study noted that assessments of lower-chlorinated congeners within toxicological and biomonitoring studies is warranted (136). Grouping the three most abundant congeners is another common method of presenting PCB exposure data. Specifically, PCB138, PCB153, and PCB180 are grouped together (i.e., $\sum \text{PCB}_{138,153,180}$) because these congeners have been reported as the three most abundant PCB congeners found in human populations in several human biomonitoring studies (37,63,137). Further, as these three congeners are thought to contribute to at least 50% of PCB exposures, once added together, their totals are sometimes multiplied by two (i.e., $\sum \text{PCB}_{138,153,180}$ in serum x 2) in order to approximate total PCBs (114,138,139).

Dioxin-like vs. Non-dioxin-like PCBs

Presenting the sum of dioxin-like PCBs is another method of aggregating PCB biomarkers in human biomonitoring studies. Of the 209 congeners, 12 PCBs² are considered dioxin-like (140). For a congener to be considered dioxin like, several criteria must be met. Specifically, the 12 dioxin-like PCB congeners include those that have: i) chlorine substitution at no more than one of the 2, 2', 6, or 6' positions; ii) a total of four or more chlorine substituents; iii) both the 4 and 4' positions chlorinated; and iv) two or more of the 3, 3', 5 and 5' positions chlorinated. Dioxin-like PCBs are of particular interest as these specific PCB congeners have been deemed especially harmful according to their interactions with the aryl-hydrocarbon receptors. As some dioxin-like PCBs are more potent than others, exposures to these congeners are calculated as a weighted sum according to their Toxic Equivalency Factor (TEF). Non-dioxin like congeners are not included in the calculation of TEFs as

² Dioxin-like congeners: PCB77, PCB81, PCB105, PCB114, PCB118, PCB123, PCB126, PCB156, PCB157, PCB167, PCB169, and PCB189.

these congeners and their metabolites do not undergo similar pathways within the body (62,141). In past decades, these dioxin-like PCBs were particularly prominent within the risk assessment of PCBs given their toxicity to human and animals. However, emerging evidence suggests exploring the potential adverse health effects posed by non-dioxin like PCBs (142). Notably, identifying differences in congener patterns can assist in the documentation of unique exposure pathways relative to the general population (143).

1.3.5 Interpreting Biomonitoring Data Related to Human Health and Exposure Magnitude

Several methods have been used to interpret the exposure magnitude of PCB biomarkers from human biomonitoring studies. For example, biomonitoring data can be compared against health-based guidance values, specific point estimates from biomarker distributions (e.g., GM, 95th percentile), biomonitoring reference values (i.e., RV95), and biomonitoring equivalents (BEs).

A Health Based Guidance Value is defined as a threshold that above which, adverse health issues are thought to occur (144). In past decades, a set of HBGV for Arochlor 1260 had been established in specific matrices for select age groups and for men and women. For example, in breastmilk the HBGV was set at 50 µg/L (145,146). Table 1.1 summarizes the previous PCB HBGV established for Arochlor 1260 (145). Currently in Canada, there are no HBGV established for PCB exposure levels as the past values had been retracted as emerging evidence indicated that they may not be adequately protective. Notably, environmental scientists have called for updated PCB HBGV since at least 2007. Since then, new epidemiological and toxicological research has been underway to establish tools for establishing guidelines (33).

Table 1.1 Health Canada guidelines for PCB (Arochlor™ 1260) in whole blood as reported in Liberda et al., 2007.

Gender and Age Category	Normal Level¹ (µg/L)	Concern Level² (µg/L)	Action Level³ (µg/L)
Children (under 18 years)	Below 5	5 or above	20 or above
Pregnant and lactating women	Below 5	5 or above	5 or above

Adult women (18-45)	Below 5	5 or above	100 or above
Adult women (46 years and above)	Below 20	20 or above	100 or above
Adult men (over 18)	Below 20	20 or above	100 or above

1. Not concerning for human health. 2. Concerning for human health 3. Action should be taken to preserve human health.

Other useful ways of interpreting exposure levels include comparing levels against point estimates, and biomonitoring equivalents (BE) (103). Point estimates can be used to compare exposure levels among populations at specific points in the biomarker distribution (e.g., 95th percentiles). Alternatively, biomarkers can be compared against population reference values (e.g., RV95s) that describe the upper margin of background contaminant exposure. These RV95s have been derived statistically from national datasets such as the CHMS. Table 1.2 summarizes these RV95 values derived from CHMS data (147). For example, age specific RV95s were set for select PCB congeners. Notably, while creating RV95s for POPs, researchers did not identify any factors that were positively associated with the selected biomarkers, thus, no participants were excluded from the distribution. PCB138, PCB153 and PCB180 showed highest RV95 levels (147).

Table 1.2 RV95s for PCBs in plasma for the general Canadian population ^a from 2007-2009 as reported in Haines et al., 2017.

Congeners	Age Group (years)								
	20-39			40-59			60-79		
	n	P95 (CI) (µg/kg lipid)	RV ₉₅ (µg/kg lipid)	N	P95 (CI) (µg/kg lipid)	RV ₉₅ (µg/kg lipid)	N	P95 (CI) (µg/kg lipid)	RV ₉₅ (µg/kg lipid)
PCB118	525	8.7 (6.4–11)	8.7	596	17 (12–22)	17	542	34 (25–43)	34
PCB138	520	17 (12–22)	17	595	44 (35–53)	44	543	65 (50–81)	65
PCB 153	518	29 (19–39)	29	593	83 ^b (50–120)	83*	543	130 (95–170)	130
PCB 156	525	3.8 (2.6–4.9)	3.8	591	9.5 (7.9–11)	9.5	541	17 (13–22)	17
PCB 163	525	5.6 (3.8–7.4)	5.6	592	13 ^b (6.1–19)	13*	541	24 (19–29)	24
PCB 170	520	6.6 ^b (4.0–9.1)	6.6	589	16 (12–20)	16	543	37 (24–50)	37
PCB 180	517	18 (13–24)	18	589	55 (42–68)	55	543	130 (92–170)	130
PCB 187	525	6.2 ^b (3.3–9.1)	6.2*	587	16 ^b (9.5–22)	16*	539	33 (27–39)	33
PCB 194	525	^c	NA	590	12 (10–14)	12	539	30 (22–38)	30
PCB201	520	3.1 ^b (1.8–4.3)	3.1*	592	11 ^b (6.3–16)	11*	531	21 (16–27)	21
ΣPCB _{138,153,180}	518	61 ^b (34–88)	61*	592	180 ^b (98–270)	180*	544	330 (260–410)	330

N: number of participants; NA: Not available; P95: 95th percentile; RV₉₅: the 95th percentile of the measure chemical concentration of the reference population, within the 95% CI. a. Based upon sampling of CHMS participants following ≥10 h of fasting b. Use data with caution as the coefficient of variation at the 95th percentile for the reference population is between 16.6% and 33.3%. c. Coefficient of variation at the 95th percentile for the reference population is too high (> 33.3%) for the estimate to be published. * Provisional reference values as RV₉₅s were derived from estimates with coefficients of variation between 16.6% and 33.3%.

BEs are also sometimes used to interpret biomarker levels. BEs are defined as the concentration of specific chemicals or metabolites that are consistent with reference values (e.g., tolerable daily intake, risk-specific dose, etc.,) and are sometimes used for risk analyses purposes (148). In Canada, authorities have created a set of BEs for certain demographics, as reported in Table 1.3 (149). To establish BE's, intake levels are developed as well as TEFs (103,148). Units of intake are also used as a standard or guidelines for safe exposure including a tolerable daily intake, reference dose or Minimum Risk Levels (MRL). MRLs for PCBs were established by the Agency for Toxic Substances and Disease Registry

and an MRL of 0.02 µg/kg/day was derived for chronic-duration oral exposure, and an MRL of 0.03 µg/kg/day was established for intermediate-duration oral exposure (37). TEFs have been created for numerous dioxins and dioxin-like compounds to assess toxicity of compounds. Notably, the World Health Organization has established such TEFs on an international level to provide information to regulatory agencies (37).

The Human Biomonitoring Health-Based Guidance Value Dashboard lists Biomonitoring Guidance Value Information from several organizations (150). For example, in serum of the $\sum\text{PCB}_{138, 153, 180} \times 2$ for children, a human biomonitoring guidance value level 1³ was set at 3.5 µg/L and a human biomonitoring level 2⁴ was set at 7µg/L (150). According to the Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (ANSES) critical concentrations levels of 600 ng/g lipid was set for $\sum\text{PCB}_{138, 153, 180} \times 1.7$ in plasma for women under the age of 45 and men under the age of three (150). ANSES also sets a critical concentration level of 1800 ng/g lipid for the $\sum\text{PCB}_{138, 153, 180} \times 1.7$ in plasma for females aged 45 and older and males aged three years and older. Finally, the Institut National de Sante Publique Du Quebec set a reference value of 900 ng/g lipid for the sum of PCBs in plasma, however the group that this threshold is for is not specified (150).

Table 1.3 Biomonitoring equivalents for PCBs as reported in St-Amand et al., 2014.

Chemical	Age	BE Male (ng/g plasma lipid)	BE Female (ng/g plasma lipid)
$1.7 \times (\sum\text{PCB}_{138, 153, 180})$	20-39	1800	N/A
	40-59	1800	N/A
	60-79	1800	N/A
	20-45	N/A	700
	46-59	N/A	1800

N/A = Statistics were not available from the original table

1.3.6 Comparing PCB Data to Other Biomonitoring Projects

Since PCB Health Based Guidance Values were retracted in Canada, to inform individuals of what levels humans should be under, researchers have often compared levels to other biomonitoring studies to understand if levels are elevated or not in a certain population. Several smaller scale biomonitoring

³ HBM-I values indicate concentration levels at which or below, pose no risk of adverse health effects.

⁴ HVM-II values indicate concentration levels at which or above, adverse health effects may occur, and exposure reduction methods along with further health advice should be implemented.

studies have compared their levels to national or larger scale biomonitoring project exposure levels (e.g., NHANES, CHMS) for risk-analysis purposes (55,151). For the purposes of this thesis, exposure levels have been compared to other national biomonitoring initiatives in Canada (i.e., the CHMS and the FNBI) to gather if the levels in this study are higher or lower compared to the general Canadian population and other Indigenous populations.

1.4 Study Objectives

This thesis aims to fill a human biomonitoring data gap in Canada with a focus on PCB exposure levels in Indigenous populations in Northern Canada. Specifically, this study will report PCB exposure status among Indigenous communities in the Northwest Territories and Yukon and evaluate potential dietary pathways of exposure. Specifically, this thesis will

1. Report whether lipid-adjusted PCB exposure levels and congener profiles differ according to participant demographics including participant sex, age, region, fatty- acid levels, smoking status and drinking status.
2. Determine if lipid-adjusted PCB exposure levels among study participants appear to be elevated in comparison to the CHMS and FNBI when stratified by age and sex.
3. Introduce diet as potential exposure source by ascertaining which traditional foods are a significant driver of PCB exposure.

2. Introduction

PCBs are a group of POPs that include more than 200 possible congeners (37). These man-made chemicals were once manufactured for their several uses in plastics, adhesives and electrical transformers, among other uses (152). As well, due to their physiochemical properties, and strong ability to not break down over time, these chemicals were ideal for uses in extreme temperatures or pressures. However, PCBs are also considered hazardous for human health, based upon several epidemiological, toxicological, and animal studies. Production of these chemicals have been banned globally since 2001 (37,42).

Adverse health effects of PCBs have been well-documented and are dependent on exposure level, duration of exposure and route of exposure. Several epidemiological and animal studies have identified such adverse health effects (37). For example, certain exposures to PCBs have been linked with neurotoxicity, immunotoxicity and have been associated with reproductive issues (69). PCBs are classified as EDCs, and have also been labelled as a class 1 carcinogen by international agencies (72).

To monitor and evaluate levels of these chemicals, as well as other contaminants, large-scale national and international human biomonitoring projects have been established (57,153). The CHMS has collected exposure levels on environmental chemicals in the general Canadian population, beginning in 2007 with its first cycle. Six cycles have been completed with its seventh underway (108–112). Another national biomonitoring project, the FNBI, was established to collect exposure levels of over 90 analytes for those living on reserve in southern parts of Canada (57).

Although exposure levels are in decline in certain parts of Canada (128,130), levels of PCBs have been detected in environmental media even after their ban. Several contaminants, including man-made chemicals (e.g., PCBs) may be found in these remote regions despite never being manufactured there, as global sea, ocean and air pathways can transport contaminants to and around Arctic areas (24,129,154). Specifically, exposure levels of these chemicals were documented in Arctic regions in Canada (79).

These contaminants are lipophilic and able to bio-magnify and persist in animal food chains (135). Thus, a well-known source of human exposure to PCBs includes diet (37). Monitoring studies have reported levels in several foods including dairy food products, meats, and vegetables (87,155–157). Other studies have reported PCB levels in fish, as fish are commonly thought to be a major dietary

source of PCB exposure (158,159). Due to their lipophilicity, it is thought that foods that are generally higher in fats, or fatty tissue may drive PCB exposure levels (37). Notably, traditional food diets have been documented as potential sources of PCB exposure levels, and foods that are commonly consumed by Indigenous communities have reported PCB levels as well (160). That being said, traditional food diets provide a plethora of health benefits and may provide an important source of food security (12,17,161).

Human biomonitoring in the Canadian north has been ongoing for the past two decades (25,79). However, some regions in subarctic and arctic Canada were not included in these national studies. To fill a human biomonitoring data gap in Canada, human biomonitoring projects were established in the Northwest Territories and Yukon in participating Indigenous communities to collect exposure levels on several contaminants, including PCBs, as well as other nutrient and vitamin levels. (104,105,121). The aim of this study is to report baseline PCB exposure levels in Indigenous communities in the Northwest Territories and Yukon, as well as report potential determinants of exposure. Additional aims of this study included identifying potential dietary sources of PCB exposure, and which dietary factors may contribute most to exposure using data from a FFQ collected at biomonitoring clinics throughout the Northwest Territories and Yukon. Since generally, elevated levels of PCBs were not found in the NWT and Yukon regions, this study, on a larger- scale, may add to existing literature exploring dietary exposures, identifying potential pathways for PCB exposure.

3. Methods

3.1 NWT and Yukon Biomonitoring Projects

This thesis contributes one facet of a larger biomonitoring study and is contextualized in Figure 3.1. Detailed methods have previously been reported within papers describing results from biomonitoring projects completed in the Northwest Territories and Old Crow, Yukon between 2016-2019 (104,105,121). In brief, in total, nine subarctic communities of the Dehcho and Sahtú regions of the Northwest Territories participated including: 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. As well, one Arctic community, Old Crow, Yukon took part. Since 2019, secondary data analysis investigating patterns among biomarker and survey variables and the return of these results to participating results has been ongoing.

Coordination with participating communities began in 2014, leading to the creation of a series of community research agreements (CRA) that were informed by local knowledge, values, and priorities. These CRAs outlined several important factors including the process of free and informed consent, and the roles and responsibilities of the parties involved. Consent as well as demographic data was documented through paper forms (and subsequently coded into a spreadsheet) while survey data was collected through electronic surveys administered on iPads. To protect anonymity, participant ID numbers were used (rather than attaching names or other identifiable information in the database).

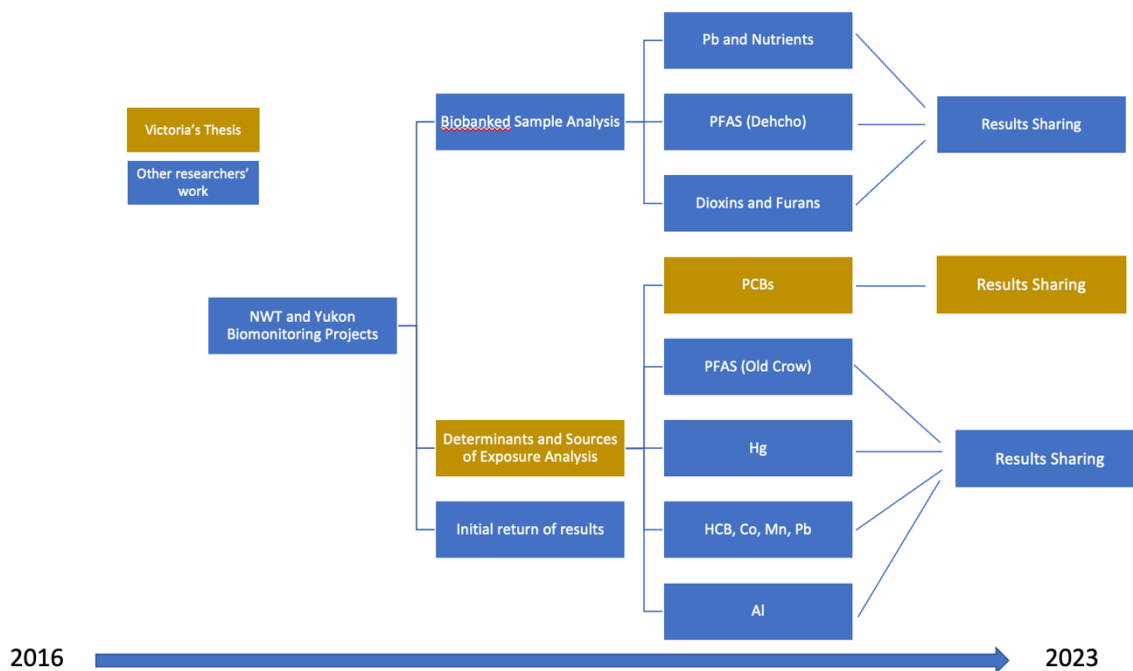


Figure 3.1 Diagram summarizing of work completed for the NWT and Yukon biomonitoring among the research team.

3.1.1 Participant Criteria

Any community members from the NWT over the age of six were eligible to participate and members over the age of four were invited to participate from the Yukon community. Those under the age of six and who were unable to provide free and informed consent (e.g., those under the influence of drugs or alcohol, individuals with Alzheimer's disease, as well as any minors who were unable to obtain the consent of their parent or guardian), and individuals unwilling to receive their personal results were also excluded from the study. In the Yukon, those over the age of four years were able to participate in the study. In total, 613 community members participated in at least one part of the biomonitoring studies across the NWT and Yukon.

3.1.2 Recruitment Methods

Recruitment methods incorporated several ethical considerations, including free and informed consent, participant confidentiality, and anonymity. As directed through the consultations, all community

members from each of the participating communities had the option of participating. Since community population sizes ranged between 36-1230 in the Dehcho and Sahtú and Old Crow, the recruitment process varied by community. For small communities (i.e., population size less than 100), all community members were invited to participate and for large communities' (i.e., population size greater than 100), participants were selected randomly through phone calls. Even within large communities, walk-in volunteers were welcome to participate. Importantly, a component of this study included an opt-in process, meaning, to maintain the free and informed consent process participants were able to take part of any part of the study.

3.1.3 Sample and Data Criteria

Between the years of 2016-2019, questionnaire data and biological samples (hair, urine, and blood) were collected from participants. Specifically, samples collection began in 2016 for the NWT regions, and in 2019 for Old Crow. Surveys and demographic data were also collected at the same time as the biomarker samples, resulting in a cross-sectional study design. Demographic data and other basic personal information were collected including age, sex, BMI, smoking status and drinking status. To identify drinking and smoking status, participants were asked if they had smoked a cigarette or drank alcohol in the last 24 hours. These responses were coded as binary (e.g., 'yes' or 'no'). Of the 613 participants who participated in the study, there were 272 whole blood samples from the NWT and 56 blood samples from the Yukon.

3.1.4 FFQ

FFQs used across the 10 communities were developed based initially on questionnaires used at the Centre of Indigenous Peoples Nutrition and Environment (16). The FFQ then underwent edits to build in local knowledge as directed by input from focus groups (16). These FFQs included a list of questions that identified which traditional foods participants had consumed over the past year, the frequency of consumption, locations where select foods were harvested, and how the foods were prepared (e.g., smoked, cooked, or raw). Categories for types of traditional foods were created in the FFQ including fish, land animals, game birds and berries. Food portion size was also documented by participants; however, for the purposes of this thesis, this variable is not included in the models. Instead, the food consumption was reported using a binary, consumer vs. no consumer approach. (162)

3.1.5 Analytical Methods

Whole blood samples were collected from participants and blood plasma was used for the analysis of POPs, specifically PCBs. Laboratory analysis of POPs were performed in the laboratory of the Centre de Toxicologie du Québec. Liquid extraction of POPs was done before POPs were analyzed using an Agilent Gas Chromatograph coupled with a Mass Spectrometer. Reference materials were used to assess method quality (e.g., National Institute of Standards and Technology SRM-1958). Limits of detections (LOD) for PCB congeners were between 0.005 (e.g., PCB123 and PCB153) and 0.5 µg/L (PCB128). The highest recovery was 90% and the lowest was 68%. Reproducibility variation was below 13% (104).

Twenty-four PCB congeners and one PCB mixture were analyzed through gas chromatography coupled with mass spectrometry. Additionally, four PCB groupings were also calculated based on the congener-specific results, including: $\sum\text{PCB}_{\text{All}}$, $\sum\text{PCB}_{\text{dioxin-like}}$, $\sum\text{PCB}_{\text{non dioxin-like}}$ and $\sum\text{PCB}_{138,153,180}$. PCB biomarker levels were adjusted according to plasma lipid concentrations to account for the level of variability in plasma lipid levels according to the equation:

$$\text{PCB biomarker level } (\mu\text{g/L}) \text{ plasma } (\text{g lipid/L}) \times 1000 = \text{PCB biomarker level } (\mu\text{g/kg lipids})$$

3.1.6 Ethics Approvals and Licenses

Ethical approval was obtained from the University of Waterloo Research Ethics Committee (#23192, #32076, #20173, #20950), the Yukon Government for Research (12-27S&E), the Vuntut Gwitchin Government. #20950), the Stanton Territorial Health Authority for Human Research (29/12/2015), and the Aurora Research Institute (#15560, #15775, #15966, #15977, #16021)

3.1.7 Statistical Methods

Summary of PCB Concentrations

Descriptive statistics for PCB exposure levels, including GMs and select percentiles (P50, P75, P95), were generated using IBM SPSS version 29. To generate 95% CIs, bootstrapping using the percentile interval method was performed (B=1000). Results were also grouped into age groups that were used in the CHMS (i.e., 20-79). To test associations between PCB congener concentrations and each of the

binary categorical variables within the survey data, a 2-sample Test (with Normal Approximation) was used. Spearman Rank Correlation Coefficient was used to test for associations between PCB biomarker concentrations and continuous variables. This thesis will use $\frac{1}{2}$ LOD when sample concentrations fell below the LOD (to maintain consistency in estimates generated in previous papers and reports for this project). Further, this approach maximizes the comparability of study data to that from several key reference studies and populations (e.g., the CHMS and the FNBI).

Multiple Linear Regression Models

To predict biomarker level from traditional food consumption, multiple linear regression models were created using SPSS version 8.1 as opposed to an explanatory model (e.g., adding in multiple foods in one model). The models chosen for this thesis explored the extent to which PCB biomarker levels differ according to traditional food consumption patterns (i.e., does eating specific traditional foods affect PCB biomarker levels in participants and, if so, by how much?). FFQ responses were coded as binary variables for the purposes of this thesis and the models used in the data analysis. For example, if a participant reported eating a particular food in the past year, their response was coded 'yes' or '1'. In contrast, if a participant reported not eating that traditional food, then their response was coded 'no' or '0'.

Groupings of traditional foods (i.e., Fish eggs, large game meat, large game organs, waterfowl, and game birds) were recoded according to whether participants reported eating any of the foods within that group in the year before data collection. The selected food groupings were created based on food consumption rates (i.e., foods that were eaten by >10% of participants) as well as those foods known to be particularly lipid rich. The list of food items included in the models were tailored to the regional-specific FFQ data. For example, multiple linear regression models for participant data from the Dehcho and Sahtú did not include Chinook as these salmon were only reportedly harvested in Old Crow, Yukon. Relatively few participants (< 15%) reported eating all these foods more than once per week, so frequency of consumption was not analyzed (163). As well, portion size was not used as a variable in the models, because species-specific portion size was not collected.

Covariables included in each of the models were age and sex. Participant age was treated as a continuous variable and sex was treated as binary. These were chosen based on results from the bivariate analyses of this thesis and to be consistent with relevant literature. As identified from initial statistical analyses from section four of this thesis, PCBs levels were significantly correlated with age

and varied between male and female participants in select regions. On that note, age and sex are also well-known co-variables with PCB exposure. In the literature, for example, it is common to include sex as a co-variable when analyzing PCB biomarkers because PCBs may metabolize differently between men and women (37). Age is also a common co-variable to explore with PCB biomarker levels as it is known that PCB levels tend to increase as age increases because they are a persistent and bio accumulative chemical (37).

The response variable analyzed for the multiple linear regression models was $\sum \text{PCB}_{138,153,180}$ (log base 10) as these are among the most detected PCBs in the literature. Focusing on using this sum as the dependent variable in the models allows avoiding repeated multiple linear regression models for multiple congeners and multiple regions.

4. Results

4.1 Summary of PCB Exposure Levels in the NWT and Yukon

4.1.1 Participation and Demographics Descriptions

Demographic variables for each of the two regions in the NWT and one community in the Yukon are shown in Table 4.1 while the census data for each of these areas are summarized in Table 4.2 (4,164). Results presented within this thesis focus exclusively on those participants that provided a blood sample (n=328) for POP analysis. Among these participants, mean and median age (43-44 years) was similar across each of the regions. As well, similar proportions of male and female participants took part in each of the Dehcho, Old Crow and Sahtú areas. However, lower proportions of younger participants (i.e., less than 25 years old) took part in Old Crow, Yukon than in the Dehcho and Sahtú regions.

Table 4.1 Demographic variables of biomonitoring project participants who provided a blood sample for chemical analysis

Demographic		Dehcho	Old Crow	Sahtú
		n (% of total)	n (% of total)	n (% of total)
Age Group	0-14	5 (3.9)	2 (3.6)	9 (6.8)
	15-24	22 (17)	6 (10.7)	18 (13.6)
	25-44	39 (30)	22 (39.3)	40 (30.3)
	45-59	37 (28.7)	16 (28.6)	34 (25.8)
	60+	26 (20)	10 (17.9)	31 (23.5)
	Missing	6	0	5
	Total	135	56	132
Sex	Male	64 (47.4)	27 (48.2)	66 (48.2)
	Female	71 (52.6)	29 (51.8)	71 (51.8)
	Total	135	56	137
Mean Age		43 (95% CI 39.7-45.6)	43 (95% CI 38.8-46.8)	44 (95% CI 40.7-47.4)
Median Age		44 (95% CI 41.0-46.0)	41 (95% CI 33.5-51.0)	44 (95% CI 37.0-48.0)

Age categories are based off 2016 census data tables.

Table 4.2 Census data 2016 for the Dehcho and Sahtú regions, NWT and Old Crow, Yukon

Demographic		Dehcho ^{1,2}	Old Crow ¹	Sahtú ²
		n (% of total)	n (% of total)	n (% of total)
Age group	0-14	310 (20.5)	40 (17.78)	357 (21.69)
	15-24	250 (16.6)	35 (15.56)	270 (16.4)
	25-44	399 (26.4)	60 (26.67)	479 (29.1)
	45-59	319 (21.1)	45 (20)	310 (18.83)
	60+	232 (15.4)	45 (20)	230 (13.97)
	Total	1,510	225	1646
Sex	Male	809 (51.5)	105 (55.3)	932 (53.5)
	Female	762 (48.5)	85 (44.7)	809 (46.5)
	Total	1571	190	1741

Age categories are based on NWT Bureau of Statistics data tables. Age and sex stratified data for one participating community (Kakisa, NWT, population 36) was unavailable in the 2016 census as well as the NWT Bureau of Statistics thus, population counts are not included in these estimates. 1. Statistics Canada (2016) 2. NWT Bureau of Statistics (2016).

Female participants that provided a blood sample appeared slightly over-represented from census data in each of the participating regions. For example, 52-53% of participants of the project self-reported as female whereas census data indicates between 44-47% of census respondent in 2016 were female. Over-representation was also observed in each of the study regions for those participants who reported ages between 45-59, as these participants made up 26-29% of the study population compared to 19-21% of the census population. Participants aged 60 and over were also slightly over-represented in the Dehcho and Sahtú. Reported ages for those 60+ for participants from this project represented 20-24% of the population compared to 14-15% from the census. In Old Crow, participants with reported ages of 25-44 were also over-represented as this age group made up 40% of the study population compared to the 27% reported from the census. Further, youth (0-14 years) were under-represented relative to census data in each of the Dehcho, Sahtú, and Old Crow. For instance, youths in this project made up 4- 7% of the study population whereas census data reports 18-22% were between the ages of 0-14. Similarly, in Old Crow, participants with reported ages 15-24 made up 10% of the study population relative to the 16% as indicated from the census.

4.1.2 Summary Statistics of PCB Concentrations in the NWT and Yukon

Lipid adjusted- plasma PCB concentrations are reported for individual PCB congeners in Table 4.3 and Table 4.4 reports PCB biomarker concentrations of specific PCB groupings most reported in the literature. In the Sahtú, some participants' values weren't reported for some congeners. Of the 24 PCB

congeners and one PCB mixture (i.e., Arochlor 1260) measured in this study, 100% of samples fell below the limit of detection for five congeners (PCB28, PCB52, PCB66, PCB101 and PCB128) and were thus excluded from further analysis. Of the remaining PCBs measured through this work, 11 were detected in at least 50% of samples in at least one of the three participating regions, including Arochlor 1260, PCB118, PCB138, PCB146, PCB153, PCB163, PCB170, PCB180, PCB187, PCB194, PCB201. These 11 PCB biomarkers as well as one PCB congener grouping (i.e., $\sum \text{PCB}_{138,153,180}$) were selected as dependent variables for the remaining statistical analyses described herein.

Interestingly, the degree of PCB congener chlorination varied with PCB detection rates among age groups. For example, some of the less-chlorinated congeners (PCB71 to PCB105) had more than 50% of the samples below the detection limit in each of the age groups. In contrast, most of the highly chlorinated PCB congeners (e.g., PCB153, PCB180, PCB187) had higher rates of detection (92-71%). Particular highly chlorinated congeners (e.g., PCB203: 51%, PCB206: 67%) were detected in less than 50% of samples in each of the regions. Unsurprisingly given the bioaccumulative nature of PCBs, detection rates increased as participant age increased for some higher-chlorinated congeners (e.g., PCB180). Further, those under 20 years had relatively low detection rates for select PCBs (e.g., Arochlor 1260, PCB74, PCB99, PCB105, PCB118, etc.).

Similar detection rates among select PCB congeners were observed in the CHMS. For example, the detection rate for PCB206 was 43% and most highly chlorinated congeners (e.g., PCB153, PCB180, PCB187) were highly detected (99-80%). Some differences in detection rates were observed compared to the CHMS. For example, some highly chlorinated PCBs were had higher detection rates (e.g., PCB203: 64%) in the CHMS. Detection rates for PCBs in this project were generally similar compared to those from the FNBI. For example, detection rates for select highly chlorinated congeners were also relatively low (e.g., PCB203: 55%, PCB206: 42%) whereas most highly chlorinated congeners (e.g., PCB153, PCB180, PCB187) were highly detected (94-68%) in the FNBI (57,108).

Table 4.3 Descriptive statistics of PCB levels in the NWT and Yukon categorized by age groups summarizing sample size, LODs (µg/L), %<LODs, GMs (GM µg/kg lipids) and percentiles (50P, 75P, 95P) (µg/kg lipids)

	Dehcho								Old Crow								Sahtú							
	Age Range	n	LOD	% <LOD	50P	75P	95P	GM	n	LOD	% <LOD	50P	75P	95P	GM	n	LOD	% <LOD	50P	75P	95P	GM		
Arochlor 1260	<20	17	0.1	64.71	<LOD	25.64 (<LOD -45)	NC	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.1	53.33	<LOD	33.33 (14.31 - 107.98)	NC	<LOD		
	20-79	112	0.1	11.61	89.6 (69.23 - 118.06)	209.1 (145.29 - 271.42)	827.75 (430.85 - 1496.81)	87 (68.85 - 110.37)	54	0.1	11.11	51.37 (39-68.69)	107.05 (64.71 - 130.25)	356.85 (178.58 - 547.17)	50.88 (38.56 - 67.17)	111	0.1	0.9	141.03 (98.21 - 216.67)	422.17 (266.67 - 615.04)	1349.2 (746.48 - 1662.59)	154.34 (124.8-195.01)		
	All ages	135	0.1	17.78	71.59 (50.86-101.96)	171.86 (135.48 - 245.28)	544.93 (404.51 - 1486.49)	71.19 (56.67-89.39)	56	0.1-1	14.29	51.37 (34.09-64.71)	103.86 (64.76-128.21)	335.54 (160.66 - 547.17)	49.6 (38.38-66.18)	137	0.1	6.6	117.5 (86.79-176.47)	422.16 (268.25 -597.4)	1336.5 (776.12 - 1592.33)	130.61 (104.1-165.51)		
PCB74	<20	17	0.03-0.08	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.03-0.08	100	<LOD	<LOD	<LOD	<LOD		
	20-79	112	0.03-0.09	95.54	<LOD	<LOD	<LOD	<LOD	54	0.09-0.2	100	<LOD	<LOD	<LOD	<LOD	111	0.03-0.2	95.5	<LOD	<LOD	<LOD	<LOD		
	All ages	135	0.03-0.09	96.3	<LOD	<LOD	<LOD	<LOD	56	0.09-0.3	100	<LOD	<LOD	<LOD	<LOD	137	0.03-0.2	96.35	<LOD	<LOD	<LOD	<LOD		
PCB99	<20	17	0.03-0.08	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.03-0.8	100	<LOD	<LOD	<LOD	<LOD		
	20-79	112	0.03-0.09	96.43	<LOD	<LOD	<LOD	<LOD	54	0.03	94.44	<LOD	<LOD	<LOD	<LOD	111	0.03-0.2	86.49	<LOD	<LOD	11.22 (8.81 - 15.7)	<LOD		
	all ages	135	0.03-0.09	97.04	<LOD	<LOD	<LOD	<LOD	56	0.03-0.3	94.64	<LOD	<LOD	<LOD	<LOD	137	0.03-0.2	88.32	<LOD	<LOD	11.51 (10.05-16.92)	<LOD		
PCB105	<20	17	0.01	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.1	100	<LOD	<LOD	<LOD	<LOD		
	20-79	112	0.01	93.75	<LOD	<LOD	2.06 (1.22 - 4.88)	<LOD	54	0.01	92.59	<LOD	<LOD	2.6 (0.97 - 4)	<LOD	111	0.01	72.97	<LOD	1.41 (1.06 - 2.3)	4.16 (2.82 - 5.46)	<LOD		

	Dehcho								Old Crow								Sahtú							
	Age Range	n	LOD	% <LOD	50P	75P	95P	GM	n	LOD	% <LOD	50P	75P	95P	GM	n	LOD	% <LOD	50P	75P	95P	GM		
	all ages	135	0.01	94.82	<LOD	<LOD	1.61 (1.26-4.86)	<LOD	56	0.01-0.1	92.86	<LOD	<LOD	3.65 (1.02-6.1)	<LOD	137	0.01	75.91	<LOD	<LOD	4.11 (2.57-5.42)	<LOD		
PCB118	<20	17	0.01	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	86.67	<LOD	<LOD	NC	<LOD		
	20-79	112	0.01	50	1.36 (1.02-1.97)	3.45 (2.3 - 4.77)	10.82 (6.6 - 31.64)	1.88 (1.56 - 2.28)	54	0.01	50	1.17 (0.85 - 1.84)	2.42 (<LOD - 3.64)	12.25 (4.29 - 18.33)	1.51 (1.19 - 1.93)	111	0.01	38.74	2.24 (1.75 - 3.47)	7.23 (4.56 - 11.48)	24.78 (16.07 - 30.98)	2.86 (2.31 - 3.58)		
	all ages	135	0.01	54.81	<LOD	2.98 (2.14-4.51)	9.68 (6.58-31.08)	<LOD	56	0.01-0.1	51.79	<LOD	2.54 (1.82 - 3.93)	11.67 (4.86-18.33)	<LOD	137	0.01	41.61	2.17 (1.49-3.15)	7.13 (4.4-10.92)	23.27 (14.37-28.88)	2.78 (2.29-3.41)		
PCB138	<20	17	0.01	70.59	<LOD	1.69 (<LOD -2.67)	NC	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	86.67	<LOD	<LOD	NC	<LOD		
	20-79	112	0.01	19.64	4.94 (4.14 - 6.22)	10.24 (7.74 - 15.41)	40.69 (19.6 - 87.19)	4.96 (3.98 - 6.16)	54	0.01	22.22	3.22 (2.36 - 3.97)	6.23 (4.24-8.14)	25.51 (9.86 - 38.33)	3.18 (2.45 - 4.18)	111	0.01	6.31	7.42 (5.47 - 11.21)	21.2 (15.47 - 31.09)	65.79 (39.13-91.9)	8.29 (6.7 - 10.4)		
	all ages	135	0.01	25.93	4.35 (3.13-5.68)	9.76 (7.42-12.69)	33.79 (19.7-85.14)	4.25 (3.39 - 5.2)	56	0.01-0.1	25	3.22 (2.36 - 4.16)	6.18 (4.25-7.27)	23.88 (9.14-38.33)	3.15 (2.44-4.14)	137	0.01	15.33	6.48 (4.88-9)	20.88 (15.07 - 28.46)	63.29 (39.34-89.83)	7.2 (5.79-9.02)		
PCB 146	<20	17	0.01	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	93.33	<LOD	<LOD	NC	<LOD		
	20-79	112	0.01	50	1.4 (<LOD -2.13)	3.81 (2.5-5.09)	13.32 (7.76 - 25.85)	1.9 (1.57 - 2.32)	54	0.01	72.22	<LOD	1.46 (0.88 - 2.73)	6.12 (2.98 - 10.33)	<LOD	111	0.01	44.14	2.36 (1.19-3.47)	6.48 (4.29 - 9.67)	24.78 (14.03-31.53)	2.62 (2.13 - 3.28)		
	all ages	135	0.01	54.81	<LOD	3.13 (2.44 - 4.29)	12.31 (7.58 - 25.68)	<LOD	56	0.01-0.1	73.21	<LOD	1.49 (0.94-2.73)	6.51 (3.16 - 10.33)	<LOD	136	0.01	46.32	2.04 (1.22-3.17)	6.32 (4.38 - 9.66)	23.46 (15.31-32.2)	2.62 (2.14-3.21)		
PCB 153	<20	17	0.01	64.71	<LOD	3.19 (1.3 - 5.75)	NC	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	40	2.86 (<LOD -4.12)	4.12 (3.01 - 14.19)	NC	2.69 (1.72 - 4.46)		
	20-79	112	0.01	8.04	12.6 (8.94 - 16.55)	28.71 (19.44-37.14)	111.98 (57.21 - 190.5)	11.6 (9.15 - 14.92)	54	0.01	9.3	6.33 (4.43 - 7.65)	13.87 (7.65 - 20.46)	41.84 (23.48 - 67.93)	6.37 (4.78 - 8.43)	111	0.01	0	19.23 (13.49 - 32.69)	56.04 (38.18 - 84.38)	196.15 (104.23 - 233.68)	21.12 (16.97 - 26.82)		
	all ages	135	0.01	14.82	9.43 (7.10-14.26)	23.44 (17.74 - 33.96)	76.75 (57.30-189.19)	9.31 (7.16-11.73)	56	0.1	12.5	6.2 (4.68-7.61)	13.4 (7.63-17.95)	39.19 (23.20-67.93)	6.16 (4.62-8.12)	137	0.01	4.38	17.14 (11.89-25)	56.04 (39.95-82.41)	193.08 (111.07 - 254.24)	18.21 (14.32-23.06)		
PCB156	<20	17	0.01	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	93.33	<LOD	<LOD	NC	<LOD		

Dehcho								Old Crow								Sahtú					
Age Range	n	LOD	% <LOD	50P	75P	95P	GM	n	LOD	% <LOD	50P	75P	95P	GM	n	LOD	% <LOD	50P	75P	95P	GM
20-79	112	0.01	55.36	<LOD	3.43 (2.25 - 4.74)	12.59 (6.38 - 20.95)	<LOD	54	0.01	72.22	<LOD	1.44 (0.88 - 2.39)	3.96 (2.55 - 5.71)	<LOD	111	0.01	51.35	<LOD	4.49 (3.33- 5.92)	11.6 (8.57 - 21.66)	<LOD
all ages	135	0.01	60	<LOD	2.96 (2.03- 4)	11.7 (5.91- 20.83)	<LOD	56	0.01- 0.1	73.21	<LOD	1.61 (0.88- 2.38)	4.55 (2.82 - 6.1)	<LOD	137	0.01	52.55	<LOD	4.49 (3.42- 6.04)	12.33 (9.23- 19.23)	<LOD
PCB 163	<20	17	0.01	100	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	93.33	<LOD	<LOD	NC	<LOD
20-79	112	0.01	43.75	1.85 (<LOD - 2.42)	4.41 (3.18 - 5.69)	14.86 (9.3 - 23.72)	2.14 (1.78 - 2.61)	54	0.1	61.11	<LOD	2.22 (1.22 - 4.1)	7.29 (4.48 - 14)	<LOD	111	0.01	39.64	2.64 (1.92 - 4.22)	8.78 (5.11 - 12.24)	28.05 (17.46- 39.51)	3.027 (2.44- 3.8)
all ages	135	0.01	49.63	1.43 (1.16- 2.12)	3.71 (2.9- 5.07)	12.79 (8.26- 23.61)	1.99 (1.66- 2.33)	56	0.01- 0.1	62.5	<LOD	2.27 (1.4- 4.1)	6.83 (5.2- 14)	<LOD	135	0.01	42.22	2.42 (1.43 - 3.97)	8.61 (5.12- 11.92)	25.68 (18.27- 40)	3 (2.41- 3.69)
PCB 167	<20	17	0.01	100	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	100	<LOD	<LOD	<LOD	<LOD
20-79	112	0.01	84.82	<LOD	<LOD	5.12 (2.08 - 8.81)	<LOD	54	0.01	98.15	<LOD	<LOD	<LOD	<LOD	111	0.01	74.77	<LOD	1.28 (1.02 - 2.06)	4.53 (2.96 - 8.25)	<LOD
all ages	135	0.01	86.67	<LOD	<LOD	3.06 (1.97- 8.65)	<LOD	56	0.01- 0.1	98.214	<LOD	<LOD	<LOD	<LOD	137	0.01	75.91	<LOD	<LOD	4.87 (2.96- 6.35)	<LOD
PCB 170	<20	17	0.01	100	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	93.33	<LOD	<LOD	NC	<LOD
20-79	112	0.01	33.04	3.74 (3.02 - 4.73)	8.14 (5.44 - 11)	32.26 (17.15 - 43.56)	3.44 (2.79 - 4.31)	54	0.01	46.3	1.7 (0.88 - 2)	3.75 (2- 5.74)	7.92 (6- 9.81)	1.73 (1.36 - 2.17)	111	0.01	33.33	3.28 (2.45 - 5.76)	11.39 (6.77 - 13.91)	31.08 (23.34 - 49.33)	3.74 (2.94 - 4.79)
all ages	135	0.01	40	3.22 (2.18- 4.17)	6.46 (5.16- 9.39)	28.94 (14.93- 40.28)	3.03 (2.44 - 3.69)	56	0.01- 0.1	48.21	1.7 (0.89- 2.04)	3.98 (2.06- 5.74)	7.78 (6.14- 9.81)	1.75 (1.39 - 2.22)	137	0.01	37.96	3.07 (1.88- 5.14)	11.39 (7.28- 13.84)	30.48 (25.4- 51.92)	3.65 (2.93- 4.55)
PCB 178	<20	17	0.01	100	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	100	<LOD	<LOD	<LOD	<LOD
20-79	112	0.01	78.57	<LOD	<LOD	4.78 (2.97 - 7.6)	<LOD	54	0.01	87.04	<LOD	<LOD	2.86 (1.66 - 4.83)	<LOD	111	0.01	54.95	<LOD	3.36 (2.17 - 4.71)	11.91 (7.46 - 14.46)	<LOD
all ages	135	0.01	81.48	<LOD	<LOD	4.35 (2.75- 7.04)	<LOD	56	0.01- 0.1	87.5	<LOD	<LOD	4.57 (1.7- 6.1)	<LOD	136	0.01	55.88	<LOD	3.41 (2.21- 4.56)	11.98 (8.19- 16.1)	<LOD
PCB 180	<20	17	0.01	82.35	<LOD	<LOD	NC	NA	NA	NA	NA	NA	NA	NA	15	0.01	86.67	<LOD	<LOD	NC	<LOD
20-79	112	0.01	14.29	12.35 (8.82- 15.28)	27.46 (17.84 - 37.04)	120.14 (60.35 - 161.09)	10.11 (7.82 - 13.26)	54	0.01	20.37	5.3 (2.74 - 6.33)	12.38 (6.33 - 18.18)	23.91 (19.41 - 33.96)	4.4 (3.25 - 5.86)	111	0.01	9.91	11.9 (8.78 - 20.27)	37.72 (23.86 - 52.54)	124.62 (88.25 - 195.98)	12.07 (9.16 - 15.87)

	Dehcho								Old Crow								Sahtú							
	Age Range	n	LOD	% <LOD	50P	75P	95P	GM	n	LOD	% <LOD	50P	75P	95P	GM	n	LOD	% <LOD	50P	75P	95P	GM		
PCB 183	all ages	135	0.01	22.22	10.29 (6.55-13.42)	24.19 (16.39-32.26)	103.95 (53.46-158.49)	7.99 (6.06-10.25)	56	0.01-0.1	23.21	5.3 (2.8 - 6.33)	12.14 (6.62-17.68)	23.68 (19.37-33.96)	4.31 (3.22-5.81)	136	0.01	18.25	10.63 (6.67-19.36)	37.72 (25.46-54.05)	125.95 (95.6-192.31)	10.56 (8.06-13.84)		
	<20	17	0.01	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	100	<LOD	<LOD	<LOD	<LOD		
	20-79	112	0.01	65.18	<LOD	2.26 (1.45 - 2.93)	8.18 (4.27 - 12.18)	<LOD	54	0.01	81.48	<LOD	<LOD	2.8 (1.61 - 4.91)	<LOD	111	0.01	56.76	<LOD	3.72 (2.83 - 5.42)	11.23 (7.55 - 16.65)	<LOD		
	all ages	135	0.01	69.63	<LOD	1.88 (1.28-2.54)	5.81 (4.11-12.03)	<LOD	56	0.01-0.1	82.14	<LOD	<LOD	4.14 (1.8-6.1)	<LOD	136	0.01	58.09	<LOD	3.77 (2.73-5.27)	11.12 (7.61-15.87)	<LOD		
	<20	17	0.01	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	86.67	<LOD	<LOD	NC	<LOD		
PCB 187	20-79	112	0.01	28.57	3.63 (2.54 - 4.8)	9 (6.39 - 12.5)	32.79 (21.23 - 56.52)	3.7 (2.98 - 4.66)	54	0.01	42.6	1.82 (0.94 - 2.22)	3.78 (2.22 - 6.13)	11.41 (7.15 - 18.87)	1.87 (1.46 - 2.39)	111	0.01	23.42	5.51 (3.75 - 8.74)	15.05 (10.13 - 23.19)	55.84 (32.43 - 70.42)	5.52 (4.33 - 7.06)		
	all ages	135	0.01	36.3	2.96 (1.96-4.31)	7.66 (5.64-10)	30.99 (17.09-55.56)	3.23 (2.57-3.98)	56	0.01-0.1	44.64	1.82 (0.96-2.23)	3.83 (2.24-6.1)	10.71 (7.23-18.87)	1.89 (1.49-2.44)	136	0.01	28.68	4.94 (3.24-7.91)	15.9 (10.85-23.21)	53.86 (37.78-71.02)	5.17 (4.07-6.53)		
	<20	17	0.01	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	100	<LOD	<LOD	<LOD	<LOD		
PCB 194	20-79	112	0.01	39.29	2.68 (1.6 - 3.51)	6.64 (4.23 - 9.07)	28.65 (16.41 - 46.31)	2.8 (2.28 - 3.51)	54	0.01	57.41	<LOD	2.56 (1.58 - 3.66)	5.26 (3.96 - 6.15)	<LOD	111	0.01	42.34	2.41 (1.26 - 4.04)	7.16 (5.5 - 11.51)	23.61 (20.43 - 40.72)	2.91 (2.33 - 3.66)		
	all ages	135	0.01	45.93	2.1 (1.25-2.97)	5.23 (3.89-7.29)	24.4 (14.2-37.93)	2.51 (2.04-3.04)	56	0.01-0.1	58.92	<LOD	2.68 (1.68-3.8)	6.05 (4.12-6.15)	<LOD	137	0.01	45.96	2.15 (1.22-3.79)	7.6 (5.63-11.68)	26.61 (20.79-40.39)	2.95 (2.36-3.68)		
	<20	17	0.01	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	100	<LOD	<LOD	<LOD	<LOD		
PCB 201	20-79	112	0.01	41.96	2.36 (1.36 - 3.24)	5.22 (3.59 - 7.75)	21.83 (14.71 - 38.24)	2.53 (2.07 - 3.14)	54	0.01	57.41	<LOD	2.53 (1.45 - 4.15)	6.28 (4.63 - 8.11)	<LOD	111	0.01	41.44	2.22 (1.67 - 4.36)	7.87 (5.54 - 10.68)	24.61 (17.2 - 38.77)	2.96 (2.37 - 3.76)		
	all ages	135	0.01	47.41	1.64 (1.22-2.69)	4.35 (3.4-7.09)	20.99 (11.04-36.21)	2.31 (1.89-2.77)	56	0.01-0.1	58.93	<LOD	2.67 (1.54-4.16)	6.24 (4.67-8.11)	<LOD	137	0.01	45.26	2.04 (1.28 - 4)	8.04 (5.27-11.86)	27.29 (22.34-40)	2.98 (2.41-3.69)		
	<20	17	0.01	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	100	<LOD	<LOD	<LOD	<LOD		

	Dehcho								Old Crow								Sahtú							
	Age Range	n	LOD	% <LOD	50P	75P	95P	GM	n	LOD	% <LOD	50P	75P	95P	GM	n	LOD	% <LOD	50P	75P	95P	GM		
	20-79	112	0.01	50.89	<LOD	3.71 (2.73 - 5.12)	19.42 (10.12 - 25.49)	<LOD	54	0.01	70.37	<LOD	1.48 (0.91 - 2.26)	3.17 (2.46 - 4.34)	<LOD	111	0.01	48.65	1.54 (1.02- 2.71)	5.22 (3.38 - 6.89)	15.16 (11.5 - 25.09)	2.18 (1.81 - 2.66)		
PCB 206	all ages	135	0.01	56.3	<LOD	3.18 (2.5- 4.23)	14.41 (8.12- 21.95)	<LOD	56	0.01- 0.1	71.43	<LOD	1.5 (0.96- 2.27)	3.48 (2.45- 6.1)	<LOD	137	0.01	51.09	<LOD	5.22 (3.65- 7.67)	15.9 (11.87- 21.15)	<LOD		
	<20	17	0.01	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	NA	15	0.01	100	<LOD	<LOD	<LOD	<LOD		
	20-79	112	0.01	66.96	<LOD	2.15 (1.35 - 3.33)	8 (5 - 12.74)	<LOD	54	0.01	81.48	<LOD	<LOD	2.02 (1.48 - 2.3)	<LOD	111	0.01	62.16	<LOD	2.58 (1.45 - 3.47)	8.33 (5.15 - 11.82)	<LOD		
	all ages	135	0.01	70.37	<LOD	1.69 (1.28- 2.73)	6.83 (4.36- 11.52)	<LOD	56	0.01- 0.1	82.14	<LOD	<LOD	2.11 (1.47- 6.1)	<LOD	137	0.01	62.04	<LOD	2.58 (1.67- 4.06)	9.18 (6.27- 12.42)	<LOD		

NA- Not available because there are not enough participants to keep anonymous or there were not enough participants to calculate this statistic. NC- Statistic not calculated. <LOD – Not calculated because there was more than 50% of the samples less than the limit of detection.

Table 4.4 Descriptive statistics of groupings of PCB levels in the NWT and Yukon categorized by age groups summarizing sample size, %<LODs, GMs (GM µg/kg lipids) and 95th Percentiles (95P).

	Age Range	n	% <LOD	Dehcho				n	% <LOD	Old Crow				n	% <LOD	Sahtú			
				50P	75P	95P	GM			50P	75P	95P	GM			50P	75P	95P	GM
ΣPCB _{All}	<20	17	64.71	<LOD	95.92 (78.32-145)	NC	<LOD	NA	NA	NA	NA	NA	NA	15	40	112.5 (73.86-139.59)	139.59 (112.5-181.84)	NC	106.27 (89.99-127.29)
	20-79	112	8.85	110.28 (92.11-140.94)	172.80 (161.17-203.5)	562.4 (331.8 - 806.65)	122.34 (107.29-140.26)	54	9.26	135.16 (128.37-148.49)	158.48 (148.49-182.15)	275.41 (211.64-388.68)	145.35 (134.9-158.60)	111	0	148.92 (122.22-166.08)	258.023 (203.167-394.75)	725.30 (492.15-909.91)	163.55 (141.48-189.57)
	all ages	135	14.81	108.28 (87.50-119.99)	164.84 (145-188.20)	469.5 (285.17-776.53)	116.34 (103.57-129.65)	56	12.5	136.95 (128.80-150.16)	161.22 (149.75-198.33)	366.29 (219.31-396.34)	148.25 (137.60-161.35)	137	4.38	148.92 (127.59-167.56)	267.23 (206.82-395.29)	701.3557 (531.70-928.85)	166.92 (146.66-190.26)
ΣPCB _{dioxin-like}	<20	17	100	<LOD	<LOD	<LOD	<LOD	NA	NA	NA	NA	NA	NA	15	80	<LOD	<LOD	NC	<LOD
	20-79	112	44.64	4.5 (4-5.24)	8.61 (6.14-11.26)	30.73 (16.36 - 66.85)	5.92 (5.16-6.89)	54	50	<LOD	5.40 (4.17-6.66)	18.27 (9.24-28)	<LOD	111	36.94	5.35 (4.58-7.11)	13.59 (8.67-22.16)	43.34 (28.59 - 61.57)	7.49 (6.36-8.89)
	all ages	135	49.63	4.65 (4.13-5)	7.55 (5.97-10.61)	24.57 (14.85 - 66.35)	5.73 (5.07-6.49)	56	51.79	<LOD	5.51 (4.24-7.16)	24.55 (9.79-28)	<LOD	137	39.42	5.39 (4.88-6.95)	13.18 (8.89-21.48)	40.47 (27.88-57.11)	7.57 (6.59-8.72)
ΣPCB _{non dioxin-like}	<20	17	64.71	<LOD	73.81 (64.58-86.11)	NC	<LOD	NA	NA	NA	NA	NA	NA	15	40	110 (70.46-136.53)	136.53 (110-177.90)	NC	102.99 (86.41-124.55)
	20-79	112	8.04	118.82 (97.53-147.54)	182.83 (169.49-231.07)	649.15 (387.12 - 942.32)	129.54 (112.43-149.41)	54	9.26	135.49 (128.44-150.11)	159.56 (152.5-195.72)	279.87 (221.8 - 397.17)	147.24 (136.33-161.20)	111	0	154.31 (124.82-178.65)	279.05 (214.67-416.67)	803.63 (551.12-1012.88)	171.17 (146.66-199.32)
	all ages	135	14.81	115.39 (89.69-130.19)	175.1 (159.28-205.41)	560 (326.38 - 847.08)	121.94 (107.53-137.34)	56	12.5	135.80 (129.10-152.95)	159.93 (152.95-215.26)	360.72 (223.4 - 397.17)	149.93 (139.09-163.16)	137	4.38	154.31 (130.67-177.90)	294.14 (224.10-422.16)	778.05 (605.50-1078.21)	174.04 (151.99-200.00)
ΣPCB _{138,153,180}	<20	17	64.71	<LOD	3.66 (3.41-5.25)	NC	<LOD	NA	NA	NA	NA	NA	NA	15	40	4.90 (3.19-6.29)	6.67 (4.90-20.94)	NC	5.70 (4.06-8.98)
	20-79	112	8.04	30.57 (21.76-38.04)	69.83 (48.12-83.98)	255.99 (144.57 - 433.6)	27.56 (21.73 - 34.49)	54	9.26	14.21 (10.31-19.20)	31.91 (19.15-47.74)	85.61 (53.93 - 139.62)	14.29 (10.99 - 18.94)	11	0	37.42 (27.45-60.83)	109.30 (79.03-169.49)	397.93 (228.80-461.64)	41.34 (32.20-52.74)
	all ages	135	14.81	25.43 (18.14-34.32)	59.67 (42.68-74.65)	211.65 (134.07-427.78)	22.41 (17.98 - 28.62)	56	12.5	14.21 (9.70-18.31)	31.44 (19.05-45.45)	80.58 (52.62-139.62)	13.97 (10.52 - 18.7)	137	4.38	34.07 (22.79-54.66)	115.52 (83.25-169.12)	394.48 (246.99-469.49)	36.58 (29.3 - 46.05)

NA- Not available because there were not enough participants to keep anonymous. NC- Statistic not calculated. <LOD - statistic not calculated because there was more than 50% of the samples less than the limit of detection. Dioxin-like PCBs include PCB105, PCB118, PCB156 and PCB167

4.1.3 Region as a Determinant of PCB Biomarker Levels

Pairwise comparisons (Tukey HSD) were used to evaluate regional differences in PCB biomarkers. PCB biomarkers varied among participating regions, with the highest levels appearing in samples from the Sahtú. Further, PCB biomarkers were generally higher in the Dehcho than in Old Crow (Figure 4.1). Between the Dehcho and Sahtú regions, six congeners showed significant differences ($p < 0.05$) in GM levels, ranging from 1.51-fold (PCB163) to 1.96 (PCB153) higher in the Sahtú. Between the Dehcho and Old Crow, three congeners showed significant differences ($p < 0.05$) in GM levels, ranging from 1.71- fold (PCB187) to 1.85- fold (PCB180) higher in the Dehcho. Notably, all GM PCB biomarkers levels were over 2-fold higher in the Sahtú compared to Old Crow. Specifically, between the Sahtú region and Old Crow, seven congeners showed significant differences ($p < 0.05$) in GM levels between regions, ranging from 2.09-fold (PCB170) to 2.96-fold (PCB153) higher in the Sahtú. Geometric mean differences observed between the regions are similarly large at the upper end of the distributions. For example, some PCB P95 levels were up to 5.3-fold higher (PCB180) in the Sahtú region compared to Old Crow. Generally, those PCB biomarkers that were detected in the largest percent of samples tended to have the largest fold differences in GM biomarker concentrations across the three regions. In contrast, the PCB congeners that were infrequently detected (i.e., %<LOD in nearly 50% of samples) tended to be at more similar PCB concentrations among the three regions.

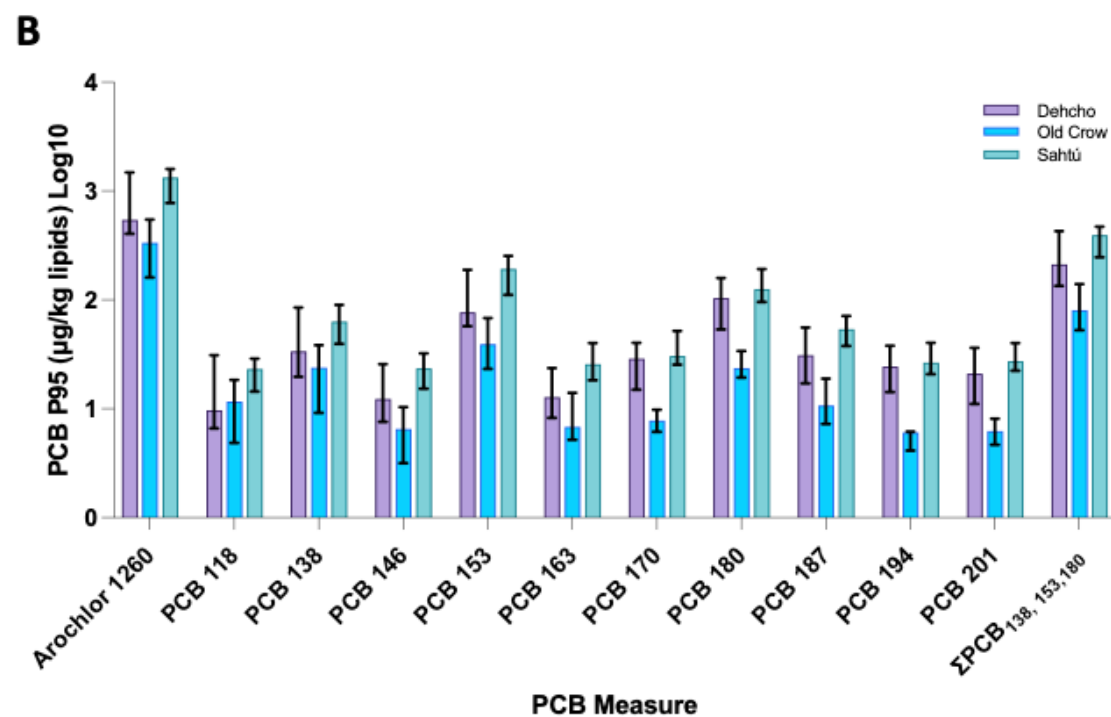
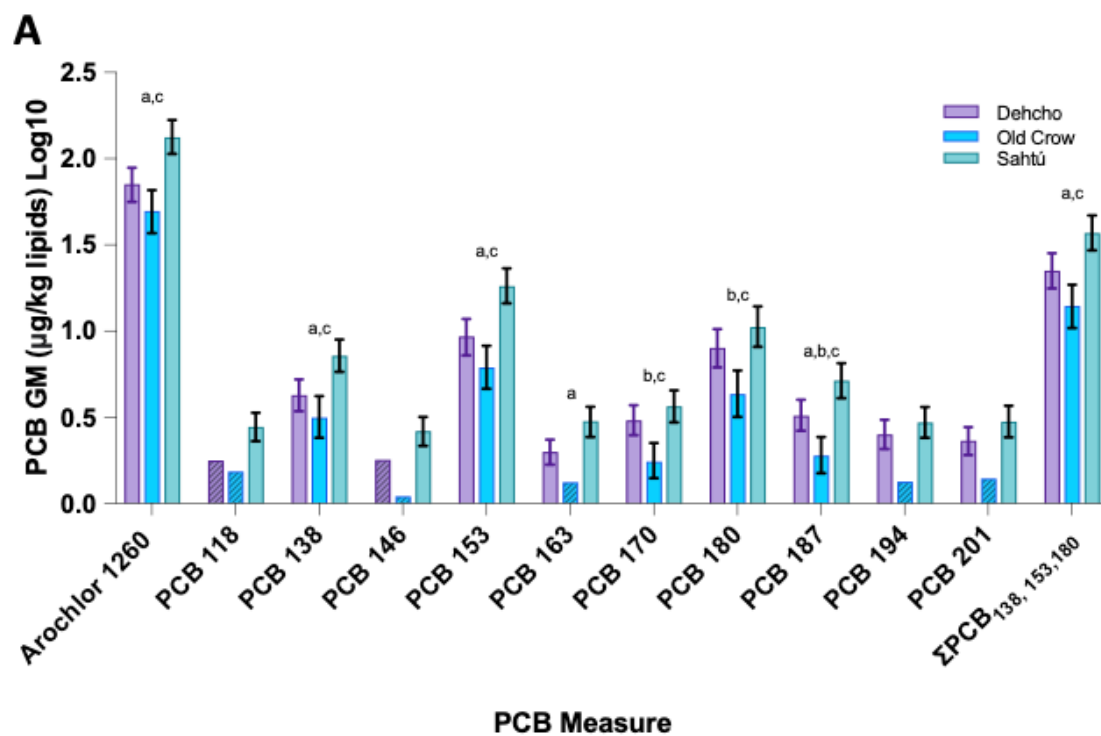


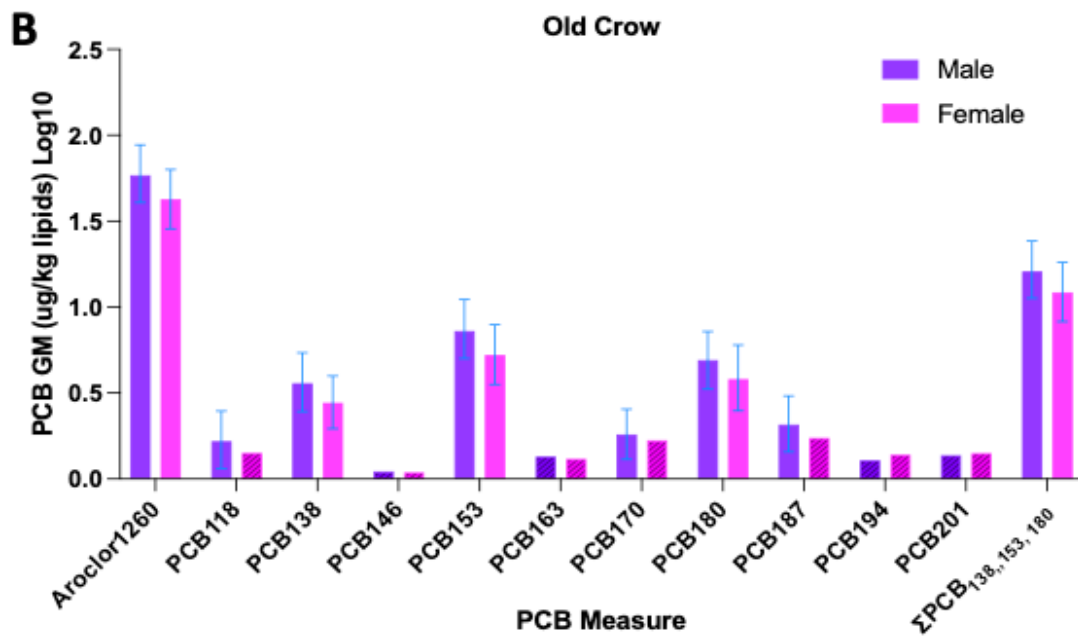
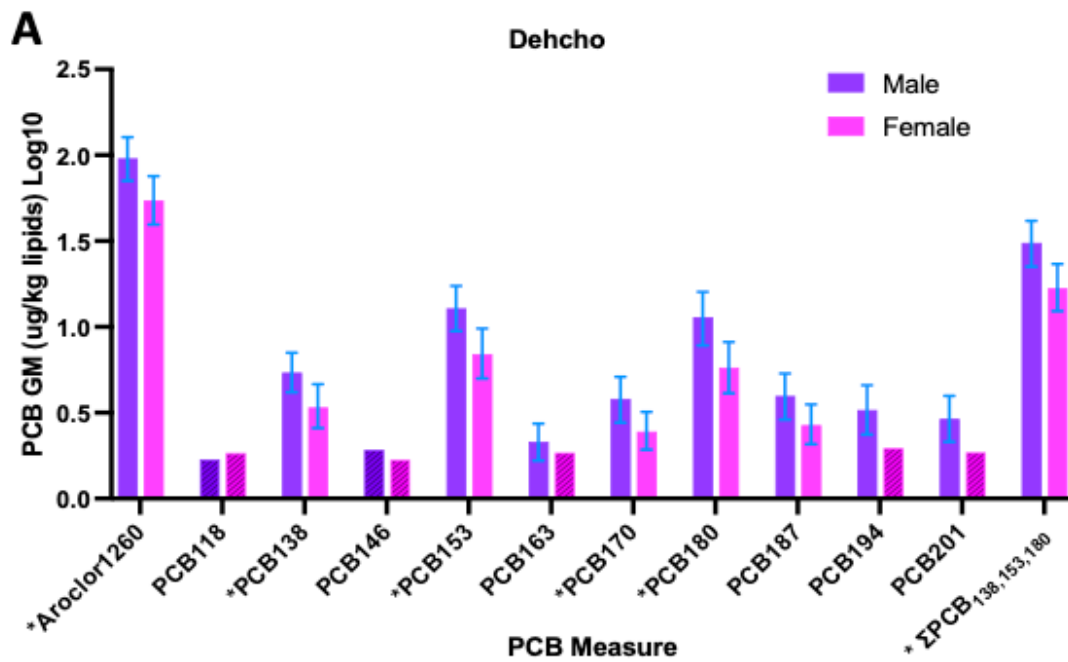
Figure 4.1 A) GMs of select PCB measures across the three participating regions B) 95th percentiles of select PCB measures across the three participating regions.

PCB exposure levels of blood samples ($\mu\text{g/kg}$ lipids) from the Dehcho and Sahtú, NWT and Old Crow, Yukon with an LOD $>50\%$ in at least one of the three regions/communities for all ages and male and female participants. Hatchmark bars depicts those measures whose %<LOD was above 50% thus GMs and CIs were not reported and considered below the limit of detection and excluded from this analysis. Significant difference ($p<0.05$, ANOVA Multiple Comparisons) means between: Dehcho and Sahtú (a), Dehcho and Old Crow (b), Sahtú and Old Crow (c). All PCB biomarker levels were log (base 10) transformed for the ANOVA tests.

4.1.4 PCBs vs. Sex

Analyses showed statistically significant differences between PCB concentrations and sex; however, these differences varied by region. For example, male participants in the Dehcho had significantly higher PCB biomarker levels than female participants. In contrast, in the Sahtú region and Old Crow, PCB biomarker levels appeared slightly higher in male than female participants, however these differences were not statistically significant (Figure 4.2). Specifically, in the Dehcho, PCB GM levels ranged from ≈ 1.55 -fold (PCB170, GM: 2.47 95%CI 1.93- 3.20) to ≈ 1.98 -fold (PCB180, GM: 5.80 95%CI 4.11-8.17) higher ($p<0.05$) in male participants compared to female participants within the Dehcho region.

Once again, those PCBs with the highest rates of detection tended to have the largest effect sizes between male and female participants in the Dehcho and those congeners with detection rates below nearly 50% of samples tended to have more similar effect sizes. For example, the detection rate for PCB180 was just over 1.6-fold higher compared to the detection rate of PCB170. Despite differences in detection rates among congeners, no significant differences among male and female participants were observed in the Sahtú and Old Crow.



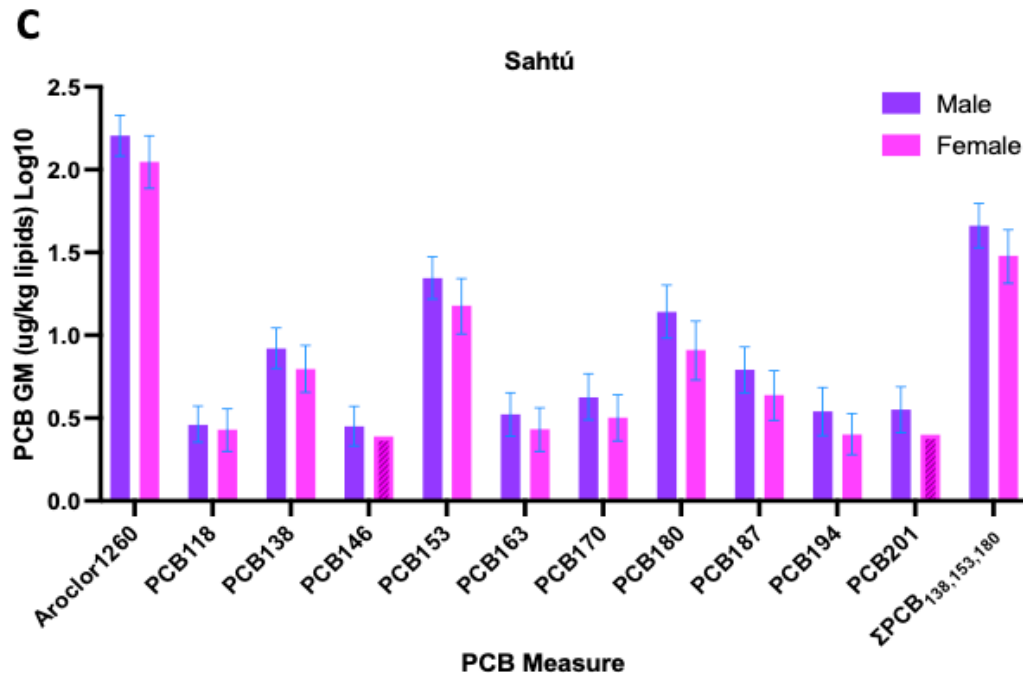


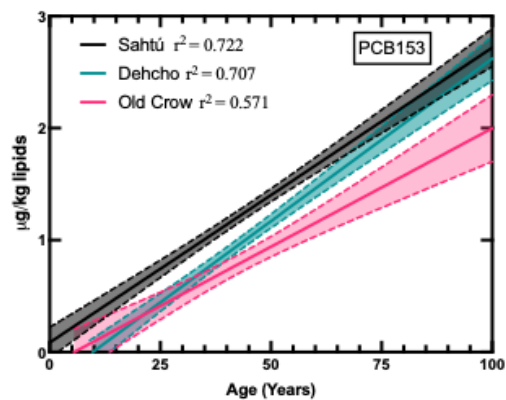
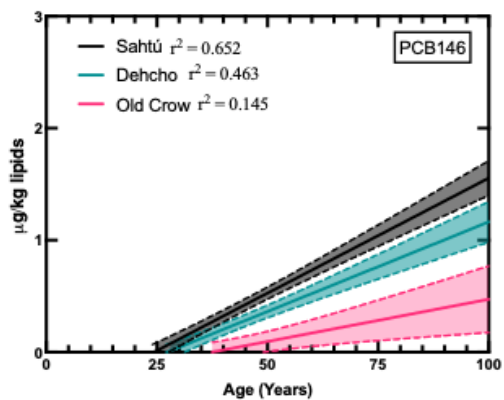
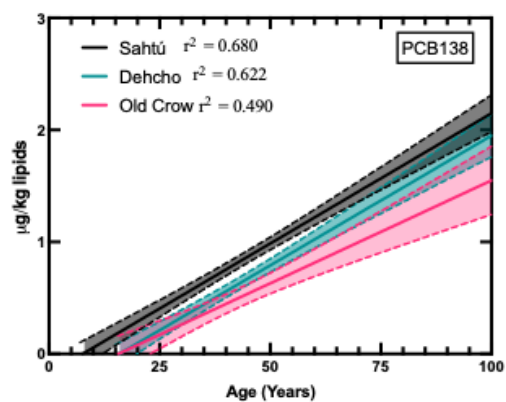
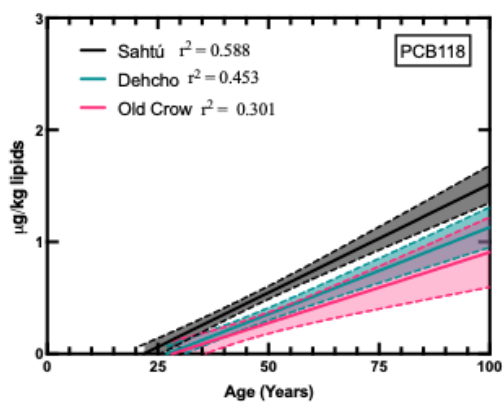
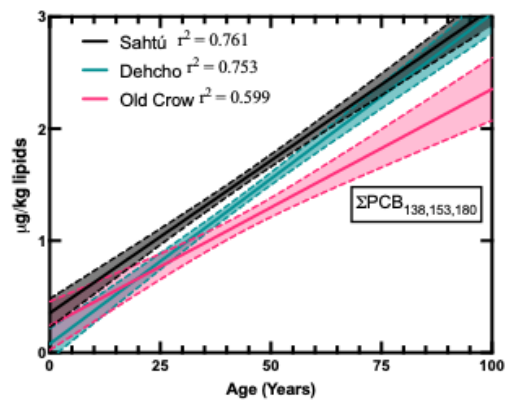
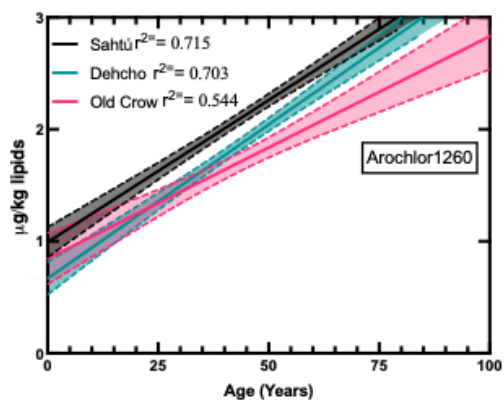
Figure 4.2 GM PCB levels ($\mu\text{g/kg}$ lipids) for men and women in the NWT and Yukon. A) Dehcho region GM PCB levels for all ages B) Old Crow GM PCB levels all ages C) Old Crow GM PCB levels.

* $p < 0.05$, independent samples T-test differences between male and female GMs in the Dehcho. Hatchmark bars depicts those measures whose %<LOD was above 50% thus GMs and CIs were not reported and considered below the limit of detection and excluded from this analysis.

4.1.5 PCBs vs. Age

Simple linear regression models were completed to observe differences between age and PCB exposure levels in Figure 4.3 and Spearman's correlations are presented in Table 4.5. PCB concentrations were positively correlated with age, however the strength of these correlations varied by congener and region. For example, in the Dehcho region correlations between PCB biomarkers and age ranged from 0.703 ($p < 0.05$) for PCB163 to 0.887 ($p < 0.05$) for PCB180. In Old Crow, correlations ranged from 0.419 ($p < 0.05$) for PCB163 to 0.788 ($p < 0.05$) for $\Sigma\text{PCB}_{138,153,180}$. In the Sahtú region, correlations ranged from 0.714 ($p < 0.05$) for PCB118 to 0.906 ($p < 0.05$) for PCB180. Notably, weaker correlations between PCB biomarker levels were observed with age in Old Crow. The relationship between PCB biomarker

concentrations and age tended to be strongest for those congeners that were more frequently detected in certain regions. For example, in the Dehcho PCB180 was the most frequently detected congener and presented the strongest correlation between concentration and age.



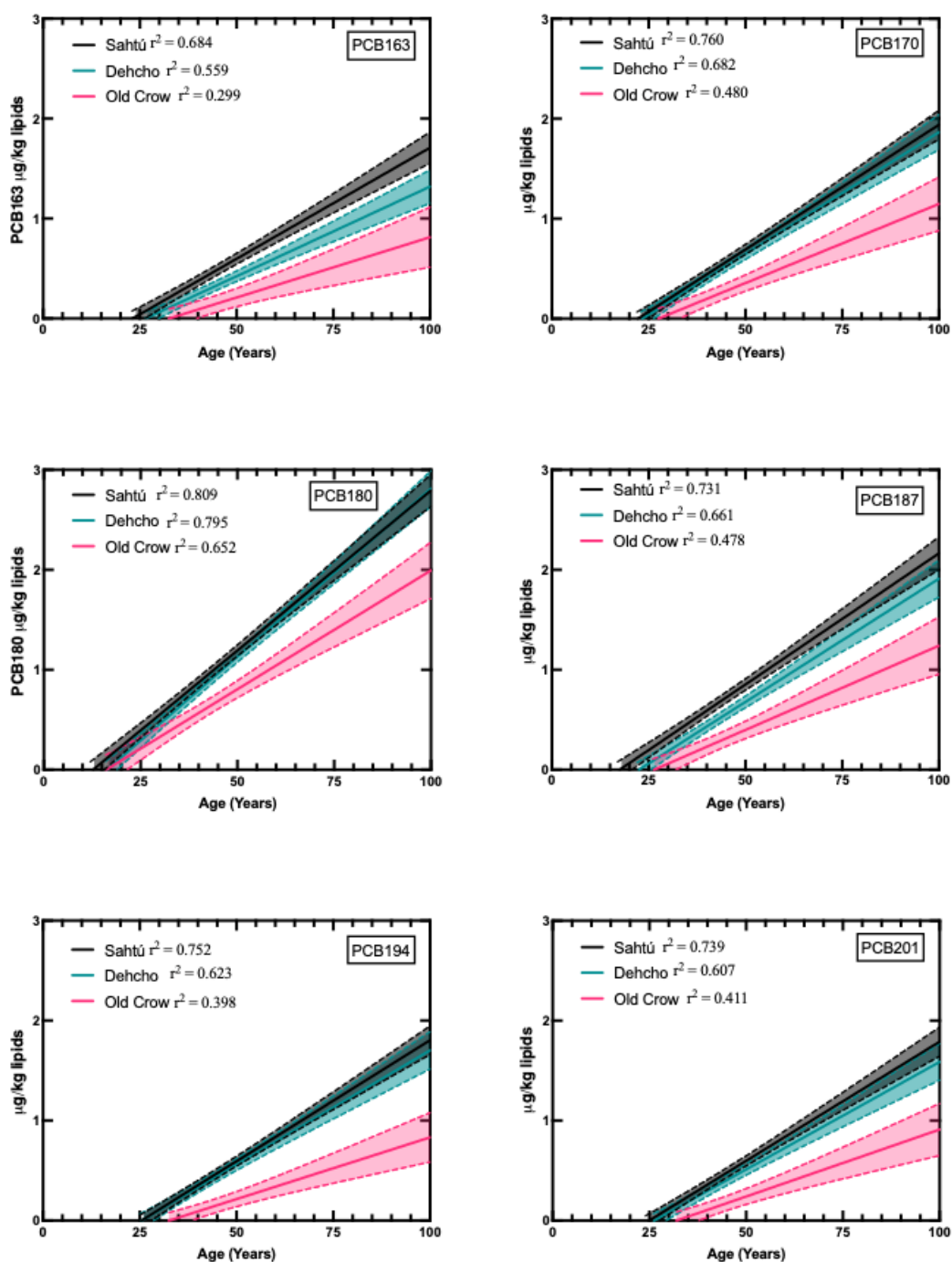


Figure 4.3 Simple linear regression between age and select Log10PCB congener biomarker levels in the NWT and Yukon.

Table 4.5 Correlations (Spearman's rho) between age and PCB exposure levels in the Dehcho Region, Old Crow and Sahtú region for all ages and men and women.

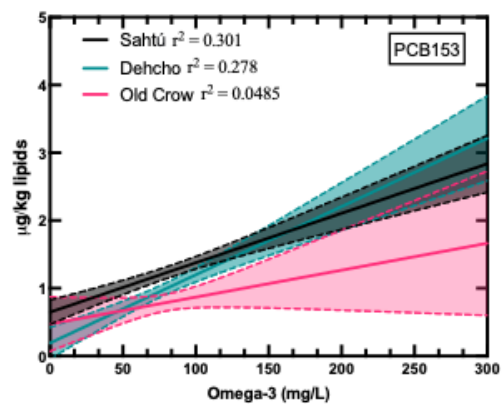
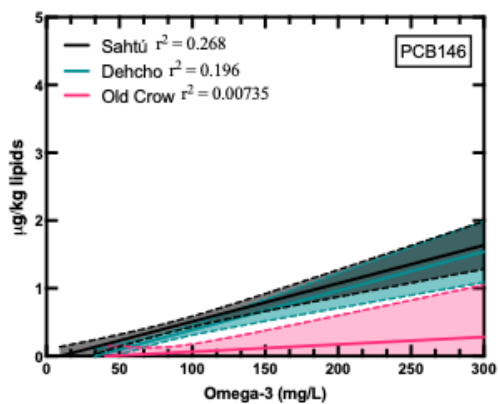
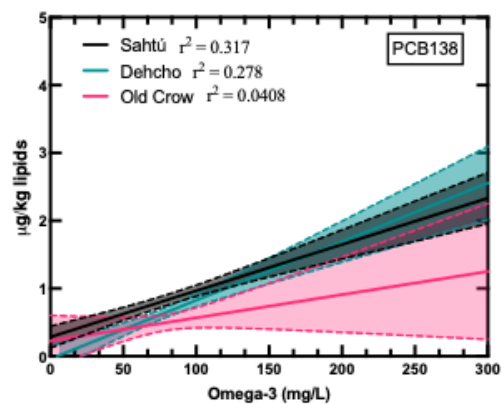
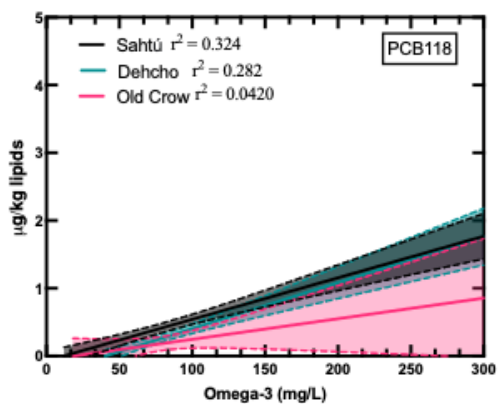
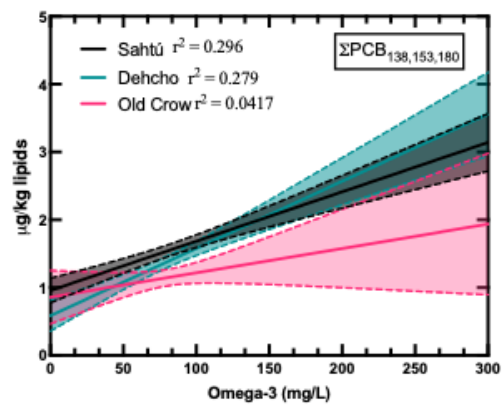
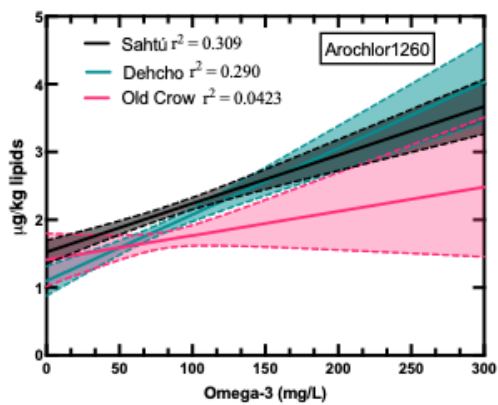
PCB Measure	Dehcho			Old Crow			Sahtú		
	Spearman's rho	p-value	95% CI	Spearman's rho	p-value	95% CI	Spearman's rho	p-value	95% CI
Aroclor1260	0.834	<0.001*	(0.77-0.88)	0.778	<0.001*	(0.66-0.85)	0.851	<0.001*	(0.79-0.89)
PCB118¹	0.584	<0.001*	(0.44-0.7)	0.517	<0.001*	(0.25-0.69)	0.714	<0.001*	(0.61-0.8)
PCB138	0.784	<0.001*	(0.7-0.84)	0.739	<0.001*	(0.56-0.85)	0.831	<0.001*	(0.76-0.88)
PCB146¹	0.575	<0.001*	(0.44-0.68)	0.17	0.21	(-0.105, 0.421)	0.741	<0.001*	(0.65-0.81)
PCB153	0.839	<0.001*	(0.78-0.89)	0.796	<0.001*	(0.67-0.88)	0.854	<0.001*	(0.8-0.9)
PCB163	0.703	<0.001*	(0.6-0.78)	0.419	0.001*	(1.7- 0.62)	0.783	<0.001*	(0.7-0.84)
PCB170	0.796	<0.001*	(0.72-0.85)	0.614	<0.001*	(0.41-0.76)	0.841	<0.001*	(0.78-0.89)
PCB180	0.887	<0.001*	(0.84-0.92)	0.806	<0.001*	(0.69-0.88)	0.906	<0.001*	(0.87- 0.93)
PCB187	0.797	<0.001*	(0.72-0.85)	0.656	<0.001*	(0.72-0.85)	0.845	<0.001*	(0.79-0.89)
PCB194	0.771	<0.001*	(0.69-0.83)	0.498	<0.001*	(0.26-0.68)	0.786	<0.001*	(0.71-0.85)
PCB201	0.748	<0.001*	(0.66-0.82)	0.518	<0.001*	(0.29- 0.69)	0.783	<0.001*	(0.7- 0.84)
ΣPCB_{138,153,180}	0.868	<0.001*	(0.82-0.91)	0.788	<0.001*	(0.66-0.87)	0.881	<0.001*	(0.83-0.92)

* = Correlation is significant at the 0.01 level using Spearman's rho. PCBs whose LOD was greater than 50% in at least one of the regions were included in this table, however, some PCBs in certain regions had LODs < 50%. ¹In the Dehcho region, PCB118 and PCB146 had % <LOD greater than 50. ²In Old Crow, PCB118, PCB146, PCB194 and PCB201 had a % <LOD greater than 50.

4.1.6 Omega-3 Fatty Acids as a Determinant

Figure 4.4 shows the simple linear regressions between PCB concentration and omega-3 fatty acids and Table 4.6 summarizes Spearman's correlations between PCB concentration and omega-3 fatty acids. Of the 12 PCB measures included in the correlation analysis between omega-3 fatty acids and PCB concentrations, all correlation coefficients were positively ($p < 0.05$) correlated in the Dehcho and Sahtú regions. For example, in the Dehcho region, correlation coefficients between PCBs and omega-3 fatty acids ranged from 0.305 (PCB146) to 0.533 ($\sum \text{PCB}_{138,153,180}$). Similarly, in the Sahtú region, correlation coefficients ranged from 0.426 (PCB194) to 0.603 (PCB138). Notably, the simple linear regressions between PCB biomarkers and omega-3 fatty acids overlapped in the Dehcho and Sahtú for each PCB measure. In contrast, PCB biomarkers were uncorrelated with omega-3 fatty acid levels in Old Crow.

PCB measures with higher detection rates showed generally stronger correlation coefficients with omega-3 fatty acid level. For example, PCB153 had the highest detection rate (14.82% < LOD) followed by Arochlor 1260 (17.78% < LOD) in the Dehcho region and had the highest correlation coefficients, (PCB153 $\rho = 0.518$, Arochlor 1260 $\rho = 0.523$) between omega-3 fatty acid level and PCB concentration. In the Sahtú regions, similar patterns were observed (i.e., PCB153 and Arochlor 1260 had the highest detection rates along with the strongest correlation coefficients). As previously mentioned, degree of chlorination tends to map onto detection rate. For example, PCB153 and Arochlor 1260 are some of the more highly chlorinated congeners and were more frequently detected in each of the study regions.



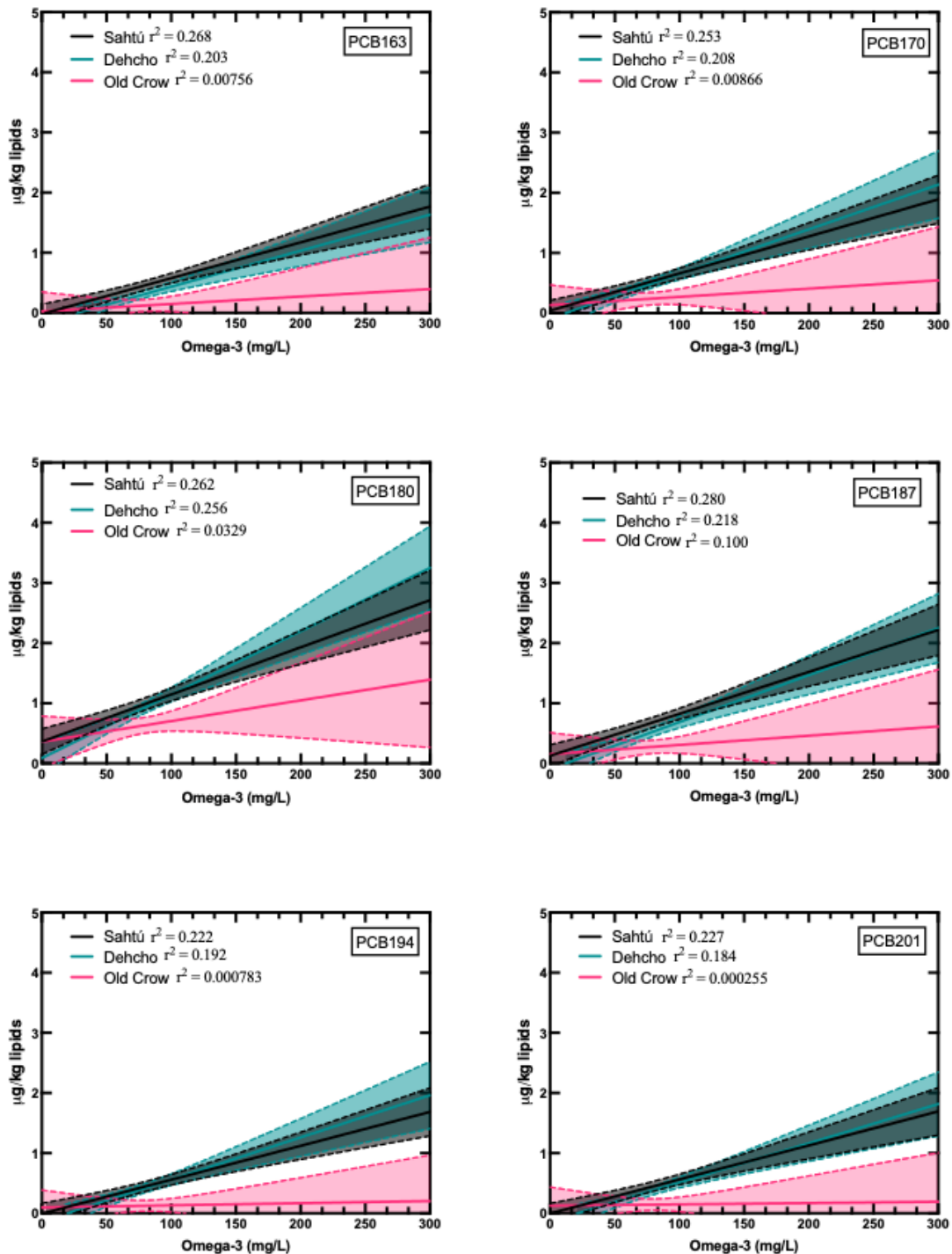


Figure 4.4 Simple linear regression graphs between omega-3 fatty acids and select Log10PCB biomarker levels in the NWT and Yukon.

Table 4.6 Correlations (Spearman's rho) between omega-3 fatty acids and PCB exposure levels in the Dehcho Region, Old Crow and Sahtú region for all ages and men and women.

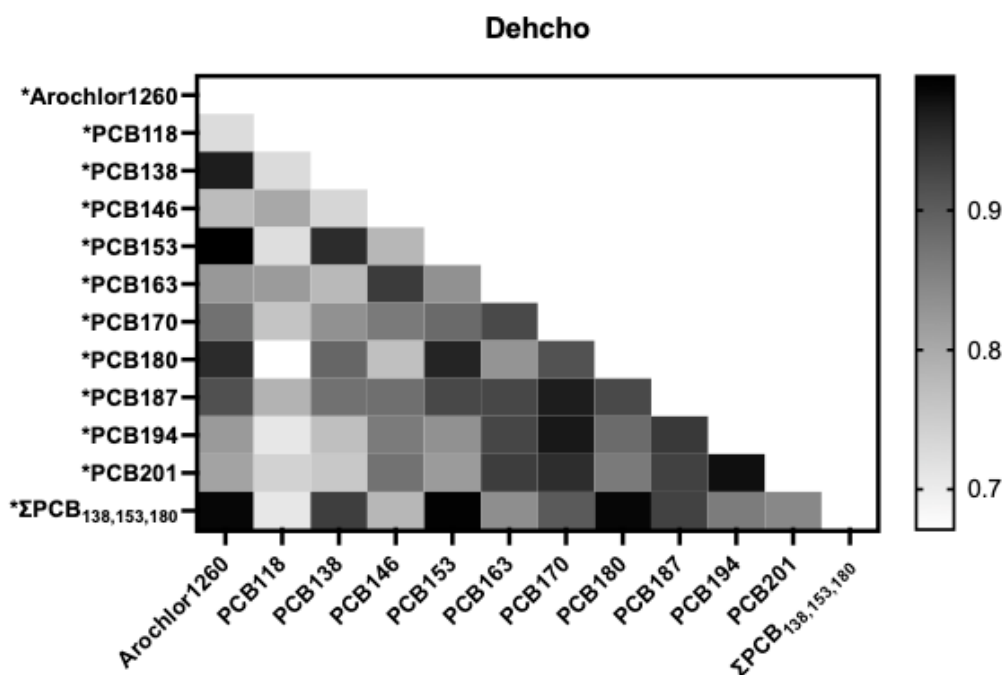
PCB Measure	Dehcho			Old Crow			Sahtú		
	Spearman's rho	p-value	95% CI	Spearman's rho	p-value	95% CI	Spearman's rho	p-value	95% CI
Aroclor1260	0.523	<.001	(0.38- 0.64	0.202	0.136	-0.07,0.45	0.593	<.001	0.47,0.70
PCB118¹	0.321	<.001	0.16- 0.47	0.216	0.109	-0.06,0.46	0.554	<.001	0.42,0.66
PCB138	0.495	<.001	0.35- 0.62	0.205	0.129	-0.07,0.45	0.603	<.001	0.48,0.70
PCB146¹	0.256	0.003	0.09- 0.41	-0.043	0.754	-0.31,0.23	0.449	<.001	0.30,0.58
PCB153	0.518	<.001	0.38,0.64	0.205	0.129	-0.07,0.45	0.589	<.001	0.46,0.69
PCB163	0.312	<.001	0.15,0.46	0.017	0.902	-0.26,0.29	0.48	<.001	0.33,0.60
PCB170	0.376	<.001	0.22,0.52	0.063	0.646	-0.21,0.33	0.498	<.001	0.36,0.62
PCB180	0.515	<.001	0.38,0.63	0.162	0.232	-0.11,0.41	0.554	<.001	0.42,0.66
PCB187	0.378	<.001	0.22,0.52	0.087	0.526	-0.19,0.35	0.538	<.001	0.40,0.65
PCB194	0.328	<.001	0.16, 0.48	-0.041	0.764	-0.31,0.23	0.426	<.001	0.27,0.56
PCB201	0.305	<.001	0.14,0.46	-0.04	0.771	-0.31,0.23	0.439	<.001	0.29,0.57
ΣPCB_{138,153,180}	0.533	<.001	0.40,0.65	0.214	0.113	-0.06,0.46	0.587	<.001	0.46,0.69

Significant level at $p < 0.01$ using Spearman's rho. 1. In Dehcho, PCB118 and PCB146 had %<LOD greater than 50. 2. In Old Crow, PCB118, PCB146, PCB194 and PCB201 had a %<LOD greater than 50.

4.1.7 Intercorrelations Among PCBs

Intercorrelations among PCB measures with >50% detection rate in at least one of the participating regions are shown in Figure 4.5. Of these PCBs, all were markedly positively correlated ($p < 0.01$). Specifically, correlation coefficients ranged from 0.671 (PCB118 and PCB180) to 0.996 (Arochlor 1260 and PCB153) in the Dehcho region. Notably, the strongest correlation coefficients were between Arochlor 1260 and PCB153 in the Sahtú ($\rho = 0.999$) and Old Crow ($\rho = 0.995$).

Some subtle differences in the strength of the correlations among PCB congeners appear between the regions. For example, very weak correlations (i.e., a lighter column) are shown for PCB 118 in the Dehcho (e.g., PCB118 and PCB180, $\rho = 0.671$) but not Old Crow (e.g., PCB118 and PCB180, $\rho = 0.705$). Similarly, weaker correlations for PCB 146 appear in Old Crow (e.g., PCB146 and PCB180, $\rho = 0.398$) than in the Dehcho (e.g., PCB146 and PCB180, $\rho = 0.767$) and Sahtú (e.g., PCB146 and PCB180, $\rho = 0.894$). Overall, looking at which columns come up light versus which come up dark present different patterns among the regions.



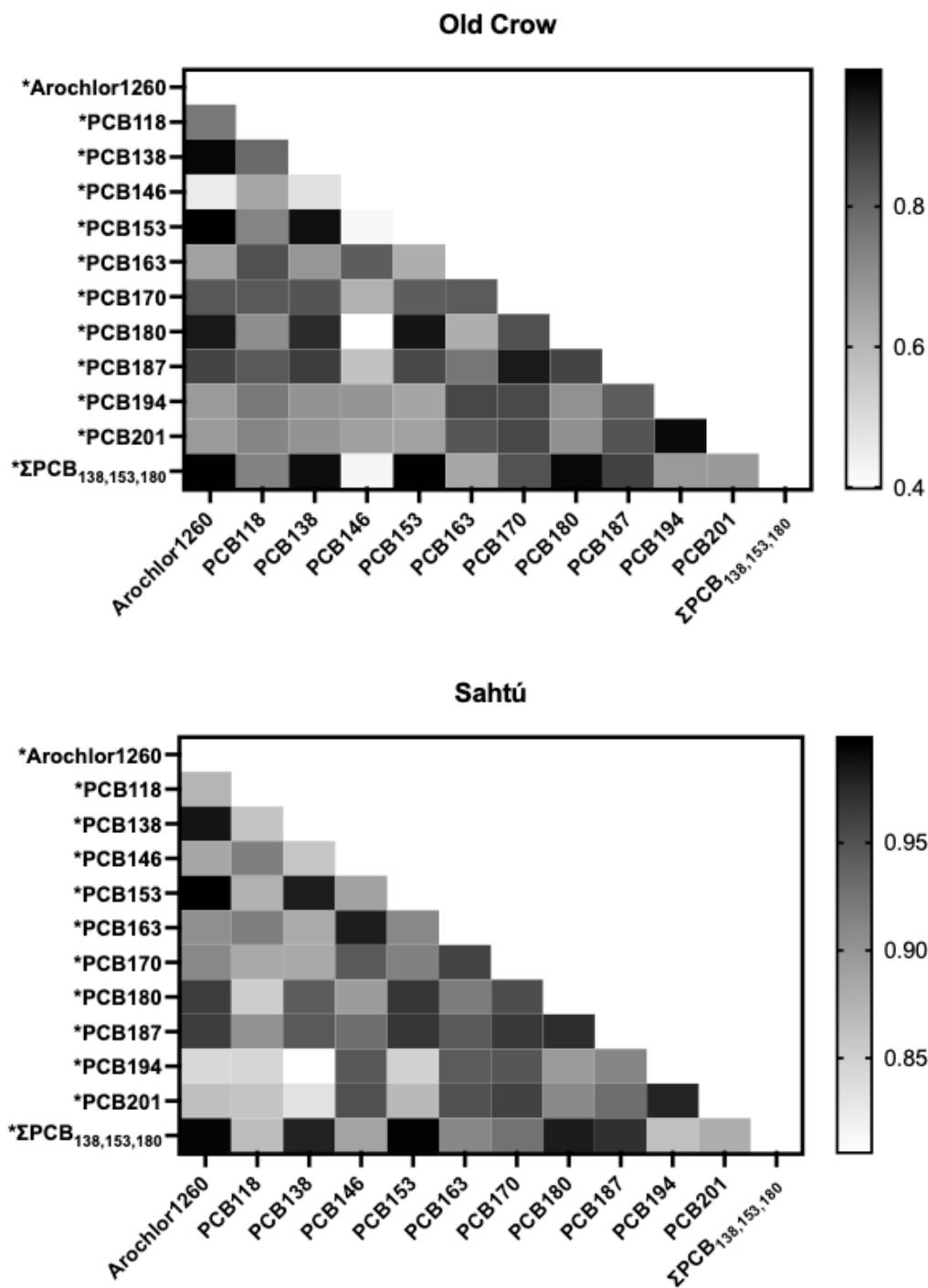


Figure 4.5 Correlation coefficients (Spearman's rho) among PCB congeners in the Dehcho and Sahtú regions, NWT and Old Crow, Yukon region

* correlations are significant at $p < 0.01$

4.1.8 PCBs vs. BMI

Correlations with BMI and PCB concentrations varied among regions with all those PCB congeners that were significantly ($p < 0.05$) associated with BMI being positive (Table 4.7). Notably, correlations were generally weaker between BMI and PCB exposure levels compared to other variables (e.g., PCB biomarkers vs. age). Among Old Crow participants, four PCB congeners were correlated with BMI, with similar correlation coefficients ranging from 0.297 ($\Sigma\text{PCB}_{138,153,180}$) to 0.307 (PCB187). As well, in the Sahtú, nine PCB measure concentrations were correlated with BMI again with very similar correlation coefficients ranging from 0.202 (PCB170) to 0.266 (PCB118). In contrast, in the Dehcho region, BMI and PCB concentrations were uncorrelated for all congeners.

Detection rates of PCB concentrations for those who provided height and weight (i.e., for the calculation of BMI) varied among the measures, with PCB153 having the highest detection rate in both Old Crow and the Sahtú region. Those measures that had generally higher detection rates were correlated with BMI in Old Crow (e.g., PCB153, 92% detection rate) the Sahtú region (e.g., PCB153, 96% detection rate) whereas those PCB measures with generally lower detection rates in Old Crow (e.g., PCB170, 64% detection rate) and the Sahtú region (e.g., PCB163, 66% detection rate) were uncorrelated with BMI. Notably, again, regional specific patterns appear between the independent and dependent variables. For example, in the Dehcho even those PCBs that were commonly detected still showed no relationship between BMI level and PCB biomarker concentration.

Table 4.7 . Correlations (Spearman's rho) between body mass index and PCB exposure levels in the Dehcho Region, Old Crow and Sahtú region for all ages and men and women

PCB Measure	Dehcho (n=119)				Old Crow (n=52)				Sahtú (n=111-1131) ¹			
	% <LOD	Correlation Coefficient	95% CI	p-value	% <LOD	Correlation Coefficient	95% CI	p-value	% <LOD	Correlation Coefficient	95% CI	p-value
Aroclor1260	15.13	0.13	(-0.056-0.315)	0.159	9.62	0.265	(-0.036-0.517)	0.057	6.19	.236*	(0.050-0.419)	0.012
PCB118	52.94	0.15	(-0.026-0.330)	0.104	50	0.236	(-0.016-0.476)	0.091	42.48	.266**	(0.060-0.436)	0.004
PCB138	21.85	0.149	(-0.025-0.311)	0.105	21.15	.297*	(0.040-0.530)	0.033	16.81	.239*	(0.053-0.422)	0.011
PCB146	52.94	-0.017	(-0.199-0.159)	0.852	71.15	0.048	(-0.229-0.348)	0.735	48.21	0.182	(-0.010-0.364)	0.054
PCB153	12.61	0.117	(-0.063-0.276)	0.205	7.69	.292*	(-0.005-0.548)	0.036	4.42	.231*	(0.033-0.414)	0.014
PCB163	47.06	-0.002	(-0.166-0.176)	0.983	61.54	0.092	(-0.187-0.358)	0.515	44.14	.209*	(0.015-0.400)	0.028
PCB170	36.13	-0.033	(-0.209-0.151)	0.726	46.15	0.248	(-0.018-0.484)	0.077	38.94	.202*	(0.013-0.368)	0.032
PCB180	18.49	0.054	(-0.128-0.229)	0.557	19.23	0.245	(-0.025-0.504)	0.08	17.7	.228*	(0.040-0.390)	0.015
PCB187	31.93	0.02	(-0.153-0.192)	0.833	42.31	.307*	(0.052-0.546)	0.027	29.46	.207*	(0.024-0.390)	0.029
PCB194	42.8	-0.09	(-0.265-0.086)	0.333	55.77	0.102	(-0.192-0.387)	0.474	47.79	0.151	(-0.038-0.329)	0.111
PCB201	44.54	-0.07	(-0.248-0.103)	0.447	55.77	0.088	(-0.211-0.361)	0.533	46.9	0.148	(-0.041-0.327)	0.119
ΣPCB_{138,153,180}	12.61	0.096	(-0.084-0.273)	0.299	7.69	.279*	(-0.009-0.527)	0.045	4.42	.242**	(0.046-0.425)	0.01

** = Correlation is significant at the p<0.01 level * =Correlation is significant at the 0.05 p-level using Spearman's rho. 1.PCB146 n= 112, PCB163 n=111, PCB187 n=112

4.1.9 PCBs vs. Lifestyle Factors

Concentrations of PCB biomarkers separated by participant smoking status are presented in Table 12 and PCB biomarker levels separated by drinking status are reported in Table 13. In the Dehcho and Sahtú regions, those who reported smoking in the last 24 hours had lower GM PCB exposure levels (for select congeners) compared to those who had not reported smoking. For example, in the Dehcho region, PCB concentrations were between 1.6-fold (PCB138) to 2.1-fold (PCB180) higher ($p<0.05$) in those who reported not smoking. In the Sahtú region, PCB concentrations ranged from $\approx$ 1.6-fold (PCB163) to $\approx$ 1.9-fold (PCB170) higher ($p<0.05$) in those who reported smoking. However, in Old Crow, those who reported smoking had generally higher PCB concentrations. PCB concentrations ranged from $\approx$ 1.7-fold (PCB138) to $\approx$ 2.1-fold (PCB153) higher ($p<0.05$) in those who reported smoking compared to those who did not. In contrast, drinking status was not significantly related to PCB biomarker levels.

Table 4.8 PCB biomarker concentrations by smoking status in the previous 24 hours in the Dehcho and Old Crow and Sahtú

Smoking Status	PCB Measure	Dehcho			Old Crow			Sahtú		
		n=81 no; n=53, yes			n=22 no; n=23 yes			n=67-69 ¹ yes; n=68		
		% <LOD	GM (95% CI)	p- value	% <LOD	GM (95% CI)	p-value	% <LOD	GM (95% CI)	p-value
No	Arochlor 1260	12.35	90.52 (65.51-119.96)	0.011*	18.18	32.66 (23.94 -45.16)	0.024*	8.82	153.09 (105.07 -213.99)	0.178
	PCB118	44.44	2.15 (1.69-2.69)	NA	63.64	<LOD	NA	32.35	3.67 (2.81 -4.81)	NA
	PCB138	22.22	5.15 (3.84 -6.74)	0.024*	27.27	2.21 (1.65 -2.3)	0.048*	19.12	8.03 (5.67 -11.10)	0.252
	PCB146	44.44	2.17 (1.71-2.73)	NA	90.91	<LOD	NA	39.71	3.28 (2.42 -4.32)	NA
	PCB153	9.88	11.99 (8.61 -15.96)	0.011*	18.18	3.88 (2.74 -5.47)	0.015*	5.88	21.26 (14.59 -30.06)	0.15
	PCB163	39.51	2.45 (1.9-3.08)	NA	81.82	<LOD	NA	35.29	3.8 (2.76-5.07)	*0.023
	PCB170	34.57	3.78 (2.81 -5.02)	0.008*	63.64	<LOD	NA	29.41	4.92 (3.48 -6.67)	*0.004
	PCB180	16.05	10.79 (7.55 -14.95)	0.005*	31.82	2.78 (1.83 -4.27)	0.048*	20.59	13.58 (8.67 -20.19)	*0.047
	PCB187	32.10	4.01 (2.91-5.34)	0.011*	54.55	<LOD	NA	26.47	6.62 (4.57 -9.22)	*0.029
	PCB194	38.27	3.17 (2.37 -4.16)	NA	77.27	<LOD	NA	36.76	4.06 (2.84 -5.48)	NA
	PCB201	37.04	2.91 (2.22 -3.78)	NA	77.27	<LOD	NA	36.76	4.04 (2.87 -5.44)	NA
	ΣPCB_{138,153,180}	9.88	29.15 (20.8 -39.18)	0.007*	22.73	9.1 (6.44 -12.85)	0.025*	14.71	44.16 (30.17-62.39)	0.109
Yes	Arochlor 1260	24.53	50.74 (36.1 -71.87)	--	13.04	63.25 (39.78 -98.61)	--	4.35	111.69 (85.89 -157.42)	--
	PCB118	69.81	<LOD	--	47.83	1.79 (1.23 -2.77)	--	50.72	<LOD	--
	PCB138	30.19	3.22 (2.45 -4.29)	--	26.09	3.9 (2.42 -6.2)	--	11.59	6.24 (4.87 -8.62)	--
	PCB146	69.81	<LOD	--	65.22	<LOD	--	52.94	<LOD	--
	PCB153	20.75	6.54	--	8.70	8.07	--	2.90	15.01	--

		(4.47 -9.44)			(5.16 -12.5)			(11.44 -21.42)	
PCB163	64.15	<LOD	--	52.17	<LOD	--	49.25	2.35 (1.82 -3.1)	--
PCB170	47.17	2.19 (1.69 -2.89)	--	39.13	2.18 (1.53 -3.1)	--	46.38	2.61 (2.03 -3.63)	--
PCB180	30.19	5.21 (3.57 -7.82)	--	21.74	5.33 (3.25 -8.09)	--	15.94	7.82 (5.85 -11.64)	--
PCB187	41.51	2.34 (1.8 -3.17)	--	39.13	2.37 (1.63 -3.46)	--	30.88	3.92 (2.96 -5.53)	--
PCB194	56.60	<LOD	--	47.83	1.57 (1.17 -2.09)	--	55.07	<LOD	--
PCB201	62.26	<LOD	--	47.83	1.69 (1.24 -2.29)	--	53.62	<LOD	--
ΣPCB_{138,153,180}	20.75	15.45 (10.83 -22.027)	--	17.39	17.74 (11.27 -27.29)	--	11.59	29.89 (22.93 -42.23)	--

* = p-level < 0.05 and is considered significant using independent samples T-test with log10 transformed PCB data. NA= statistic not available because PCB measure is GM <LOD. -- = p-value is shown in the no drinking status section of the table

1. PCB146 n=68, PCB163 n=67, PCB187 n=68

Table 4.9 PCB biomarker concentrations by alcohol consumption status in the previous 24 hours in the Dehcho, Old Crow and Sahtú

Drinking Status	PCB Measure	Dehcho			Old Crow			Sahtú		
		n=111 no; n=18 yes			n=43 no; n=3 yes			n=115-117 no; n=20 yes		
		% <LOD	GM (95% CI)	p-value	% <LOD	GM (95% CI)	p-value	% <LOD	GM (95% CI)	p-value
No	Arochlor 1260	19.82	69.32 (52.41-89.07)	0.77	0.00	44.16 (31.95-60.47)	0.96	7.69	134.67 (104.180-173.25)	0.89
	PCB118	56.76	<LOD	NA	33.33	1.4 (1.1-1.8)	0.89	44.44	2.77 (2.24-3.41)	0.91
	PCB138	28.83	4.14 (3.22-5.17)	0.59	33.33	2.9 (2.14-3.88)	0.75	17.09	7.29 (5.77-9.23)	0.83
	PCB146	54.05	<LOD	NA	66.67	<LOD	0.64	49.14	2.68 (2.17-3.34)	0.63
	PCB153	16.22	9.09 (6.77-11.79)	0.84	0.00	5.41 (3.83-7.5)	0.98	5.13	18.41 (14.17-23.83)	0.88
	PCB163	49.55	2.07 (1.71-2.5)	NA	33.33	1.22 (0.97-1.55)	0.8	44.35	3.05 (2.41-3.8)	0.7
	PCB170	42.34	3.08 (2.43-3.84)	0.68	33.33	1.6 (1.24-2.05)	0.67	41.03	3.71 (2.91-4.74)	0.79
	PCB180	24.32	7.95 (5.81-10.58)	0.97	33.33	3.73 (2.61-5.15)	0.91	19.66	10.56 (7.79-14.27)	0.94
	PCB187	39.64	3.27 (2.54-4.12)	0.67	33.33	1.73 (1.35-2.24)	0.99	30.17	5.29 (4.07-6.82)	0.71
	PCB194	45.95	2.63 (2.08-3.28)	0.35	33.33	1.23 (1.01-1.53)	0.44	47.01	3.09 (2.45-3.87)	0.34
	PCB201	46.85	2.44 (1.95-3.02)	NA	33.33	1.27 (1.0-1.61)	0.5	47.01	3.1 (2.45-3.9)	0.4
	ΣPCB _{138,153,180}	16.22	22.1 (16.72-28.73)	0.89	33.33	12.37 (9.01-16.87)	0.96	13.68	37.37 (28.71-48.67)	0.93
Yes	Arochlor 1260	11.11	76.61 (56.11-88.53)	--	18.60	42.94 (16.41-111.25)	--	0	125.43 (78.59-193.04)	--
	PCB118	50.00	1.69 (1.51-2.08)	--	58.14	<LOD	--	25	2.81 (1.87-4.19)	--

PCB138	11.11	4.88 (3.42-5.23)	--	27.91	2.41 (0.74,7.0)	--	5	6.68 (4.21-10.18)	--
PCB146	66.67	<LOD	--	79.07	<LOD	--	30	2.31 (1.53-3.35)	--
PCB153	11.11	9.77 (7.21-11.73)	--	16.28	5.33 (1.94-13.75)	--	0	17.09 (10.54-26.64)	--
PCB163	61.11	<LOD	--	69.77	<LOD	--	30	2.71 (1.74-4.18)	--
PCB170	33.33	2.71 (2.48-3.71)	--	53.49	<LOD	--	20	3.33 (2.16-5.12)	--
PCB180	11.11	8.05 (6.15-10.26)	--	27.91	4.02 (0.74-13.75)	--	10	10.53 (5.76-17.55)	--
PCB187	22.22	2.87 (2.63-3.99)	--	48.84	1.74 (0.74,3.75)	--	20	4.56 (2.74,7.28)	--
PCB194	50.00	1.99 (2.06-3.05)	--	65.12	<LOD	--	40	2.25 (1.4-3.6)	--
PCB201	55.56	<LOD	--	65.12	<LOD	--	35	2.34 (1.47-3.61)	--
ΣPCB_{138,153,180}	11.11	23.15 (17.66-28.29)	--	20.93	12.02 (3.43-34.5)	--	10	35.37 (21.88-55.78)	--

* p-level < 0.05 and is considered significant using independent samples T-test with log10 transformed PCB data. Number of participant samples varied in the Saktú (PCB146 n=116, PCB163 n= 115, PCB187 n=116)

4.1.10 Comparing PCB Exposure Levels to the CHMS and the FNBI

Comparing by Age

Reference studies were used to describe whether the levels of PCBs in the NWT and the Yukon were elevated or not compared to the Canadian general population and other Indigenous populations in southern areas of Canada (57,108). These levels for each of these populations are summarized in Tables 14-16) for select age groups. These age groups reflect those that were used in the in the CHMS data tables. Notably though, the FNBI age stratification included those that were aged 60-99 (whereas in the CHMS the maximum age was 79).

Among participating community members aged 20-39, PCB levels were generally lower than or similar to the CHMS and FNBI GM levels. In the Dehcho, three PCB biomarkers were up to 3-fold (Arochlor 1260, PCB153 and PCB180) lower than the CHMS. In contrast, this pattern was not observed with the FNBI as PCB biomarker levels among those aged 20-39 were similar to those observed in the FNBI. In Old Crow, PCB biomarkers were up to 3.5-fold (Arochlor 1260, PCB138, PCB153, PCB180) lower than the CHMS. In contrast, FNBI levels were similar to this study region levels except for PCB153, which was 1.9-fold lower than FNBI levels. In the Sahtú, only PCB 180 was 1.9-fold lower than the CHMS and all PCB biomarkers were similar to the FNBI.

Among participants aged 40-59, PCBs were generally lower to or similar to CHMS and FNBI levels. Specifically, in the Dehcho region nine PCB biomarkers were up to 2.5-fold (Arochlor 1260, PCB138, PCB153, PCB163, PCB170, PCB180, PCB187, PCB194, PCB201) lower than the CHMS. Similar patterns were observed with FNBI levels where the same nine PCBs were up to 2.3-fold lower than the FNBI. In Old Crow, 11 PCB biomarkers were up to 2.8-fold (Arochlor 1260, PCB118, PCB138, PCB153, PCB156, PCB163, PCB170, PCB180, PCB187, PCB194, PCB201) lower than the CHMS. Similar patterns were observed with six PCBs in Old Crow compared to the FNBI where levels (PCB156, PCB170, PCB180, PCB187, PCB194, PCB201) were up to 1.9-fold lower in Old Crow. In the Sahtú region, two PCB biomarkers were up to 1.9-fold (PCB156 and PCB118) lower than the CHMS. In contrast, all PCB biomarkers in the Sahtú were similar to the FNBI.

Among those over the age of 60 years, PCB levels were either higher than or similar to CHMS and FNBI levels with the exception of Old Crow, where levels were lower than or similar to CHMS and FNBI levels. For example, in the Dehcho two PCB biomarkers were up to 1.7-fold (PCB187 and PCB201) higher than the CHMS. In contrast, all PCB biomarkers were similar to the FNBI. Similar patterns were observed in the Sahtú, where 12 PCB biomarkers were up to 2.9-fold (Arochlor 1260,

PCB146, PCB153, PCB163, PCB170, PCB178, PCB180, PCB183, PCB187, PCB194, PCB201, PCB203) higher than the CHMS. Accordingly, only Arochlor 1260 was 1.5-fold higher than the FNBI and all other PCBs were similar to the FNBI. Notably, in Old Crow, all PCB biomarkers were up to 4.3-fold (Arochlor 1260, PCB118, PCB138, PCB146, PCB153, PCB, PCB156, PCB163, PCB170, PCB180, PCB187, PCB194, PCB201, PCB203, PCB206) lower than the CHMS. Compared to the FNBI, all but one PCB (PCB180) were up to 5.3-fold lower than the FNBI.

Table 4.10 Dehcho region PCB GM levels compared to CHMS and FNBI PCB GM Levels (µg/kg lipids) by age group

NWT and Yukon Biomonitoring Study (µg/kg lipid)					Reference Studies (CHMS: ng/g lipid, FNBI: µg/kg lipid)		
Dehcho n= 32 (20-39 years), n= 54 (40-59 years), n=26 (60-79 years)					CHMS: n= 525 (20-39 years), n=596 (40-59 years), n=545 (60-79 years) FNBI: n=184-185 (20-39 years), n=206 (20-59 years), n=80 (60-99 years)		
Age Group	PCB Measure ¹	% <LOD	Dehcho GM (95% CI)	Comparison to CHMS	Comparison to FNBI	CHMS GM (95% CI)	FNBI GM (95% CI)
20-39	Arochlor 1260	40.63	24.4 (18.2 -34.0)	↓	↔	73.77 (60.86–89.42)	42.1 (25.76-68.80)
	PCB 74	100	<LOD	--	--	NA	NA
	PCB 99	100	<LOD	--	--	NA	NA
	PCB 105	100	<LOD	--	--	NA	NA
	PCB 118	84.38	<LOD	--	--	2.63 (2.18–3.17)	NA
	PCB138	59.38	<LOD	--	--	5.26 (4.43–6.24)	2.85 (1.85-4.38)
	PCB 146	90.63	<LOD	--	--	NA	NA
	PCB 153	28.13	3.09 (2.22 -4.41)	↓	↔	8.27 (6.49–10.56)	5.28 (3.20-8.72)
	PCB 156	93.75	<LOD	--	--	NA	NA
	PCB 163	90.63	<LOD	--	--	NA	NA
	PCB 167	100	<LOD	--	--	NA	NA
	PCB 170	84.38	<LOD	--	--	NA	NA
	PCB 178	100	<LOD	--	--	NA	NA
	PCB 180	50	2.10 (1.56-3.03)	↓	↔	6.05 (5.07–7.22)	3.80 (2.21-6.53)
	PCB 183	90.63	<LOD	--	--	NA	NA
	PCB 187	81.25	<LOD	--	--	NA	NA
	PCB 194	90.63	<LOD	--	--	NA	NA
	PCB 201	90.63	<LOD	--	--	NA	NA
	PCB 203	90.63	<LOD	--	--	NA	NA
	PCB 206	96.88	<LOD	--	--	NA	NA
40-59	Arochlor 1260	0	94.1 (76.6-116)	↓	↓	189.26 (167.49–213.86)	184.57 (132.46-257.19)
	PCB 74	98.15	<LOD	--	--	NA	NA
	PCB 99	100	<LOD	--	--	NA	NA
	PCB 105	98.15	<LOD	--	--	NA	NA
	PCB 118	51.85	<LOD	--	--	4.80 (4.08–5.65)	4.23 (3.00-5.95)

	PCB138	5.56	5.07 (4.12- 6.23)	↓	↓	12.54 (11.05–14.24)	11.45 (8.30-15.79)
	PCB 146	50	1.59 (1.31 -1.96)	↔	↔	2.29 (1.92–2.73)	2.94 (1.92-4.48)
	PCB 153	0	12.67 (10.23 -15.78)	↓	↓	24.13 (21.38–27.23)	23.70 (16.79-33.46)
	PCB 156	59.26	<LOD	--	--	3.50 (3.09–3.96)	2.82 (2.01-3.96)
	PCB 163	37.04	1.87 (1.54 -2.28)	↓	↓	4.10 (3.54–4.75)	3.97 (2.77-5.70)
	PCB 167	92.59	<LOD	--	--	NA	NA
	PCB 170	18.52	3.38 (2.69 -4.16)	↓	↓	6.40 (5.63–7.27)	7.36 (5.31-10.21)
	PCB 178	92.59	<LOD	--	--	NA	NA
	PCB 180	0	11.5 (9.28 -14.2)	↓	↓	21.20 (18.68–24.06)	21.71 (15.03-31.38)
	PCB 183	72.22	<LOD	--	--	NA	NA
	PCB 187	11.11	3.74 (2.97 -4.68)	↓	↓	4.93 (4.20–5.78)	7.17 (4.88-10.52)
	PCB 194	27.78	2.47 (1.96 -3.07)	↓	↓	3.93 (3.34–4.62)	4.71 (3.24-6.84)
	PCB 201	33.33	2.14 (1.73 -2.62)	↓	↓	3.28 (2.83–3.80)	5.01 (3.37-7.44)
	PCB 203	51.85	<LOD	--	--	2.76 (2.40–3.17)	3.44 (2.33-5.08)
	PCB 206	79.63	<LOD	--	--	NA	NA
60-79	Arochlor 1260	0	355 (260 -488)	↔	↔	343.72 (299.79–394.09)	420.67 (299.22-591.41)
	PCB 74	84.62	<LOD	--	--	8.55 (7.40–9.88)	NA
	PCB 99	84.62	<LOD	--	--	NA	NA
	PCB 105	76.92	<LOD	--	--	NA	NA
	PCB 118	3.85	6.24 (4.38 -9.29)	↔	↔	9.67 (8.01–11.68)	10.96 (6.87-17.49)
	PCB138	0	18.4 (13.4 -25.6)	↔	↔	21.55 (18.33–25.34)	25.38 (18.09-35.60)
	PCB 146	0	6.49 (4.77 -8.96)	↔	↔	4.44 (3.71–5.32)	6.92 (4.77-10.04)
	PCB 153	0	49.2 (36.3 -67.6)	↔	↔	44.00 (38.55–50.24)	55.04 (38.95-77.76)
	PCB 156	0	6.08 (4.70 -8.18)	↔	↔	6.47 (5.84–7.17)	7.08 (5.14-9.74)
	PCB 163	0	7.87 (6.16 -10.3)	↔	↔	7.96 (6.92–9.15)	9.98 (7.21-13.80)
	PCB 167	50	1.75 (1.28 -2.54)	--	--	NA	NA
	PCB 170	0	15.2 (11.7 -20.0)	↔	↔	12.03 (10.94–13.24)	18.97 (13.69-26.30)

PCB 178	23.08	2.40 (1.76 -3.30)	↔	↔	2.32 (2.03–2.67)	3.81 (2.61-5.55)
PCB 180	0	53.1 (39.8 -71.8)	↔	↔	41.27 (37.52– 45.39)	56.21 (39.79- 79.41)
PCB 183	19.23	3.20 (2.27 -4.51)	↔	↔	3.10 (2.70–3.57)	4.70 (3.29-6.70)
PCB 187	0	15.9 (11.6 -21.69)	↑	↔	9.57 (8.18–11.21)	18.93 (13.36- 26.82)
PCB 194	0	13.2 (9.44 -18.5)	↔	↔	8.48 (7.60–9.46)	14.46 (10.12- 20.65)
PCB 201	0	11.6 (8.47 -16.1)	↑	↔	7.27 (6.47–8.18)	15.16 (10.59- 21.69)
PCB 203	0	7.88 (5.87 -10.62)	↔	↔	6.05 (5.45–6.71)	9.87 (6.86- 14.19)
PCB 206	3.85	4.28 (3.25 -5.71)	↔	↔	2.90 (2.52–3.33)	5.94 (4.25-8.32)

n = sample size. NA= not applicable because GM was not provided by reference study. <LOD- Less than the limit of detection. -- = Levels cannot be compared since GMs were not provided by the reference studies or were not calculated from Dehcho. Arrows indicate that levels are above (↑), below (↓), or similar (↔) to levels reported in the reference studies based on 95%CI overlapping (e.g., if the GM was higher in this study and if CIs did not overlap between the CHMS or the FNBI then the GMs were considered higher compared to the reference studies.) 1. PCB Measures include those that were collected by the reference studies in the NWT and Yukon Biomonitoring (e.g., PCB groupings were not collected by the reference studies).

Table 4.11 . Old Crow community PCB GM levels compared to CHMS and FNBI PCB GM Levels (µg/kg lipids) by age group

NWT and Yukon Biomonitoring Study (µg/kg lipid)						Reference Studies (CHMS: ng/g lipid, FNBI: µg/kg lipid)	
Old Crow n= 26 (20-39 years), n= 18 (40-59 years), n=10 (60-79 years)						CHMS: n= 525 (20-39 years), n=596 (40-59 years), n=545 (60-79 years) FNBI: n=184-185 (20-39 years), n=206 (20-59 years), n=80 (60-99 years)	
Age Group	PCB Measure ¹	% <LOD	Old Crow GM (95% CI)	Comparison to CHMS	Comparison to FNBI	CHMS GM (95% CI)	FNBI GM (95% CI)
20-39	Arochlor 1260	23.1	23.38 (17.77-29.96)	↓	↔	73.77 (60.86–89.42)	42.1 (25.76-68.80)
	PCB 74	100	<LOD	--	--	NA	NA
	PCB 99	100	<LOD	--	--	NA	NA
	PCB 105	100	<LOD	--	--	NA	NA
	PCB 118	88.5	<LOD	--	--	2.63 (2.18–3.17)	NA
	PCB138	46.2	1.49 (1.17-1.89)	↓	↔	5.26 (4.43–6.24)	2.85 (1.85-4.38)
	PCB 146	100	<LOD	--	--	NA	NA
	PCB 153	19.2	2.83 (2.11-3.64)	↓	↓	8.27 (6.49–10.56)	5.28 (3.20-8.72)
	PCB 156	100	<LOD	--	--	NA	NA
	PCB 163	96.2	<LOD	--	--	NA	NA
	PCB 167	100	<LOD	--	--	NA	NA
	PCB 170	84.6	<LOD	--	--	NA	NA
	PCB 178	100	<LOD	--	--	NA	NA
	PCB 180	42.3	1.74 (1.31- 2.26)	↓	↔	6.05 (5.07–7.22)	3.80 (2.21-6.53)
	PCB 183	96.2	<LOD	--	--	NA	NA
	PCB 187	84.6	<LOD	--	--	NA	NA
	PCB 194	96.2	<LOD	--	--	NA	NA
	PCB 201	96.2	<LOD	--	--	NA	NA
	PCB 203	100	<LOD	--	--	NA	NA
	PCB 206	100	<LOD	--	--	NA	NA

40-59	Arochlor 1260	0	94.58 (66.74- 137.38)	↓	↔	189.26 (167.49– 213.86)	184.57 (132.46- 257.19)
	PCB 74	100	<LOD	--	--	NA	NA
	PCB 99	88.9	<LOD	--	--	NA	NA
	PCB 105	83.3	<LOD	--	--	NA	NA
	PCB 118	22.2	2.26 (1.43- 3.62)	↓	↔	4.80 (4.08–5.65)	4.23 (3.00-5.95)
	PCB138	0	5.87 (4.098- 8.657)	↓	↔	12.54 (11.05–14.24)	11.45 (8.30-15.79)
	PCB 146	55.6	<LOD	--	--	2.29 (1.92–2.73)	2.94 (1.92-4.48)
	PCB 153	0	12.12 (8.54- 17.51)	↓	↔	24.13 (21.38–27.23)	23.70 (16.79-33.46)
	PCB 156	50	1.24 (0.87- 1.802)	↓	↓	3.50 (3.09–3.96)	2.82 (2.01-3.96)
	PCB 163	44.4	1.73 (1.09- 2.79)	↓	↔	4.10 (3.54–4.75)	3.97 (2.77-5.70)
	PCB 167	94.4	<LOD	--	--	NA	NA
	PCB 170	16.7	2.71 (1.81- 3.92)	↓	↓	6.40 (5.63–7.27)	7.36 (5.31-10.21)
	PCB 178	77.8	<LOD	--	--	NA	NA
	PCB 180	0	8.91 (6.35- 12.35)	↓	↓	21.20 (18.68–24.06)	21.71 (15.03-31.38)
	PCB 183	72.2	<LOD	--	--	NA	NA
	PCB 187	5.56	3.13 (2.14 - 4.61)	↓	↓	4.93 (4.20–5.78)	7.17 (4.88-10.52)
	PCB 194	33.3	1.69 (1.18- 2.38)	↓	↓	3.93 (3.34–4.62)	4.71 (3.24-6.84)
	PCB 201	33.3	1.78 (1.22- 2.59)	↓	↓	3.28 (2.83–3.80)	5.01 (3.37-7.44)
	PCB 203	55.6	<LOD	--	--	2.76 (2.40–3.17)	3.44 (2.33-5.08)
	PCB 206	77.8	<LOD	--	--	NA	NA
60-79	Arochlor 1260	0	125.81 (85.13- 200.41)	↓	↓	343.72 (299.79– 394.09)	420.67 (299.22- 591.41)
	PCB 74	100	<LOD	--	--	8.55 (7.40–9.88)	NA
	PCB 99	90	<LOD	--	--	NA	NA
	PCB 105	90	<LOD	--	--	NA	NA
	PCB 118	0	3.28 (2.17- 5.45)	↓	↓	9.67 (8.01–11.68)	10.96 (6.87-17.49)
	PCB138	0	7.62 (5.19- 12.16)	↓	↓	21.55 (18.33–25.34)	25.38 (18.09-35.60)
	PCB 146	30	1.75 (1.03- 3.01)	↓	↓	4.44 (3.71–5.32)	6.92 (4.77-10.04)
	PCB 153	0	16.42 (11.00- 26.56)	↓	↓	44.00 (38.55–50.24)	55.04 (38.95-77.76)

PCB 156	40	1.49 (0.91- 2.42)	↓	↓	6.47 (5.84–7.17)	7.08 (5.14-9.74)
PCB 163	0	2.90 (1.97 - 4.58)	↓	↓	7.96 (6.92–9.15)	9.98 (7.21-13.80)
PCB 167	100	<LOD	--	--	NA	NA
PCB 170	0	4.27 (2.95- 5.95)	↓	↓	12.03 (10.94–13.24)	18.97 (13.69- 26.30)
PCB 178	70	<LOD	--	--	2.32 (2.03–2.67)	3.81 (2.61-5.55)
PCB 180	0	13.72 (9.50- 19.41)	↓	↔	41.27 (37.52–45.39)	56.21 (39.79-79.41)
PCB 183	60	<LOD	--	--	3.10 (2.70–3.57)	4.70 (3.29-6.70)
PCB 187	0	4.87 (3.14- 7.29)	↓	↓	9.57 (8.18–11.21)	18.93 (13.36-26.82)
PCB 194	0	3.16 (2.33- 4.23)	↓	↓	8.48 (7.60–9.46)	14.46 (10.12-20.65)
PCB 201	0	3.63 (2.60- 4.99)	↓	↓	7.27 (6.47–8.18)	15.16 (10.59-21.69)
PCB 203	20	1.85 (1.25- 2.64)	↓	↓	6.05 (5.45–6.71)	9.87 (6.86- 14.19)
PCB 206	40	1.18 (0.86- 1.61)	↓	↓	2.90 (2.52–3.33)	5.94 (4.25-8.32)

n = sample size. NA= not applicable because GM was not provided by reference study. <LOD- Less than the limit of detection. -- = Levels cannot be compared since GMs were not provided by the reference studies or were not calculated from Old Crow. Arrows indicate that levels are above (↑), below (↓), or similar (↔) to levels reported in the reference studies based on 95%CI overlapping (e.g., if the GM was higher in this study and if the CIs did not overlap between the CHMS or the FNBI then the GMs were considered higher compared to the reference studies.) 1. PCB Measures include those that were collected by the reference studies and in the NWT and Yukon Biomonitoring (e.g., PCB groupings such as $\sum\text{PCB}_{138,153,180}$ were not collected by the reference studies).

Table 4.12 Sahtú region PCB GM levels compared to CHMS and FNBI PCB GM levels (µg/kg lipids) by age group

NWT and Yukon Biomonitoring Study (µg/kg lipid)						Reference Studies (CHMS: ng/g lipid, FNBI: µg/kg lipid)	
Sahtú n= 41-43 ¹ (20-39 years), n= 43 (40-59 years), n=26 (60-79 years)						CHMS: n= 525 (20-39 years), n=596 (40-59 years), n=545 (60-79 years) FNBI: n=184-185 (20-39 years), n=206 (20-59 years), n=80 (60-99 years)	
Age Group	PCB Measure ²	% <LOD	Sahtú GM (95% CI)	Comparison to CHMS	Comparison to FNBI	CHMS GM (95% CI)	FNBI GM (95% CI)
20-39	Arochlor 1260	2.33	60.2 (47.0 -77.4)	↔	↔	73.77 (60.86–89.42)	42.1 (25.76-68.80)
	PCB 74	100	<LOD	--	--	NA	NA
	PCB 99	97.7	<LOD	--	--	NA	NA
	PCB 105	97.7	<LOD	--	--	NA	NA
	PCB 118	72.1	<LOD	--	--	2.63 (2.18–3.17)	NA
	PCB138	14	3.46 (2.73 -4.46)	↔	↔	5.26 (4.43–6.24)	2.85 (1.85-4.38)
	PCB 146	83.3	<LOD	--	--	NA	NA
	PCB 153	0	7.94 (6.19 -10.22)	↔	↔	8.27 (6.49–10.56)	5.28 (3.20-8.72)
	PCB 156	93	<LOD	--	--	NA	NA
	PCB 163	80.5	<LOD	--	--	NA	NA
	PCB 167	100	<LOD	--	--	NA	NA
	PCB 170	76.7	<LOD	--	--	NA	NA
	PCB 178	92.9	<LOD	--	--	NA	NA
	PCB 180	25.6	3.13 (2.33 -4.22)	↓	↔	6.05 (5.07–7.22)	3.80 (2.21-6.53)
	PCB 183	90.5	<LOD	--	--	NA	NA
	PCB 187	52.4	<LOD	--	--	NA	NA
	PCB 194	88.4	<LOD	--	--	NA	NA
	PCB 201	81.4	<LOD	--	--	NA	NA
	PCB 203	93	<LOD	--	--	NA	NA
	PCB 206	97.7	<LOD	--	--	NA	NA

40-59	Arochlor 1260	0	164.8 (123.53 - 216.11)	↔	↔	189.26 (167.49–213.86)	184.57 (132.46-257.19)
	PCB 74	100	<LOD	--	--	NA	NA
	PCB 99	90.7	<LOD	--	--	NA	NA
	PCB 105	79.1	<LOD	--	--	NA	NA
	PCB 118	25.6	2.89 (2.19 -3.82)	↓	↔	4.80 (4.08–5.65)	4.23 (3.00-5.95)
	PCB138	2.33	8.68 (6.52 -11.37)	↔	↔	12.54 (11.05–14.24)	11.45 (8.30-15.79)
	PCB 146	30.2	2.62 (1.99-3.46)	↔	↔	2.29 (1.92–2.73)	2.94 (1.92-4.48)
	PCB 153	0	22.7 (16.9-29.82)	↔	↔	24.13 (21.38–27.23)	23.70 (16.79-33.46)
	PCB 156	39.5	1.89 (1.49 -2.40)	↓	↔	3.50 (3.09–3.96)	2.82 (2.01-3.96)
	PCB 163	20.9	3.27 (2.43 -4.33)	↔	↔	4.10 (3.54–4.75)	3.97 (2.77-5.70)
	PCB 167	79.1	<LOD	--	--	NA	NA
	PCB 170	9.3	4.52 (3.43 -5.81)	↔	↔	6.40 (5.63–7.27)	7.36 (5.31-10.21)
	PCB 178	48.8	1.55 (1.24 -1.94)	--	--	NA	NA
	PCB 180	0	15.7 (11.8 -20.3)	↔	↔	21.20 (18.68–24.06)	21.71 (15.03-31.38)
	PCB 183	53.5	<LOD	--	--	NA	NA
	PCB 187	6.98	6.41 (4.75 -8.42)	↔	↔	4.93 (4.20–5.78)	7.17 (4.88-10.52)
	PCB 194	20.9	3.19 (2.46 -4.10)	↔	↔	3.93 (3.34–4.62)	4.71 (3.24-6.84)
	PCB 201	25.6	3.09 (2.34- 4.05)	↔	↔	3.28 (2.83–3.80)	5.01 (3.37-7.44)
	PCB 203	32.6	2.14 (1.70 -2.72)	↔	↔	2.76 (2.40–3.17)	3.44 (2.33-5.08)
	PCB 206	58.1	<LOD	--	--	NA	NA
60-79	Arochlor 1260	0	647.51 (490.49 - 849.34)	↑	↑	343.72 (299.79–394.09)	420.67 (299.22-591.41)
	PCB 74	80	<LOD	--	--	8.55 (7.40–9.88)	NA
	PCB 99	60	<LOD	--	--	NA	NA
	PCB 105	20	2.10 (1.57 -2.70)	--	--	NA	NA
	PCB 118	4	11.39 (8.19 - 15.83)	↔	↔	9.67 (8.01–11.68)	10.96 (6.87-17.49)
	PCB138	0	31.8 (23.5 -41.9)	↔	↔	21.55 (18.33–25.34)	25.38 (18.09-35.60)
	PCB 146	0	11.6 (8.72 -15.26)	↑	↔	4.44 (3.71–5.32)	6.92 (4.77-10.04)

PCB 153	0	93.16 (69.84 - 122.8)	↑	↔	44.00 (38.55–50.24)	55.04 (38.95-77.76)
PCB 156	0	7.74 (6.07 -9.73)	↔	↔	6.47 (5.84–7.17)	7.08 (5.14-9.74)
PCB 163	0	14.1 (10.5 -18.6)	↑	↔	7.96 (6.92–9.15)	9.98 (7.21-13.80)
PCB 167	24	2.33 (1.66 -3.21)	--	--	NA	NA
PCB 170	0	18.7 (14.4 -23.7)	↑	↔	12.03 (10.94–13.24)	18.97 (13.69- 26.30)
PCB 178	0	5.90 (4.46 -7.71)	↑	↔	2.32 (2.03–2.67)	3.81 (2.61-5.55)
PCB 180	0	71.3 (53.9 -91.4)	↑	↔	41.27 (37.52–45.39)	56.21 (39.79-79.41)
PCB 183	4	5.68 (4.02-7.65)	↑	↔	3.10 (2.70–3.57)	4.70 (3.29-6.70)
PCB 187	0	27.9 (21.3 -36.5)	↑	↔	9.57 (8.18–11.21)	18.93 (13.36-26.82)
PCB 194	0	15.2 (11.4 -19.4)	↑	↔	8.48 (7.60–9.46)	14.46 (10.12-20.65)
PCB 201	0	15.2 (11.5 -19.5)	↑	↔	7.27 (6.47–8.18)	15.16 (10.59-21.69)
PCB 203	0	9.34 (7.06 -12.0)	↑	↔	6.05 (5.45–6.71)	9.87 (6.86- 14.19)
PCB 206	8	4.56 (3.32 -6.02)	↔	↔	2.90 (2.52–3.33)	5.94 (4.25-8.32)

n = sample size. NA= not applicable because GM was not provided by reference study. <LOD- Less than the limit of detection. -- = Levels cannot be compared since GMs were not provided by the reference studies or were not calculated for Sahtú. Arrows indicate that levels were above (↑), below (↓), or similar (↔) to levels reported in the reference studies based on 95%CI (e.g., if the GM was higher in this study and if the CIs did not overlap between the CHMS or the FNBI then the GMs were considered higher compared to the reference studies.) 1. PCB146 n=42, PCB163 n=41, PCB178 n=42, PCB183 n=42, PCB187 n=42 2. PCB Measures include those that were collected by the reference studies and in the NWT and Yukon Biomonitoring (e.g., PCB groupings were not collected by the reference studies).

Comparing by Sex

The CHMS and FNBI were used as reference studies to indicate if levels of PCBs in the study regions were elevated or not in. These reference levels as well as sex-stratified PCB levels in each of the regions are reported in Tables 4.13-4.15.

Among participating women from each of the participating regions, PCB levels were generally lower than or similar to the reference study levels. Specifically, in the Dehcho, PCB levels were up to 3.1-fold lower (PCB138, PCB153, PCB170, PCB180) than the CHMS. In contrast, PCB levels in the Dehcho were all similar to FNBI levels. In Old Crow, all PCBs were up to 3.8-fold (Arochlor 1260, PCB138, PCB153, PCB180) lower than the CHMS. However, compared to the FNBI only PCB138 was 2.1-fold lower in Old Crow and all other PCBs had similar levels. Finally, in the Sahtú region, most PCB exposure levels were similar to the CHMS, with the exception of three PCBs (PCB118, PCB138, PCB180) which were up to 1.9-fold lower than the CHMS. In contrast, all PCB levels in the Sahtú were similar to the FNBI.

Participating men from the study regions had PCB levels that were generally lower than or similar to the CHMS and the FNBI with the exception of certain PCB biomarkers in the Sahtú region. For example, in the Dehcho, Arochlor 1260 and PCB138 were up to 2.8-fold lower than the CHMS. In contrast, all biomarker levels were similar to the FNBI. In Old Crow, all PCB biomarkers (Arochlor 1260, PCB118, PCB138, PCB153, PCB170, PCB180, PCB187) were up to 3.2-fold lower than the CHMS. Likewise, two PCBs (PCB170, PCB180) were up to 2.5-fold lower compared to the FNBI. In the Sahtú region, all PCBs were similar to the CHMS, except for PCB187, whose levels were 1.6-fold higher compared to the CHMS. In contrast, all PCBs in the Sahtú were lower compared to the FNBI.

CI around the PCB biomarker estimates differed between the CHMS and FNBI for both age and sex stratified comparisons. CHMS CI are smaller compared to FNBI CI due to a larger sample size in the CHMS compared to the FNBI. For example, PCB187 levels in the oldest age group in the Sahtú, were higher in the Sahtú region compared to the CHMS, but between the FNBI and CHMS, PCB187 levels were higher in the FNBI (i.e., Sahtú levels > CHMS levels, FNBI levels > CHMS, Sahtú ~ FNBI).

Table 4.13 Dehcho region PCB GM levels compared to CHMS and FNBI PCB GM levels (µg/kg lipids) by sex

Sex	PCB Measure ¹	NWT and Yukon Biomonitoring Study (µg/kg lipid)				Reference Studies (CHMS, ng/g lipid) (FNBI, µg/kg lipid)	
		Dehcho n= 71 (F), n=65 (M)				CHMS: n=865 (F), n= 801 (M), FNBI: n=283-284 (F), n=187 (M)	
		% <LOD	Dehcho GM (95% CI)	Comparison to CHMS	Comparison to FNBI	CHMS GM (95% CI)	FNBI GM (95% CI)
F	Arochlor 1260	26.8	54.4 (39.5 -75.4)	--	--	152.67 (131.51–177.22)	87.80 (61.29-125.78)
	PCB 74	95.8	<LOD	--	--	NA	NA
	PCB 99	97.2	<LOD	--	--	NA	NA
	PCB 105	93	<LOD	--	--	NA	NA
	PCB 118	53.5	<LOD	--	--	5.13 (4.37–6.04)	3.15 (2.37-4.19)
	PCB138	38	3.40 (2.57- 4.64)	↓	↔	10.53 (9.21–12.05)	5.83 (4.26-7.98)
	PCB 146	56.3	<LOD	--	--	2.05 (1.79–2.35)	NA
	PCB 153	22.5	6.95 (5.02- 9.78)	↓	↔	18.46 (15.61–21.83)	10.99 (7.57-15.95)
	PCB 156	63.4	<LOD	--	--	2.71 (2.47–2.99)	NA
	PCB 163	52.1	<LOD	--	--	3.35 (2.95–3.80)	NA
	PCB 167	85.9	<LOD	--	--	NA	NA
	PCB 170	47.9	2.47 (1.93- 3.20)	↓	↔	4.46 (3.97–5.01)	3.52 (2.61-4.73)
	PCB 178	87.3	<LOD	--	--	NA	NA
	PCB 180	29.6	5.80 (4.11-8.17)	↓	↔	14.60 (12.87–16.56)	8.78 (5.81-13.27)
	PCB 183	77.5	<LOD	--	--	NA	NA
	PCB 187	43.7	<LOD	↔	↔	3.66 (3.16–4.25)	3.50 (2.46-4.98)
	PCB 194	53.5	2.68 (2.08-3.53)	--	--	2.78 (2.48–3.11)	NA
	PCB 201	53.5	<LOD	--	--	2.50 (2.25–2.79)	NA
	PCB 203	63.4	<LOD	--	--	2.21 (2.01–2.43)	NA
	PCB 206	76.1	<LOD	--	--	NA	NA
M	Arochlor 1260	7.81	95.85 (70.79- 127.35)	↓	↔	148.43 (129.50–170.13)	112.35 (71.21-177.26)
	PCB 74	96.9	<LOD	--	--	NA	NA
	PCB 99	96.9	<LOD	--	--	NA	NA
	PCB 105	96.9	<LOD	--	--	NA	NA
	PCB 118	56.3	<LOD	--	--	3.83 (3.19–4.60)	2.58 (1.74-3.81)
	PCB138	12.5	5.43 (4.17- 7.06)	↓	↔	9.75 (8.44–11.27)	7.05 (4.69-10.80)

PCB 146	53.1	<LOD	--	--	1.99 (1.70–2.33)	NA
PCB 153	6.25	12.9 (9.45- 17.3)	↔	↔	18.15 (15.67–21.03)	14.53 (9.08-23.25)
PCB 156	56.3	<LOD	--	--	2.58 (2.29–2.90)	NA
PCB 163	46.9	2.15 (1.67- 2.74)	↔	↔	3.10 (2.70–3.56)	2.70 (1.84- 3.96)
PCB 167	87.5	<LOD	--	--	NA	NA
PCB 170	31.3	3.81 (2.77- 5.12)	↔	↔	4.74 (4.15–5.40)	4.49 (2.94-6.84)
PCB 178	75	<LOD	--	--	NA	NA
PCB 180	14.1	11.4 (7.80- 16.0)	↔	↔	15.85 (13.98–17.97)	12.37 (7.63-20.04)
PCB 183	60.9	<LOD	--	--	NA	NA
PCB 187	28.1	3.96 (2.89- 5.35)	↔	↔	3.78 (3.22–4.44)	4.39 (2.73-7.05)
PCB 194	37.5	3.29 (2.36- 4.57)	↔	↔	3.06 (2.66–3.52)	3.06 (2.06-4.56)
PCB 201	40.6	2.92 (2.14- 3.97)	↔	↔	2.69 (2.38–3.05)	3.30 (2.14- 5.10)
PCB 203	48.4	2.20 (1.66- 2.90)	↔	↔	2.28 (2.04–2.56)	2.45 (1.69-3.56)
PCB 206	64.1	<LOD	--	--	NA	NA

n = sample size. NA= not applicable because GM was not provided by reference study. <LOD= Less than the limit of detection. -- = Levels were not compared since GMs were not provided by the reference studies or were not calculated for Dehcho. Arrows indicate that levels are above (↑), below (↓), or similar (↔) to levels reported in the reference studies based on 95%CI overlapping (e.g., if the GM was higher in this study and if the CIs did not overlap between the CHMS or the FNBI then the GMs were considered higher compared to the reference studies.) 1. PCB Measures included those that were collected by the reference studies and in the NWT and Yukon Biomonitoring (e.g., PCB groupings were not collected by the reference studies).

Table 4.14 Old Crow community PCB GM levels CHMS and FNBI PCB GM levels (µg/kg lipids) by sex

Sex	PCB Measure ₁	NWT and Yukon Biomonitoring Study (µg/kg lipid)				Reference Studies (CHMS, ng/g lipid) (FNBI, µg/kg lipid)	
		% <LOD	Old Crow GM (95% CI)	Comparison to CHMS	Comparison to FNBI	CHMS: n= 865 (F), n=801 (M) FNBI: n=283-284 (F), n=187 (M)	
						CHMS GM (95% CI)	FNBI GM (95% CI)
F	Arochlor 1260	20.7	42.54 (28.56- 63.15)	↓	↔	152.67 (131.51–177.22)	87.80 (61.29-125.78)
	PCB 74	100	<LOD	--	--	NA	NA
	PCB 99	100	<LOD	--	--	NA	NA
	PCB 105	100	<LOD	--	--	NA	NA
	PCB 118	55.2	<LOD	--	--	5.13 (4.37–6.04)	3.15 (2.37-4.19)
	PCB138	31	2.78 (1.96- 3.98)	↓	↓	10.53 (9.21–12.05)	5.83 (4.26-7.98)
	PCB 146	69	<LOD	--	--	2.05 (1.79–2.35)	NA
	PCB 153	17.2	5.27 (3.55-7.89)	↓	↔	18.46 (15.61–21.83)	10.99 (7.57-15.95)
	PCB 156	72.4	<LOD	--	--	2.71 (2.47–2.99)	NA
	PCB 163	62.1	<LOD	--	--	3.35 (2.95–3.80)	NA
	PCB 167	100	<LOD	--	--	NA	NA
	PCB 170	55.2	<LOD	--	--	4.46 (3.97–5.01)	3.52 (2.61-4.73)
	PCB 178	93.1	<LOD	--	--	NA	NA
	PCB 180	31	3.81 (2.49-6.01)	↓	↔	14.60 (12.87–16.56)	8.78 (5.81-13.27)
	PCB 183	82.8	<LOD	--	--	NA	NA
	PCB 187	51.7	<LOD	--	--	3.66 (3.16–4.25)	3.50 (2.46-4.98)
	PCB 194	58.6	<LOD	--	--	2.78 (2.48–3.11)	NA
	PCB 201	58.6	<LOD	--	--	2.50 (2.25–2.79)	NA
	PCB 203	72.4	<LOD	--	--	2.21 (2.01–2.43)	NA
	PCB 206	82.8	<LOD	--	--	NA	NA
M	Arochlor 1260	7.41	58.49 (40.61- 88.04)	↓	↔	148.43 (129.50–170.13)	112.35 (71.21-177.26)
	PCB 74	100	<LOD	--	--	NA	NA

PCB 99	88.9	<LOD	--	--	NA	NA
PCB 105	85.2	<LOD	--	--	NA	NA
PCB 118	48.1	1.66 (1.15-2.48)	↓	↔	3.83 (3.19–4.60)	2.58 (1.74-3.81)
PCB138	18.5	3.61 (2.47- 5.42)	↓	↔	9.75 (8.44–11.27)	7.05 (4.69-10.80)
PCB 146	77.8	<LOD	--	--	1.99 (1.70–2.33)	NA
PCB 153	7.41	7.27 (5.02- 11.06)	↓	↔	18.15 (15.67–21.03)	14.53 (9.08-23.25)
PCB 156	74.1	<LOD	--	--	2.58 (2.29–2.90)	NA
PCB 163	63	<LOD	--	--	3.10 (2.70–3.56)	2.70 (1.84- 3.96)
PCB 167	96.3	<LOD	--	--	NA	NA
PCB 170	40.7	1.82 (1.3- 2.55)	↓	↓	4.74 (4.15–5.40)	4.49 (2.94-6.84)
PCB 178	81.5	<LOD	--	--	NA	NA
PCB 180	14.8	4.92 (3.33- 7.21)	↓	↓	15.85 (13.98–17.97)	12.37 (7.63-20.04)
PCB 183	81.5	<LOD	--	--	NA	NA
PCB 187	37	2.07 (1.44- 3.04)	↓	↔	3.78 (3.22–4.44)	4.39 (2.73-7.05)
PCB 194	59.3	<LOD	--	--	3.06 (2.66–3.52)	3.06 (2.06-4.56)
PCB 201	59.3	<LOD	--	--	2.69 (2.38–3.05)	3.30 (2.14- 5.10)
PCB 203	70.4	<LOD	--	--	2.28 (2.04–2.56)	2.45 (1.69-3.56)
PCB 206	81.5	<LOD	--	--	NA	NA

n = sample size. NA= not applicable because GM was not provided by reference study. <LOD= Less than the limit of detection. -- = Levels were not compared since GMs were not provided by the reference studies or were not calculated for Old Crow. Arrows indicate that levels are above (↑), below (↓), or similar (↔) to levels reported in the reference studies based on 95%CI overlapping (e.g., if the GM was higher in this study and if the CIs did not overlap between the CHMS or the FNBI then the GMs were considered higher compared to the reference studies.). 1. PCB measures included those that were collected by the reference studies and in the NWT and Yukon Biomonitoring (e.g., PCB groupings were not collected by the reference studies).

Table 4.15 Sahtú region PCB GM levels compared to CHMS and FNBI PCB GM levels (µg/kg lipids) by sex

Sex	PCB Measure ²	NWT and Yukon Biomonitoring Study (µg/kg lipid)				Reference Studies (CHMS, ng/g lipid, FNBI, µg/kg lipid)	
		Sahtú n= 69-71 ¹ (F), n=65 (M)				CHMS: n= 865 (F), n=801 (M), FNBI: n=283-284 (F), n=187 (M)	
		% <LOD	Sahtú GM (95% CI)	Comparison to CHMS	Comparison to FNBI	CHMS GM (95% CI)	FNBI GM (95% CI)
F	Arochlor 1260	11.3	111.48 (76.99-160.29)	↔	↔	152.67 (131.51–177.22)	87.80 (61.29-125.78)
	PCB 74	95.8	<LOD	--	--	NA	NA
	PCB 99	87.3	<LOD	--	--	NA	NA
	PCB 105	73.2	<LOD	--	--	NA	NA
	PCB 118	49.3	2.69 (1.99- 3.60)	↓	↔	5.13 (4.37–6.04)	3.15 (2.37-4.19)
	PCB138	22.5	6.26 (4.52- 8.67)	↓	↔	10.53 (9.21–12.05)	5.83 (4.26-7.98)
	PCB 146	51.4	<LOD	--	--	2.05 (1.79–2.35)	NA
	PCB 153	7.04	15.11 (10.17- 22.01)	↔	↔	18.46 (15.61–21.83)	10.99 (7.57-15.95)
	PCB 156	56.3	<LOD	--	--	2.71 (2.47–2.99)	NA
	PCB 163	49.3	2.71 (1.99- 3.65)	↔	--	3.35 (2.95–3.80)	NA
	PCB 167	74.6	<LOD	--	--	NA	NA
	PCB 170	45.1	3.18 (2.30-4.37)	↔	↔	4.46 (3.97–5.01)	3.52 (2.61-4.73)
	PCB 178	60	<LOD	--	--	NA	NA
	PCB 180	25.4	8.15 (5.37- 12.18)	↓	↔	14.60 (12.87–16.56)	8.78 (5.81-13.27)
	PCB 183	57.1	<LOD	--	--	NA	NA
	PCB 187	37.1	4.36 (3.06- 6.11)	↔	↔	3.66 (3.16–4.25)	3.50 (2.46-4.98)
	PCB 194	49.3	2.52 (1.9- 3.36)	↔	--	2.78 (2.48–3.11)	NA
	PCB 201	52.1	<LOD	--	--	2.50 (2.25–2.79)	NA
	PCB 203	56.3	<LOD	--	--	2.21 (2.01–2.43)	NA
	PCB 206	63.4	<LOD	--	--	NA	NA
M	Arochlor 1260	1.52	160.59 (120.6-213.15)	↔	↔	148.43 (129.50–170.13)	112.35 (71.21-177.26)
	PCB 74	97	<LOD	--	--	NA	NA
	PCB 99	89.4	<LOD	--	--	NA	NA
	PCB 105	78.8	<LOD	--	--	NA	NA

PCB 118	33.3	2.88 (2.26- 3.74)	↔	↔	3.83 (3.19–4.60)	2.58 (1.74-3.81)
PCB138	7.58	8.33 (6.3- 11.06)	↔	↔	9.75 (8.44–11.27)	7.05 (4.69-10.80)
PCB 146	40.9	2.82 (2.15- 3.72)	↔	--	1.99 (1.70–2.33)	NA
PCB 153	1.52	22.12 (16.5- 29.82)	↔	↔	18.15 (15.67–21.03)	14.53 (9.08-23.25)
PCB 156	48.5	2.15 (1.70- 2.78)	↔	--	2.58 (2.29–2.90)	NA
PCB 163	34.8	3.33 (2.46- 4.49)	↔	↔	3.10 (2.70–3.56)	2.70 (1.84- 3.96)
PCB 167	77.3	<LOD	--	--	NA	NA
PCB 170	30.3	4.22 (3.09- 5.85)	↔	↔	4.74 (4.15–5.40)	4.49 (2.94-6.84)
PCB 178	51.5	<LOD	--	--	NA	NA
PCB 180	10.6	13.84 (9.61- 20.07)	↔	↔	15.85 (13.98–17.97)	12.37 (7.63-20.04)
PCB 183	59.1	<LOD	--	--	NA	NA
PCB 187	19.7	6.18 (4.50- 8.49)	↑	↔	3.78 (3.22–4.44)	4.39 (2.73-7.05)
PCB 194	42.4	3.47 (2.48- 4.83)	↔	↔	3.06 (2.66–3.52)	3.06 (2.06-4.56)
PCB 201	37.9	3.56 (2.57- 4.89)	↔	↔	2.69 (2.38–3.05)	3.30 (2.14- 5.10)
PCB 203	45.5	2.48 (1.89- 3.28)	↔	↔	2.28 (2.04–2.56)	2.45 (1.69-3.56)
PCB 206	60.6	<LOD	--	--	NA	NA

n = sample size. NA= not applicable because GM was not provided by reference study. <LOD- Less than the limit of detection. -- = Levels cannot be compared since GMs were not provided by the reference studies or were not calculated for Sahtú. Arrows indicate that levels are above (↑), below (↓), or similar (↔) to levels reported in the reference studies based on 95%CI overlapping (e.g., if the GM was higher in this study and if the CIs did not overlap between the CHMS or the FNBI then the GMs were considered higher compared to the reference studies.). 1. PCB146 n=42, PCB163 n=41, PCB178 n=42, PCB183 n=42, PCB187 n=42 2. PCB measures include those that were collected by the reference studies and in the NWT and Yukon Biomonitoring (e.g., PCB groupings such as $\sum$ PCB_{138,153,180} were not collected by the reference studies).

4.2 Dietary Exposure Sources using FFQ Data

4.2.1 Study Region Demographics, PCB Exposure Levels and the FFQ

Study Region Demographics

Plasma sample distribution and FFQ participation are summarized in Tables 4.16 and 4.17. Those under 20 years were least likely to have both provided blood samples while those between 20-39 years (Old Crow) and 40-59 years (Dehcho and Sahtú) were most likely. The percent of men and women who provided blood samples were generally similar to each other in each region. Notably, FFQ participation was highest in Old Crow and was lowest in the Sahtú.

Among those that provided a blood sample and FFQ data, women had slightly higher participation numbers compared to men in select regions (e.g., Dehcho). Compared to census data (Table 4.2), individuals less than 20 years were underrepresented while older persons were slightly overrepresented in the Dehcho and Sahtú regions. Notably, in Old Crow, those in the fraction of 20-39 years were significantly higher than observed in the Dehcho and Sahtú (despite similar distributions among the three regions according to census data).

Table 4.16 Demographic details of participants who provided a blood sample and measure for PCBs

	Dehcho	Old Crow	Sahtú	Pooled
PCB Blood Samples	n=135	n=56	n=137	n=329
Sex				
Male	64 (48%)	27 (48%)	66 (48%)	158 (48%)
Female	71 (42%)	29 (52%)	71 (52%)	171 (52%)
Age (Years)				
<20	17 (13%)	2 (4%)	15 (11%)	34 (10%)
20-39	32 (24%)	26 (46%)	43 (31%)	101 (31%)
40-59	54 (40%)	16 (29%)	43 (31%)	113 (34%)
60+	26 (19%)	10 (18%)	31 (23%)	68 (21%)
Mean Age (95% CI)	43 (39.79-45.55)	43 (38.13- 47.25)	44 (40.73- 47.68)	43 (41.30-45.29)
Survey				
FFQ¹	82 (60%)	51 (91%)	56 (41%)	189 (57%)

Select demographic information and summary of participants in the study who only provided blood samples for PCB analysis.¹ The Food Frequency numbers shown are those who provided blood samples and filled out the FFQ.

Table 4.17 Demographic details of participants who provided a blood sample as well as completed the FFQ

	Dehcho	Old Crow	Sahtú	Pooled
PCB blood samples	n=82	n=51	n=56	n=189
Sex				
Male	35 (43%)	25 (49%)	26 (46%)	86 (46%)
Female	47 (57%)	26 (51%)	30 (54%)	103 (54%)
Age (years)				
<20	9 (11%)	2 (4%)	5 (9%)	16 (8%)
20-39	19 (23%)	24 (47%)	17 (30)	60 (32%)
40-59	34 (41%)	16 (31%)	21 (38%)	71 (37%)
60+	17 (21%)	9 (18%)	12 (21%)	38 (21%)
Mean Age (95% CI)	44 (40.19-47.66)	42 (37.75-47.00)	45 (40.38- 49.65)	44 (41.25- 46.48)

Baseline PCB Parameter Results

Table 4.18 summarizes $\Sigma\text{PCB}_{138,153,180}$ among i) participants that provided blood samples; ii) participants that provided blood samples and took part in the FFQ. Within each participating region, biomarker levels were remarkably similar among subsets (i.e., those who that provided blood samples had similar levels of $\Sigma\text{PCB}_{138,153,180}$ relative to those who provided blood and took part in the FFQ). This pattern also remained true when results from the three participating regions were pooled. $\Sigma\text{PCB}_{138,153,180}$ was considerably higher in the Sahtú than Old Crow. and appeared higher in the Sahtú than the Dehcho in both subsets. When regions were pooled, male participants appeared to have slightly higher $\Sigma\text{PCB}_{138,153,180}$ than female participants in both subsets. Finally, similar patterns between age and $\Sigma\text{PCB}_{138,153,180}$ were observed for both participant subsets.

Table 4.18 GMs for those who provided blood samples and those who provided blood samples and participated in the FFQ for $\Sigma\text{PCB}_{138, 153, 180}$ ($\mu\text{g/kg}$ lipids)

	Dehcho GM (95% CI)	Old Crow GM (95% CI)	Sahtú GM (95% CI)	Pooled GM (95% CI)
Provided blood samples				
n	135	56	137	328
Total	22.41 (17.98 -28.62)	13.97 (10.52 -18.7)	36.58 (29.3 -46.05)	25.28 (21.83- 29.45)
Sex				
Male	30.88 (22.88-41.16)	16.13 (11.04-24.33)	45.87 (33.4-61.65)	32.62 (26.53-40.55)
Female	16.79 (12.41-23)	12.22 (8.19-17.98)	29.18 (20.33-41.69)	20.01 (16.24-24.84)
Age				
<20	4.47 (3.58- 5.61)	7.49 (3.06- 18.29)	5.70 (3.98- 8.48)	5.13 (4.21- 6.43)
20-39	7.03 (5.23- 9.55)	6.22 (4.95- 7.92)	14.42 (11.45- 18.63)	9.25 (7.85- 11.04)
40-59	29.98 (24.44- 36.52)	27.52 (19.68- 39.27)	47.61 (36.13- 61.8)	35.17(29.98- 40.90)
60+	124.52 (92.18- 167.88)	38.17 (25.91- 58.18)	199.51 (150.69- 256.58)	125.39 (101.19-155.66)
Provided blood samples and participated in FFQ				
n	82	51	56	189
Total	22.17 (16.60- 29.72)	13.29 (10.05- 17.36)	38.01 (27.25 -52.84)	22.65 (18.89- 27.12)
Sex				
Male	33.65 (22.94- 50.65)	13.94 (9.90-20.21)	45.84 (27.92- 72.38)	28.6 (21.91- 37.27)
Female	16.25 (11.14- 23.41)	12.69 (8.49 -18.47)	32.32 (20.33- 50.27)	18.65 (14.47-24.22)
Age				
<20	4.31 (3.34-5.88)	7.49 (3.01- 18.29)	4.82 (2.89- 7.12)	4.78 (3.69- 6.41)
20-39	7.28 (5.26-53.55)	6.51 (4.95- 8.44)	15.22 (10.16- 23.72)	8.58 (6.97- 10.65)
40-59	26.61 (20.1- 34.77)	24.96 (17.53-36.59)	52.52 (38.50- 73.26)	32.07 (26.34- 38.69)
60+	119.15 (78.92-171.98)	33.05 (24.04- 44.78)	173.08 (125- 240.43)	99.12 (72.34- 133.32)

FFQ Survey Results

Food consumption profiles are presented in Table 4.19 for all participants who completed the FFQ for foods selected to be analyzed for this study, whereas Table 4.20 summarizes the FFQ results of respondents who also provided blood samples. Among the regions, the most common groups of food consumed were certain fish species and land animals. Notably, consumption of walleye was lower in the Sahtú (7%) compared to the Dehcho (49%) and northern pike was more commonly consumed in the Dehcho (54%) compared to Old Crow (10%) and the Sahtú (18%). Percent reporting consumption for certain fish species varied across the regions, for example, in the Dehcho, whitefish was the most consumed fish, followed by northern pike and then lake trout. In the Old Crow, chinook was the most consumed fish followed by whitefish and then inconnu. In the Sahtú region, whitefish was the most consumed, followed by lake trout and then inconnu. Notably, large game meat was among the highly consumed foods, whereas fish eggs were not as commonly eaten. Those who provided blood samples have similar dietary profiles compared to all the FFQ participants. Markedly, all the consumption profiles fell within a 10% change between the datasets. For example, among the pooled dataset, large game animals (97%-98%) and whitefish (86%) were the most consumed foods between the datasets. In the Sahtú, fish-eating birds were similarly consumed among both datasets (45%) whereas in Old Crow, large game meat had similar consumption patterns (100%) among both datasets but in the Dehcho, Walleye (49%) had similar percent consuming among both datasets.

Table 4.19 Food consumption profiles among participants

		Dehcho Participants n=154 (%)	Old Crow Participants n=71 (%)	Sahtú Participants n=83 (%)	Pooled Dataset n=308 (%)
Fish	Whitefish	144 (94%)	58 (82%)	63 (76%)	265 (86%)
	Inconnu	43 (28%)	15 (21%)	25 (30%)	83 (27%)
	Lake trout	85 (55%)	11 (15%)	62 (75%)	158 (52%)
	Northern Pike	91 (59%)	6 (8%)	13 (16%)	110 (36%)
	Walleye	76 (49%)	-	4 (5%)	80 (26%)
	Chinook	-	63 (89%)	-	63 (20%)
Fish Eggs (total)		49 (32%)	31 (44%)	30 (36%)	110 (36%)
¹Large Game Meat		146 (95%)	71 (100%)	81 (98%)	298 (97%)
²Large Game Organs		83 (54%)	58 (82%)	47 (57%)	188 (61%)
³Fish Eating Birds (aquatic birds)		95 (62%)	29 (41%)	37 (45%)	161 (52%)
⁴Game Birds		106 (68%)	38 (54%)	57 (69%)	201 (65%)

- food was not reported eaten in this region and thus excluded from the analysis

¹Large Game Meat include those who ate the meat of woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

²Large game organs include those who ate the organs (liver, kidney, bones in soup, bone marrow, fat) from woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

³Fish eating birds include those who ate the meat of black duck, fish duck, long-tailed duck, pintail, swan, canvasback, white-winged scoter, mallard.

⁴Game birds include those who ate spruce grouse, sharp-tailed grouse, ptarmigan, black duck, mallard, fish duck, oldsquaw (long-tailed duck), wigeon, speckle belly goose, canvasback, Canada goose, snow goose, pintail, white-winged scoter, swan.

Table 4.20 Food consumption proportions for those who completed the FFQ and provided blood samples.

		Dehcho Participants n=82 (%)	Old Crow Participants n=51 (%)	Sahtú Participants n=56 (%)	Pooled Dataset n=189 (%)
Fish	Whitefish	77 (93%)	43 (84%)	44 (79%)	164 (86%)
	Inconnu	20 (24%)	12 (24%)	15 (27%)	48 (25%)
	Lake trout	47 (57%)	11 (22%)	46 (82%)	105 (55%)
	Northern Pike	44 (54%)	5 (10%)	10 (18%)	60 (32%)
	Walleye	40 (49%)	-	4 (7%)	45 (24%)
	Chinook	-	45 (88%)	-	45 (24%)
Fish Eggs (total)		24 (29%)	24 (47%)	19 (34%)	68 (36%)
¹ Large Game Meat		79 (96%)	51 (100%)	55 (98%)	186 (98%)
² Large Game Organs		48 (59%)	40 (78%)	34 (61%)	123 (65%)
³ Fish Eating Birds (aquatic birds)		52 (68%)	20 (39%)	25 (45%)	97 (51%)
⁴ Game Birds		60 (73%)	28 (55%)	40 (71%)	129 (68%)

- food was not reported eaten in this region and thus excluded from the analysis

¹Large Game Meat include those who ate the meat of woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

²Large game organs include those who ate the organs (liver, kidney, bones in soup, bone marrow, fat) from woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

³Fish eating birds include those who ate the meat of black duck, fish duck, long-tailed duck, pintail, swan, canvasback, white-winged scoter, mallard.

⁴Game birds include those who ate spruce grouse, sharp-tailed grouse, ptarmigan, black duck, mallard, fish duck, oldsquaw (long-tailed duck), wigeon, speckle belly goose, canvasback, Canada goose, snow goose, pintail, white-winged scoter, swan.

4.2.2 Multiple Linear Regression Models Among Pooled Datasets

To assess the relationship between traditional food intake and PCB concentrations, multiple linear regression models (n=185) were completed for the dependent variable, $\sum \text{PCB}_{138,153,180}$ and selected traditional foods and are shown in Table 27. Among the traditional foods that were included in the multiple linear regression models, controlling for age and sex, only lake trout, fish eating birds and game birds were associated with increased Log $\sum \text{PCB}_{138, 153, 180}$. Further, as described by their beta coefficients (i.e., the magnitude in increase of Log $\sum \text{PCB}_{138, 153, 180}$, for every one unit increase in traditional food consumption), the effect sizes of these relationships were remarkably similar. Notably, large game animals had a negative association with PCB exposure levels in each of the regions and in the pooled analysis, however these associations were not considered statistically significant (p>0.05).

No beta coefficients for any of the foods included in the multiple linear regression models were found to be significantly negative.

Table 4.21 Multiple Linear Regression Models for PCB Concentrations for Traditional Food Consumption, Controlling for Age and Sex among all Study Regions

		$\Sigma\text{PCB}_{138,153,180}$ Parameter Estimate (beta)	Std. Error	95% CI	p-value
Fish	Whitefish	-0.057	0.0712	(-0.196, 0.083)	0.425
	Inconnu	0.006	0.0579	(-0.108, 0.119)	0.923
	Lake trout	0.152*	0.0476	(0.059, 0.245)	0.001
	Northern Pike	0.07	0.0521	(-0.032, 0.172)	0.18
	Walleye	-0.098	0.0566	(-0.209, 0.013)	0.082
	Chinook	-0.017	0.1267	(-0.266, 0.231)	0.891
Fish Eggs (total)		0.098	0.051	(-0.002, 0.198)	0.055
¹ Large Game Meat		-0.349	0.193	(-0.728, 0.029)	0.07
² Large Game Organs		0.081	0.0511	(-0.019, 0.182)	0.111
³ Fish Eating Birds (aquatic birds)		0.136*	0.0487	(0.085, 0.276)	0.005
⁴ Game Birds		0.159*	0.0514	(0.058, 0.26)	0.002

¹Large Game Meat include those who ate the meat of woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

²Large game organs include those who ate the organs (liver, kidney, bones in soup, bone marrow, fat) from woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

³Fish eating birds include those who ate the meat of black duck, fish duck, long-tailed duck, pintail, swan, canvasback, white-winged scoter, mallard.

⁴Game birds include those who ate spruce grouse, sharp-tailed grouse, ptarmigan, black duck, mallard, fish duck, oldsquaw (long-tailed duck), wigeon, speckle belly goose, canvasback, Canada goose, snow goose, pintail, white-winged scoter, swan.

5. Discussion

5.1 Summary of PCBs

The below section contextualizes PCB exposure levels observed in Indigenous communities that participated in human biomonitoring research between 2016-2019. In addition, potential associations with key variables including region, sex, age, omega-3 fatty acid, BMI, smoking status and drinking status are compared to observations from previous studies. As well, this section explores the extent to which results from participating communities of the Northwest Territories and Yukon were similar to those from nationally representative studies (e.g., CHMS and the FNBI) as well as other northern biomonitoring projects in Canada.

5.1.1 Comparing Results to Other Northern Biomonitoring Projects

In general, PCB levels were much lower than those of other biomonitoring studies conducted in northern regions (see supplemental tables in Appendix). In fact, levels of PCBs in the 10 participating communities of this project were significantly lower than most of the other studies reported within recent syntheses of Arctic Indigenous PCB biomonitoring data (33,79,146,165). For example, average adult PCB concentration levels in the NWT and Yukon Biomonitoring projects ranged from 3.18- 8.29 µg/kg lipids (PCB138), 6.37- 21.12 µg/kg lipids (PCB153) and 4.4-12.07 µg/kg lipids (PCB180), compared to the 2017 Nunavik adult concentrations of 14-29 µg/kg lipids (PCB138), 30-70 µg/kg lipids (PCB153) and 13-40 µg/kg lipids (PCB180) (33). Higher levels in Nunavik and other Arctic regions of the NWT and Nunavut are likely related to the importance of marine animals within the diets of the coastal Inuit populations with whom many of these other projects were partnered. Specifically, these marine animals commonly eaten by Inuit contain higher amounts of PCBs (33,166). Across the Inuit Nunangat, including Nunavik, Nunavut, Nunatsiavut, and the ISR, beluga, seals and other marine animals were reported as frequently consumed (167). In contrast, among the participating communities of the Northwest Territories, marine mammals are not part of the traditional diets of these regions (33). Notably, beluga muktuk was reportedly consumed by 24% of participants in Old Crow. Despite this, PCB biomarkers were consistently lower in Old Crow than the participating Dene regions of the Northwest Territories.

Although most PCB exposure levels in participating communities were lower than most other Arctic and subarctic biomonitoring studies, some PCB levels were similar or higher compared to one community in northern Quebec (165). Specifically, Arochlor 1260 GM levels were 0.80 µg/L in the Sahtú compared to 0.76 µg/L in the community of Waskaganish. Similarly, PCB153 GM exposure levels were 0.11 µg/L in the Sahtú compared to 0.09 µg/L in the community of Waskaganish (165). These somewhat higher PCB biomarker levels in the Sahtú may be due to the relative frequency of consumption of traditional foods between the Sahtú and the community of Waskaganish. Among the participating regions of the biomonitoring project presented herein, the mean frequency per week of eating a variety of traditional food categories (e.g., land animal organs, fish, berries, land animal meat) ranged from 1.3 to 5.2 times per week (16). In the community of Waskaganish, frequency of consumption (month) appeared slightly lower and ranged from 6.15-9.74 (165). However, the differences noted in traditional food consumption may also be due to methodological differences in the implementation of the FFQ. Further, differences in PCB levels among these studies could also be related to the types of food consumed, portion sizes, and demographic differences.

5.1.2 Comparing Results to Nationally Representative Biomonitoring Studies

PCB exposure levels, stratified by age and sex, were compared with nationally representative studies (i.e., CHMS and FNBI). Among those participants below the age of 60 in all the study regions, all PCB congeners were within the normal range (i.e., below, or similar to the CHMS or FNBI levels). As well, in Old Crow, participants over 60 also had PCB levels within the normal range. In contrast, in the Dehcho and Sahtú regions, participants over 60 years had elevated levels of select PCB congeners relative to the CHMS and/or FNBI. Specifically, for participants over 60 years in the Dehcho region, average levels of PCB187 and PCB201 appeared elevated compared to the CHMS. Among participants over 60 years in the Sahtú, Arochlor 1260 and 11 congeners (i.e., PCB146, PCB153, PCB163, PCB170, PCB178, PCB180, PCB183, PCB187, PCB194, PCB201 and PCB203) appeared elevated compared to the CHMS. As well in the Sahtú, Arochlor 1260 was observed at an elevated level compared to the FNBI. When results were pooled across age and stratified by sex, levels appeared within the normal range (i.e., lower or similar to CHMS or FNBI levels) in all study regions, with the exception of PCB187 (whose level was elevated compared to only the CHMS) in the Sahtú region for men (108). Like previously reported for the CHMS, average levels of GM and 95th percentile PCB biomarkers from each of the regions for adults aged 20-79, fell significantly below the calculated PCB BEs for males aged 20-79 and for female participants aged 20-79 (149).

The observations that PCB levels were elevated PCB in older age groups (but not among younger participants) may be, in part, attributed to dietary transitions among Indigenous communities (168). For example, among Arctic populations, a general decline in consumption of traditional food intake has been reported (33). As well, studies have noted that diets of younger Indigenous populations may map more closely to the diets of the general Canadian population (15,169,170). However, some foods among the study regions may be more frequently consumed now than in the past. For example, the average per week of lake trout consumption from a previous study report completed by the Centre for Indigenous Peoples' Nutrition and Environment was 0.7 in the Dehcho. In contrast, as reported in a 2020 paper describing FFQ data from this project, lake trout consumption was reportedly 1.3 times/week among Sahtú participants and 1 time/week in the Dehcho (16,171). As well, some work was done to model estimated dietary intake of traditional foods among Arctic populations and reported an increase in traditional food intake compared to past generations (172). Alternatively, this pattern of elevated levels among older participants in some regions may also be partly explained by declining levels of PCBs in the environment following the phase out of PCBs. Thus, it is not yet known if declining traditional food intake or declining environmental levels are most contributing to the age and region-specific patterns in PCB biomarkers.

5.1.3 PCB Levels Among the Regions

Differences in exposure levels among the participating regions were observed. Generally, PCB levels appeared higher in the Sahtú than the Dehcho and lowest in Old Crow. Differences in PCB concentrations, ranging from 1.5-fold to almost 3-fold higher, among the study regions were observed for several PCB biomarkers, including Arochlor 1260, PCB138, PCB153, PCB163, PCB170, PCB180, PCB187 and $\sum\text{PCB}_{138,153,180}$. Differences in exposure levels observed between the regions could be due in part from dietary differences. For example, in a 24-hour recall completed in the Dehcho and Sahtú regions, a larger percentage of Sahtú participants (42%) reported eating traditional foods on the day before samples were collected than in the Dehcho (31%) (170). Perhaps even more importantly, frequency of consumption of specific types of food varied among the regions. For example, in the Dehcho, lake trout were reported eaten once per week and in the Sahtú, lake trout were reported eaten 1.3 times per week (16). Notably, lake trout are often at a higher trophic level and higher fat content compared to the species most often eaten in the Dehcho and thus may contain more PCBs (26,173,174). Interestingly, although participants in Old Crow predominately ate Chinook Salmon (another lipid rich fish) in the year prior to the collection of the biological samples, the levels of PCBs among participants

in Old Crow were remarkably low. Thus, the factors related to diet and PCB biomarker levels among the participating regions are not yet fully understood.

Differences in PCB biomarkers among regions may also reflect differences in environmental levels of PCBs between the Sahtú, Dehcho, and Old Crow. For example, long running monitoring studies have noted substantially higher PCB levels in lake trout in Great Bear Lake (160.9 ng/g), than in Great Slave Lake (12.9-16.2 ng/g) (175). This is particularly notable given that Great Bear Lake is one of the most important sources for subsistence fishing in the Sahtú while Great Slave Lake was one of the predominant sources of fish several of the participating Dehcho communities. However, lake trout analyzed in Great Bear Lake were older (19.9 years) compared to lake trout in Great Slave Lake (7.5-10.9 years) (175). Since PCBs are bio accumulative, older, and bigger lake trout are expected to have higher PCB levels than younger, smaller lake trout. To better understand differences among lakes, size- or age-standardized contaminant levels in fish species must be known (176,177). Further, it would be useful to know if differences exist in the age or size of fish consumed in the Dehcho vs. Sahtú and if these large differences in PCB levels in fish between lakes correspond to differences in PCB levels in people's meals.

Regional differences in PCB concentrations have also been observed among other northern biomonitoring studies. For example, PCB concentrations were 4.4-fold higher for PCB118, 5.65-fold higher for PCB138, 7.5-fold higher for PCB153, and 5.29-fold higher for PCB180 in Baffin-Inuvik mothers compared to Inuvik-Dene/Metis mothers (35). Among other factors, this study noted more frequent eating of traditional foods were all associated with higher PCB levels. The increased consumption of marine mammals in the Baffin region was also a potential source of elevated exposure levels compared to more inland regions (35). Another biomonitoring study among the Cree of northern Quebec noted regional differences in PCB concentration levels. Levels appeared higher in more inland communities compared to more coastal communities and suggested local point sources (e.g., improper decommissioning of radar lines, mining operations) as an explanation for these differences (178). Thus, having an in-depth understanding of environmental, lifestyle, and dietary differences among the participating study regions would be beneficial.

5.1.4 PCB Levels among Male and Female Participants

PCBs exposure levels were compared between men and women from the participating communities. In the Dehcho, male participants had up to 2-fold higher PCB exposure levels for Arochlor 1260,

PCB138, PCB170, PCB180 and $\Sigma\text{PCB}_{138,153,180}$ than female participants. In contrast, in Old Crow and the Sahtú, PCB concentrations appeared slightly higher in male than female participants, however these results were not statistically significant. Like the results from the Dehcho, differences among men and women were observed in several other northern biomonitoring studies (33). For example, generally, men had PCB levels up to 3-fold higher than women in the ISR, Nunavut, and Nunatsiavut regions for PCB99, PCB118, PCB138, PCB153 and PCB180 between the years 2004- 2008 (79). In contrast, similar levels among men and women participants were observed in the Qanuilirpitaa? 2017 Inuit Health Survey, where PCB levels (PCB138, PCB153, PCB80) ranged from 29-70 $\mu\text{g/kg}$ lipids in men and 29-62 $\mu\text{g/kg}$ lipids in women participants from Nunavik (33).

There are many possible reasons why differences in between men and women would be observed. First, diets or food consumption may differ between men and women. Among the NWT participating regions, male and female participants were of similar ages, but adult male participants had a higher frequency/week of food groups consumption for all the food groups compared to adult women participants. Likewise, in a recent cross-sectional study, researchers reported differences in dietary choices between Inuit men and women in Nunavik. Men's diet was more country food dominant (73.3%) compared to women's diet (26.7%). Logistic regression models also reflected these results, as women were less likely to fall into the country food dominant profile (OR 0.33, 95%CI 0.2-0.52) compared to men (179). Interestingly, only the Dehcho region showed significant differences in PCB exposure levels between men and women. Thus, exploring the region-specific rates of traditional food intake and other food consumption parameters among men and women of the participating study regions may provide further insight of the differences and similarities in exposure levels among men and women. It's notable that several other potential covariables may explain the regional patterns in sex-based differences (e.g., difference in breastfeeding history, parity status) (180). However, questions related to these topics were not asked as part of the study, so the role of these variables on the data presented herein cannot currently be evaluated.

5.1.5 PCB Levels and Age

PCB exposure levels were strongly correlated with age, as expected for a persistent and bio accumulative contaminant (37). Increasing PCB levels with age have been observed among other biomonitoring studies (33). For example, in Nunavik, PCB GM levels were up to 6.4-fold higher in men aged 50-82 compared to men aged 18-49 and up to 9.3-fold higher in women of the same age groups, for PCB138, PCB153 and PCB180 (33). Results from the International Polar Inuit Health

Survey also noted a strong correlation ($p < 0.001$) between total PCBs and age (181). Notably, the slope of the relationship between PCBs and age was lower in Old Crow than the Sahtú and Dehcho regions. Differences in slope among regions may correspond to differences in long term exposure rates ($\mu\text{g/kg/d}$) among regions. For example, in this study, PCB biomarker levels were lowest in Old Crow, suggesting exposure sources are more pronounced in the Dehcho and Sahtú. Interestingly, there is emerging evidence that genetic factors or ethnicity may affect the toxicokinetic and body burden of some contaminants (182–184). It is as of yet unknown whether such genetic factors may have played a role in the regional patterns observed for the relationship between PCB biomarkers and age.

5.1.6 Intercorrelations Among PCB Congeners

All PCBs analyzed in this study were strongly correlated with one another, suggesting if one PCB is detected at elevated levels, it is likely that other PCBs will also be similarly elevated. Previous studies conducted in Canada have recognized this pattern (185–187). For example, in a biomonitoring study conducted in Nunavik among Inuit participants, all PCB congeners were highly correlated with one another ($r = 0.71\text{--}0.98$; $p < 0.0001$) (188). Although literature suggests individual congener analyses is beneficial (41), other literature have used one PCB congener (e.g., the congener with the highest rate of detection) as the dependent variable to conduct further analyses, since strong intercorrelations among individuals PCB congeners exist (187). However, when selecting one congener or groups of congeners, some associations among PCB levels and variables may be occasionally missed or masked. For example, when comparing PCB exposure levels between those who reported smoking and those who did not, in the Sahtú region, $\sum\text{PCB}_{138, 153, 180}$ levels appeared similar between the two groups, whereas the individual congener PCB180 exposure levels appeared higher in those who did not smoke (relative to those who reported smoking in the last 24 hours). The reverse was also occasionally observed. For example, GM PCB180 levels in Old Crow was not associated with BMI, however $\sum\text{PCB}_{138, 153, 180}$ was.

There are practical limits to the number of highly correlated congeners and should be analyzed with respect to their statistical determinants (e.g., related to multiple comparison; time constraints). PCBs that were most detected among participants (e.g., detected in at least 80% of samples) were more likely to show statistical differences across levels of a factor than other PCBs with lower detection rates (e.g., detected in approximately 50% of samples). For example, in Old Crow, PCB170 (46% detection rate) was not associated with BMI, however PCB153 (92% detection rate) was. Further, in the Sahtú, congeners above a 55% detection rate showed a significant positive association between PCB exposure

levels and BMI. In contrast, for those PCBs detected in less than 55% of samples, no associations were detected between biomarker concentration and BMI. In conclusion, future work analyzing statistical determinants of PCB biomarkers should focus on those detected in at least 55% of samples.

5.1.7 PCB Levels and Fatty Acids

Lipid-adjusted PCB levels were positively correlated with n-3 PUFAs in the Dehcho and Sahtú regions. PCBs are known to preferentially partition into lipids (37). In contrast, n-3 PUFA levels were not correlated with PCB biomarkers in Old Crow. Among some other northern biomonitoring projects, n-3 PUFA were associated with higher PCB exposure levels (186,189) and studies have often included omega-3 fatty acids as co-variables when reporting PCB concentration level associations with outcomes (190,191). For example, simple linear regressions revealed n-3/n-6 PUFA ratios were associated with lipid-adjusted PCB153 levels among a study of pregnant Inuit women in Nunavik (189). Notably, correlations between PCB biomarkers and fatty-acids among the study regions were just as present with lipid-adjusted PCB levels compared to unadjusted levels (i.e., µg/L). This suggests that the correlation between PCBs and n-3 PUFAs extends beyond simple lipid partitioning of PCBs and instead points towards a common dietary source of n-3 PUFA and PCBs in the Dehcho and Sahtú. For instance, people who eat more lake trout may have highest n-3 PUFA levels and highest PCB levels. In contrast, the lack of a correlation between PCBs and n-3 PUFA in Old Crow suggests that the foods that contribute most to n-3 PUFA intakes in this community are relatively low in PCBs.

5.1.8 PCB Levels and Lifestyle Factors

Higher PCB levels were associated with BMI in Old Crow for PCB138, PCB153 and PCB187 and in the Sahtú for Arochlor1260, PCB118, PCB138, PCB153, PCB163, PCB170, PCB180, PCB187 and $\sum\text{PCB}_{138,153,180}$. In contrast, no correlations between PCBs and BMI were observed in the Dehcho region. Notably, BMI and PCB exposure level associations were not as consistent nor as strong as observed for other factors, such as age and omega-3 fatty acid level. One study conducted in northern Canada found blood PCB levels were associated with lower BMI ($\beta = -0.33$, $p < 0.001$) among Inuit youth from Nunavik (192). Other studies have also reported inconsistent associations between PCB exposure levels and BMI (84,193–195). Interestingly, some hypotheses of these inconsistencies stem from participant toxicokinetic of PCB biomarkers. For instance, it was theorized that high BMI status may lead to lower PCB biomarkers during times of increased exposure while low BMI status may lead to higher PCB biomarkers during times of decreased exposure (196,197). To fully understand the

relationship between BMI and PCB biomarker levels, results related to genetic polymorphisms and clearance rates of PCBs might be required.

No associations were observed between drinking status and PCB biomarkers, perhaps due to the nature of the question asked (i.e., self-reported alcohol consumption in the past 24 hours). Previous epidemiological studies have showed, for instance, that mothers who reported drinking during pregnancy at least once per week had PCB levels three times higher compared to those who did not report drinking (198). Future studies could focus examine, instead of alcohol consumption in the previous 24 hours, measures of frequency and/or magnitude of alcohol use. That being said, it is important to remember that topics related to substance can be stigmatizing and, if examined further, must be done respectfully and consider the issues of under-reporting due to stigma. As well, culturally-sensitive approaches to definitions of drink-size and frequency may also be required. Community leaders and researchers may be best-positioned to determine: i) whether this should be done; ii) if it should, how to best ask such questions in a non-stigmatizing way.

In the Dehcho and Sahtú, some PCB biomarkers (e.g., Arochlor 1260, PCB138, PCB153, PCB163, PCB170, PCB180, PCB187) were lower among those who reported smoking in the last 24 hours (compared to those who did not). In contrast, Old Crow participants who smoked had higher PCB biomarkers (e.g., Arochlor 1260, PCB138, PCB153, PCB180 and $\sum\text{PCB}_{138,153,180}$) than those who had not smoked. Similarly, one study reported an association between predicted serum PCB153 levels among pregnant Inuit women and daily cigarette use (189). In contrast, with a study of older Canadian adults, no associations between PCB levels and daily smoking were reported (185). This regional interaction between the relationship between smoking and PCB biomarkers could relate to demographic or dietary differences between smokers in the three participating regions. These differences might be confounded by region-specific differences in the age distributions of those who reported smoking versus those who reported not smoking, and a regression model that includes age and region as co-variables may aid in determining if confounding has occurred.

5.2 PCB Levels and Traditional Foods

The section below describes the observed association between select groups of traditional foods and PCB exposure levels. Diet is a well-known source of PCB exposure and using data provided from northern Indigenous communities, some potential patterns between PCB exposure levels and traditional

food consumption were identified below. However, positive associations between PCB concentration levels and dietary factors differed between type of traditional food.

5.2.1 Fish and Fish Eggs

When pooling results across all ten participating communities, lipid adjusted PCB concentrations were higher in those who ate lake trout (Table 4.21). When stratified by region, lake trout was not significantly associated with lipid adjusted PCB level (Supplemental Tables 2-4). However, in these regional-specific models, eating northern pike was associated with higher PCB biomarkers (after controlling for age and sex). Some studies exist that evaluate links between fish and PCB or other contaminant biomarkers (35,199,200). For example, surprisingly, fish consumption (e.g., Arctic char, salmon, lake trout) among pregnant Inuit mothers (Nunavik) was uncorrelated (e.g., Pearson correlation; -0.06) with PCB exposure levels, despite women reporting eating fish most often during pregnancy, compared to other foods (199). However, food consumption data was only collected during pregnancy and consumption patterns collected during this study did not necessarily map onto lifetime traditional food intake, which is important to consider due to the bioaccumulative nature of PCBs (199). More recently, one study reported parameter estimates that indicated increased PCB levels (PCB153, PCB180, and PCB138) in those who reported consuming traditional foods (fish, land animal, marine mammal, birds and plant foods) (35). In regions outside of Canada, but still located within the arctic and subarctic, more studies linking PCBs and traditional foods including fish consumption have been established. For example, in Greenlandic Inuit, researchers found eating total traditional foods, including fish, had notably higher (11 to 16 times) PCB blood levels compared to less frequent consumption of traditional foods (200).

In studies conducted within the research team for the NWT and Yukon projects, Old Crow participants who reported eating whitefish, had on average 28% higher blood cobalt levels, and no associations were observed between whitefish or chinook for blood manganese, urinary manganese, urinary cobalt, and plasma HCB (162). Notably, Old Crow participants who reported eating whitefish had lower blood and urinary lead levels (162). In the Dehcho, the only association between traditional food intake and contaminant levels, indicated lower urinary lead levels were associated with lake trout consumption. No associations between consumption of whitefish and lake trout were observed for some previously studied contaminants including hexachlorobenzene, cobalt, manganese, and lead among the Dehcho and Sahtú communities (162). Notably, results of pooled participating communities reported

consumption of whitefish associated with lower urinary lead levels. Further, consuming lake trout explained elevated mercury hair exposure levels in the NWT and Yukon projects, whereas consuming grayling explained elevated blood mercury concentrations (162,201). Clearly, some patterns among fish consumption and contaminant levels are revealing themselves and perhaps, a Principal Components Analysis of contaminant data would be useful to further understand the role that multiple contaminants may have in relation to traditional food intake. As well, region-specific, and pooled results show different patterns, suggesting regional-specific sources may be influencing exposure levels.

Previous studies have identified levels of PCBs in some fish species and their eggs, including lake trout, northern pike and walleye (i.e., fish types eaten in the Dehcho, Sahtú and Old Crow) in northern parts of Alberta, Saskatchewan and British Columbia, Yukon and Quebec (92,202–204). However, PCB levels may vary with fish species. For example, high trophic fish may show higher PCB exposure levels because PCBs are able to bio-magnify within food chains (90). Also, bottom-feeder fish may have higher PCB levels as they are more likely to be exposed from sediments containing PCBs (89). Lipid-rich fish may also contain higher concentration levels as PCBs are lipophilic (205). PCB concentrations (13.85 ± 718 to 23.20 ± 15.34 ng/g lipid wet weight) have been reported in lake trout from Great Slave Lake in the Northwest Territories (26). However, size and age are also correlated with higher PCB levels, indicating size and age of fish may predict tissue concentrations of PCBs in fish exposure (206). As well, preparation of food consumed is notable, as previous literature has stated that cooking methods and preparation may affect contaminant exposure levels in foods (207).

Several papers have described an association between eating fish and PCB exposures (83,85,86,92). Notably, data collected from the First Nations Food and Nutrition Survey indicated lake trout as one of the top ten contributors to PCB intake in those who consumed traditional foods in southern regions of Canada (92). Specifically, mean intake of PCBs from lake trout was 3.96 (2.58–5.35) ng/day (92). Although dietary intake models describing contaminant intake have been developed for methylmercury and hexachlorobenzene for participating communities of the Northwest Territories and Yukon, to date these models have not been adapted according to the concentrations of PCBs in wild-harvested foods.

5.2.2 Large Game Meat and Organs

When pooling results across participating communities, large game meat (i.e., those who ate the meat of woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear) and organs (i.e., those who ate liver, kidney, bones in soup, bone marrow, fat from woodland caribou, barren land

caribou, bison, moose, white-tailed deer, and/or bear) were not associated with higher PCB concentration levels among study participants (Table 4.21). This same observation (i.e., no association between PCB biomarkers and the meat or organs of large game) was also seen when results were stratified by region (Supplemental Tables 2-4).

Limited literature exists among other targeted northern Canadian biomonitoring projects that explore links between consumption of large game meat recorded through FFQs and PCB exposure levels. However, one study conducted in northern Quebec, using FFQ data and food sample contaminant data reported a low risk of exposure to large game meat including bear (*Ursus americanus*) and caribou (*Rangifer tarandus*) and moose (*Alces alces*) (204). Of note, other researchers working on these NWT and Yukon projects discovered associations between several other contaminant levels and large game consumption. For example, in Old Crow, caribou kidneys, moose bones in soup or stew and caribou kidneys were 22%, 86% and 58% average higher in blood manganese, urinary manganese and blood lead levels, respectively. In the Dehcho and Sahtú, moose and caribou organ consumption were also associated with increased levels of HCB. Only in the Sahtú, was caribou bone marrow consumption associated with increased levels of urinary lead levels whereas caribou organ consumption was associated with lower levels of urinary manganese. In pooled participating communities, consumption of several large game meats was associated with increased contaminant exposure. Specifically, moose and caribou organs were associated with higher plasma HCB levels, urinary lead levels and blood lead levels. In contrast, some large game organs were associated with lower urinary manganese concentrations. With respect to mercury exposure levels, consumption of select large game meats were not used in a final model to explain hair or mercury exposure levels(162,201). Typically, exposure studies aim to use FFQ data in combination with measured contaminant levels in foods to model estimated dietary intakes, Initial links between contaminant exposure levels and key large game meat have been identified and may be used to help explain potential sources of PCB exposure levels for future studies, as exposures sources may be similar among contaminants. However, future studies are required to complete estimated dietary intakes for PCBs among participating regions.

Findings from this thesis are consistent with a 2021 study reporting fish and waterfowl as main contributors of PCB intake in First Nation communities in southern communities in Canada, as opposed to bear or other large game meat (92). Levels of PCBs have been reported in traditional foods from large game species. For example, a 2016 study measured organic pollutants in moose liver from the Northwest Territories and reported PCB levels, ranging from 0.39-0.65 ng/g wet weight (32). As well,

samples collected from First Nations communities reported an average of 12.85 ng/g in black bear fat (92). In northern Quebec, concentrations of PCBs ranged from 0.0002- 0.0006 mg/kg in bear samples (204). Interestingly, large game meat was reported as frequently consumed in each of the study regions, suggesting although some foods may be commonly eaten within communities, they do not appear to be significantly associated with PCB exposure. Gathering site-specific, species-specific, and relatively recent levels of PCBs in large game meat would allow the creation of estimated intake rates of PCB exposures.

5.2.3 Game Birds

The pooled multiple linear regression models showed an association with increased PCB concentrations among study participants who ate fish-eating birds (i.e., those who ate the meat of black duck, fish duck, long-tailed duck, pintail, swan, canvasback, white-winged scoter and/or mallard) and game birds (i.e., those who ate spruce grouse, sharp-tailed grouse, ptarmigan, black duck, mallard, fish duck, oldsquaw [long-tailed duck], wigeon, speckle belly goose, canvasback, Canada goose, snow goose, pintail, white-winged scoter and/or swan) (Table 4.21). Also, when stratified by regions, Dehcho participants who reported eating fish-eating birds indicated increased PCB exposure levels, whereas in the Sahtú and Old Crow, no associations were observed (Supplemental Tables 2-4). Consumption of waterfowl as a source of PCB exposure has been reported in other studies in Arctic and subarctic regions in Canada and outside of Canada. For example, in Greenland, consumption of birds as monthly meal frequencies was positively correlated ($\rho=0.16$, $p<0.05$) with Arochlor 1260 and $\sum\text{PCB}_{14}$ ⁵ blood concentrations (208). In the Canadian Arctic, total traditional food consumption (including birds) was associated with higher levels of PCBs (PCB118, PCB138, PCB153, PCB180) in Inuvik-Inuit and Inuvik-Dene/Metis mothers (35). Among other studies conducted within the research team for the NWT and Yukon projects, researchers noted in the Sahtú, consumption of birds were associated with plasma HCB levels. As well, waterfowl was identified as a key variable in a model explaining sources of hair and blood mercury exposure levels (162). These results indicate that birds may be a common source of contaminant exposure among the study regions.

Literature reports historical concentrations of select PCBs in aquatic seabirds in the Canadian Arctic (209). Another study quantified PCBs in waterfowl across Canada from the years 1988-1995 and

⁵ PCB28, PCB 52, PCB99, PCB101, PCB105, PCB118, PCB128, PCB138, PCB153, PCB156, PCB170, PCB180, PCB183, PCB187

reported PCB levels in several species across regions in Canada, including the NWT and Yukon. For example, the median value of PCBs in long-tailed duck was 0.053 mgkg⁻¹ wet weight (210). Organochlorine levels including PCBs were reported in ducks from Indigenous communities in northern Quebec with mean levels ranging from 0.005 mg/kg in PCB194 to 0.5 mg/kg in PCB153 (204). In fact, ducks from these northern Quebec Indigenous communities had highest organochlorine levels among all traditional foods included in the study. Waterfowl were also listed as traditional foods with highest levels of PCBs including duck meat and ptarmigan meat among First Nation communities in southern Canada (92).

A recent study conducted in subarctic Canada identified an association between consuming goose and higher risk of exposure ($R_{95} > 1.00 \times 10^{-6}$) to PCB153 for men, and consuming duck with a higher risk of exposure for boys, men and women (204). In southern parts of Canada, duck meat (5.34 ng/day, 95% CI 2.29–8.39) and ptarmigan meat (6.23 ng/day 95% CI ND–13.05) were among the top ten traditional foods contributing to PCB intake (92). Among the participating study regions, birds were grouped together based on whether they were known as hunting birds or birds that eat fish. However, not all bird species will contain similar amounts of PCBs, as some species may be fattier or have more biomagnified PCBs in them based on their diets. Thus, it would be useful to know the species-specific levels of PCBs among the study regions and other species-related information of these birds. For example, history of the bird (e.g., age, size, dietary profile, region where species are located) is an important factor to remember when reporting a food as a source of PCB. As well, how much traditional food (i.e., bird) that is consumed plays a key role in assessing risk between diet and contaminant concentrations.

5.3 Limitations

5.3.1 Sample Size

The participating communities are all remote northern regions in Canada, and such remote regions, are generally known to have limitations surrounding identifying epidemiological trends and patterns because of small sample size (211). Due to small sample size among the regions, some associations may not have been detected when analyzing regional-specific statistical determinants of PCB biomarker data. To address this limitation, FFQ and biomarker data was pooled across regions, as previously reported for methylmercury, HCB, manganese, cobalt, and lead (162,201). That being said, the regional-specific multiple linear regression models results (described in Supplementary Tables 2-4)

offer insights on potential differences in exposure pathways among regions. Further, northern partners have expressed a preference for region-specific communications. For example, each region has asked for one-page summaries of findings and key messages and recommendations. Thus, stratifying multiple linear regression models results by region enables the creation of region-specific communication products as well as presents hypotheses regarding potential regional differences in PCB exposures that can be further characterized through environmental monitoring projects in participating regions.

5.3.2 Detection Limits

An LOD is the lowest detectable value that can be measured during laboratory analysis of samples (212). It is common in environmental monitoring and human biomonitoring data to have samples below the detection limit (<LOD). Several methods have been proposed for handling nondetectable data (Supplemental Table 1). For instance, for samples <LOD, sometimes using maximum likelihood estimates are used (213). Imputing samples with <LOD of $\frac{1}{2}$ LOD was a limitation of this study. For example, over reporting or under reporting of PCB concentrations can occur and may bring uncertainty to the study. In general, there is no universal standard for handling non-detectable biomonitoring data. This methodological decision was chosen to maintain consistency in estimates generated in previous paper and reports for this project. Further, using this method helps in maintaining the comparability of data to biomarker data generated in several key reference studies and populations. However, other methodological decisions would also aid in consistency between studies including reporting the percentage of non-detectable data, determining whether the LOD varies during the study, or between reference studies (57,108).

5.3.3 Study Design

Cross-sectional studies cannot establish a causal relationship. For example, since blood samples and traditional food intake were collected at the same time, the timeline of the onset of those variables cannot be established. Thus, this study cannot claim that any of these selected demographic, lifestyle and dietary variables cause participants to have observed PCB exposure levels. However, relationships and associations between independent (e.g., consumption of traditional food) and dependent variables (e.g., PCB exposure levels) offer directions for environmental sampling projects and source apportionment models that better test hypotheses on the contribution of specific foods to PCB exposure in the Northwest Territories and Yukon.

5.3.4 Interpretation of PCB Biomonitoring Data

It is important to note that levels presented in this paper cannot be directly compared against any health-based guidance values. Such guidelines exist for other contaminants including lead and mercury, as extensive epidemiological and toxicological information exists for certain contaminants (214,215). However, following the retraction of Arochlor 1260 health-based guidance values, no health-based guidance values are available from Canadian health authorities for PCBs. To mitigate against this limitation, comparisons were made to levels observed from the general Canadian population, and from other First Nations populations. Specifically, levels observed among the participating regions were compared to GMs and 95th percentiles from the CHMS, and GMs from the FNBI.

5.3.5 FFQ Data Gaps

Using food questionnaires to collect dietary information has some limitations. Some information bias may be present, as this is a self-reported questionnaire. As well, evidence suggests that overestimation may be present, as the FFQ included reporting eating of over 30 different fish species and preparation methods (216). Several steps were taken to mitigate these limitations. First, the FFQ used in this study were developed based on previously created FFQs from the Centre for Indigenous Peoples' Nutrition and Environment and on local knowledge of traditional food. Next, only those species that were frequently consumed were used in the multiple linear regression models model to help address overestimation. As well, FFQs are an established tool used when exploring relationships between an outcome and dietary exposure, especially when identifying persistent pollutant (i.e., contaminants that remain in the human body over a long period of time) exposures. Further, using binary coded FFQ data limited the knowledge of the roles that amount of food and food portion size had in PCB exposure levels. However, this methodological decision was chosen as it helped mitigate issues surrounding small sample size. Using binary data allowed for more participant data to be included in the regression models.

5.3.6 Recruitment

This study allowed all those members of the community to participate under the terms of the CRA, meaning those who wished to participate were welcome to. Thus, results may not be representative of the community and some selection bias may be present. To mitigate this limitation, census data was collected and reported to assess the representativeness of the sample data among the study regions and these differences among the demographics of the study were noted. Part of this difference occurred

because children under the age of five or six were excluded from the study, and among several participating communities, youth attend high school in neighboring communities, therefore they were not present in the community at the time sample collection occurred. An opt-in framework was useful in that it was an agreed upon framework among the communities and provided, perhaps, a higher participation rate for the entire human biomonitoring project.

5.3.7 Multiple Linear Regression Models

The multiple linear regression models has some data gaps. First, variation in the model (i.e., r^2) is not reported, thus, some variation might be present along with residual confounding. However, co-variables (i.e., age and sex) were included in the model to account for some variation. $\sum \text{PCB}_{138,153,180}$ was used as the dependent variable in the models, as these congeners followed the main patterns identified previously. For example, increasing age was strongly associated with level of PCB exposure, male participants showed higher PCB levels in these congeners in the Dehcho region, and these congener exposure levels also differed between the study regions. Future linear regression models could include dioxin-like PCB congeners that were not reported within this thesis. Further, using those congeners that appeared outside of the normal range for those over the age of 60, (e.g., Arochlor 1260, PCB146, PCB153, PCB163, PCB170, PCB178, PCB180, PCB183, PCB187, PCB194, PCB201, PCB203), as the dependent variable in multiple linear regression models may determine if consuming traditional foods was associated with elevated levels. As well, this PCB measure is commonly used in literature, and levels of PCB153 and PCB180 were higher in this study compared to the CHMS in select areas and for select populations (i.e., in older participants in the Sahtú region). Previous studies conducted within this research groups used similar models to explore associations between contaminants and traditional food intake, suggesting these models are an adequate first step in determining these associations.

5.4 Conclusion Summary and Implications

These results provide baseline PCB levels in residents from the Sahtú and Dehcho regions of the Northwest Territories and Old Crow, Yukon. Also, the work evaluated the extent to which dietary differences within and among regions may have contributed to varying PCB levels. As well, initial correlations and associations between concentration levels and age, sex, region, smoking status, drinking status, BMI and omega-3 fatty acid levels were also reported. Exposure levels were generally lower than or similar to the CHMS and the FNBI, with the exception of select congeners (e.g., Arochlor

1260, PCB146, PCB153, PCB163, PCB170, PCB178, PCB180, PCB183, PCB187, PCB194, PCB201, PCB203) in older participants in the Sahtú region. As well, some traditional foods were associated with higher PCB levels after accounting for age and sex in the multiple linear regression models. Unlike patterns that have been observed for manganese in caribou organs, and lead in whitefish, lake trout and wild berries, (162), no traditional foods were significantly associated with lower PCB exposure levels. Notably, traditional food consumption patterns also varied between the regions in the NWT and Yukon. These results provide important information related to dietary exposure assessments that may explain sources of PCB exposure in northern Canada. However, traditional foods are also very important in communities for a multitude of reasons, including their nutritional benefits, maintaining sustenance, food security and culturally significant activities. Some public health implications that could come from these results surround the messaging of eating traditional foods. Regional health authorities could use these results to prioritize key messages relayed to communities. For example, exposure levels were observed outside of the normal range for only those older than 60 and certain foods were only associated with PCB levels in certain regions (e.g., waterfowl in the Dehcho region). Importantly, to strengthen messaging, the benefits of traditional foods should also be highlighted. To do this, more work should be completed that examines the nutrient (e.g., omega-3 fatty acids, vitamins) and other benefits (e.g., well-being, food security) of these traditional foods.

6. Conclusions

This thesis involved participants from Indigenous communities of the Sahtú, Decho and Old Crow regions in Canada. In the Northwest Territories, the Sahtú and Decho regions are home to Dene, Metis and Inuit Indigenous communities, each with their own rich cultural heritage and connection to the land. These regions are characterized by natural landscapes, including vast boreal forests, rugged mountains, and pristine lakes and rivers. Similarly, the community of Old Crow in the Yukon is an Indigenous community with a deep connection to the land and its traditional ways of life. Located in the northern Yukon, Old Crow is surrounded by stunning wilderness areas, including the vast Arctic tundra and the Porcupine River watershed. Understanding and valuing the unique place-based characteristics of these regions and communities is beneficial to better appreciate their importance, protect their natural and cultural heritage, and work together to meet the needs of community members.

This thesis compliments other human biomonitoring research related to contaminant and nutrient exposure levels conducted in the Sahtú, Decho and Old Crow regions of the Northwest Territories and Yukon. Fostering partnerships and initial data collection for the Yukon and NWT biomonitoring projects began in 2016 and since then, several findings have been distributed back to participating communities and to the research community. In June of 2023, findings from this thesis were shared with the community of Fort Good Hope and Tulita. Return of results to other communities are underway and/or planned. From these community forums we heard feedback from elders, guardians, and community members. Specifically, this research focused on a quantitative analysis of one contaminant (i.e., PCB exposure levels) in the NWT and Yukon study regions and its potential determinants and sources.

Several data gaps related to contaminant exposures in the western Arctic and subarctic regions of Canada existed prior to this thesis:

1. There was a lack of comprehensive biomonitoring data in the study regions for some contaminants, including PCBs, which made it challenging to assess the extent of exposure to these contaminants among Indigenous communities.
2. Information gaps existed on the key roles those international initiatives had in reducing and monitoring PCB transport and fate, and trends of PCB exposures in northern Canadian regions.
3. Before this research, little was known about the demographic differences of PCB exposures among the study regions.

4. Some gaps remained regarding the extent to which traditional foods were considered a significant source of PCB exposure.

This thesis has filled some of those gaps and provides important information to knowledge users including public health professionals, researchers, and local community members. For instance, this work reports baseline PCB exposure levels in residents of northern Indigenous communities and reporting these levels is a first step for researchers in determining trends of contaminant exposure levels in northern regions. Results may be used in national reports related to contaminant monitoring in Canada. Public health professionals or decision-makers may use these documented levels as a resource to identify if international initiatives banning production and use of chemicals are working. Importantly, this data aids in leading an investigation of whether interventions are being equitably distributed throughout the country in hopes of addressing the environmental injustice that Arctic communities face. While providing knowledge towards global initiatives, the biomonitoring projects established in the Dehcho, Sahtú and Old Crow may also pave pathways related to contaminant surveillance for small-scale, local, community-driven research. Further, understanding the determinants (e.g., sex, age, and geographic location) of PCB exposure levels can help prioritize public health interventions (e.g., exposure guidelines, educational materials) for better knowledge translation to specific demographics. Next, understanding the sources of PCB exposure (e.g., traditional food intake) can help prioritize sampling efforts related to environmental PCB exposures. For example, environmental scientists may use this information to set local fish or biota monitoring efforts targeting regions or areas (e.g., the Sahtú region) where PCB exposure levels were found to be higher compared to other study regions. Moreover, these results provide foundational work for research in future dietary sampling efforts related to traditional food intake and contaminant exposure. For example, these results can be used as a good starting point in identifying priority foods (e.g., lake trout and waterfowl) to use to create estimated daily intake rates if ever risk-communications strategies were needed. Long-term positives that may come from the research presented in this thesis include discussions on how to present risk-related information and knowledge translation. Policy makers and other organizational stakeholders may use these data to develop policy measures to reduce PCB exposure while also promoting healthy diets.

Key Findings and Contributions

Reporting PCB exposure levels based on relevant demographic, biological and lifestyle variables resulted in a deeper understanding of the patterns related to PCB exposure levels. Results showed the

Sahtú region had highest exposure levels and Old Crow had the lowest. Results also showed men had higher exposure levels compared to women participants in the Dehcho region, and older participants had PCB exposures that were higher compared to younger participants. Next, results showed omega-3 fatty acids were positively correlated with PCB exposure levels in the Sahtú and Dehcho regions. Further, results showed that BMI was positively associated with PCB exposure levels in the Sahtú region and Old Crow. Next, in Old Crow, smoking was associated with higher PCB exposure levels, whereas in the Dehcho and Sahtú regions, not smoking was associated with higher PCB exposure levels. So now it is known that age, sex, region omega-3 fatty acid level, BMI and smoking status may determine one's PCB exposure levels. Notably, results showed different patterns among the regions and among each PCB congener.

Importantly, these exposure levels were compared to national exposure levels collected from the general Canadian population and other Indigenous populations within Canada. Levels were notably lower in the youngest age category for all PCB congeners, compared to both the CHMS levels and the FNBI levels. In the oldest age groups, levels were mostly similar to national biomonitoring levels with a few exceptions for individual congeners that had elevated levels. These exposure data also show that PCBs remain a declining contaminant after their ban, suggesting that international initiative to ban the use and production of PCBs may be working, and importantly, are working for northern Indigenous populations who are likely more disproportionately exposed to persistent and transportive contaminants.

This thesis incorporated results based off FFQ data, which was collected at the same time as plasma samples for PCB exposure levels analysis. Regression models were built for each of the three regions, as well as a pooled analysis including each of the regions. Consumption profiles were different for each food and food grouping as well as between the regions. Each of the multiple linear regression models included age and sex as co-variables. Results showed some traditional foods were associated with higher PCB exposure levels including lake trout, aquatic birds, and game birds. Notably, no foods were associated with lower PCB exposure levels, however, for several foods no associations were found, and the strength of beta estimates varied between each of the models.

This thesis provides a better understanding of exposure status in Indigenous communities in northern Canada. Within this document, initial lipid-adjusted levels in the participating regions are presented along with a deeper understanding of the demographic, lifestyle and dietary factors contributing to PCB exposure. Overall, these results incorporate another layer of understanding of how and why these

forever chemicals are found in human exposure levels in Arctic and subarctic environments. Importantly, these results add to the importance of regional specific biomonitoring, as levels can vary among arctic and subarctic regions.

Future Work

Since it is known now that the selected variables are associated with PCB exposure levels, future work should explain the extent to which each variable plays a role in PCB exposure levels. For example, perhaps multiple models that incorporate each of these variables may help explain the variation observed among the study regions. Future work could implore more advanced models exploring potential interactions between variables such as lifestyle (e.g., moving to the arctic or away from the arctic) or demographic factors, other contaminant concentration levels, and other exposure determinants including diet. It is useful to highlight high-level results, but it is also important to report levels with co-variables because otherwise certain trends or patterns might be masked. Other possible work could include modelling to explore variations in food consumption, for example, amount of each traditional food consumed in relation to exposure levels. Further research is needed to understand the long-term effects of exposure to these contaminants, particularly among vulnerable populations, such as Indigenous communities.

As previously mentioned, community forums were held to listen to participating community feedback surrounding these human biomonitoring projects. During these conversations, interest in follow-up studies to explore trends of contaminants in the study regions were shared. To understand region-specific temporal trends of PCB exposure, follow-up including long-term human biomonitoring studies (e.g., additional collection of biological samples through the years) in each of the participating regions would be required. As well, important questions regarding the effects that climate change has on contaminant concentrations were also shared. Further work could collect region-specific biomarker levels in fish and birds as well as environmental media to come to conclusions around why these exposure level patterns are being observed. Joint work should be completed to understand which parameters are playing a bigger role.

Localized and recent efforts to collect PCB levels in fish or birds of similar size, age, and lipid content as well as other foods from each of the study regions would aid in the understanding of these exposure level differences observed between the regions. Notably, future work showing the contribution to nutrient intake could help in understanding the benefits associated with traditional foods. Furthermore,

dietary exposure assessments are complex and require further work to establish stronger associations as well as identify other factors related to sources of PCB exposure including variability of traditional foods with respect to amount of food consumed, thus, other models should be developed that encompass the complex nature of diet and contaminant exposure.

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Appendices

Appendix A: Supplemental Tables

Supplemental Table 1. Select previous biomonitoring studies with varying approaches for handling biomarker concentrations below the detection limit.

Citation	Biomonitoring Study	Method used for Samples <LOD	Chemicals
Saravanabhavan G. et al., 2017	CHMS	½ LOD	Metals and trace elements
Aker et al., 2022	2017 Nunavik Inuit Health Survey	½ LOD	Plasticizers and plastic constituents
Alampi JD., 2021	MIREC	LOD/√2	Various toxicants (e.g., metals, organochlorine pesticides, PCBs)
England-Mason G. et al., 2022	Alberta Pregnancy Outcomes and Nutrition	LOD/√2	Phthalate metabolites
Arbuckle et al., 2016	CHMS	½ LOD	Bisphenol A, phthalates and lead
Rawn DFK., et al., 2012	CHMS	LOD/√2	PCDD/F and PCB
Beckingham BA., et al., 2022	NHANES	LOD/√2	Phthalates
Bernardo BS., et al., 2019	MIREC	“fill-in” approach	PCBs
Curren MS., et al., 2014	Inuvik Region (NWT) and Baffin Region (Nunavut) and southern Canada	Only POPs above LOD were included	POPs and metals
Curren MS., et al., 2015	Inuvik Region (NWT) and Baffin Region (Nunavut)	½ LOD	POPs and metals
Drysdale M. et al.,	Old Crow, Yukon	½ LOD	Various contaminants

Supplemental Table 2: Multiple Linear Regression Model outputs for PCB concentrations for Traditional food consumption, Controlling for Age and Sex in the Dehcho region.

Dehcho n=79					
		PCB138+153+180 Parameter Estimate (beta)	Std. Error	95% CI	p-level
Fish	Whitefish	0.013	0.1332	(-0.248, 0.274)	0.924
	Inconnu	0.048	0.0798	(-0.108, 0.204)	0.547
	Lake trout	-0.015	0.0668	(-0.146, 0.116)	0.824
	Northern Pike	0.192*	0.0616	(0.071, 0.313)	0.002
	Walleye	0.039	0.0656	(-0.09, 0.167)	0.552
	Chinook	-	-	-	-
Fish Eggs (total)		0.231*	0.0701	(0.093, 0.368)	<.001
¹ Large Game Animals		-0.274	0.206	(-0.677, 0.13)	0.184
² Large Game Animal Organs		0.178*	0.0653	(0.05, 0.306)	0.006
³ Aquatic Birds		0.155*	0.0692	(0.02, 0.291)	0.025
⁴ Game Birds		0.141	0.0753	(-0.007, 0.288)	0.062

* p-value<0.05 and considered significant.

¹Large Game Meat include those who ate the meat of woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

²Large game organs include those who ate the organs (liver, kidney, bones in soup, bone marrow, fat) from woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

³Fish eating birds include those who ate the meat of black duck, fish duck, long-tailed duck, pintail, swan, canvasback, white-winged scoter, mallard.

⁴Game birds include those who ate spruce grouse, sharp-tailed grouse, ptarmigan, black duck, mallard, fish duck, oldsquaw (long-tailed duck), wigeon, speckle belly goose, canvasback, Canada goose, snow goose, pintail, white-winged scoter, swan.

Among the participating regions, the most associations were found in the Dehcho region multiple linear regression models between PCB concentrations and traditional food intake. Specifically, among the traditional foods that were included in this multiple linear regression models, controlling for age and sex, of the fish, northern pike was associated with increased PCB exposure levels of Log Σ PCB_{138, 153, 180} as well as other foods including fish eggs, large game animal organs and aquatic birds. Specifically, the magnitude in increase of Log Σ PCB_{138, 153, 180} for every increase in traditional food intake varied across species and ranged from 0.155 (aquatic birds) to 0.231 (fish eggs). No negative beta coefficients were considered significant. Food consumption patterns were generally similar between regions and PCB concentrations varied across regions. For example, consumption patterns in each food were similar across regions for the majority of foods excluding walleye, northern pike and lake trout. PCB concentrations in the Dehcho region generally fell in between the Sahtú region and Old Crow concentrations.

Supplemental Table 3: Multiple Linear Regression Model outputs for PCB concentrations for Traditional food consumption, Controlling for Age and Sex in the community of Old Crow.

Old Crow n=51		PCB138+153+180			
		Parameter Estimate (beta)	Std. Error	95% CI	p- level
Fish	Whitefish	0.062	0.1083	(-0.151, 0.274)	0.569
	Inconnu	0.001	0.0942	(-0.184, 0.186)	0.993
	Lake trout	-0.089	0.0983	(-0.281, 0.104)	0.368
	Northern Pike	-0.107	0.1357	(-0.373, 0.159)	0.429
	Walleye	-	-	-	-
	Chinook	-0.017	0.1267	(-0.266, 0.231)	0.891
Fish Eggs (total)		0.125	0.0784	(-0.029, 0.279)	0.111
¹ Large Game Animals		NA	NA	NA	NA
² Large Game Animal Organs		-0.042	0.0963	(-0.231, 0.147)	0.663
³ Fish Eating Birds (aquatic birds)		0.047	0.0794	(-0.066, 0.245)	0.575
⁴ Game Birds		0.035	0.081	(-0.124, 0.194)	0.663

NA = Parameter estimate not available because it is redundant (i.e., 100% consumption of large game animals).
-food was not on the FFQ in this region/community.

¹Large Game Meat include those who ate the meat of woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

²Large game organs include those who ate the organs (liver, kidney, bones in soup, bone marrow, fat) from woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

³Fish eating birds include those who ate the meat of black duck, fish duck, long-tailed duck, pintail, swan, canvasback, white-winged scoter, mallard.

⁴Game birds include those who ate spruce grouse, sharp-tailed grouse, ptarmigan, black duck, mallard, fish duck, oldsquaw (long-tailed duck), wigeon, speckle belly goose, canvasback, Canada goose, snow goose, pintail, white-winged scoter, swan.

In the community of Old Crow, among the foods included in the analysis for this study, no significant associations were observed between PCB exposure levels and traditional food consumption. When looking at PCB exposure levels and food consumption patterns, Old Crow PCB concentrations were lowest compared to the Dehcho and Sahtú regions (based on 95% CI), and food consumption patterns were similar between regions for most foods, excluding select fish species (e.g., walleye, northern pike, and lake trout).

Supplemental Table 4: Multiple Linear Regression Model Output for PCB Concentrations for Traditional Food Consumption, Controlling for Age and Sex in the Sahtú region.

Sahtú n=55					
		PCB138+153+180 Parameter Estimate (beta)	Std. Error	95% CI	p-level
Fish	Whitefish	-0.121	0.0966	(-0.31, 0.068)	0.21
	Inconnu	-0.08	0.0903	(-0.257, 0.097)	0.375
	Lake trout	0.099	0.1012	(-0.1, 0.297)	0.329
	Northern Pike	-0.186	0.1036	(-0.389, 0.017)	0.073
	Walleye	-0.27	0.1709	(-0.605, 0.065)	0.115
	Chinook	-	-	-	-
Fish Eggs (total)		0.018	0.0842	(-0.147, 0.183)	0.831
¹ Large Game Animals		-0.248	0.3026	(-0.841, 0.345)	0.413
² Large Game Animal Organs		0.145	0.0788	(-0.009, 0.3)	0.065
³ Fish Eating Birds (aquatic birds)		0.146	0.0818	(-0.005, 0.315)	0.063
⁴ Game Birds		0.139	0.086	(-0.03, 0.308)	0.106

-foods were not consumed in this region/community and were excluded from the analysis.

¹Large Game Meat include those who ate the meat of woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

²Large game organs include those who ate the organs (liver, kidney, bones in soup, bone marrow, fat) from woodland caribou, barren land caribou, bison, moose, white-tailed deer, and/or bear.

³Fish eating birds include those who ate the meat of black duck, fish duck, long-tailed duck, pintail, swan, canvasback, white-winged scoter, mallard.

⁴Game birds include those who ate spruce grouse, sharp-tailed grouse, ptarmigan, black duck, mallard, fish duck, oldsquaw (long-tailed duck), wigeon, speckle belly goose, canvasback, Canada goose, snow goose, pintail, white-winged scoter, swan.

When looking at the Sahtú region, no significant associations were observed between PCB exposure levels and traditional food consumption in the Sahtú region for foods included in the multiple linear regression models. The relationship between exposure levels and food consumption among the regions show PCB levels were generally highest in the Sahtú region compared to the Dehcho region and Old Crow (based on 95% CI), whereas food consumption patterns within foods were generally similar between the regions, except for select fish species. (e.g., walleye, northern pike and lake trout).

Supplemental Table 5. GM Concentrations of PCB138, PCB153 and PCB180 (µg/kg lipids) among all Northern Communities

Region	Demographic (Sample size)	PCB138	PCB153	PCB180	ΣPCBs
Dehcho, NWT, 2017	Adults (n=112)	4.96 (3.98 -6.16)	11.6 (9.15 -14.92)	10.11 (7.82 -13.26)	122.34 (107.29- 140.26)
Old Crow, Yukon, 2019	Adults (n=54)	3.18 (2.45 -4.18)	6.37 (4.78 -8.43)	4.4 (3.25 -5.86)	145.35 (134.9-158.60)
Sahtú, NWT, 2017	Adults (n=111)	8.29 (6.7 -10.4)	21.12 (16.97 -26.82)	12.07 (9.16 -15.87)	163.55 (141.48-189.57)
Inuvialuit Settlement Region (Inuvik), 2007- 2008 (AMAP, 2015)	Adult Inuit men (n=92)	69 (0.9–855)	148 (1.9–2730)	70 (2.2–1346)	NA
	Adult Inuit women (n=187)	30 (0.8–445)	62 (0.8–4408)	26 (0.8–3040)	NA
Nunavut, 2007-2008 (AMAP, 2015)	Adult Inuit men (n=650)	69 (0.7–1273)	195 (0.7–5747)	109 (0.8–4766)	NA
	Adult women (n= 977)	43 (0.8–1985)	106 (0.8–6181)	51 (0.9–4765)	NA
Baffin Region, Nunavut, 2005-2007 (AMAP,2009)	Inuit mothers (n=99)	NA	42 (6.2-276)	NA	NA
Nunavik (Quebec), 2004 (AMAP, 2015)	Adult men (n=408)	77 (3.0–1400)	190 (6.3–3400)	110 (6.2–1900)	NA
Nunavik (Quebec), 2004 (AMAP, 2015, Dallare et al., 2009))	Adult Inuit	78.03 (71.41–85.26)	180.06 (163.71–198.06)	93.28 (84.53–102.93)	635.98 (579.33–698.18)
	Adult Inuit women (n=506)	73 (3.7–2500)	160 (5.7–5800)	75 (3.3–3500)	NA
Nunavik (Quebec), 2017 (AMAP, 2021)	Adult Inuit men (n=251)	29 (6.4-200)	70 (16-660)	40 (6.9-470)	NA
	Adult Inuit women (n=249)	29 (6.0-240)	62 (12-570)	28 (4.9-350)	NA
	Pregnant Inuit women (n=97)	14 (1.3- 91)	30 (3.1-190)	13 (1.8-100)	NA
Nunatsiavut (Labrador) (AMAP, 2015)	Adult Inuit men (n=98)	39 (0.7–672)	112 (1.3–1622)	94 (0.7–927)	NA

	Adult Inuit women	24 (1.0–436)	61 (2.2–1291)	44 (1.1–904)	NA
Alaska, US, St Lawrence Island (AMAP, 2021)	Adult Men (n=31)	NA	NA	NA	702 (138-1604)
	Adult women (n=40)	NA	NA	NA	460 (124-1565)

NA: Not available from the original sources

Supplemental Table 6. GM Concentrations of PCB138, PCB153 and PCB180 (µg/L lipids) among all Northern Communities

Region	Demographic (sample size)	Arochlor 1260	PCB118	PCB138	PCB153	PCB170	PCB180	PCB187
Dehcho, NWT, 2017	>6 yrs (n=135)	0.42 (0.33- 0.53)	<LOD	0.025 (0.02- 0.03)	0.055 (0.04- 0.07)	0.018 (0.014- 0.022)	0.047 (0.035- 0.062)	0.019 (0.015- 0.024)
Old Crow, Yukon, 2019	>4 yrs (n=56)	0.34 (0.27- 0.48)	<LOD	0.026 (0.022- 0.033)	0.048 (0.037- 0.063)	0.017 (.014- 0.020)	0.036 (0.028- 0.048)	.018 (0.015- 0.022)
Sahtú, NWT, 2017	>4 yrs (n=136)	0.80 (0.62- 1.016)	0.019 (0.016- 0.023)	0.045 (0.035- 0.056)	0.11 (0.087- 0.14)	0.024 (0.019- 0.03)	0.066 (0.049- 0.087)	0.033 (0.026- 0.042)
James Bay Cree, Mistissini 2005-2009	>14 yrs (n=189)	5.57	0.12	0.31	0.76	0.16	0.56	0.21
James Bay Cree, Wemindji, 2005-2009	>14 yrs (n=142)	4.51	0.10	0.27	0.63	0.15	0.51	0.19
James Bay Cree, Eastmain, 2005-2009	>14 yrs (n=111)	1.92	0.05	0.12	0.24	0.07	0.19	0.08
James Bay Cree, Waskaganish, 2005- 2009	>14 yrs (n= 109)	0.76	0.03	0.05	0.09	0.03	0.08	0.04
James Bay Cree, Chisasibi, 2005-2009	>14 yrs (n=183- 184)	3.64	0.08	0.21	0.49	0.12	0.37	0.15
James Bay Cree, Whapmagoostui, 2005- 2009	>14 yrs (n=108)	4.02	0.09	0.24	0.53	0.14	0.42	0.17
James Bay Cree, Waswanipi, 2005-2009	>14 yrs (n= 103)	1.89	0.06	0.12	0.24	0.07	0.19	0.09

James Bay Cree, Oujé-Bougoumou, 2005-2009	>14 yrs (n=169)	6.62	0.16	0.38	0.89	0.20	0.61	0.26
James Bay Cree, Nemaska, 2005-2009	>14 yrs (n=71)	2.78	0.06	0.16	0.38	0.09	0.25	0.11

Appendix B: Plain Language and Visual Summaries



April 2023



Factors Linked with PCB Biomonitoring Results in the Dehcho Region, NWT

THE PROJECT

Human biomonitoring studies were held in Old Crow, Yukon as well as communities in the Sahtú and Dehcho regions, Northwest Territories in 2016-2020. Levels of a group of contaminants called PCBs and essential nutrients like omega-3 fatty acids, were measured in blood samples from volunteer participants. Participants also shared information on the traditional foods they had eaten over the previous year.

PCB LEVELS IN THE NORTHWEST TERRITORIES



Average levels of **polychlorinated biphenyls (PCBs)** were in the usual ranges seen in southern parts of Canada. For example, PCB levels for younger participants were similar if not lower than the usual range. But, other subgroups had higher than usual levels. For example, some PCB levels for older participants were between 2 and 3-times higher than usually observed in southern parts of Canada.

In the Dehcho, participants over 60 years had higher than usual levels for 2 PCBs while the other 18 PCBs measured were in the usual range. In the Sahtú, participants over 60 years had higher than usual levels for 12 of the 20 PCBs measured.



In the Dehcho, participants with elevated PCBs also had higher levels of omega-3 fatty acid levels in their blood samples. This positive link between PCBs and omega-3 fatty acids was also found in other northern regions.

What are PCBs?

PCBs are a large group of human-made industrial chemicals that were banned worldwide in 2001. PCBs can build up in fish, animals, and people as they get older. Most people are exposed to PCBs from the foods they eat.

What are omega-3 fatty acids?

Omega-3 fatty acids are a healthy type of fats that are good for heart health and brain development.

Most people in Canada don't get enough omega-3 fatty acids in their diets. Fish and seafood are rich in these healthy fats.

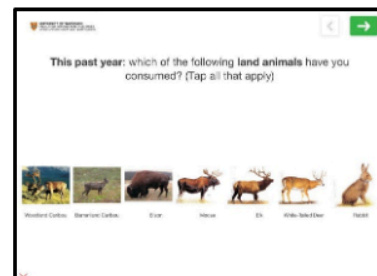
RESEARCH QUESTION:

Were differences in participant PCB levels linked with the traditional foods they reported eating over the previous year?

WHAT WAS DONE?

We compared participants' blood PCB levels with their answers to questions on which traditional foods they ate over the past year. We also compared their PCB levels to their age and sex and whether they smoked cigarettes.

These results tell us whether people who eat a certain traditional food have either higher or lower levels of PCBs than those who didn't eat that food.



KEY RESULTS AND MESSAGES



LARGE GAME: Dehcho participants who ate organs from large game, like moose or caribou, had higher levels of PCBs in blood. No links were found between PCB levels and the meat from large game. Large game meat and organs, including muscle tissue, kidneys, and liver are excellent sources of protein, iron, and other nutrients.



FISH: Dehcho participants who ate northern pike and/or fish eggs had higher PCB levels in blood. In other northern regions, there were links between eating lake trout and higher levels of PCBs in blood. Fish are excellent sources of many nutrients, including Vitamin D, and protein. Whitefish and lake trout are especially rich in omega-3 fatty acids.



Birds: Dehcho participants who ate waterfowl that eat fish, like canvasback and fish duck, had higher levels of PCBs in blood. In other northern regions, participants who ate waterfowl and/or upland game birds had higher levels of PCBs in blood. Many birds harvested in the Northwest Territories, including waterfowl, are rich in iron, omega-3 fatty acids, and other nutrients.



SMOKING: Dehcho participants who smoked cigarettes had lower levels of PCBs. But, smokers had higher levels of several other contaminants, such as lead, cadmium, and cancer-causing chemicals called PAHs. Reducing your exposure to tobacco smoke lowers your exposure to many contaminants.

The results from this study reinforce the message that the health benefits of traditional foods generally outweigh contaminant risks.

Finding links between blood PCB levels and the foods people ate cannot prove which foods contributed most to PCB exposures in the Northwest Territories. But, knowing these links can help inform community decisions on future environmental monitoring.

Combining results from the food surveys with local environmental monitoring data will help us show which foods are driving PCB exposures in the Northwest Territories and Old Crow.

For any questions or comments, please contact:

Please contact Dr. Brian Laird, University of Waterloo: brian.laird@uwaterloo.ca / 519-888-4567x42720



April 2023



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PCB LEVELS IN THE NORTHWEST TERRITORIES



Average levels of **polychlorinated biphenyls (PCBs)** were in the usual ranges seen in southern parts of Canada. For example, PCB levels for younger participants were similar if not lower than the usual range. But, other subgroups had higher than usual levels. For example, some PCB levels for older participants were between 2 and 3-times higher than usually observed in southern parts of Canada.

In the **Sahtú**, participants over 60 years had higher than usual levels for 12 of the PCBs while the other 8 PCBs measured were in the usual range. In the Dehcho, participants over 60 years had higher than usual levels for 2 of the 20 PCBs measured.



In the **Sahtú**, participants with elevated PCBs also had higher levels of omega-3 fatty acid levels in their blood samples. This positive link between PCBs and omega-3 fatty acids was also found in other northern regions.

What are PCBs?

PCBs are a large group of human-made industrial chemicals that were banned worldwide in 2001. PCBs can build up in fish, animals, and people as they get older. Most people are exposed to PCBs from the foods they eat.

What are omega-3 fatty acids?

Omega-3 fatty acids are a healthy type of fats that are good for heart health and brain development.

Most people in Canada don't get enough omega-3 fatty acids in their diets. Fish and seafood are rich in these healthy fats.

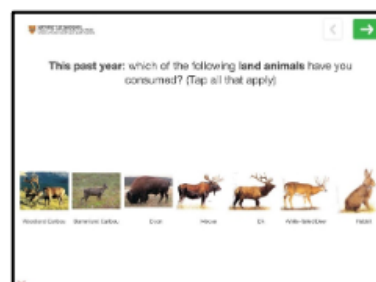
RESEARCH QUESTION:

Were differences in participant PCB levels linked with the traditional foods they reported eating over the previous year?

WHAT WAS DONE?

We compared participants' blood PCB levels with their answers to questions on which traditional foods they ate over the past year. We also compared their PCB levels to their age and sex and whether they smoked cigarettes.

These results tell us whether people who eat a certain traditional food have either higher or lower levels of PCBs than those who didn't eat that food.



KEY RESULTS AND MESSAGES



LARGE GAME: No links were found between PCB levels and the meat or organs from large game among participants from the Sahtú. Large game meat and organs, including muscle tissue, kidneys, and liver are excellent sources of protein, iron, and other nutrients.



FISH: No links were found between PCB levels and fish or fish eggs, among the Sahtú participants. In other northern regions, there were links between eating lake trout, northern pike and/or fish eggs and higher levels of PCBs in blood. Fish are excellent sources of many nutrients, including Vitamin D, and protein. Whitefish and lake trout are especially rich in omega-3 fatty acids.



Birds: There were no links between eating certain birds and higher PCB levels in blood in among Sahtú participants. In other northern regions, participants who ate waterfowl and/or upland game birds had higher levels of PCBs in blood. Many birds harvested in the Northwest Territories, including waterfowl, are rich in iron, omega-3 fatty acids, and other nutrients.



SMOKING: Sahtú participants who smoked cigarettes had lower levels of PCBs. But, smokers had higher levels of several other contaminants, such as lead, cadmium, and cancer-causing chemicals called PAHs. Reducing your exposure to tobacco smoke lowers your exposure to many contaminants.

The results from this study reinforce the message that the health benefits of traditional foods generally outweigh contaminant risks.

Finding links between blood PCB levels and the foods people ate cannot prove which foods contributed most to PCB exposures in the Northwest Territories. But, knowing these links can help inform community decisions on future environmental monitoring.

Combining results from the food surveys with local environmental monitoring data will help us show which foods are driving PCB exposures in the Northwest Territories and Old Crow.

For any questions or comments, please contact:

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UNIVERSITY OF
WATERLOO

FACULTY
OF HEALTH

Factors Linked with PCB Biomonitoring Results in Old Crow, Yukon

THE PROJECT

Human biomonitoring studies were held in Old Crow, Yukon as well as communities in the Sahtú and Dehcho regions, Northwest Territories in 2016-2020. Levels of a group of contaminants called PCBs and essential nutrients like omega-3 fatty acids, were measured in blood samples from volunteer participants. Participants also shared information on the traditional foods they had eaten over the previous year.

PCB LEVELS IN THE YUKON



Average levels of **polychlorinated biphenyls (PCBs)** were in the usual ranges seen in southern parts of Canada. For example, PCB levels for younger participants were similar if not lower than the usual range. But, other subgroups in the Northwest Territories had higher than usual levels. For example, some PCB levels for older participants were between 2 and 3-times higher than usually observed in southern parts of Canada.

In the Old Crow, all participants including those over 60 years had levels found in the usual range. In the Dehcho, higher than usual levels for 2 PCBs while the other 18 PCBs measured were in the usual range. In the Sahtú, participants over 60 years had higher than usual levels for 12 of the 20 PCBs measured.



In the Old Crow, participants with elevated PCBs also had higher levels of omega-3 fatty acid levels in their blood samples. This positive link between PCBs and omega-3 fatty acids was also found in other northern regions.

What are PCBs?

PCBs are a large group of human-made industrial chemicals that were banned worldwide in 2001. PCBs can build up in fish, animals, and people as they get older. Most people are exposed to PCBs from the foods they eat.

What are omega-3 fatty acids?

Omega-3 fatty acids are a healthy type of fats that are good for heart health and brain development.

Most people in Canada don't get enough omega-3 fatty acids in their diets. Fish and seafood are rich in these healthy fats.

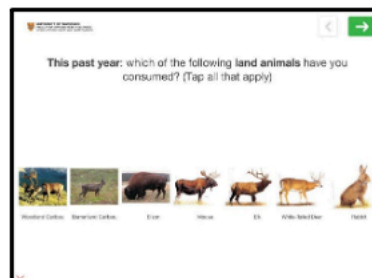
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We compared participants' blood PCB levels with their answers to questions on which traditional foods they ate over the past year. We also compared their PCB levels to their age and sex and whether they smoked cigarettes.

These results tell us whether people who eat a certain traditional food have either higher or lower levels of PCBs than those who didn't eat that food.



KEY RESULTS AND MESSAGES



LARGE GAME: No links were found between PCB levels and the meat or organs from large game among participants in Old Crow. Large game meat and organs, including muscle tissue, kidneys, and liver are excellent sources of protein, iron, and other nutrients.



FISH: There were no links between eating certain fish and/or fish eggs and PCB levels in blood among Old Crow participants. In other northern regions, there were links between eating lake trout and higher levels of PCBs in blood. Fish are excellent sources of many nutrients, including Vitamin D, and protein. Whitefish and lake trout are especially rich in omega-3 fatty acids.



BIRDS: No links were found between Old Crow participants who ate certain birds and higher blood PCB levels. In other northern regions, participants who ate waterfowl and/or upland game birds had higher levels of PCBs in blood. Many birds harvested in the Yukon, including waterfowl, are rich in iron, omega-3 fatty acids, and other nutrients.



SMOKING: Old Crow participants who smoked cigarettes had lower levels of PCBs. Smokers also had higher levels of several other contaminants, such as lead, cadmium, and cancer-causing chemicals called PAHs. Reducing your exposure to tobacco smoke lowers your exposure to many contaminants.

The results from this study reinforce the message that the health benefits of traditional foods generally outweigh contaminant risks.

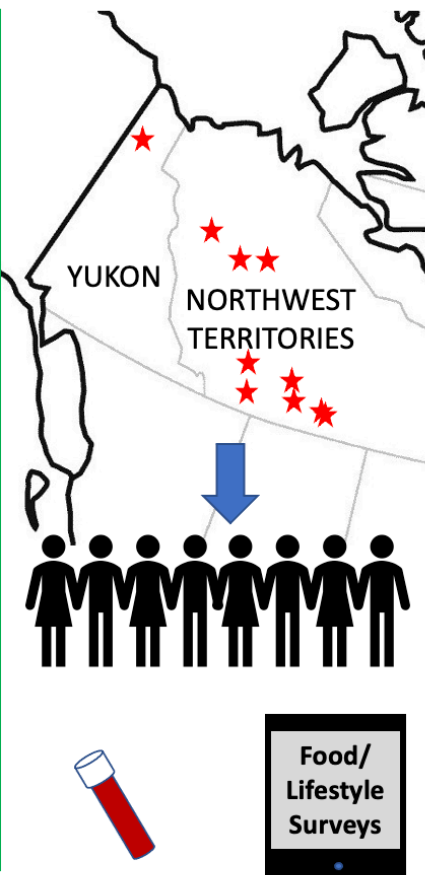
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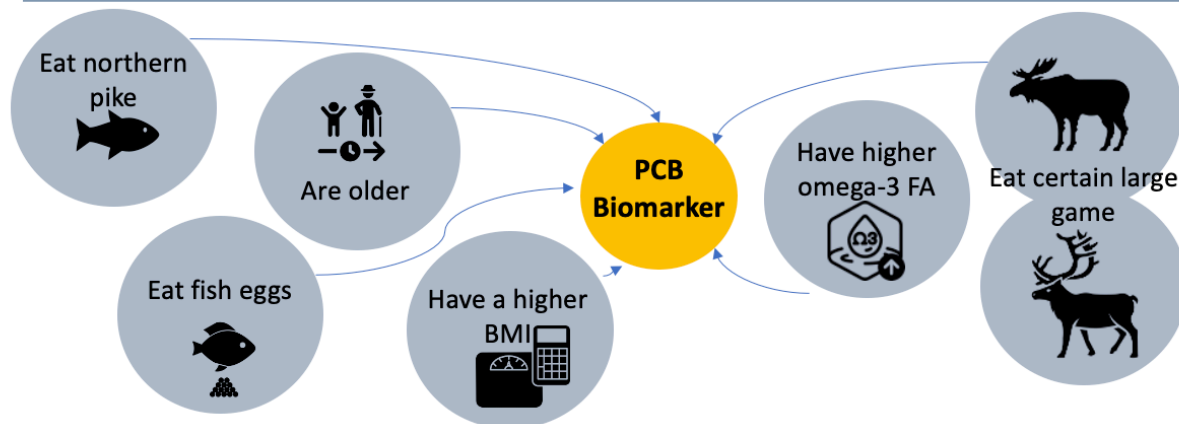
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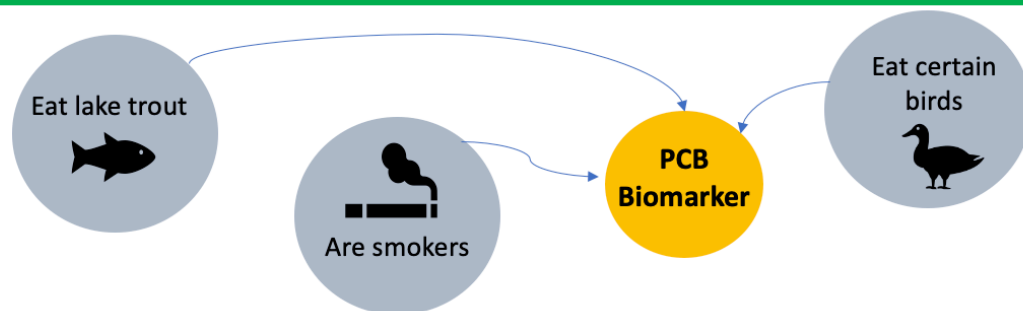
HUMAN BIOMONITORING DATA



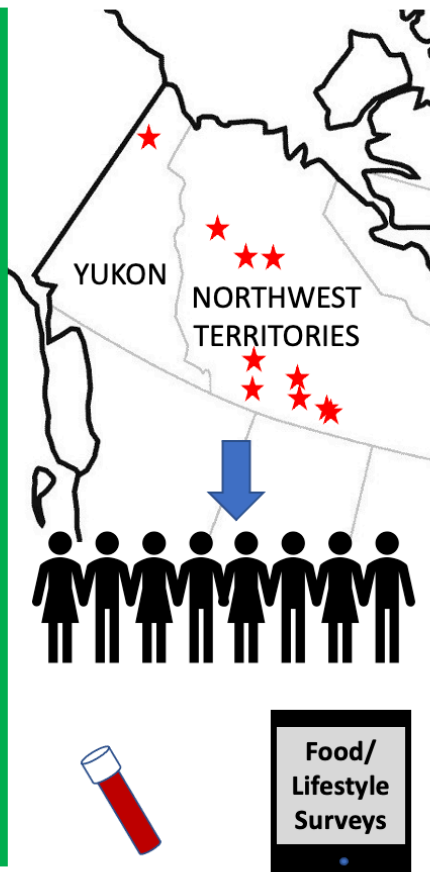
Regression analyses showed HIGHER average **PCB biomarker** levels for participants in the **Dehcho** who:



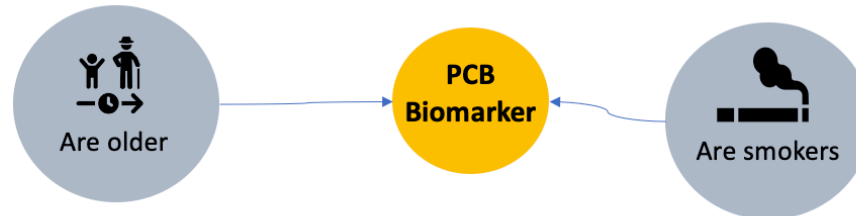
Regression analyses showed HIGHER average **PCB biomarker** levels for participants in other **Northern regions** who:



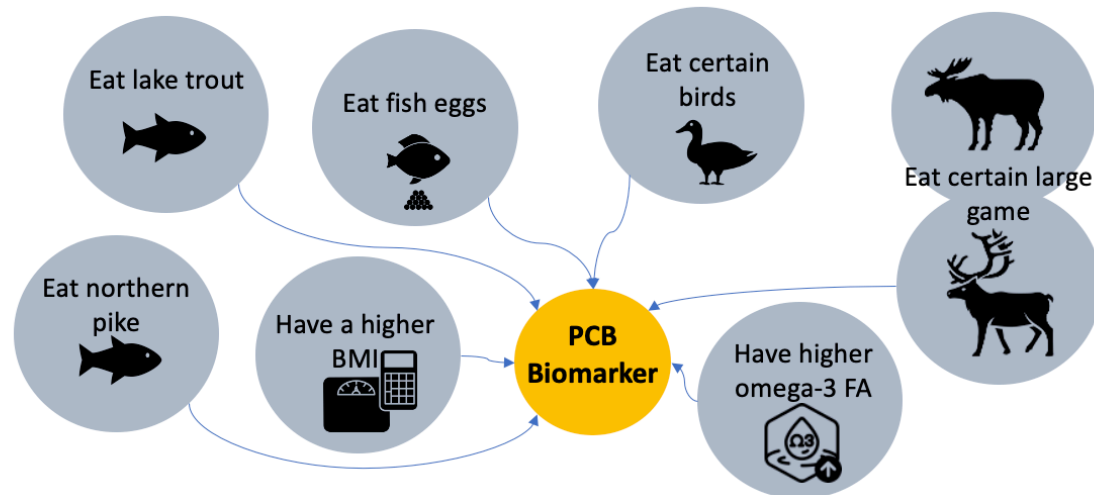
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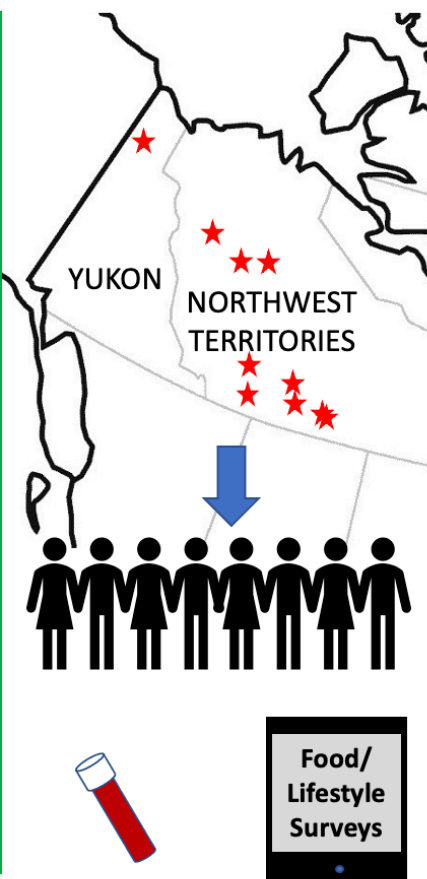


Regression analyses showed HIGHER average **PCB biomarker** levels for participants in the **Old Crow** who:

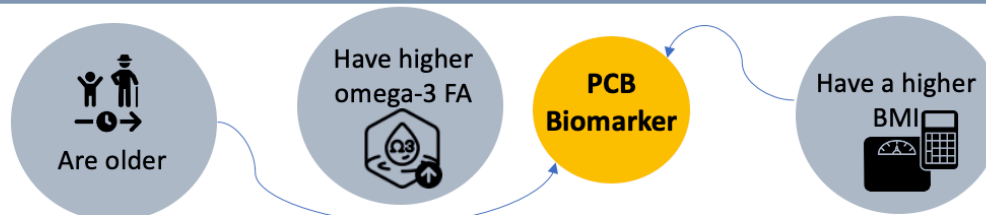


Regression analyses showed HIGHER average **PCB biomarker** levels for participants in other **Northern regions** who:





Regression analyses showed HIGHER average **PCB biomarker** levels for participants in the **Sahtú** who:



Regression analyses showed HIGHER average **PCB biomarker** levels for participants in other **Northern regions** who:

