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The Status of Contaminants in Fish and Marine Mammals in the Inuvialuit Settlement Region

Submitted to:

The Fisheries Joint Management Committee
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Summary

This report summarizes the status of contaminants in fish and wildlife in the Inuvialuit Settlement Region (ISR) of northern Canada. Its objective is to provide the Fisheries Joint Management Committee (FJMC) with guidance on the present levels of major contaminants in wildlife and fish in the ISR and to help establish priorities. Background information is provided on the source of the contaminants, their toxicity, and the current levels in marine mammals and fish. An assessment of whether the contaminants are increasing or decreasing is included, where possible. Data were taken from several sources, including scientific papers and reports and the data files of individual researchers.

The report follows the general outline of other reviews by dividing the contaminants into three major groups: 1) organochlorine contaminants and pesticides, or persistent organic pollutants (POPs), 2) metals, like mercury, cadmium and arsenic and 3) radionuclides. Information is provided on eight organochlorine contaminants, four metals and radionuclides (as a group). The available data provide reasonably good coverage of beluga blubber and muktuk from several hunting areas and ringed seal blubber from most major coastal communities. Data are also available for freshwater and anadromous fish from the ISR and the northern NWT, but the coverage of lakes within the ISR is spotty and there are very few data for marine fish. Levels in caribou and waterfowl are presented for background information and to compare with the marine mammal data.

For the organic contaminants, PCBs, chlordane and toxaphene are the greatest concern because they accumulate to very high levels in marine mammals. Freshwater fish can also have very high levels of PCBs and toxaphene, but this has not been reported for fish from lakes in the ISR. The highest concentrations are generally found in the polar bear, followed by beluga. The levels in beluga are emphasized in this review because of its use as a traditional food. The concentrations of most organic contaminants in the ISR are equal to, or less than, the levels reported for the same species elsewhere in the Canadian Arctic, and several studies show an increasing trend from the west to east for many organochlorines. Time trends in Holman Island ringed seals show that many residues declined during the 1970's, but very few declined further during the 1980's. Contaminants such as HCB (hexachlorobenzene) and HCH (hexachlorocyclohexane) are of lesser concern because they accumulate less in the upper trophic levels than do PCBs, chlordane and toxaphene. Few data are available for the relatively toxic dieldrin in ringed seals.

Metal contaminants cause as much concern as organochlorines in the North. Mercury exceeds the consumption guideline in some species of marine mammals, freshwater fish and waterfowl. This will probably lead to consumption advisories in the future, as is common throughout North America. A survey of broad whitefish in five ISR lakes reported very low mercury

concentrations in muscle. There are also indications that the levels of mercury are rising, and faster in the western Arctic than in the eastern Arctic. More research is needed in this area, including studies to determine the variability of mercury levels in major freshwater and marine fish species and the concentrations of selenium in food items. The FJMC should maintain an active interest in this issue, and coordinate and assist research to ensure that optimum information is derived from ongoing studies.

Other metals are usually a lesser concern but should be monitored for new developments. Cadmium concentrations are high in beluga and ringed seal liver and kidney, and the kidneys in some caribou herds, but low in the muscle of all species, including fish and waterfowl. Few data are available for arsenic, but freshwater fish in some lakes in the NWT have very high levels and more data should be collected from the ISR. Lead is generally not a concern, but fragmented lead shot may be ingested in traditional foods and can reach toxic levels.

Radionuclides are either natural in origin (e.g. uranium, radium and lead-210) or produced in nuclear reactions (e.g. cesium-137). Cesium-137, which was produced primarily by atmospheric nuclear tests in the 1960's, has been shown to be declining in the Arctic with an environmental half-life of about 8 years, and will continue to decline with no new sources. Based on studies in Alaska and the ISR, there appears to be no movement of nuclides from the massive nuclear waste areas in the Former Soviet Union to the North American Arctic. A survey of radionuclides in beluga for the FJMC in 1995 showed trace levels of cesium-137, but no evidence of other man-made radionuclides.

The levels of contaminants in muktuk were compared to the acceptable daily (ADI) and weekly intake levels (AWI) from Health Canada to help set priorities for further monitoring. The assessment assumes muktuk as the only source of the contaminant. Using average values, small amounts of muktuk were close to recommended daily intake for PCBs and chlordane. Mercury was also close to the ADI level because of the high proportion of methylmercury. Monitoring for contaminants should continue into protective factors in the diet, and research into the cumulative effects of all contaminants combined should be encouraged. It is important to emphasize that these concerns need to be balanced against the social, nutritional and cultural benefits of the traditional foods.

Recommendations include the need for more data on contaminants in marine and freshwater fish, particularly at common fishing sites. Also, the FJMC should be proactive in ensuring that large surveys and monitoring programs with marine mammals include sites within the ISR, and that the data are reported back to the FJMC to continue expanding the database. Changes away from large scale surveys by the NCP, and changes in DFO personnel, suggest that the FJMC may have to play an larger role in obtaining this information in the future. In this way the FJMC can ensure that monitoring is continued in a cost effective manner and that questions regarding contaminants from communities are addressed in a timely fashion.

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1.0 Introduction

The contamination of fish and mammals by organochlorine pesticides and metals remains a major concern to the people of the Inuvialuit Settlement Region (ISR). Studies conducted over the last 25 years have confirmed the presence of compounds such as DDT, PCBs, chlordanes and toxaphene at high levels in marine mammals throughout the Canadian Arctic. These compounds are transported into the Arctic from Asia and Europe by atmospheric and oceanic currents. Mercury, which has natural and man-made sources, also accumulates in fish and mammals and may exceed levels that are considered to be safe for consumption by humans. Some reports indicate that the highest levels of mercury in the Canadian Arctic are found in beluga in the ISR (Jensen *et al.* 1997). This issue remains a major priority to northern peoples who rely on traditional country foods for a large portion of their diet.

The need for a status report on the levels of contaminants in the ISR is clear. Research and contaminant monitoring programs in several government departments are continually generating new data, both within the ISR and elsewhere. Health Canada and other agencies are also continuing to assess the hazards and risks from these contaminants in light of new information. This report will pull together much of this new information to assess the status of contaminants in fish and wildlife in the ISR. The report will place the information in the context of concentrations in the same species in other areas of the Arctic, whether the contaminants appear to be increasing or decreasing through time, and how close the contaminants are to “toxic” levels. The objectives of the report are 1) to summarise what is known of contaminants in the region and 2) to help set priorities for the Fisheries Joint Management Committee (FJMC) in terms of work that is needed in the ISR to define contaminant issues.

2.0 Scope of Report

This report is an update of the report by Hamilton (1993) which summarized contaminant data for marine mammals and fish in the ISR. Most of the data contained in this report is taken from the earlier report and updated using recent reports and scientific papers (e.g. Muir *et al.* 1999, Braune *et al*. 1999a). These sources are generally considered to be the most reliable method of obtaining information because of the numerous review steps that authors have to take before the reviews or papers go into print. These steps ensure that few errors make it into print and that the data are consistent with previous studies in terms of their analytical methods, quality control and other factors. One of the difficulties in determining the levels of contaminants in any species is that data are reported in several ways for each study. For example, studies funded under the Northern Contaminants Program (NCP) require mid-year reports which give one value, then published papers report another value when the analyses are completed and then review papers roll together data from several studies for different values. For this report, the values reported in journal papers are reported first, followed by reviews and individual data sets.

One major source of information about the status of contaminants in the Canadian Arctic is the Canadian Arctic Contaminants Assessment Report (CACAR) from the Department of Indian and Northern Affairs (Jensen *et al*. 1997). CACAR summarises most of the research conducted on contaminants in the Arctic from the 1970's up to 1996 (the end of Phase I of the Northern Contaminants Program). More information is available at the NCP web site (www.inac.gc.ca/ncp). Internationally, major programs by the Arctic Monitoring And Assessment Program (AMAP) and the monitoring of radiation by the International Atomic Energy Agency (IAEA) provide data on contaminants throughout the Arctic. Data from these agencies will be used to give an overall assessment of contaminants in the Arctic and for data to compare with those from the ISR. Some programs, such as the Fish Inspectorate of DFO, have changed significantly since the early 1990's and there are no new data on fish from the ISR since 1994. A summary of information sources on the Internet is given in Table 1.

This report summarizes the concentrations of major contaminants in marine, freshwater and terrestrial species, including waterfowl and terrestrial animals where possible, to give some perspective of the major dietary sources of the contaminants to people. The geographical coverage for studies reporting contaminants concentrations in marine mammals in the ISR is good and most major species have been sampled enough times that a reasonably complete assessment of contaminants levels can be constructed (Figure 1). Other contaminants, like radionuclides, have not been reported as much as others, but enough data are available to make general assessments. Data from marine and terrestrial species are reported to give a context for the high levels reported for marine species. Organochlorine contaminants, for example, are highest in beluga and ringed seals but very low in caribou, whereas, radionuclides like cesium-137 and polonium-210 are much higher in caribou than in any other species. Indeed, the consumption of caribou probably accounts for >95% of the intake of those compounds for people who eat a mixed diet of land and marine animals. This report will present a balanced view of the dietary intake of contaminants by including some of these additional food items.

Table 1 Additional sources of information for contaminants and assessments of the toxicity and risk from the contamination of foods. All Web site addresses are accurate as of May, 2000.

Source	Information Available	Internet Address
Health Canada - Bureau of Chemical Hazards	General information on chemical safety, including human health risk reports of the Priority Substances List Assessments	http://www.hc-sc.gc.ca/ehp/ehd/bch/index.htm
Agency for Toxic Substances and Disease Registry	General information about the toxicity of chemicals, including Public Health sheets	http://www.atsdr.cdc.gov/toxfaq.html
Arctic Monitoring and Assessment Program	General information on pollution in the Arctic, including contaminants, petroleum and radiation.	http://www.amap.no/ or http://www.grida.no/ and choose the AMAP link
U.S. National Parks Service	Environmental contaminants encyclopedia; detailed scientific reviews of a large number of contaminants	http://www1.nature.nps.gov/toxic/
U.S. Environmental Protection Agency	some background information on fish and wildlife consumption advisories due to contaminants (mostly mercury) in the US and Canada	http://www.epa.gov/ost/fish/
U.S. Environmental Protection Agency	Mercury Report to the U.S. Congress	http://www.epa.gov/ttnuatw1/112nmerc/mercury.html
Environmental Defense Fund (US)	chemical and toxicological profiles for 6,500 chemicals	http://www.scorecard.org/chemical-profiles/
Oak Ridge National Laboratory (US)	Reports on ecological risk assessment including background information on chemical toxicity to wildlife	http://www.hsrd.ornl.gov/ecorisk/ecorisk.html
USGS Patuxent Wildlife Research Center	Contaminants hazard reviews for most major compounds found in the ISR - available online or on disk	http://www.pwrc.nbs.gov/new/chrback.htm

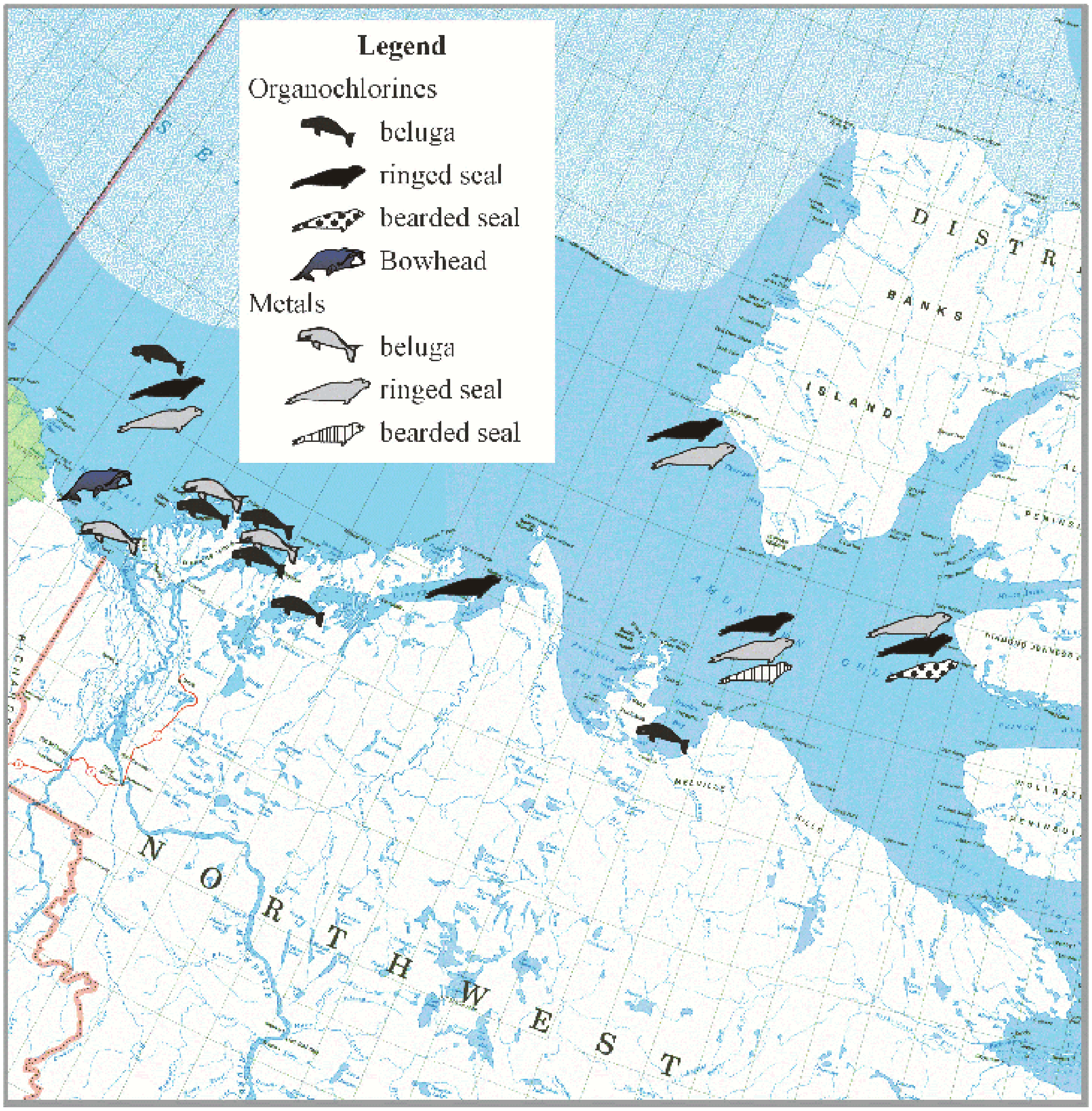

Figure 1 Map of the Inuvialuit Settlement Region (ISR) showing the locations of marine mammals analysed in contaminant studies. Beluga from Shingle Point and Kendall Island were also analysed for radionuclides. Contaminant data for the individual sites is in the Appendix.

3.0 Summary of Contaminants

This report follows the same general format as many other reviews of contaminants in the North. Contaminants fall into three major groups: 1) persistent organic pollutants, which include pesticides and industrial contaminants like PCBs, 2) metals, which include mercury, lead and cadmium and arsenic, and 3) radionuclides. Other priority issues such as air pollutants and ultraviolet radiation will not be discussed because they are generally not considered to be contaminants in that they do not accumulate in biota. Large monitoring and research programs over the last 30 years have produced a lot of information on contaminants from the Canadian Arctic and elsewhere. This research has identified a number of contaminants that are generally considered to be of greater significance because the levels may be hazardous to people or fish and wildlife.

Key organochlorine contaminants are listed in Table 2; metals and radionuclides are listed in Table 3. Data on the sources of the contaminants, species which tend to have the highest concentrations and the sites of accumulation in the organism are listed, with guidelines for provisional weekly or daily intake of the contaminants from Health Canada and the U.S. Agency for Toxic Substances and Disease Registry (see Table 1). The data on tolerable daily and weekly intake were obtained from the Bureau of Chemical Safety, Health Protection Branch of Health and are accurate as of May, 2000.

3.1 Persistent Organic Pollutants (POPs)

Persistent organic pollutants (POPs), which are also called organochlorine contaminants, provide the best evidence of pollution from the south moving into the Arctic by atmospheric or oceanic currents and entering the northern food web. Many of these compounds have never been used to a large degree in northern Canada. They accumulate in fat and biomagnify up the food chain to the extent that very high levels are observed in polar bear and beluga. POPs share several general characteristics:

1) they originate from human activities,
2) they are very persistent in the environment, often remaining in their original form, or as a stable breakdown product, for decades in soil and water,
3) they bioaccumulate to much higher concentrations in the upper trophic levels than in water, soil or in the lower trophic levels, and
4) they are toxic at relatively low concentrations.

Table 2 Summary of major organochlorine contaminants found in the ISR. The table also summarises the species which have the highest concentrations of the contaminants, the target organ and the recommended levels of intake from the Bureau of Chemical Safety, Health Canada and the US Agency for Toxic Substances and Disease Registry (ATSDR).

Compound	**Source**	**Species with Highest Levels**	**Target Site in the Animal**	**Tolerable/ Acceptable Intake[1] (ug·kg^{-1}·d or µg·kg^{-1}·wk^{-1})**	**Minimum Risk Levels in Humans by Ingestion[2]**	
					MRL (µg·kg^{-1} BW·d^{-1})	**Uncertainty Factor**
HCB (hexachloro-benzene)	industrial by-product	polar bear, beluga	fat	TDI (HCB) = 0.5 TDI (ECBz) = 0.5	0.02	1000
HCH (hexachloro-cyclohexane)	insecticide (still used in Asia)	polar bear, beluga	fat	TDI = 0.3 Alpha TDI = 0.3 Beta TDI = 0.3 Gamma TDI = 1.0	Alpha = 8 Beta = 0.6 Gamma (lindane) = 0.01	Alpha = 100 Beta = 300 Gamma = 1000
DDT	insecticide in Asia and cent. America	polar bear, beluga, walrus	fat	ADI = 20	p,p'- DDT = 0.5	100
PCBs (polychloro-biphenyls)	discontinued industrial product	polar bear, beluga, walrus	fat	PTDI = 1.0	Aroclor 1254 = 0.02	300
Chlordane	discontinued insecticide	polar bear, beluga	fat	TDI = 0.05	0.6	100
Toxaphene (Chloro-bornanes)	discontinued insecticide	beluga, walrus, freshwater fish	fat	TDI = 0.2	1.0	300
Dioxins/furans	industrial by-product	marine species	fat	-	2,3,7,8 TCDD = 0.000001 2,3,4,7,8 TCDF = 0.00003	TCDD = 90 PCDF = 3000
Dieldrin	discontinued insecticide	polar bear, beluga	fat	TDI = 0.1	0.05	100

Table 3 Summary of major metal and radionuclide contaminants found in the ISR. The table also summarises the species with the highest concentrations of the contaminants, the target organ of accumulation and the recommended levels of maximum intake from Health Canada and from the ATSDR in the United States.

Compound	Source	Species with Highest Levels	Site of Accumulation in the Animal	Tolerable/ Acceptable Intake[1] ($ug \cdot kg^{-1} \cdot d$ or $\mu g \cdot kg^{-1} \cdot wk^{-1}$)	Minimum Risk Levels in Humans by Ingestion[2]	
					MRL ($\mu g \cdot kg^{-1}$ $BW \cdot d^{-1}$)	Uncertainty Factor
Mercury	natural and industrial by-product	beluga, freshwater fish	liver	PTDI = 0.71 (children and women of child-bearing age = 0.1 to 0.2) PTDI Hg-Meth = 0.47	methylmercury = 0.3	4
Cadmium	natural and industrial by-product	caribou, moose, ringed seal, beluga	kidney, liver	PTWI = 7.0	0.2	10
Lead	natural and local contamination (lead shot)	lead shot in waterfowl and ptarmigan	muscle	PTDI = 3.57	none	none
Arsenic	natural	freshwater fish	liver	PTDI = 2.0	0.3	3
Uranium	natural	plants, water	kidney, bone	-	2.0	30
Cesium-137	man-made	caribou	muscle	7.6×10^4 $Bq \cdot y^{-1}$ (3)	-	-
Polonium-210	natural	caribou	liver, kidney	4.2×10^3 $Bq \cdot y^{-1}$	-	-
Radium-226	natural	fish, caribou	bone	3.57×10^3 $Bq \cdot y^{-1}$	-	-

1 - Data from Berti *et al.* (1998); TDI is tolerable daily intake; PTDI is provisional tolerable daily intake; ADI is acceptable daily intake; PTWI is provisional tolerable weekly intake. Other values from “Health-based tolerable daily intakes/ concentrations and tumorigenic doses/ concentrations for priority substances” Health Report H46-2/96-194E.

2 - Minimum Risk Levels (MRL) are from the Agency for Toxic Substances and Disease Registry (ATSDR), Atlanta, Georgia. Values reported are for chronic (> 365 days) or intermediate (15 - 364 days) exposure through the diet. Doses are on a $\mu g \cdot kg^{-1}$ $BW \cdot d^{-1}$ basis.

3 - values determined from acceptable annual intake of 1 $mSv \cdot y^{-1}$ for protection of the public and effective dose coefficients given by the International Committee on Radiation Protection (Annals of the ICRP, Publication 68, 1994).

Because they are almost all more fat soluble than water soluble, POPs increase significantly in concentration through the various steps of the food web and reach potentially toxic levels in the species at the top. The marine system, which has many steps from water to phyto- and zooplankton up to polar bears, shows the highest concentration of organic compounds. Also, marine organisms in the Arctic have very large fat stores for warmth and energy storage that collect and retain the fat soluble contaminants. Similarly, species such as northern pike, lake trout and Arctic char in some inland lakes accumulate very high levels of compounds, such as toxaphene, because the size and structure of the lake allows long, complex food webs which can accumulate organic pollutants. Some compounds, like DDT, may also be present at high concentrations in predatory birds and can cause significant biological effects, such as eggshell thinning. These compounds cause concern among scientists and the public because they can be present in high concentrations in harvested wildlife and in human breast milk.

Table 2 summarizes the probable source of organic contaminants found in the northern environment. These compounds are either pesticides, like DDT and lindane ((-HCH), or were used in industry and remain in the environment, even though their use was stopped several years ago (e.g. PCBs). Considerable work has been done to determine how the contaminants are transported into the Arctic. Many of the organochlorine contaminants (i.e., chlordane, hexachlorobenzene (HCB), hexachlorocyclohexane (HCH)) have never been used on a broad scale in the Canadian Arctic and their presence in water, snow, air, soil and wildlife in the Arctic indicates large amounts of the materials coming in from southern regions, where the compounds are used on agricultural crops or for pest control. POPs may be transported through the atmosphere and deposited in the colder temperatures of the Arctic by the mechanism known as cold condensation (Wania and MacKay 1993). The long-range transport of pollutants has led to international negotiations by Canada in an effort to control and reduce these compounds at their source. Some organic contaminants may also be transported into the Arctic by ocean currents.

There are several common features of the accumulation of organic contaminants in organisms which help to interpret trends and the results reported here:

1. Adult female animals tend to have lower levels of the contaminants than males because they lose some of the compounds when fat stores are mobilised during nursing.
2. The levels of contaminants are often related to the condition of the animal. When the animals do not feed, such as during the moulting period in ringed seals, they will lose a lot of fat and the levels of fat soluble contaminants change.
3. Some compounds increase in concentration with the age of the animal, possibly because of changes in diet or the ability to excrete the compound from its body tissues.
4. Some contaminants are metabolised, or broken down, by some groups of organisms. This may be the reason that the levels of some contaminants are very low in some groups of organisms (mammals), but high in others (fish). The breakdown products of the

contaminants could also be toxic to the animal, but may not be measurable with the normal testing procedures, and are usually not reported.

The following sections describe the general characteristics of each of the priority contaminants and summarize the data for marine and freshwater species from the ISR, relative to values reported from other areas. These data are summarized for the major compounds in Table 4 for the major compounds and for each of the major species in the Appendix 1.

3.1.1 *Hexachlorobenzene (HCB)*

Background

Chlorobenzenes are a group of relatively long-lived compounds which are formed as industrial by-products or used as pesticides. Several chlorobenzenes (di-, tri-, tetra-, penta- and hexachlorobenzenes) are found in the northern environment, but hexachlorobenzene (HCB) is often at the highest concentration. HCB is primarily a by-product of waste incineration and the production of chlorinated compounds, although small amounts are used as a pesticide and for seed dressing. HCB is lipophilic (i.e. attracted to fats) and accumulates in biota, but less so than compounds like PCBs and chlordanes. It is one of the dominant organochlorine residues in air and snow, comprising over 20% of the total organic residues in air in the Arctic, but the relative fraction declines to less than 5% in polar bear, as chlordanes and PCBs increase in relative importance (Norstrom and Muir 1994).

Concentrations in Biota

The highest levels of HCB in the ISR are found in beluga blubber, where an average concentration of 1177 ng·g^{-1} ww was reported for 3 animals taken at Paulatuk in 1994 (Muir *et al.* 1995). These levels are high relative to other areas of the Arctic. Overall, beluga collected between 1991 and 1995 in the Mackenzie Delta and the Eskimo Lakes areas showed averages of 315 to 956 ng·g^{-1} ww which are about the same as in the rest of the Canadian Arctic. Polar bears have slightly lower levels than beluga (Muir *et al.* 1988). Generally, the beluga populations around Baffin Island show slightly higher levels than the rest of the Canadian Arctic, with a maximum up to 1305 ng·g^{-1} ww (Jensen *et al*. 1997). Muktuk from East Whitefish, Hendrickson Island and Paulatuk had much lower levels than blubber, and ranged from 3.6 to 56.3 ng·g^{-1} ww (Muir *et al*. 1995).

Ringed seals generally have much lower levels of HCB than beluga taken from the same area. Seals collected at Sachs Harbour in 1987 and 1988 had HCB levels of 5.1 to 13.2 ng·g^{-1} ww, equivalent to, or lower than, the same species collected in the eastern Arctic (Muir *et al*. 1995). There was a decrease (38.9 to 19.3 ng·g^{-1}) in HCB levels in Holman Island ringed seals from 1981 to 1991 (Addison and Smith 1998), suggesting that HCB is declining in the Arctic as its use declines in the south.

Table 4 Comparison of contaminant data within the ISR relative to other areas of the Canadian North. Data are from several sources. See Appendix for full data sets.

Contaminant	Species	Tissue	Highest Average Value for Species in ISR (ng·g^{-1} ww)	Maximum Reported in Canadian Arctic
HCB	beluga	blubber	1177	1305 (Baffin Is.)
	ringed seal	blubber	23	187 (Ellesmere Island)
	waterfowl	breast muscle	range for fish-eating birds = 1.6 - 18.3	range = 1.1 - 120 (eastern Arctic)
	caribou	fat	13.4	42.6 (Victoria Island)
	fish	whole fish	Arctic char = 6.2	not available
HCH	beluga	blubber	987	515 (Baffin Isl.)
	ringed seal	blubber	117	435 (S. Hudson Bay)
	waterfowl	breast muscle	range for fish-eating birds = nd - 9.9	range = nd - 2.4 (eastern Arctic)
	caribou	fat	6.4	15.5 (Victoria Is.)
	fish	whole fish	Arctic char = 40	burbot = 13.7 (Trout Lake)
Chlordanes	beluga	blubber	2596	4236 (Hudson Bay)
	ringed seal	blubber	431	1596 (Hudson Bay)
	waterfowl	breast muscle	range for fish-eating birds = 2.9 - 75.7	range = tr - 105 (eastern Arctic)
	caribou	fat	0.64	0.8 (Victoria Island)
	fish	whole fish	Arctic char = 12	burbot = 62.8 (Great Slave Lake)

Table 4 (cont'd)

Contaminant	Species	Tissue	Highest Average Value for Species in ISR ($ng \cdot g^{-1}$ ww)	Maximum Reported in Canadian Arctic
PCBs	beluga	blubber	6,293	6,800 (Baffin Island)
	ringed seal	blubber	1280	2066 (Hudson Bay)
	waterfowl	breast muscle	range for fish-eating birds = 1.1 - 909	range = 8.8 - 1695 $ng \cdot g^{-1}$ (eastern Arctic)
	caribou	fat	6.1	6.6 (Victoria Island)
	fish	liver	burbot = 152 (assuming 45% lipid)	burbot = 1267 (Lake Laberge)
Toxaphene	beluga	blubber	7,777	14,550 (Baffin Is.)
	ringed seal	blubber	341	661 (Hudson Bay)
	waterfowl	breast muscle	no data reported	no data reported
	caribou	fat	no data	no data
	fish	fillet or liver	burbot liver = 170 (assume 10% lipid)	burbot liver = 2,301 (Lake Laberge, Yukon)
DDT	beluga	blubber	3506	11,200 (Hudson Bay)
	ringed seal	blubber	780	1662 (Hudson Bay)
	waterfowl	breast muscle	range for fish-eating birds = 1.0 - 1120	range = 2.6 - 951 (eastern Arctic)
	caribou	fat	0.71	None
	fish	whole	Arctic char = 4.9	burbot = 3433 (Lake Laberge)

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Table 4 (cont'd)

Contaminant	Species	Tissue	Highest Average Value for Species in ISR (µg/g^{-1} ww)	Maximum Reported in Canadian Arctic
Mercury	beluga	liver	27.4	27.4
	ringed seal	liver	32.9	32.9
	waterfowl	breast muscle	1.93	1.93
	caribou	kidney	1.9	2.2
	fish (walleye)	muscle	1.34	
Cadmium	beluga	kidney	9.68	22.4 (eastern)
	ringed seal	kidney	21.1	47.7 (eastern)
	waterfowl	breast muscle	range for fish-eating birds = < 65 - 438	< .030 - .11 (eastern)
	caribou	kidney	9.5	30 (Finlayson herd)
	fish	sucker flesh	0.055	0.33
Arsenic	beluga	-	no data	no data
	ringed seal	-	no data	no data
	waterfowl	meat	range for fish-eating birds = < 0.030 - 0.23	0.007 -0.72
	caribou	heart	30	no data
	fish	inconnu flesh (smoke dried)	1.73 (dw)	1.76 (Slave River)

Table 4 (cont'd)

Contaminant	Species	Tissue	Highest Average Value for Species in ISR (ng/g^{-1} ww)	Maximum Reported in Canadian Arctic
Lead	beluga	-	no data	no data
	ringed seal	-	no data	no data
	waterfowl	ptarmigan meat	0.025	no data
	caribou	heart (cooked)	.240	no data
	fish	Arctic char meat boiled	0.16	no data

Lockhart *et al*. (1992) report ΣCBz levels in fish muscle from below detection limits to 1.8 ng·g^{-1} ww from several sites in the NWT, much lower than the levels reported for beluga or ringed seals. A survey of broad whitefish in five ISR lakes reported very low concentrations of 0.3 to 4.05 ng·g^{-1} ww in muscle (Lockhart *et al*. 1993). Berti *et al.* (1998) report levels of 65 ng·g^{-1} ww in smoked/dried whitefish fillets. The highest values reported for caribou are >100 ng·g^{-1} lipid in fat, although the levels in the rest of the animal are much lower when expressed on a wet weight basis.

Toxicity

HCB has been defined by Health Canada and Environment Canada as “toxic” under the Canadian Environmental Protection Act (CEPA), an assessment that is based largely on the potential for biological effects in mink and predatory birds, like the peregrine falcon (CEPA 1993a). Although HCB has relatively low toxicity, the CEPA assessment report lists several studies documenting effects on liver, immune function, and reproduction in mammals. In 1996, Health Canada recommended a tolerable daily intake (TDI) of 0.5 µg·kg BW·d^{-1} for total chlorobenzenes and for HCB, or a total daily intake of 35 µg for a 70 kg person. That level is the equivalent of 1 kg of muktuk, assuming an HCB level of 35 ng·g^{-1}.

SUMMARY **HCB is present in traditional foods in the ISR but, for any given species, the levels are lower than in other areas of the Canadian Arctic. The highest levels in the ISR are in beluga, however these levels are probably not high enough to warrant major concern. Also, levels may be staying the same or declining. Because of the toxicity of HCB, the moderate levels found in beluga should be monitored to ensure that levels do not significantly increase.**

3.1.2 *Hexachlorocyclohexane (HCH)*

Background

HCH is comprised of several major components, all of which have slightly different toxicological properties. The technical HCH mixture is comprised of 55-70% α-HCH, 5-14% β-HCH and 10-18% γ-HCH. The γ-HCH isomer (which is the only major isomer in lindane) is used directly as an insecticide for grasshoppers, rice insects and other soil pests in North America, Japan and Europe (Li 1999). Sometimes the technical mixture, with all the major components, is used because it is less expensive. Banning the use of the technical mixture in China, India and Russia resulted in declines in Arctic air very quickly in 1982 and in 1990 (Li 1999). The β- isomer is considered the most toxic isomer because of its persistence and its long half-life in blood (7.2 years) relative to the γ- isomer (1 day).

There is some evidence of a conversion from the (- to "-isomer under environment conditions and by UV-radiation (Oehme and Mano 1984).

Concentration in Biota

HCHs form about 70% of the organochlorine residues in air and snow but less than 5% in polar bears as PCBs and chlordanes form a greater proportion of organic residues. One of the highest 'HCH concentrations in the Canadian Arctic was in 7 male beluga from East Whitefish in the ISR. The average concentration in those beluga was 987.4 ngAg^{-1}, with a maximum value of 1166 ngAg^{-1} (Muir *et al*. 1995). Other collections analysed at the same time had 'HCH levels between 200 and 300 ngAg^{-1}, consistent with the levels reported for beluga blubber in the rest of the Canadian Arctic. With the exception of the one collection, the 'HCH concentration in beluga is relatively constant at 300 to 500 ngAg^{-1} ww. A concentration range of 8.7 to 42.1 ngAg^{-1} ww was reported for beluga muktuk (Muir *et al*. 1995). 'HCH is generally lower in ringed seal blubber and a value of 117 ngAg^{-1} ww is cited by Jensen *et al*. (1997) for Holman Island seals. Levels are much lower in freshwater fish, with a maximum value from the ISR of 12 ngAg^{-1} ww in Arctic char muscle, relative to a maximum of 40.3 ngAg^{-1} ww (SD = 12.1; n=6) in burbot liver from Trout Lake in the NWT (Jensen *et al*. 1997). Lockhart *et al*. (1993) report average levels of 0.19 to 3.52 in the muscle of broad whitefish from 5 lakes in the ISR.

There is some evidence that the levels of HCH in biota are changing through time. Reduction in the use of technical HCH in China and Russia resulted in clear declines of "- and $-HCH in Arctic air (Li 1999), however the levels of these two forms are continuing to increase in the surface waters of the Arctic Ocean. Addison and Smith (1998) reported no change in the two HCH isomers in ringed seal at Holman between 1972 and 1991. The concentration of $-HCH, the most toxic form, has increased slowly in seabird eggs over the last ten years, consistent with the trends in surface waters. The (- isomer is very low in the eggs and appears to be remaining constant (Braune *et al*. 1999b).

Toxicity

The individual isomers vary greatly in their toxicity. Health Canada suggests a tolerable daily intake (TDI) of 0.3 µgAkg^{-1} BW, or about 21 µgAd^{-1} for a 70 kg person. This can be achieved by consuming about 1 kg muktuk per day at a concentration of 20 ngAg^{-1} ww (Muir *et al*. 1995). A project funded under the NCP is examining the toxicity of HCH, the trends through time and the exposure in humans eating a diet high in HCHs. An analysis of contaminants and diets in aboriginal communities in the NWT by Berti *et al*. (1998) reported that there were no health risks from HCH exposure in communities in Gwich'in area, even though the ingestion of beluga was considered in the latter communities.

SUMMARY HCHs are present in all food items in the Arctic, but the levels within the ISR are not particularly high compared to other regions for any species.

Whether concentrations in HCH are increasing or decreasing through time is still under discussion. This issue should be addressed in the ISR by ensuring that long-term sampling programs include sites within the ISR to establish trends specific to that region. Presently, the levels of HCH in foods do not appear to be approaching toxic levels in beluga muktuk.

3.1.3 *DDT (Dichlorodiphenyltrichloroethane)*

Background

DDT is one of the first organic contaminants reported in marine mammals in the Arctic in the 1970s and there is a lot of information available about its use and distribution. Technical DDT compounds were used for insect control after WW II in North America, but their use there has now been restricted for two decades. The insecticide is still used in Asia, and Central and South America. The major components are DDT, DDD and DDE. Because DDT breaks down to DDE, the DDT/DDE ratio is an important indicator of the freshness of the source of the total DDT found in samples. Most samples in the Arctic are comprised almost entirely of DDE (low DDT/DDE ratio), while in southern areas, like the St. Lawrence River, the ratios are higher because of inputs from recent sources.

DDT residues are well known for their ability to cause eggshell thinning in birds (see Blus 1996 for review), but DDE also disrupts hormone metabolism and the activity of liver enzymes. Retrospective studies of POPs levels in seabird and peregrine falcon eggs report that the level of DDT has declined markedly since the mid-1970's, from about 7500 ng·g^{-1} ww between 1982 and 1986 to 4450 ng·g^{-1} by the mid 1990's (Jensen *et al*. 1997). A retrospective analysis of DDT residues in seal blubber from Holman Island showed that levels in 1981 had declined to about 20% of the levels in 1972 while DDE declined to about 50% of the 1972 value (Addison and Smith 1998). After that, however, both residues remained constant until 1991.

Concentrations in Biota

Total DDT levels can exceed 11,000 ng·g^{-1} ww (SD = 8,231; n=7) in the blubber of male beluga but mean values for the species are in the range of 3,000 to 4000 ng·g^{-1} ww. The highest level reported in the ISR is 5894 ng·g^{-1}, which was reported for four male beluga at East Whitefish in 1990, although values from most areas in the ISR are about 2500 to 3500 ng·g^{-1} in blubber. Levels in muktuk are lower at 150 to 300 ng·g^{-1} (Muir *et al.* 1995). ΣDDT levels in walrus and ringed seal blubber and polar bear fat are lower than beluga blubber, or about 500 and 1000 ng·g^{-1} ww, respectively (Jensen *et al*. 1997).

A comparison of ΣDDT levels in freshwater fish species reported the highest levels in burbot liver (38 to 39 ng·g^{-1} ww), with lower levels reported in Arctic char. Much lower concentrations were reported in lake and broad whitefish, and lake trout. Lockhart *et al*.

(1992) reported much higher total DDT levels in burbot liver from southern lakes than in 5 sites of the Mackenzie River. Lockhart *et al.* (1993) reported levels ranging from 0.16 to 4.76 in broad whitefish muscle from five inland lakes in the ISR. Waterfowl from the western Arctic had ΣDDT levels ranging from 32 - 530 ng·g^{-1} significantly higher than the levels reported for fish (Jensen *et al.* 1997).

Toxicity

DDT and its metabolites are fairly toxic to humans and wildlife. CACAR reports that total DDT in human breast milk may occasionally exceed the guideline levels of 1,000 ng ΣDDT·g^{-1} lipid in some areas of the Arctic, suggesting that ΣDDT levels should continue to be monitored. Health Canada has an ADI of 20 µg·kg^{-1} BW·d^{-1}, which translates into a daily ingestion of 1,400,000 ng per day for a 70 kg adult. This would require a daily ingestion of about 7 kg of muktuk, assuming an average level of 200 ng·g^{-1} ΣDDT in muktuk. The Canadian Council of Ministers of the Environment (CCME) also published a tissue residue guideline of 14 ng·g^{-1} BW for the protection of wildlife consumers of aquatic biota. Based on tissue levels of ΣDDT in beluga and other marine mammals these tissue levels may be exceeded in several species.

SUMMARY **DDT remains a significant concern in northern Canada because of high concentrations in predatory birds and evidence of lower, but continuing, input of DDT through the atmosphere. The highest concentrations are generally found in beluga and are low in freshwater fish and in terrestrial animals. Within the ISR, ΣDDT concentrations are about 2,000 to 3,000 ng·g^{-1} on average in beluga blubber, which is considered to be in the middle of the range for beluga in the Canadian Arctic. Lower levels are present in ringed seals, freshwater fish, waterfowl and caribou.**

3.1.4 *Polychlorinated Biphenyls (PCBs)*

Background

PCBs remain one of the major organic contaminants found in biota in the Arctic because they are biomagnified more than many other organic contaminants. PCBs are industrial liquids that were used in transformers and electrical machinery because of their stability and their physical properties. There are 209 different chlorine arrangements on the biphenyl ring, each of which is termed a congener. Each congener has unique physical, chemical and toxicological properties. For this reason, some PCB congeners are relatively non-toxic (e.g. PCB138, PCB153) while others (e.g. PCB126, PCB105) are considered to be very toxic because they bind to hormonal receptor sites in the same manner as tetrachlorodibenzo-*p*-dioxin (TCDD), although less efficiently. Hence, the toxicity of PCB

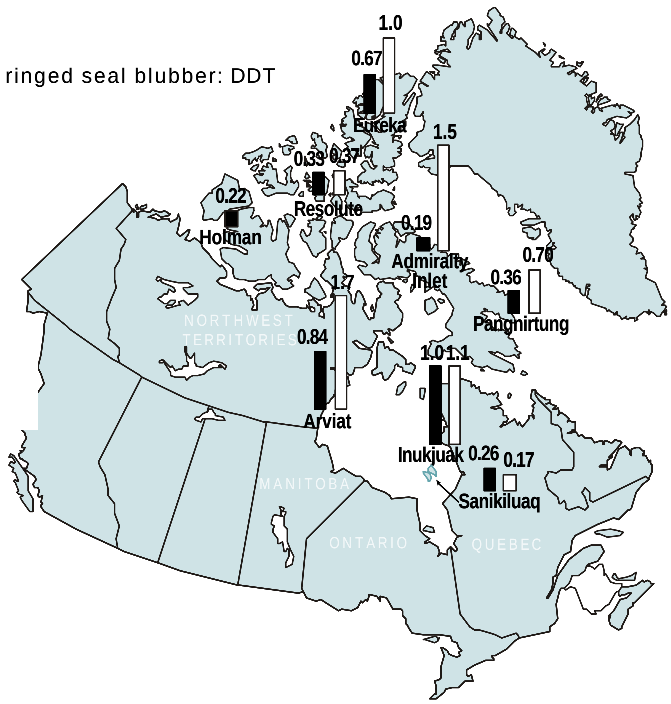

Figure 2 DDT concentration ($\mu g \cdot g^{-1}$ wet weight) in ringed seals in the Canadian Arctic showing increasing trends from west to east. Graph is from the Canadian Arctic Contaminants Assessment Report (CACAR) (Jensen *et al.* 1997).

mixtures is generally expressed in terms of toxicity equivalent factor (TEFs) or quotient (TEQ) relative to TCDD. Most analyses of PCBs conducted over the last ten years are reported as the total of a number of individual congeners (e.g., 40 or 60 congeners) which are usually represented by ΣPCB. Before that, PCBs were measured as Aroclor mixtures, which were the original industrial product.

Although PCBs transport to the Arctic via the atmosphere, there is increasing evidence of PCB contamination from local sources throughout the Canadian Arctic. Several DEW line stations contain old transformers and electrical equipment containing PCBs. In some cases, local transport of PCB residues, by either particulate transport or by evaporation/condensation, can result in a halo of contamination around the sites (Bright *et al.* 1995a). Contamination of the marine system near the sites, such as that near Cambridge Bay, has also occurred (Bright *et al.* 1995b). The effects of this contamination on the local biota are largely unknown.

Concentration in Biota

Despite being banned in North America in the late 1970's, PCBs remain one of the major residues found in the marine food web. In general, the highest levels are found in polar bears. The CACAR reports average concentrations as high as 20,000 ng·g^{-1} lipid in blubber samples taken from 25 bears in McLure Strait (Jensen *et al*. 1997). In contrast, levels in beluga blubber range from 1,000 to 4,000 ng·g^{-1} ww, with a maximum average value in the ISR of 6293 ng·g^{-1} reported in four males taken from East Whitefish in 1990. Other than that extreme value, concentrations tend to be about the same as in the rest of the Arctic (3,000 to 4,000 ng·g^{-1}). Much lower concentrations are reported for muktuk (214 to 317 ng·g^{-1}) (Muir *et al*. 1995). Levels in ringed seal blubber are about 500 to 2000 ng·g^{-1} ww. The concentrations of PCBs dropped markedly in ringed seals in the western Arctic between 1971 and 1981, however there was no further significant decrease as of 1991 (Addison and Smith 1998). Stern and Addison (1999) reported little change in the levels of PCBs in Holman ringed seals between 1981 and 1996. Comparisons of PCB levels in polar bears, ringed seals and beluga across the Canadian Arctic indicate a slight trend of increasing levels from the west to the east (Figure 3). Clearly, ΣPCB remain one of the major organic pollutants of concern in the Arctic because of their ability to bioaccumulate to very high levels in wildlife.

The PCB levels for a particular freshwater fish species show large variability, probably because of the differences in methods of PCB analysis, variability in the levels of fat in the fish and the structure of the food web in the lake where the fish were harvested. In general, the fish species with the highest lipid levels have the highest PCB concentrations. PCB concentrations in burbot liver in the western Canadian Arctic range from about 2 ng·g^{-1} to levels greater than 100 ng·g^{-1} in the east arm of Great Slave Lake (Jensen *et al*. 1997). Similarly, Arctic char range from about 1 up to 290 ng·g^{-1} ww in muscle. An assessment of contaminants in mink in the Northwest Territories reported ΣPCB levels ranging from 7.02 (Inuvik) to 73.1 ng·g^{-1} ww (Fort Providence) (Poole *et al*. 1998), similar to the generally low levels found in caribou and other terrestrial animals. Hares and voles which were collected from the same areas as the mink, and provide a good estimate of the levels in the diet of the mink, had ΣPCB levels <10 ng·g^{-1} ww at all sites they were collected.

Toxicity

The potential for biological effects in wildlife from PCB exposure has led to considerable research in northern Canada and Europe to document PCB levels and to measure potential effects. Braune *et al*. (1999a) summarised guidelines which indicate that several fish and bird species in the North contain PCB levels that exceed guideline levels for human consumption and levels at which reproduction in mink may be affected. AMAP (1997) conducted a similar analysis for samples collected throughout the circumpolar region (Figure 4) and concluded that the highest tissue levels were observed in harbour porpoise, polar bear (circumpolar and in Svalbard) and Arctic fox from Svalbard. None of the data reported thus far for the ISR indicate that any species consistently approach the levels at which effects are expected to occur. Health Canada sets a provisional tolerable daily intake of 1.0 µg·kg^{-1} BW, or a total of 70 µg for a 70-kg person, but the ATSDR is much more conservative and recommends a value of 0.02 µg·kg^{-1} BW·d^{-1}, or only 14,000 ng·d^{-1}. Assuming a ' PCB concentration of 250 ng·g^{-1}, the two guidelines would be exceeded by 280 and 56 grams, respectively. Because of their ability to biomagnify in upper trophic levels, their known toxicity, and the potential for local contamination, PCBs remain one of the major contaminant groups which must be monitored in the ISR.

SUMMARY **Because of their ability to biomagnify and their toxicity, PCBs are one of the predominant residues at the top of the marine food web. Very high concentrations are reported for polar bears. The concentration in beluga in the ISR appear to range from about 3500 to 6000 ng·g^{-1} in blubber. PCBs in ringed seal blubber from Holman Island declined during the 1980's but have stayed the same or increased in the last 10 years, despite the phaseout of PCBs in the south. These factors suggest that PCBs are a high priority for continued monitoring in marine mammals and fish in the ISR.**

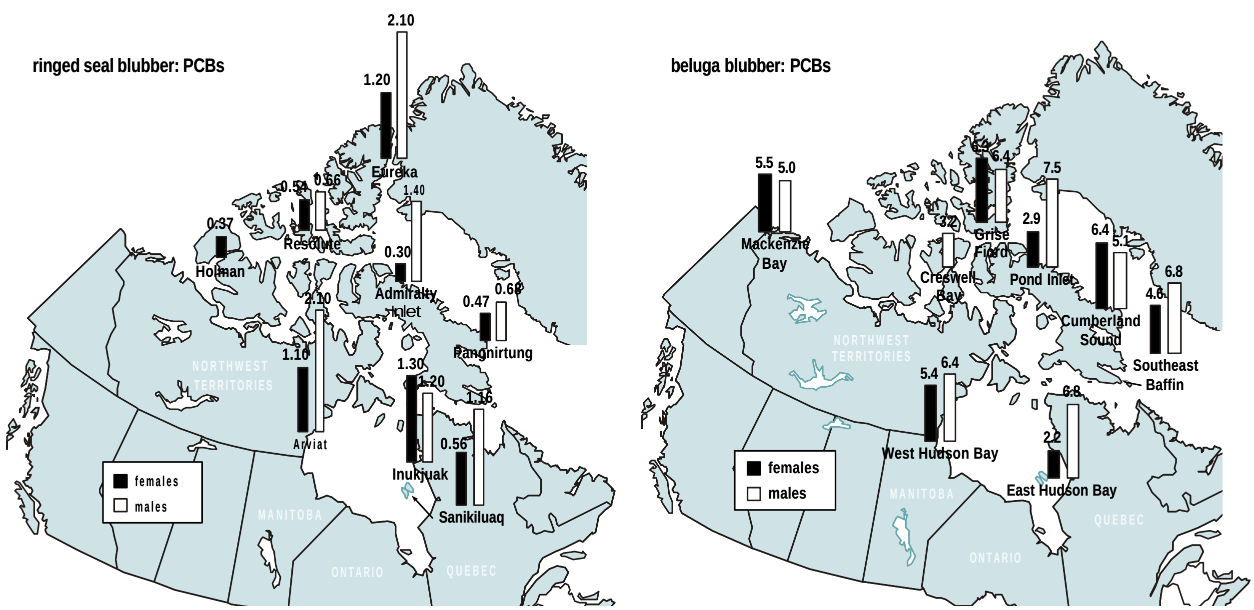

Figure 3 PCB concentration (µg·g^{-1} ww) in ringed seals and beluga in the Canadian Arctic showing increasing trends from east to west. Graph is from CACAR (Jensen *et al.* 1997).

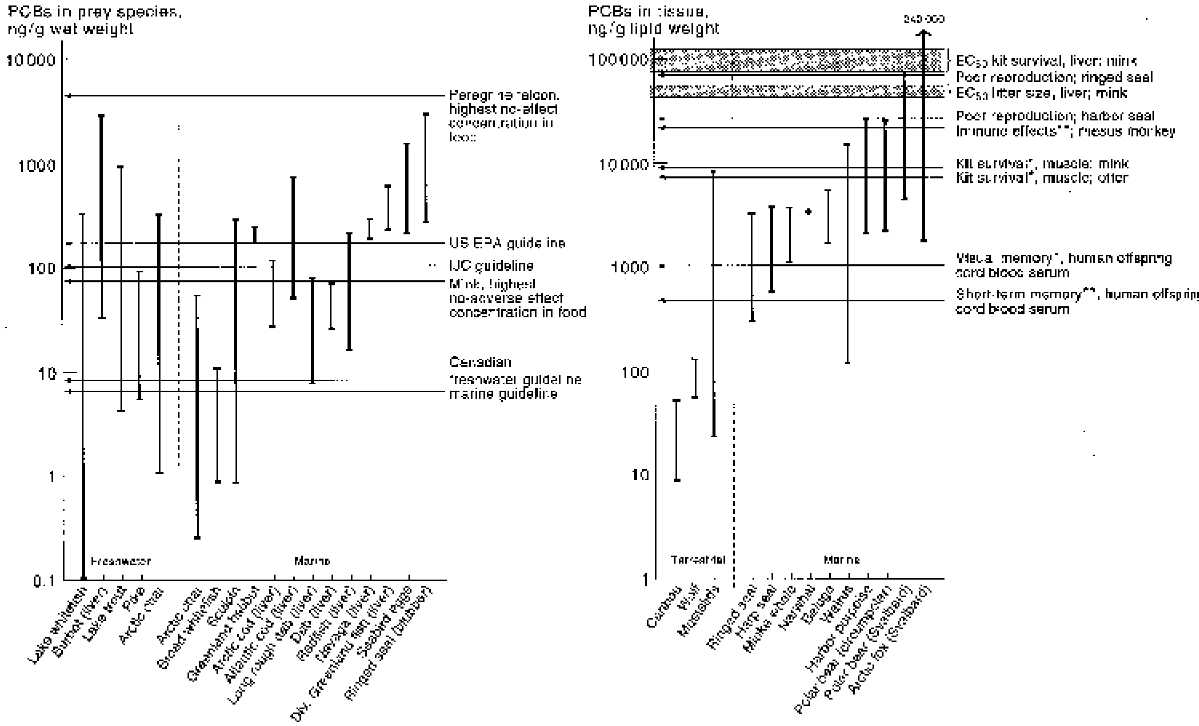

Figure 4 Concentration of PCBs in arctic mammals and birds relative to the concentrations known to cause effects in the animals. Figure on top (left) is the PCB concentration in the diet that is known to cause effects in the predator species. The concentrations found in several species harvested in the Arctic are on the bottom axis. Figure on right is the tissue PCB concentration at which effects are expected to occur, with examples from species harvested throughout the Arctic. (From AMAP 1997).

3.1.5 *Chlordane*

Background

Technical chlordane is comprised of more than 140 compounds (Dearth and Hites 1991), of which *cis* and *trans*-chlordane and *cis* and *trans*-nonachlor are the key components. Over 70,000 tons of technical chlordane has been produced since 1946, and it has an environmental half-life of 10 to 20 years. Technical heptachlor is also a major component of technical chlordane but because of its greater toxicity, small amounts of it were manufactured and used separately. The most dominant form of chlordane in fish and wildlife is the metabolite oxychlordane, which comprises over 80% of the residues in some bird species at the top of the marine food web (Kawano *et al*. 1988). Chlordane residues are very hydrophobic and accumulate to the same extent as PCBs, forming almost 30% of the total organochlorine residues in polar bears. Total chlordane (ΣCHL) concentrations increase from <5 ng·g^{-1} ww in plankton (Hargrave *et al*. 1992) to 2000 to 4000 in beluga blubber (Jensen *et al*. 1997).

Concentrations in Biota

Typical levels in beluga blubber in the ISR are about 1500 to 2500 ng·g^{-1}, with muktuk considerably lower at 119 to 162 ng·g^{-1} (Muir *et al*. 1995). Concentrations up to 431 ng·g^{-1} (Sachs Harbour) were reported for ringed seal blubber in the ISR by Weis and Muir (1997), which were slightly lower than the levels reported elsewhere in the Canadian Arctic. Addison and Smith (1998) reported no change in oxychlordane levels between 1981 and 1991 for both male and female ringed seals from Holman Island.

In general, chlordanes do not seem to accumulate to a great extent in freshwater or marine fish. Maximum levels reported for the NWT in CACAR (Jensen *et al*. 1997) are 62.8 ng·g^{-1} ww (SD = 25.5; n=29) in the liver of burbot collected in the east arm of Great Slave Lake, followed by the muscle of Arctic char from Cornwallis Island (47.3 ng·g^{-1} ww; SD = 23.5; n=12). Lockhart *et al*. (1992) report total chlordane levels of 0.2 to 10 ng·g^{-1} in the muscle of lake whitefish collected in several communities from the NWT, including Fort Good Hope and Fort Simpson. Broad whitefish from five lakes in the ISR had levels of 0.67 to 8.9 ng·g^{-1} ww, significantly lower than those in marine mammals (Lockhart *et al*. 1993).

Toxicity

The toxicity of chlordane is not well defined and large uncertainty factors are used when estimating potential effects in humans and wildlife. Health Canada recommends a tolerable daily intake (TDI) of 0.05 µg·kg^{-1} BW, or 3.5 µg·d^{-1} for a 70 kg adult. At a level of 125 ng·g^{-1} in muktuk, this level would be exceeded by consuming only 28 g of muktuk. The ATSDR recommends a minimum risk level of 0.6 µg·kg^{-1} BW·d^{-1}, which would equal about 280 g of muktuk at this concentration.

SUMMARY **Together, chlordanes and PCBs account for >80% of the residues found in polar bears and >60% in beluga. Oxychlordane, a toxic metabolite, is the major form in mammals and birds and its concentration in the tissues of some mammals approaches those expected to cause major effects. Temporal data indicate little change in chlordane in the top trophic levels since the 1980's. Chlordanes are a top priority for monitoring in the marine environment because of the high concentrations which can result due to biomagnification of the individual isomers.**

3.1.6 *Toxaphene*

Background

Toxaphene, also known as chlorobornane or polychlorinated camphenes (PCC), is a complex mixture of compounds that are produced by the chlorination of camphene. There are potentially >30,000 individual compounds that can be formed in the process and several hundred have been found in technical toxaphene mixtures (Glassmeyer *et al.* 1997). The methodology for the analysis of toxaphene is still under debate, and after several years of analysis, the best methods to report toxaphene concentrations and its individual components are still unclear. Toxaphene was used as an insecticide to treat cotton pests and as a pesticide on soybeans and livestock. It was also used as a piscicide to remove fish from lakes prior to the placement of other species for sport fishing.

Concentrations in Biota

A comparison of toxaphene levels using similar methods of measurement (Jensen *et al*. 1997) show that total concentrations can exceed the very high level of 14,000 ngAg^{-1} ww, which was found in the blubber of male beluga in Hudson Bay and near Kimmirut on south Baffin Island (Jensen *et al*. 1997). Concentrations in Beaufort Sea beluga are less than the extreme, with average levels of 6000 to 7000 ngAg^{-1} ww (Jensen *et al*. 1997). Muir *ewt al.* (1995) report toxaphene levels in muktuk of 312 to 468 ngAg^{-1}. Hargrave *et al.* (1993) report levels almost as high as those in beluga in benthic amphipods from the Arctic Ocean, (maximum value of >3800 ngAg^{-1} ww), suggesting that marine fish may also be exposed to high levels. Beluga muktuk values are around 300 to 400 ngAg^{-1} ww. As with other POPs, ringed seals tend to have much lower levels of toxaphene than beluga. Weis and Muir (1997) reported toxaphene concentrations of 215 ngAg^{-1} in the blubber of Tuktoyaktuk ringed seals and 341 ngAg-1 in Sachs Harbour seals.

Toxaphene is one of the major organic contaminants that accumulate to very high levels in the fish of some inland lakes. Routine surveys of POPs in fish reported very high toxaphene levels in Lake Laberge and the east arm of Great Slave Lake. Concentrations in burbot liver of 2301 ngAg^{-1} ww and 1533 ngAg^{-1} ww were reported for two Yukon lakes (Jensen *et al*. 1997). Detailed food chain analysis using stable isotopes showed that the high concentrations are probably due to the structure of the food chain such that lake trout and burbot feed at a higher trophic level than in other lakes (Kidd *et al*. 1995). A survey of broad whitefish in the ISR reported levels of 3.1 to 48.1 ngAg^{-1} (Lockhart *et al*. 1993), much lower than the extremes noted elsewhere.

Toxicity

At present, there are not enough data to establish time trends for toxaphene in biota in the north. The concentrations of toxaphene found in some fish species exceed those expected to affect collagen formation in fish (Jensen *et al*. 1997) and the Canadian Council of

Ministers of the Environment (1999) has published a tissue residue guideline of 6300 ng·g^{-1} in the diet for the protection of wildlife (http://www.ec.gc.ca/ceqg-rcqe/tissue.htm). The concentrations observed in beluga and in some individual fish in Lake Laberge approach, or exceed, the CCME guideline for the protection of wildlife. Health Canada recommends a tolerable daily intake of 0.2 µg·kg^{-1} BW·d^{-1}, or 14,000 ng·d^{-1} for a 70 kg adult. Assuming a level of 350 ng·g^{-1}, the guideline would be exceeded by 40 g of muktuk. Until the analysis of toxaphene is standardized, however, this assessment is meaningless.

SUMMARY **Toxaphene reaches very high concentrations in beluga and in the top predator species in some lakes. These high concentrations exceed the levels that are considered to be potentially toxic to wildlife, and possibly humans. There are serious questions about the analysis of toxaphene however, and values may change as the methods of analysis change. Also, toxaphene toxicity is poorly understood and the food guidelines are estimated with large uncertainty factors. Toxaphene in freshwater fish and marine mammals should be monitored in freshwater fish and marine mammals in the ISR.**

3.1.7 *Polychlorinated dibenzo-p-dioxins (PCDD) and furans (PCDF)*

Background

Because of their extreme toxicity to some mammal and bird species and the high concentrations observed in the biota in some environments, dioxins (PCDDs) and furans (PCDFs) remain a concern in the Arctic. Sources of dioxins and furans include incinerators, some manufacturing processes, and chlorination in pulp and paper plants. Some herbicides were once a major source of dioxins but changes in manufacturing processes have significantly reduced the output by this route. Sites with extensive dioxin/furan contamination include some industrial areas in the Great Lakes and the receiving waters of bleached kraft pulp and paper mills. There are several types of dioxins and furans, the most toxic of which is the congener 2,3,7,8 - TCDD.

Concentration in Biota

Several surveys of dioxins and furans in northern samples have been conducted but, overall, the levels are not high enough to warrant major concern. A survey in northern ringed seal, polar bear and beluga found that the most toxic dioxin (TCDD) was detectable in all seal samples and all but one polar bear sample (range of concentrations = 2 to 37 ng·kg^{-1} ww) but was not detected in any beluga blubber samples (Norstrom *et al.* 1990). The toxic furan (TCDF) was detected in all seal blubber samples and one of the three beluga blubber samples (range of 2 to 7 ng·kg^{-1} ww). None of the polar bear fat samples had detectable TCDF, suggesting that the compound is metabolised. Subsequent research showed that PCBs are of more concern than dioxins, since they have similar toxic action.

Stern and Addison (1999) reported very low levels of dioxins and furans in ringed seals collected from Holman Island in 1996. No clear decreasing trends were evident between 1981 and 1996, however this could partly be due to the large variability in the data because the values were so low (Stern and Addison 1999).

An extensive sampling program in the Slave River at Fort Smith reported that virtually 100% of the dioxin/furan residues in walleye and burbot were comprised of the toxic 2,3,7,8- TCDD and -TCDF, evidence that bleached kraft paper mills upstream from Fort Smith are major sources of the compounds (Jensen *et al*. 1997). In contrast to the marine mammal data and Slave River study, terrestrial animals generally have levels of dioxins/furans residues that are below detection limits. A survey of four caribou herds reported that dioxin/furan congeners were at or below detection in all samples tested, except for the relatively non-toxic, combustion-related octachlorodibenzo-*p*-dioxin (OCDD) (Hebert *et al*. 1996). PCDF congeners were observed in the herds but concentrations remained low. By themselves, dioxins and furans are not likely to produce toxic effects in the Arctic. It is not known if levels are changing through time.

Toxicity

Most consumption guidelines for dioxins and furans are extremely conservative because of the uncertainties about potential effects. The Agency for Toxic Substances and Disease Registry (ATSDR) in the U.S. recommends a minimum risk level (Table 2) of 0.000001 $\mu g \cdot kg^{-1}$ $BW \cdot d^{-1}$, however that level is exceeded by almost all foods in the south and north. These levels will remain very conservative until better data are available on the potential effects of low levels of dioxins and furans.

SUMMARY **Except at sites of localised contamination, PCDD/Fs concentrations are not significant in the Arctic. Of the compounds with dioxin-like toxicity, PCBs are a greater concern because of their higher concentrations. Few time trend data are available for PCDD/F. Given the expense of the analysis for PCDD/F's, and the lack of evidence for high levels in northern species, these compounds should be occasionally be monitored, but not routinely analysed, in harvested wildlife and fish in the ISR.**

3.1.8 *Dieldrin*

Background

Dieldrin was used as a soil insecticide in the US until 1987, when most uses were banned. It is currently used for termite control. It is also the major degradation product of aldrin, which is no longer used as an insecticide.

Concentration in Biota

The mean concentration of dieldrin in marine mammal blubber varies considerably between populations of any species. For example, levels in beluga range from 7 ng·g^{-1} ww (NW Greenland) to 1447 ng·g^{-1} ww (SD = 661; n=6) in males near south Baffin Island. Beluga in the ISR have levels in the range of 300 to 450 ng·g^{-1} in blubber, but much lower levels (20 to 29 ng·g^{-1} ww) are reported in muktuk (Muir *et al*. 1995). In general, the levels of dieldrin are lower in ringed seal blubber than beluga blubber, but there are no values reported for seals from the ISR in the major studies of contaminants in ringed seals (Muir *et al.* 1995, Weis and Muir 1997, Jensen *et al*. 1997). One set of data for ringed seals from Holman Island (Addison and Smith 1998) show dieldrin levels at a maximum of 87.6 ng·g^{-1} lipid, which is probably equivalent to about 80 ng·g^{-1} ww (assuming 90% fat in lipid). The same authors reported no decline in dieldrin residues in ringed seals between 1981 and 1991 at Holman Island.

Toxicity

Dieldrin is highly toxic and can cause damage to the nervous system. ATSDR reported liver effects in animals at ingested doses of approximately 80 ng·g^{-1} BW·d^{-1} and immunological effects at about 900 ng·g^{-1} BW·d^{-1}. Health Canada recommends a guideline of 0.1 µg·kg^{-1} BW·d^{-1}, or about 7,000 ng per day for a 70 kg person, which is equivalent to between 240 and 410 grams (1 lb) of muktuk.

SUMMARY **Although its concentration is low relative to other POPs in biota, the high toxicity of dieldrin, and the fact that tissue levels exceed those known to cause effects in laboratory animals, warrants some consideration. Temporal trend studies suggest that levels of dieldrin are presently remaining constant.**

3.1.9 *New compounds*

Polybrominated and polychlorinated diphenyl ethers (PBDE; PCBE) are flame retardants that share the same basic chemical structure and physical properties of the more widely studied POPs. They have been observed at relatively high concentrations in samples from Europe, and in air samples in northern Canada. Stern and Addison (1999) report levels of 10.2 ng·g^{-1} ww of brominated DPE and 60.4 ng·g^{-1} chlorinated DPE in beluga from Baffin Island. Research is currently ongoing, some of it in the ISR, to determine the level of contamination in marine mammals.

Butyltins (BT) are a group of organotin compounds that have been used as stabilizers in plastic and as biocides on boats and nets (Takahashi *et al.* 1999). As with the other POPs considered here, BTs are of concern because of their extensive use, persistence and toxicity. Tributyltin (TBT), which is used in the marine environment, has been implicated in the loss of reproduction in gastropods and shell anomalies in oysters. At the moment no data are available for the levels of TBTs in marine mammals or fish in the ISR.

SUMMARY The FJMC should encourage research into new compounds and their effects on people and wildlife. Many of the compounds which have been reported in animals and fish from Europe are probably present in the ISR, although at lower levels. The FJMC should encourage and expedite the collection of samples to monitor the presence of these compounds in wildlife and fish.

3.2 Metals

Metals generally receive less attention than POPs because they are not so clearly linked with anthropogenic activities, except in local areas of contamination such as mines, communities or industrial sites. The sources of many of these compounds are unclear. It is not known how much of the major metals, like mercury and cadmium, come from industry in the South and how much comes from rocks and the environment of the Arctic. Mines and natural sources can lead to local contamination of uranium, arsenic, lead and other elements in ground and surface waters in northern Canada. The effects of these localised sources of contamination are not known in northern ecosystems.

The adverse effects of many metals in wildlife and fish are reasonably well known from laboratory studies but their effects on wild populations are not clearly understood. Some metals are required by the animals for proper nutrition (e.g. copper, manganese, iron) and organisms have internal mechanisms to regulate high levels of these metals that may be in their diet. Other metals are not essential and will interfere with the normal functioning of biological systems. In some cases, the high levels of one metal may interfere with the normal metabolism of another metal, resulting in sickness and disease in the animals. High levels of molybdenum, for example, may interfere with the normal uptake and metabolism of copper, resulting in a copper deficiency disease. Similarly, high levels of selenium appear to protect people and humans against the effects of high levels of mercury and allow the animal to deposit the mercury in its body in a non-toxic form. These issues must be addressed separately for each metal, and the cumulative effects of the metals are still unclear.

3.2.1 *Mercury*

Background

Mercury contamination remains one of the top priorities in the Arctic because high concentrations have been reported in many freshwater fish and marine mammal species (Wagemann *et al.* 1995) which are part of traditional diets. Mercury is present throughout the environment as metallic mercury (Hg^0) or organic mercury (CH_3-Hg; $(CH_3)_2$-Hg), with the methylation process occurring in sediments of lakes and in the gut of some organisms.

Mercury is released to the atmosphere during the burning of fossil fuels and during incineration and moves through the atmosphere by the cold condensation process in the same manner as the POPs. The AMAP (1997) has estimated that 60% of the mercury in the environment is released from industrial processes. Mercury is also released from soils and sediments within the Arctic and it is not clear how much of the mercury found in northern fish and marine mammals comes from industry in the south. A review of mercury toxicology, sources and risk is presented in the Report to Congress on mercury by the U.S Environmental Protection Agency (USEPA 1997). The document is available at (http://www.epa.gov/ttnuatw1/112nmerc/mercury.html).

Concentration in Biota

Several reviews show that mercury concentrations are very high in some northern species, and that levels are much higher in the west (e.g. the ISR) than the east for many species. Wagemann *et al*. (1996) reported an average total Hg concentration of 27.1 µg·g^{-1} ww in 77 beluga livers from the western Arctic (1993-94), compared to 10.2 µg·g^{-1} for 73 beluga livers from the east (1993-94). Similarly, ringed seal livers from the western Arctic had an average value of 32.9 µg·g^{-1} ww compared to 8.34 µg·g^{-1} ww from the eastern Arctic (Figure 5). The high levels in both species seem to be balanced by selenium, suggesting that the high levels may not be affecting the animals directly. Beluga collected from 1994 to1996 at Hendrickson Island had about 1 µg·g^{-1} in muktuk and 30 to 40 µg·g^{-1} in liver (L. Lockhart, Freshwater Institute, DFO, pers. comm.). Importantly, about 90% of the mercury in beluga muscle and skin (muktuk) is the more toxic methyl-Hg, compared to only about 15% in the liver (Wagemann *et al*. 1997, 1998). This would place the levels of methylmercury at about 1 µg·g^{-1} in muktuk and 4 µg·g^{-1} in liver.

The concentration of Hg increased significantly between 1981/84 and 1993/94 for beluga and between 1972/73 and 1987/93 for ringed seals in the western Arctic (Wagemann *et al*. 1996). Comparison of the increase of Hg with age showed that beluga were accumulating Hg twice as fast as the beluga in 1981/84 and the ringed seals were accumulating Hg three times as quickly in 1987/93 than in 1972/73. An increase in Hg concentration of a similar magnitude has been reported in the eggs of some species of northen seabirds (Braune *et al*. 1999b). Lake sediments also show enriched Hg levels in surface slices, indicating higher flux rates of Hg into the lakes in recent years (Lockhart *et al*. 1995). These three lines of evidence suggest that the high Hg concentrations found in marine mammals and fish are continuing to increase, with higher rates present in the west. It is not known if the increasing levels are the result of increased amounts entering the Arctic or due to factors within the Arctic.

High levels of Hg are reported for some fish species in many lakes of the NWT and consumption advisories have been issued in some cases. Studies have also shown very low levels in common species, like broad whitefish (Lockhart *et al*. 1993). The Fish

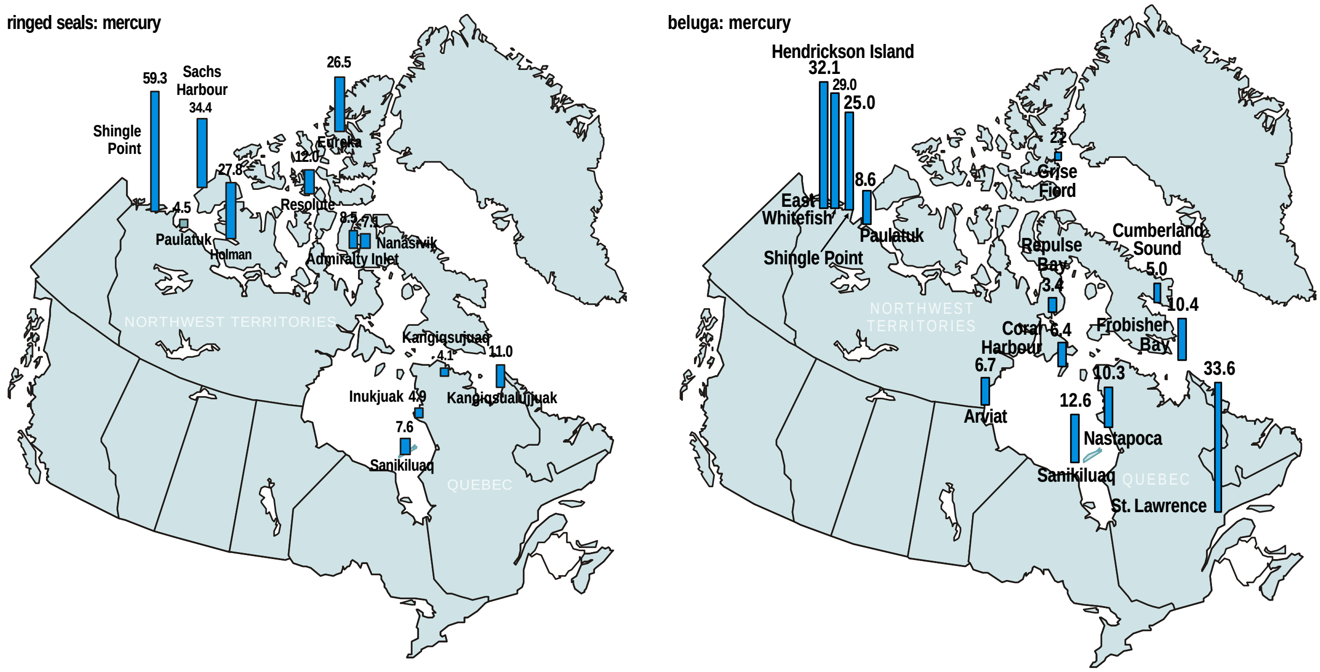

Figure 5 Mercury levels (µg·g^{-1} wet weight) in ringed seal and beluga liver across the Canadian Arctic showing higher levels in the west. Graph is from CACAR (Jensen *et al*. 1997).

Inspectorate reports an average concentration of 0.47 µg·g^{-1} in northern pike and 0.06 µg·g^{-1} in lake whitefish from the Mackenzie Delta. Lake trout and inconnu from Yaya Lake in the ISR collected in 1995 had mercury levels of 0.21 and 0.17 µg·g^{-1} (Lockhart, pers. comm.). Other lakes have species like lake trout and walleye exceeding the food guideline by a large margin (Lockhart, pers. comm., Jensen *et al*. 1997). CACAR also reports mercury levels in fish-eating birds ranging from 0.26-1.9 µg·g^{-1} in breast muscle, marginally higher than the levels in the east. Clearly, all major species of wildlife in the ISR have the potential for levels of mercury that exceed the Canadian and WHO guidelines if the exposure conditions are right. Studies also show that the mercury is probably balanced by selenium in the diet, and hence the mercury may not be toxic. More research is needed in this area.

Toxicity

The mercury concentrations observed in beluga and ringed seal are very much greater than the Health Canada guideline of 0.5 µg·g^{-1} ww for the consumption of commercial fish and 0.2 µg·g^{-1} ww for subsistence fisheries. Long-term exposure to mercury can cause permanent damage to the brain, kidneys and developing fetuses, although many mammals may have mechanisms which protect against mercury toxicity (Lockhart *et al*. 1999). Health Canada recommends a provisional weekly intake of 5 µg·kg^{-1} BW, or about

350 µg per week for a 70 kg adult, or about 350 g of muktuk per week. Lower values are recommended for pregnant women and children. The World Health Organisation also recommends a weekly intake of 5 µg·kg^{-1} BW total mercury and an intake of 3.3 µg·kg^{-1} BW per week of methylmercury. The US agencies recommend a daily minimum risk level of 0.3 µg·kg^{-1} BW for methylmercury.

SUMMARY **Several pieces of evidence indicate that mercury is a top priority because of high concentrations in marine and freshwater species which will probably lead to consumption advisories. The concentrations in marine mammals and predatory fish have apparently increased markedly in the last 10 years, and levels appear to be continuing to increase. Dietary guidelines are exceeded by some marine mammal tissues and some species of fish from some lakes. More information is required on the distribution of mercury and selenium in foods throughout the ISR and an assessment of the rate of intake in traditional foods in the area.**

3.2.2 *Cadmium*

Background

Cadmium is a non-essential metal that is observed throughout the Arctic. It can accumulate to relatively high levels in the kidney of marine and terrestrial biota, although the concentration in meat is low. Cadmium was declared “toxic” by Environment Canada (CEPA 1994) and a tissue residue guideline of 30 µg·g^{-1} ww was recommended for wildlife. This guideline is based on a level in the kidney at which dysfunction begins to occur. Biological effects in the kidney from elevated Cd exposure have been observed in laboratory studies and, in extreme cases, in humans exposed to very high levels in food and water. The source of Cd in the Arctic is unknown. A small flux of Cd undoubtedly occurs by atmospheric deposition but dispersed sources of Cd within the Arctic probably generate the most of the Cd found in water and biota.

Concentration in Biota

Ringed seals have the highest levels of Cd reported in wildlife in the ISR, although the concentrations are lower than those in the eastern Canadian Arctic. An average value of 21.1 µg·g^{-1} was reported for the kidney of 145 ringed seals collected in Sachs Harbour and Holman Island, compared to 47.7 µg·g^{-1} in the kidney of 114 ringed seals from the east (Jensen *et al*. 1997). Wagemann *et al.* (1996) report cadmium concentrations of 9.7 µg·g^{-1} in the kidney of 78 beluga from the west, much lower than the level of 22.4 µg·g^{-1} reported in 139 beluga in the east.

Several studies have been conducted on Cd in caribou from the Yukon (Gamberg and Scheuhammer 1994), the NWT and Nunavut (Elkin and Bethke 1995) and northern

Quebec (Crête *et al.* 1989). There is considerable variability in the levels of Cd through the Arctic but the highest levels are in the Yukon, where caribou in mineral-rich areas have kidney Cd levels approaching 100 $\mu g \cdot g^{-1}$ ww (assuming 30% dw in kidney) (Gamberg 1997). Figure 6 summarises data on Cd levels in several species of Yukon wildlife from a survey conducted by the Yukon Contaminants Committee.

Toxicity

Cadmium has been termed "toxic" in the CEPA assessment by Health Canada and Environment Canada and has been grouped as a possible carcinogen. Health Canada uses the World Health Organisation recommended provisional weekly intake (PTWI) of 7 $\mu g \cdot kg^{-1}$ $BW \cdot wk^{-1}$ or 1 $\mu g \cdot kg^{-1}$ $BW \cdot d^{-1}$. This corresponds to a total intake of 70 $\mu g \cdot d^{-1}$ for a 70 kg adult. The ATSDR recommends a more conservative value of 0.2 $\mu g \cdot kg^{-1}$ $BW \cdot d^{-1}$. A major factor for consideration in human health assessments with cadmium is the level of smoking in individuals, since smoking represents a large source of Cd to humans. An assessment of Cd levels in several wildlife species in the Yukon by DIAND and Health Canada led to the recommendation that 1 moose kidney can be safely consumed annually, and as few as 7 caribou kidneys (depending on the herd), but the consumption of kidneys from other species was virtually unlimited (Table 5). The consumption of meat was also unlimited. Fish do not efficiently accumulate cadmium to the same extent as mammals and low levels have been reported throughout the Canadian north (Lockhart *et al*. 1992).

SUMMARY **Cd is found at high levels in kidney and liver of marine mammals and some terrestrial wildlife, although the levels in muscle remain low in all species. Tissue Cd levels often exceed those recommended by Environment Canada under the PSL assessment (30 $\mu g \cdot g^{-1}$) for the protection of wildlife, apparently from natural sources. Health Canada sets a relatively conservative value on the guidelines for consumption of Cd-rich foods which can be exceeded by liver and kidney of some wildlife species. Waterfowl muscle and fish are very low in Cd.**

3.2.3 *Lead*

Background

Lead is a highly toxic metal that accumulates in the liver, kidney, spleen and skeleton. It affects the nervous, reproductive and cardiovascular systems. In humans, the greatest concern is for pregnant women and children where nervous effects are most severe. In the Arctic, lead levels are low in wildlife except in localised areas where leaded petroleum products have been released or in populations that have been exposed to lead shot. There was a large decline in the lead levels in sediments and glacial ice when lead was removed from gasoline, indicating that the flux to the Arctic from industrial processes and combustion sources was reduced.

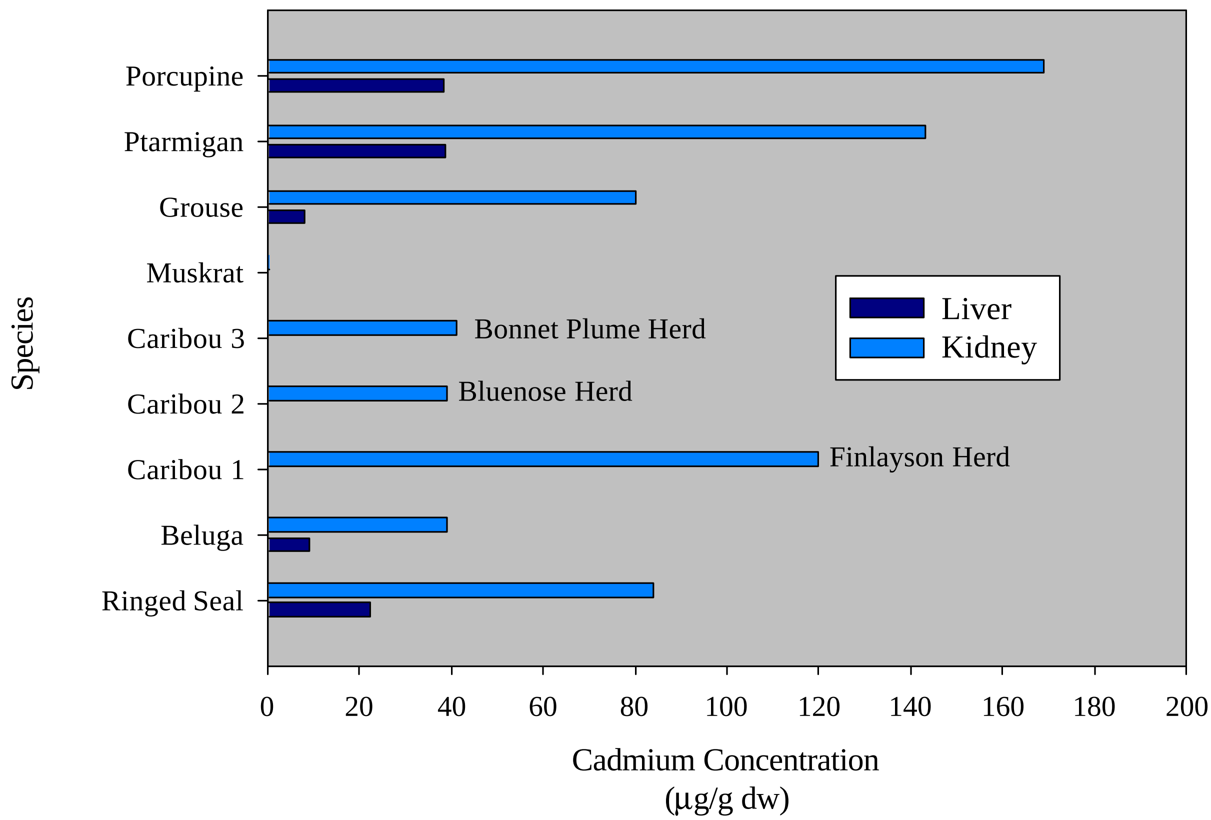

Figure 6 Concentration of Cd ($\mu g \cdot g^{-1}$) in the liver and kidney of several wildlife species taken from the Yukon showing wide variation with species and site of collection. Data are from Gamberg (1997) and Jensen *et al*. (1997).

Table 5 Recommended rates of consumption of liver and kidney of wildlife species in the Yukon, based on some of the data shown in Figure 6. Data indicate the regional and species differences in Cd concentrations. There are no restrictions on meat. Data are from the Yukon Contaminants Committee.

Species	Maximum # of Livers per year Recommended for Consumption	Maximum # of Kidneys per year Recommended for Consumption
Caribou		
Bonnet Plume	16	32
Nahanni	13	28
Porcupine	12	25
Forty-Mile	12	20
Wolf Lake	8	15
Finlayson	5	8
Tay	4	7
Moose	1	1
Sheep	No Limit	178
Goat	26	382
Beaver	46	15
Porcupine	17	13
Snowshoe Hare	No Limit	485

Concentration in Biota

Beluga and ringed seal have very low (< 1 $\mu g \cdot g^{-1}$ ww) lead levels in muscle and internal organs. Jensen *et al*. (1997) report one population of walrus with 1.43 $\mu g \cdot g^{-1}$ in liver but the average levels in beluga liver throughout the Arctic (215 samples) was 0.02 $\mu g \cdot g^{-1}$. Similarly, broad whitefish collected in five ISR lakes showed lead levels of 0.0046 to 0.017 $\mu g \cdot g^{-1}$ in liver and were below detection limits in all muscle samples.

Toxicity

Lead has a high toxicity to the nervous system and Health Canada recommends a provisional daily intake of 3.57 $\mu g \cdot kg^{-1}$ $BW \cdot d^{-1}$, which is derived from the WHO level of 25 $\mu g \cdot kg^{-1}$ $BW \cdot wk^{-1}$. Normally, this value is not exceeded however very high levels of lead have been reported for moose blood (Berti *et al*. 1998). Lead poisoning has also been documented in northern Québec and Nunavut in people who have accidently incidently ingested lead shot fragments in hunted traditional foods. There is a high incidence of lead-related toxicity in some groups of children as a result of this poisoning.

SUMMARY **Pb is generally not a major concern in the Arctic because of low levels in most wildlife species. High Pb levels reported in moose blood and in the blood of children who have ingested lead shot. Ingestion of lead shot is a serious problem for many people consuming traditional foods in which Pb-shot fragments may be present. In general Pb fluxes to the Arctic are much lower since Pb was removed from gasoline.**

3.2.4 *Arsenic*

Background

Arsenic is not generally considered to be a major contaminant in the Arctic. Concentrations of this metal can be very high in fish locally, however, and the potential for large scale contamination is great considering the massive amounts in some areas of the Arctic (e.g. Yellowknife). Arsenic is produced as a by-product of mining gold or uranium but small amounts of arsenic are used as a wood preservative. The chemistry of arsenic is very complex and many forms of arsenic are low in toxicity.

Concentration in Biota

Recent major reviews of metals in marine mammals (Jensen *et al*. 1997; Wagemann *et al*. 1998) do not include arsenic as one of the metals reviewed. A review of contaminants in marine mammal specimens archived in the U.S. reports As levels in Alaskan ringed seal liver of 0.17 to 2.4 $\mu g \cdot g^{-1}$ ww (n = 13) and 0.05 to 0.62 $\mu g \cdot g^{-1}$ ww in beluga liver (Becker *et al*. 1997). Much more work has been done on fish. Berti *et al*. (1998) report levels of

1.2 $\mu g \cdot g^{-1}$ in loche (burbot) liver and 1.96 $\mu g \cdot g^{-1}$ in cisco from Great Bear Lake. The survey of ISR broad whitefish by Lockhart *et al.* (1993) did not include As.

Toxicity

Arsenic is a known carcinogen and its inorganic compounds were defined as "toxic" under CEPA legislation (CEPA 1993b). It is considered to be a no-threshold toxicant, meaning there is believed to be some chance of adverse health effects at any level of exposure. Data used in the CEPA assessment indicated that levels of As in the diet of fish-eating mammals near gold mines are high enough to potentially cause adverse effects in aquatic and terrestrial organisms. Health Canada uses the WHO provisional tolerable weekly intake of 15 $\mu g \cdot kg$ BW, or a daily ingestion level of 150 $\mu g \cdot d^{-1}$ for a 70 kg adult. Concentrations of 1.2 $\mu g \cdot g^{-1}$ and above have been reported in burbot liver, and inconnu and cisco flesh in the western Arctic (Berti *et al.* 1998). Maximum breast muscle concentrations in grazing birds in the eastern Arctic reached 0.9 $\mu g \cdot g^{-1}$ ww but only 0.4 $\mu g \cdot g^{-1}$ in molluscivores in the west (Braune *et al*. 1999a). These studies indicate that As may be high regionally but seldom exceeds the values required to exceed the dietary value of 150 $\mu g \cdot d^{-1}$ for adult humans.

SUMMARY **Arsenic is primarily a local contamination concern, but its high toxicity and carcinogenicity can make it a major local concern in areas where large amounts are present. Recent assessments of As toxicity also indicate that the recommended levels in the human diet may be reduced. High concentrations are reported for some fish and bird species but more information is needed on the levels of As in northern aquatic systems.**

3.3 Radionuclides

Background

Radionuclides are compounds like metals that decay over time and give off energy that can cause biological changes that lead to cancer. Radiation exposure has been a northern concern for about 40 years for several reasons. Abandoned uranium mines, Cosmos 954, a Russian satellite that deposited radioactive debris across a large area in the NWT, and the disclosure that large areas of northern Russia and parts of the Arctic Ocean are contaminated with nuclear waste have all increased the need for information about these compounds in the Canadian north. Caribou are also known to efficiently accumulate and retain radionuclides that have deposited on lichen. Because of the almost universal use of caribou throughout the Canadian north for food, and the cultural and social aspects of caribou hunting in northern cultures, the monitoring of contamination of caribou for radiation is a priority in many communities.

Radionuclides come from either natural or man-made sources. The most common source of natural radiation is uranium-238, which decays through a long decay chain of several isotopes to lead. The decay chain includes uranium-238, thorium-232, radium-226, radon-222 (radon gas), lead-210 and polonium-210 and many others. Because of its long half-life, U-238, which is the dominant uranium isotope in uranium deposits, is not considered to be toxic by radiation but is chemically toxic, particularly to the kidney. The other isotopes in the U-238 decay chain can produce high levels of exposure in localised areas, particularly around uranium mine sites.

Abandoned uranium mines are a concern of many communities in northern Canada. Various levels of uranium mining took place at Port Radium (Great Bear Lake), Rayrock Mine (Sherman Lake) and, to a lesser extent, the Stark Lake Mine (Great Slave Lake). The most radioactive site is at Port Radium, which was mined for radium, silver, cobalt and uranium at different times between 1930 and 1985. Radioactive tailings are distributed on the land and over a large area in the Bay around the site. The full extent of the contamination around the site is unknown, as are the potential effects in biota. Tailings areas at the Rayrock mine were largely remediated by DIAND in the late 1990's and pose less risk of local contamination. The Stark Lake mine is a relatively minor site with a small footprint of contamination. The Russian satellite Cosmos 954 deposited nuclear waste debris from Great Slave Lake to Baker Lake in 1978, however the debris was identified in a massive cleanup operation and removed. The amount of material was relatively small, although highly radioactive, and any remaining material probably decayed away very quickly.

People in the Arctic are mostly exposed to radiation through natural sources in food, with the highest levels found in caribou. Two of the natural isotopes, lead-210 (Pb-210) and polonium-210 (Po-210) reach relatively high levels in some caribou herds because of the natural deposition of the lead-210 from the atmosphere onto lichen, which is then eaten by the caribou. The Pb-210 and Po-210 accumulate in the caribou liver and kidney (Macdonald *et al.* 1996; Thomas et al. 1994). The major contributor to radiation dose is polonium-210 which is a high-energy alpha-emitting isotope of uranium-238.

The man-made isotope cesium-137 was produced in atmospheric nuclear weapons tests in the 1960's and in the Chernobyl nuclear accident in 1986 and deposited onto lichen throughout northern Canada. A recent analysis indicates that the Yukon and parts of Alaska received some of the highest rates of deposition of Cs-137 in 1965 (Wright *et al.* 1999). The Cs-137 deposits onto lichen and accumulates in caribou muscle. Several large scale surveys have monitored the levels of radioactive contaminants in caribou after atmospheric nuclear weapons tests and Chernobyl. Cesium-137 concentrations during the 1960's reached >2000 $Bq \cdot kg^{-1}$ (1 Bq = 1 disintegration per second) in caribou muscle, however the levels are currently 100 to 200 $Bq \cdot kg^{-1}$ in most areas, and are continuing to decline with an environmental half-life of about 8 years (Macdonald *et al*. 1996). In contrast, Cs-137 levels in European reindeer exceeded 50,000 Bq·kg^{-1} in some herds after Chernobyl. Several studies have shown that the slightly enhanced risk of illness caused by the natural and man-made nuclides is more than balanced by the social, cultural and nutritional benefits of the caribou.

People in coastal communities in northern Canada and Alaska have voiced concerns about the possibility for nuclear wastes moving from contaminated sites in the Former Soviet Union (FSU) to the North American Arctic. Several sites on land, major rivers and in the Arctic Ocean, including the island of Novaya Zemlya , are known to be contaminated by nuclear waste, discarded reactors and nuclear accidents. Radionuclides are transported to the Arctic Ocean but are diluted to very low levels. A large program to assess the dangers to indigenous peoples in Alaska concluded that there was little evidence of contamination moving to Alaska and that there was presently no additional risks from the contamination (Layton *et al*.1997). Detailed surveys of radionuclide levels in the Arctic Ocean report the presence of low levels of man-made nuclides that probably derive from waste sites, or nuclear waste processing plants in Europe and Britain (Macdonald and Bewers 1996). Transport can also occur by ice rafts from the contaminated sites transporting plutonium and other nuclides around the Arctic ocean (Landa *et al*. 1998).

Concentrations in Biota

Radionuclides are generally not routinely measured in field surveys of contaminants. By far, the most data are available for caribou because of concerns about the accumulation of Cs-137. A large survey was conducted by Health Canada after the Chernobyl accident in 1986 and another large survey was conducted in 1992/93 by Macdonald *et al*. (1996). The only man-made nuclide observed in caribou muscle was Cs-137, which ranged from 100 to 200 Bg·kg^{-1} ww across the Arctic. A survey of beluga in the western Arctic for the FJMC (Table 6) did not reveal any detectable levels of man-made radionuclides other than Cs-137 at very low levels (< 3 Bq·kg^{-1} ww). Very low levels of cesium-137 are present in waterfowl and fish.

Toxicity

Radiation exposure occurs as the energy from decaying radionuclides is absorbed by the body. The radionuclides can be distributed in the soil or tailings at a contaminated site, or deposited in the body from the ingestion of food and water or the inhalation of air. The radiation dose, with the units of Gray·year^{-1} (Gy·y^{-1}) or milliSieverts per year (mSv·y^{-1}), is measured as the amount of energy absorbed per kg body mass. The average background dose for people in Canada is about 3 - 4 mSv·y^{-1}, although the doses in northerners who eat a large amount of caribou may be as high as 10 mSv·y^{-1}. The maximum allowable additional dose to members of the public from industrial exposure is 1 mSv·y^{-1}. The limit is based on the increased probability of cancers caused by the radiation exposure.

Several guidelines are available for the exposure of radiation in humans. In Canada, the AECB recommends that the public not be exposed to doses from industrial sources exceeding 1 $mSv \cdot y^{-1}$. The guidelines for the levels in diet in Table 3 are calculated using this value and dose conversion factors from the International Commission for Radiological Protection (ICRP) for the specific nuclides. The recommended levels are very high relative to the amounts of the nuclides in biota, and radiation only becomes a concern near a locally contaminated area such as a mine. The levels observed in beluga and other biota are well below the values which would cause concern.

SUMMARY **Radiation remains a concern in the North for several reasons. Contamination of caribou with Cs-137 from atmospheric nuclear tests in the 1960's, the nuclear accident at Chernobyl, the debris from Cosmos 954 satellite, the potential for long range transport of radioactive contamination from Russia, and contaminated sites like Port Radium all add to the ongoing concern about radiation exposure. Cs-137 has declined in caribou with an environment half-life of about 8 years since the 1960's and will continue to decline with no new sources. Surveys of beluga in the ISR for the FJMC and fish in the Arctic Ocean by the U.S. government show low, and in some cases undetectable, levels of man-made isotopes. There is presently no evidence of contamination from the Russian nuclear wastes in the Beaufort Sea.**

Table 6 The concentration of radionuclides in beluga harvested from east Whitefish, Hendrickson Is., Paul Lake and Shingle Point. Concentrations are in $Bq \cdot kg^{-1}$ ww.

Radionuclide	Liver	Kidney	Muktuk	Bone
cesium-137	0.61 ± 0.16	0.41 ± 0.03	0.75 ± 0.58	< 10
cesium-134	< 0.74	< 0.36	< 0.27	< 7.4
potassium-40	107 ± 4.98	44.6 ± 0.34	44.2 ± 22.3	< 47.4
radium-226	< 5.0	< 2.4	< 2.0	< 52.7
cobalt-60	< 0.74	< 0.30	< 0.25	< 4.4
lead-210	< 2.0	< 2.0	< 1.75	< 32.1

4.0 Summary

This review summarizes data on contaminants in wildlife and fish from the ISR and compares the data to the levels of the contaminants in other areas of the Arctic. Overall, the quality of these data and the coverage for major species, particularly marine mammals, is good. More data are needed for marine fish species. For organic contaminants, the levels in marine mammals in the Beaufort Sea are generally lower than in the eastern Canadian Arctic, although the contaminants levels in some polar bear populations are among the highest reported anywhere.

To help establish priorities, the acceptable daily or weekly intake levels of the contaminants from Canadian and U.S. health agencies are reported relative to the amounts present in traditional foods, like muktuk. The contaminants of concern are PCBs, chlordane and mercury, mostly because of high concentrations in marine mammals. Mercury will continue to be a high profile issue because of high levels in marine mammals and some fish species, and the likelihood that consumption advisories or warnings will be issued for some foods. Factors such as the levels of selenium in food, which apparently protects the consumer from the effects of mercury, need to be investigated further, particularly in relation to the foods in the ISR. It is also important that the FJMC continue to monitor the issue of contaminants as new data on environmental levels, time trends and contaminant toxicity continue to be produced. These new data may significantly change the priority of specific compounds and help refocus the efforts of the FJMC onto emerging issues. Also, the FJMC should work with programs like the NCP and the communities to ensure that food species are continually monitored in a cost-effective manner to help determine if levels are increasing or decreasing in the ISR.

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Appendix 1

Summary of Organochlorine and Metal Concentrations in Marine Mammals and Fish From the ISR

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Table A1 Organochlorine pesticides in beluga from the ISR. The data are arranged as average values, followed by standard deviations. The range of values are given below the means when possible. Concentrations are in ng·g^{-1} wet weight.

Location	Year	Sex	N	Tissue	ΣCBz	ΣHCH	ΣCHLOR	ΣDDT	ΣPCB	Toxaphene	Dieldrin	Ref
S. Beaufort Sea	1984-87	M	10	blubber	650 ± 150	230 ± 60	1750 ± 0.41	2200 ± 830	3330 ± 2320	3830 ± 1160	230 ± 50	1
		F	2	blubber	-	170	0.67	0.67	1.23	1.38	-	1
Eskimo Lakes	1989	M	8	blubber	798 ± 309	429 ± 116	2003 ± 699	3262 ± 1548	4879 ± 1557	6859 ± 3166	479 ± 189	2
		F	5	blubber	315 ± 159	361 ± 157	683 ± 288	598 ± 275	1506 ± 640	2571 ± 1060	207 ± 89.1	2
East Whitefish	1990	M	4	blubber	720 ± 118 630 - 920	226 ± 88 160 - 430	1780 ± 730 930 - 3049	5894 ± 2687 2500 - 9400	4300 ± 1332 2750 - 6116	4694 ± 1809 2700 - 7100	264 ± 124 120 - 510	3
		F	1	blubber	320	149	240	350	611	1300	86	3
	1994	M	7	blubber	92.0 ± 1.8 90.6 - 96.0	987.4 ± 80.6 939.1 - 1166	2596 ± 142.2 2408 - 2820	3419 ± 506.3 3029 - 4334	6293 ± 681.2 5400 - 7467	7777 ± 1214 6814 - 10261	421.4 ± 63.6 313.5 - 522.9	4
		M	44	muktuk	28.4 ± 16.7 3.6 - 52.7	19.0 ± 11.9 8.7 - 36.9	119.5 ± 82.2 15.5 - 260.1	179.6 ± 142.2 10.3 - 442.6	213.9 ± 132.7 34.8 - 441.1	351.3 ± 253.4 83.5 - 821.1	20.5 ± 13.2 4.2 - 41.2	4
Hendrickson Island	1994	F	5	blubber	862 ± 109 702 - 995	394.7 ± 174.1 213.1 - 664.8	2456 ± 328.6 2062 - 2868	3503 ± 563.1 2736 - 4321	5299 ± 1460 3489 - 6786	6171 ±1673 4280 - 8641	436.0 ± 139.7 342.4 ± 671.8	4
			5	muktuk	35.6 ± 6.3 28.6 - 43.1	19.5 ± 3.5 13.4 - 22.2	120.3 ± 33.3 97.7 - 179.2	169.4 ± 81.1 100.6 - 301.9	218.5 ± 60.3 168.2 - 308.7	312.8 ± 136.4 197.6 - 548.4	22.3 ± 8.2 15.2 - 36.3	4
		M	20	blubber	910 ± 134 692 -1180	320.8 ± 49.9 241.3 - 447.3	2431 ± 416.7 2023 - 3449	3506 ± 929.5 1787 - 6080	4882 ± 1878 3026 - 9037	5900 ±2333 3525 - 11401	397.1 ± 131.5 18.5 - 687.1	4
			6	muktuk	40.4 ± 11.5 27.3 - 56.3	23.2 ± 10.2 13.6 - 42.1	162.7 ± 41.3 132.7 - 223.3	271.6 ± 71.6 213.5 - 371.0	316.9 ± 96.1 227.8 - 482.8	467.8 ± 104.6 360.1 - 652.4	29.0 ± 8.9 21.8 - 44.9	4

Table A1(cont'd) Organochlorine pesticides in beluga from the ISR

Location	Year	Sex	N	Tissue	ECBz	EHCH	ECHLOR	EDDT	EPCB	Toxaphene	Dieldrin	Ref
Paulatuk	1994	M + F	3	blubber	1177 ± 59.5 1142 - 1246	466.2 ± 42.2 432.8 - 513.7	2409 ± 60.2 2365 - 2478	2460 ± 123.1 2335 - 2581	3903 ± 217.1 3693 - 4126	5320 ± 199.1 5146 - 5537	386.3 ± 81.6 297.6 - 458.0	4
				muktuk	29.7 ± 6.2 22.6 - 33.9	24.9 ± 9.2 18.5 - 35.5	119.4 ± 25.5 90.7 - 139.4	159.8 ± 73.7 94.5 - 239.8	212.5 ± 59.7 149.9 - 268.8	318.6 ± 119.7 195.0 - 433.9	23.7 ± 5.6 17.4 - 28.2	4
Kendall Island	1990	M	4	blubber	540 ± 331 65 - 840	258 ± 165 103 - 480	886 ± 532 168 - 1450	2540 ± 2515 148 - 6000	1880 ± 1194 256 - 2883	2510 ± 1420 920 - 4300	159 ± 88 45 - 250	3
		F	1	blubber	790	185	1254	5300	4466	4000	280	3

References

1 - Muir *et al.* (1990)
2 - Jensen *et al.* (1997)
3 - Thomas and Hamilton (1992)
4 - Muir *et al.* (1995)

Table A2 Organochlorine pesticides in ringed seal from the ISR. The data are arranged as average values, followed by standard deviations. The range of values are given below the means when possible. Data from Weis and Muir (1997) are presented as means with 95% confidence intervals (CI). Concentrations are in $ng \cdot g^{-1}$ wet weight.

Location	Year	Sex	N	Tissue	ΣCBz	ΣHCH	ΣChlor	ΣDDT	ΣPCB	Toxaphene	Dieldrin	Ref
Holman Island	1972	M	15	blubber	-	-	-	1310 ± 310	4100 ± 1.4	-	-	1
		F	13	blubber	-	-	-	610 ± 270	2000 ± 900	-	-	1
	1972	M	12	blubber	-	-	-	1110 ± 510	3690 ± 1340	-	-	2
		F	9	blubber	-	-	-	550 ± 210	1830 ± 820	-	-	2
	1981	M	16	blubber	-	-	-	780 ± 560	1280 ± 750	-	-	2
		F	15	blubber	-	-	-	330 ± 140	580 ± 250	-	-	2
	1989	M	4	blubber	-	117 ± 38.5	143 ± 49.8	269 ± 211	241 ± 44.3	-	-	3
	1991	F	-	blubber	-			217 ± 170	366 ± 110	-	-	4
Sachs Harbour	1972	-	3	liver	-	-	-	22 ± 13	40 ± 60	-	-	5
			5	blubber	-	-	-	1538 ± 876	920 ± 770	-	-	5
	1983-89	-	-	blubber	-	-	431 C.I. = 356 - 521	414 C.I. = 325 - 527	588 C.I. = 482 - 716	341 C.I. = 273 - 426	-	6
	1987	-	4	blubber	13.20	60.0	81.9	105	118.0	50	4.3	7
		-	2	blubber	10.8	56.3	83.5	68.0	78.0	122.0	3.5	7
	1988	-	11	blubber	6.1	22.0	42.3	38.0	58.0	12.0	5.0	7
		-	10	blubber	5.1	23.4	34.4	36.0	52.0	13.0	4.1	7
Tuktoyaktuk	1983-89	-	-	blubber	-	-	350 C.I. = 207 - 590	251 C.I. = 140 - 451	561 C.I. = 335 - 938	205 C.I. 86.2 - 488	-	6
E. Beaufort Sea	1988	M	11	blubber	-	270 ± 200	420 ± 150	380 ± 160	580 ± 230	190 ± 80	-	8
		F	10	blubber	-	230 ± 90	340 ± 130	360 ± 360	520 ± 240	130 ± 50	-	8
S. Beaufort Sea	1986	M+F	7	blubber	-	290 ± 90	410 ± 260	290 ± 140	630 ± 300	340 ± 480	-	8

References

1 - Addison and Smith (1974)
2 - Addison *et al.* (1986)
3 - Cameron *et al.* (1997)
4 - Addison (1995; cited in Jensen *et al.* 1997)
5 - Bowes and Jonkel (1975)
6 - Weis and Muir (1997)
7 - Kingsley and Byers (1990)
8 - Muir *et al.* (1992b)

Table A3 Organochlorine pesticides in bearded seal and bowhead whale from the ISR. The data are arranged as average values, followed by standard deviations. The range of values are given below the means when possible. Concentrations are in ng·g^{-1} wet weight.

Location	Year	Sex	N	Tissue	ECBz	EHCH	ECHLOR	EDDT	EPCB	Toxaphene	Dieldrin	Ref
Bearded Seal												
Holman Island	-	-	2	blubber	10	60	90	80	250	-	4.2	1
						50 - 80	80 - 100	.07 - .09	190 - 310		3.3 - 10	
	-	-	2	kidney	0.43	2.0	4.7	10	16	-	1.2	1
					0.05 - 0.8	0.9 - 3.1	3.5 - 10	.58 - 20	10 - 20		1.3 - 2	
	-	-	1	liver	0.3	1.9	10	3.8	3.0	-	.24	1
	-	-	2	muscle	0.05	2.1	2.6	1.1	0.51	-	0.1	1
					0.03 - .07	0.9 - 3.2	2.4 - 2.7	0.4 - 2.2	0.49 - .53		<0.1 - .2	
Bowhead												
Shingle Point			1	blubber	80	140	100	140	200	380	60	2

References

1 - Thomas (1990)

2 - Muir and Segstro (1992, unpublished data)

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Table A4 Metals in beluga from the ISR. The data are arranged as average values, followed by standard deviations. Concentrations are in μg/g^{-1} wet weight. The range of values are given below the means when possible.

Location	Year	Sex	N	Tissue	Cadmium	Copper	Arsenic	Mercury	Selenium	Zinc	Ref
S. Beaufort Sea (Kugmallit Bay)	1972	M+F	7	liver	-	-	-	6.26 ± 3.71	-	-	1
				muscle	-	-	-	0.71 ± 0.14	-	-	1
	1977	M+F	8	liver	-	-	-	30.62 ± 20.5	-	-	2
		M+F	11	muscle	-	-	-	2.12 ± 1.15	-	-	2
				blubber	-	-	-	0.08 ± 0.09	-	-	2
S. Beaufort Sea (MacKenzie Delta)	1981-84	M+F	43	liver	2.27 ± 1.45	-	-	11.82 ± 12.1	6.22 ± 5.26	-	3
				kidney	9.55 ± 4.47	-	-	2.83 ± 1.06	2.44 ± 0.75	-	3
			34	muscle	0.12 ± 0.23	-	-	1.07 ± 1.47	0.61 ± 1.47	-	3
Western Arctic*	1993-94	-	28	muktuk	0.002 ± 0.001	0.47 ± 0.08	-	0.78 ± 0.41	4.02 ± 1.17	65.8 ± 4.8	4
			76	muscle	0.019 ± 0.015	0.74 ± 0.16	-	1.34 ± 0.67	0.41 ± 0.088	25.7 ± 6.8	4
			77	liver	2.27 ± 1.04	11.3 ± 7.09	-	27.1 ± 24.7	18.8 ± 13.9	27.9 ± 5.01	4
			79	kidney	9.68 ± 3	2.1 ± 0.28	-	4.91 ± 2.84	-	26.4 ± 3.88	4
Hendrickson Island	1994	-	32	liver	2.44 ± 0.85 1.3 - 5.0	-	-	35.1 ± 29.3 5.6 - 109	19.0 ± 14.4 5.1 - 58.7	-	5
			33	kidney	8.84 ± 2.61 3.8 - 13.5	-	-	4.71 ± 2.68 1.4 - 13.6	-	-	5
				muscle	0.02 ± 0.01 0.01 - 0.05	-	-	1.32 ± 0.67 0.43 - 3.44	0.39 ± 0.10 0.24 - 0.66	-	5

Table A4 (cont'd) Metals in beluga from the ISR.

Location	Year	Sex	N	Tissue	Cadmium	Copper	Arsenic	Mercury	Selenium	Zinc	Ref
Hendrickson Island			33	muktuk	-	-	-	0.73 ± 0.39 0.23 - 1.93	3.56 ± 0.89 1.03 - 5.75	-	5
	1995	-	18	liver	2.27 ± 0.51 1.4 - 3.02	-	1.07 ± 0.51 0.48 - 2.1	43.99 ± 35.1 6.4 - 125	19.4 ± 10.7 6.4 - 41.3	-	5
				kidney	9.11 ± 2.91 5.7 - 15.4	-	1.96 ± 1.48 0.69 - 6.69	6.73 ± 3.46 1.86 - 15.0	4.36 ± 1.36 2.25 - 6.66	-	5
			17	muscle	-	-	0.45 ± 0.30 0.19 - 1.2	1.62 ± 0.68 0.71 - 3.01	0.39 ± 0.08 0.22 - 0.52	-	5
				muktuk	-	-	2.36 ± 1.75 0.6 - 7.7	0.77 ± 0.35 0.26 - 1.5	4.39 ± 0.70 3.13 - 5.8	-	5
	1996	-	15	liver	2.34 ± 1.16 0.9 - 5.1	-	0.84 ± 0.26 0.41 - 1.5	33.9 ± 29.1 9.1 - 96.9	18.2 ± 13.2 6.2 - 45.5	-	5
				kidney	11.3 ± 6.23 3.84 - 25.3	-	1.90 ± 0.6 1.0 - 3.1	8.05 ± 3.54 2.2 - 13.0	4.79 ± 1.66 2.06 - 8.99	-	5
				muscle	-	-	0.48 ± 0.15 0.19 - 0.74	1.73 ± 0.71 0.65 - 3.36	0.37 ± 0.06 0.30 - 0.50		5
			14	muktuk	-	-	2.76 ± 0.84 1.2 - 4.3	1.04 ± 0.42 0.48 - 1.85	4.25 ± 0.83 3.4 - 6.0	-	5

References

1 - Lutz and Armstrong (1978)
2 - Imperial Oil (1978) as cited in Muir *et al.* (1992b)
3 - Wagemann *et al.* (1990), cited in Wagemann *et al.* (1996)
4 - Wagemann *et al.* (1996)
5 - Lockhart, L. DFO, Winnipeg, MB (pers. comm.)

Table A5 Metals in ringed seals and bearded seals in the ISR. Concentrations are in µg/g^{-1} ww. The range of values are given below the means when possible.

Location	Year	Sex	N	Tissue	Cadmium	Copper	Arsenic	Mercury	Selenium	Zinc	Ref
Ringed Seal											
S. Beaufort Sea	1972	-	13	liver	-	-	-	1.0 ± 1.16	-	-	1
				muscle	-	-	-	0.23 ± 0.11	-	-	1
Amundsen Gulf (Holman Is.)	1972	-	83	liver	-	-	-	27.5 ± 30.1	-	15.24 ± 7.75	1
		-		muscle	-	-	-	0.72 ± 0.33	-	-	1
	1976	-	112	liver	-	-	-	5.54 ± 15.0	-	14.96 ± 6.42	1
Sachs Harbour (Thesiger Bay)	1987	-	6	liver	4.07 0.1 - 7.8	5.2 3.2 - 8.9	-	29.4 0.7 - 63.8	14.3 0.2 - 31.2	35.2 24.4 - 44	2
	1987	-	7	liver	4.57 0.5 - 9.5	9.35 3.5 - 17.1	-	27.1 0.6 - 1991	14.9 1.4 - 31	43.2 35.6 - 49	2
western Arctic**	1987 -93	M+F	113-118	muscle	0.041 ± 0.043	1.09 ± 0.16	0.052 ± 0.05	0.41 ± 0.29***	0.51 ± 0.14	27.1 ± 5.31	3
		M+F	140 - 142	liver	5.6 ± 3.14	10.8 ± 6.65	0.083 ± 0.118	32.9 ± 35.2****	15.2 ± 12.9	41.5 ± 5.78	3
				kidney	21.1 ± 14.2	6.48 ± 2.08	-	2.05 ± 1.34	-	38.7 ± 10.7	3
Bearded Seal											
Amundsen Gulf	1973	-	6	liver	-	-	-	14.3 ± 17.0	-	34.2 ± 33.2	4
		-	3	muscle	-	-	-	0.53 ± 0.35	-	-	

* - includes samples from Hendrickson Is. (n = 45), Paulatuk (n = 3), Shingle Point (n = 5), east Whitefish (n = 26) and the Mackenzie Delta (n = 46) (Wagemann *et al*. 1996).
** - includes data from Shingle Point (n = 3), Paulatuk (n = 10), Sachs Harbour (n = 123) and Holman (n = 14) (Wagemann *et al.* 1996).
*** - value reported is total mercury, which includes 94% methyl-mercury, based on a subset of 39 samples (Wagemann *et al*. 1998).
**** - value reported is total mercury which includes 2.7% methyl mercury, based on a subset of 39 samples (Wagemann *et al*. 1998)

References

1 - Smith and Armstrong (1978)
2 - Kingsley and Byers (1990)
3 - Wagemann *et al.* (1996)
4 - Lockhart, L., DFO, Winnipeg, MB (pers. comm.)

Table A6 Organochlorines in marine and freshwater fish from the ISR. The data are average values, followed by standard deviations. The range of values are given below the means when possible. Concentrations are in ng·g^{-1} wet weight. Asterisk (*) indicates that concentration is in ng·g^{-1} lipid. The range of values are given below the means when possible.

Species	Location	Year	N	Tissue	ECBz	EHCH	EChlor	EDDT	EPCB	Toxaphene	Ref
Arctic Char	Phillips Bay, Beaufort Sea	1986	9	muscle	1.3 ± .36	4.4 ± 2.4	2.2 ± 0.96	0.97 ± .19	1.3 ± 1.3	7.3 ± 3.5	1
				whole	5.1 ± 3.9	35 ± 1.5	12.0 ± 3.5	3.8 ± 1.7	3.8 ± 0.82	44 ± 12	1
	s. Beaufort Sea	-	9	whole	-	40 ± 20	10	4 ± 1.0	4.0 ± 1.0	44 ± 14	2
	Queen Maud Gulf	1984	4	muscle	-	-	-	-	35 ± 24	-	3
	Rat River	1986	10	muscle	2.1 ± .53 1.4 - 3.2	0.52 ± 0.22 0.24 - 0.8	-	1.3 ± .48 0.5 - 1.9	0.7 ± 0.39 0.34 - 1.3	4.1 ± 1.5 2.2 - 6.6	1
			10	whole	6.2 ± 1.8 4.2 - 10	2.0 ± 1.6 0.2 - 4.7	-	4.9 ± 1.7 2.8 - 8.2	1.3 ± 0.75 0.2 - 2.7	16 ± 6.2 4.8 - 26	
Pacific herring	Tuk Harbour	1984	pool	muscle	-	12.5	-	4.1	5	74	4
Inconnu	Tuk Harbour	1984	1	muscle	-	0.2	3.3	3.5	2.5	24	4
Broad Whitefish	Canyanek Creek	1990	4	muscle	-	-	27 ± 11*	13 ± 9*	38 ± 6*	-	5
			6	muscle	-	-	30 ± 10*	13 ± 6*	44 ± 52*	-	
	Tuk Harbour	1985	2	muscle	-	<.1.0	< 1.0	< 1.0	< 1.0	-	4
	Campbell Lake	1992		muscle	0.77 ± 0.81	1.72 ± 2.38	1.86 ± 1.64	0.86 ± 1.18	1.73 ± 0.92	5.86 ± 2.86	6
	Travaillant Lake	1992		muscle	0.57 ± 0.15	0.46 ± 0.11	0.67 ± 0.11	0.31 ± 0.05	1.86 ± 0.69	3.39 ± 0.66	6
	Lake 100	1988		muscle	4.05 ± 1.54	3.52 ± 2.25	8.90 ± 2.47	4.76 ± 2.18	8.73 ± 5.11	48.1 ± 14.5	6
	Mackenzie R. at Horseshoe Bend	1992		muscle	0.30 ± 0.18	0.19 ± 0.11	1.03 ± 0.65	0.16 ± 0.12	0.84 ± 0.43	3.10 ± 1.69	6
	Kugaluk River	1989		muscle	1.40 ± 0.83	1.09 ± 0.55	1.69 ± 0.68	0.67 ± 0.30	6.19 ± 3.99	11.9 ± 12.1	6

References

1 - Diet Study 1986 (Anon)

2 - Hendzel and Regier in Muir *et al.* (1987)

3 - Environmental Protection Service (1985) cited in Muir *et al.* (1992b)

4 - Muir *et al.* (1987)

5 - Muir et al (1992a)

6 - Lockhart *et al.* (1996)

Table A7 Metals in marine and freshwater fish from the ISR. Data are average values, followed by standard deviations. Concentrations are $\mu g \cdot g^{-1}$ ww. The range of values are given below the means when possible.

Species	Location	Year	N	Tissue	Cadmium	Copper	Mercury	Selenium	Zinc	Ref
Arctic char	Amundsen Gulf	1972	12	muscle	-	-	0.049 ± 0.017	-	-	1
	Kuuk River	1987	6	muscle	-	-	0.051	-	-	7
	Kagloryuak River	1989	6	muscle	-	-	0.064	-	-	7
	Naloagyuk River	1989	6	muscle	-	-	0.04	-	-	7
	Kuujjua River	1992	6	muscle	-	-	0.047	-	-	7
Pacific herring	Tuktoyaktuk Harbour	1984	2	liver	-	-	0.05 ± 0.03	3.26 ± 0.90	-	2
				muscle	< 0.05	-	0.02 ± 0.0	0.51 ± 0.06	-	2
Broad whitefish	Tuktoyaktuk Harbour	1984	2	liver	< 0.05	28.4	0.08	0.68	40.3	2
				muscle	< 0.05	0.48	0.01	0.39 ± 0.19	14.4	2
				kidney	0.09	0.76	0.06 ± 0.01	1.21 ± 1.01	46.8 ± 2.62	2
	Mackenzie Delta	1977	21	muscle	0.09 ± 0.05 0.03 - 0.2	-	0.01 ± 0.01 <0.01 - 0.1	-	5.06 ± 1.13	6
		1992	11	muscle	-	-	0.06 ± 0.04 0.02 - 0.14	-	-	5
	Campbell Lake	1992	10	muscle	<0.002	-	0.072 ± 0.022	-		
				liver	0.15 ± 0.08		0.14 ± 0.054			
	Travaillant Lake	1992	4	muscle	<0.002	-	0.023 ± 0.002	-	-	
				liver	0.21 ± 0.099	-	0.10 ± 0.08	-	-	
	Lake 100	1988	4	muscle	<0.002	-	0.016 ± 0.003	-	-	
				liver	0.75 ± 0.19	-	0.10 ± 0.041	-	-	
	Mackenzie R. at Horseshoe Bend	1992	12	muscle	<0.002	-	0.062 ± 0.028	-	-	
				liver	0.084 ± 0.062	-	0.10 ± 0.039	-	-	
	Kugaluk River	1989	10	muscle	<0.002	-	0.027 ± 0.01	-	-	
				liver	0.20 ± 0.11	-	0.083 ± 0.046	-	-	

Table A7 (cont'd) Metals in marine and freshwater fish from the ISR.

Species	Location	Year	N	Tissue	Cadmium	Copper	Mercury	Selenium	Zinc	Ref
Fourhorn sculpin	Tuktoyaktuk Harbour	1984	2	liver	0.56 ± 0.02	3.30 ± 1.21	0.19 ± 0.06	1.11 ± 0.17	40.1 ± 1.41	2
				muscle	< 0.05	0.95 ± 0.06	0.18 ± 0.03	0.37 ± 0.01	20.6 ± 1.17	2
Flounder	Tuktoyaktuk Harbour	1984	2	liver	37.02	-	0.03 ± 0.04	1.61 ± 0.35	-	2
				muscle	< 0.05	-	0.03 ± 0.01	0.49 ± 0.04	-	2
		1986-87	17	muscle	-	-	0.356 ± 0.385	-	-	3
			30	muscle	-	-	0.307 ± 0.234	-	-	3
Arctic cod	Kugmallit bay	1984	6	liver	-	-	-	0.48 ± 0.22	-	2
				muscle	<0.05	-	0.02 ± 0.01	0.42 ± 0.06	-	2
Lake trout	Yaya Lake	1977	18	muscle	0.06 ± 0.05 0.01 - 0.23	-	0.12 ± 0.06 0.03 - 0.3	-	4.34 ± 0.61 3.2 - 5.6	6
		1995	28	muscle	-	-	0.21 ± 0.11 0.06 - 0.45	0.74 ± 0.29 0.09 - 1.2	-	4
Inconnu	Yaya lake	1995	30	muscle	-	-	0.17 ± 0.04 0.1 - 0.24	0.44 ± 0.07 0.34 - 0.59	-	4
	Mackenzie Delta	1977	10	muscle	0.01 <.01 - 0.01	0.23 0.15 - 0.4	0.15 0.1 - 0.23	0.41 0.35 - 0.54	4.09 3.7 - 5.0	5
		1981	6	muscle	0.002 0.0 - 0.01	0.56 0.5 - 0.6	0.09 0.03 - 0.13	0.47 0.4 - 0.54	3.69 3.2 - 4.4	5
		1992	5	muscle	-	-	0.17 ± 0.05 0.09 - 0.23	-	-	5
Northern pike	Mackenzie Delta	1992	11	muscle	-	-	0.47 ± 0.18 0.21 - 0.74	-	-	5
Arctic cisco	Beaufort Sea	1977	20	muscle	0.120 ± 0.05 0.02 - 0.2	-	0.02 ± 0.01 <1 - 0.04	-	7.73 ± 1.82 5.4 - 13.0	6
	Tuft Point, Mackenzie Delta	1977	20	muscle	0.09 ± 0.05 <0.01 - 0.2	-	0.02 ± 0.04 <0.01 - 0.2	-	5.76 ± 1.16 4.2 - 9.8	6

References

1 - Smith and Armstrong (1975)
2 - Muir *et al*. (1987)
3 - Thomas (1990)
4 - Lockhart, L. DFO, Winnipeg, MB (pers. comm.)
5 - Fish Inspectorate (1999, M. Hendzel, pers. comm.)
6 - Beak Consultants Ltd. (1978)
7 - Lockhart *et al*. (1993)